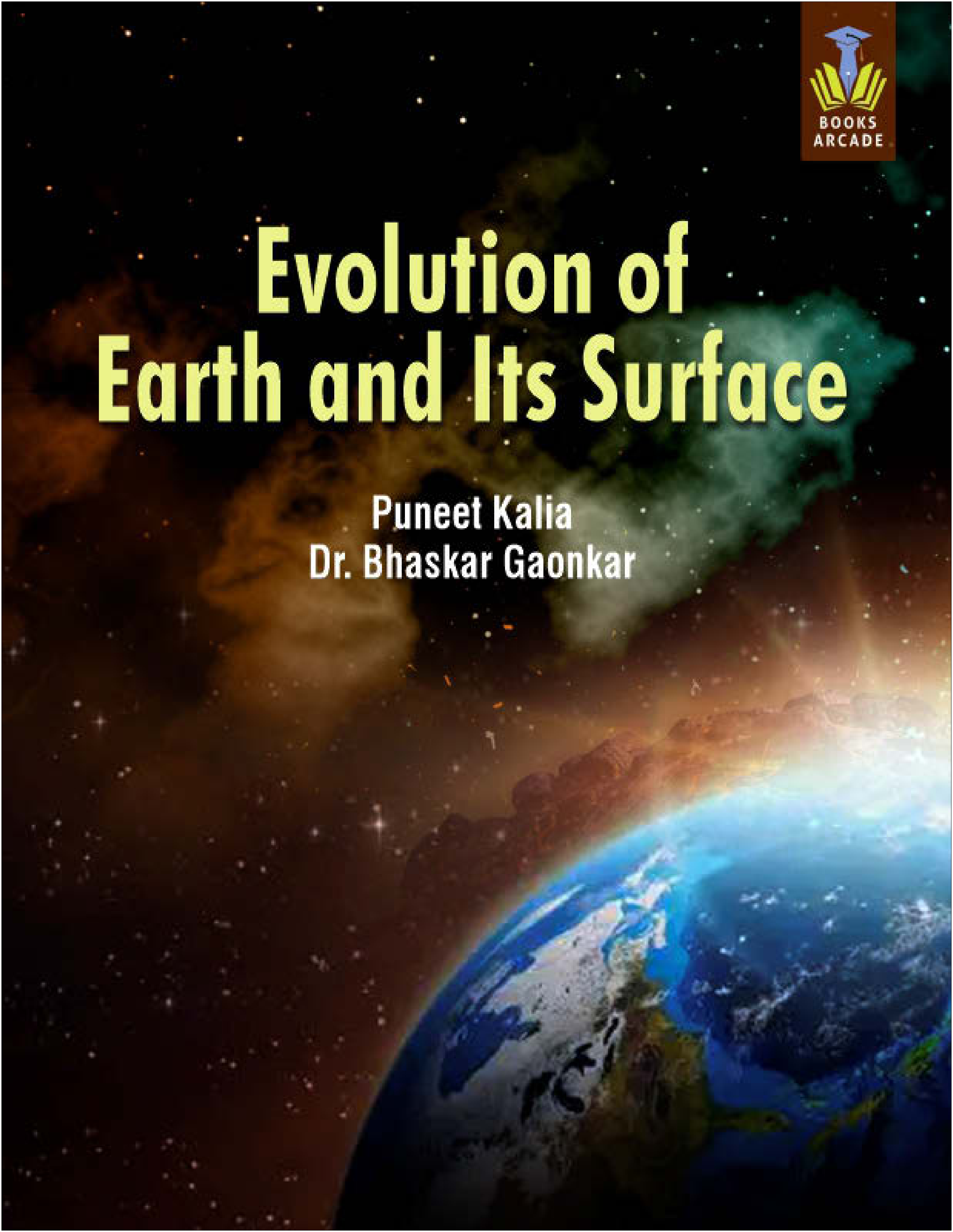

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Evolution of Earth and Its Surface

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Dr. Bhaskar Gaonkar

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CHAPTER 1

ORIGIN OF EARTH AND SYSTEM PROCESSES

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Solar System

The Milky Way galaxy's outer spiral arm is where our solar system is situated. The Sun, our star, and everything gravitationally associated to it, including the moons Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune, are what try to compensate our solar system. There are several dozens more moons, as well as millions of asteroids, comets, and meteoroids.

The night sky comprises more planets than stars irrespective of our own solar system. The Milky Way has hundreds of planetary systems circling other stars, and new planets are frequently being identified. The Milky Way is just one of maybe 100 billion galaxies in the creation, and most of the hundreds of billions of stars in it are believed to have their own planets.

While our planet may appear to be a little dot in the wide multiverse, we are not alone. It would appear that there are many planets in our existence, a network of numerous stars, and several families of objects, some of which may have life of their own.

Namesake

There are many planetary systems like ours in the universe, with planets orbiting a host star. Our planetary system is called “the solar system” because we use the word “solar” to describe things related to our star, after the Latin word for Sun, "solis."

Size and Distance

Our solar system extends much farther than the eight planets that orbit the Sun. The solar system also includes the Kuiper Belt that lies past Neptune's orbit. This is a sparsely occupied ring of icy bodies, almost all smaller than the most popular Kuiper Belt Object dwarf planet Pluto as display in below Figure 1.

Figure 1: Represented that the Pluto Planet.

Beyond the fringes of the Kuiper Belt is the Oort cloud. This giant spherical shell surrounds our solar system. It has never been directly observed, but its existence is predicted based on mathematical models and observations of comets that likely originate there.

The Oort cloud is made of icy pieces of space debris - some bigger than mountains – orbiting our Sun as far as 1.6 light-years away. This shell of material is thick, extending from 5,000 astronomical units to 100,000 astronomical units. One astronomical unit (or AU) is the distance from the Sun to Earth, or about 93 million miles (150 million kilometers). The Oort Cloud is the boundary of the Sun's gravitational influence, where orbiting objects can turn around and return closer to our Sun.

The Sun's heliosphere doesn't extend quite as far. The heliosphere is the bubble created by the solar wind – a stream of electrically charged gas blowing outward from the Sun in all directions. The boundary where the solar wind is abruptly slowed by pressure from interstellar gases is called the termination shock.

This edge occurs between 80-100 astronomical units.

Two NASA spacecraft launched in 1977 have crossed the termination shock: Voyager 1 in 2004 and Voyager 2 in 2007. Voyager 1 went interstellar in 2012 and Voyager 2 joined it in 2018. But it will be many thousands of years before the two Voyagers exit the Oort-Cloud.

Moons

There are more than 200 known moons in our solar system and several more awaiting confirmation of discovery. Of the eight planets, Mercury and Venus are the only ones with no moons. The giant planets Jupiter and Saturn lead our solar system’s moon counts. In some ways, the swarms of moons around these worlds resemble mini versions of our solar system. Pluto, smaller than our own moon, has five moons in its orbit, including the Charon, a moon so large it makes Pluto wobble. Even tiny asteroids can have moons. In 2017, scientists found asteroid 3122 Florence had two tiny moons as shown in below Figure 2.

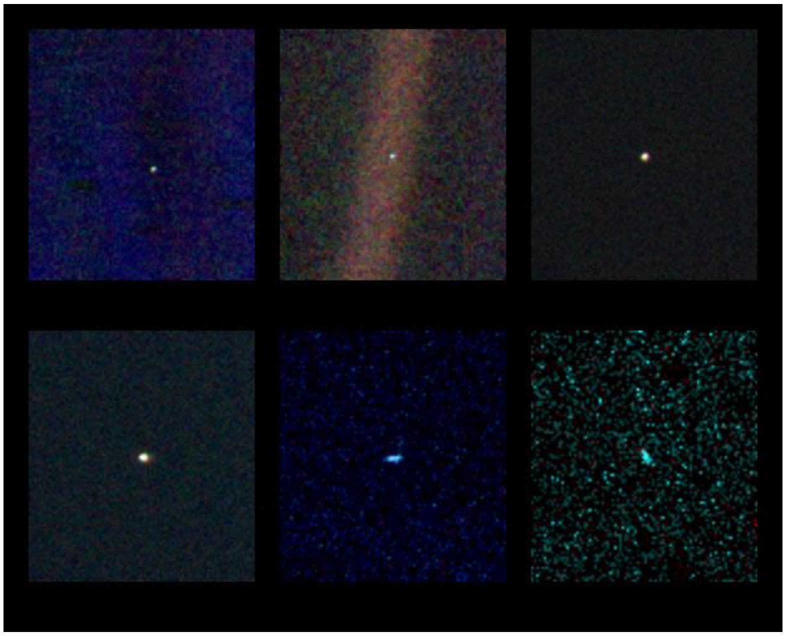

Figure 2: Represented that the Tiny Moons.

Formation

Our solar system formed about 4.5 billion years ago from a dense cloud of interstellar gas and dust. The cloud collapsed, possibly due to the shockwave of a nearby exploding star, called a supernova. When this dust cloud collapsed, it formed a solar nebula a spinning, swirling disk of material.

At the center, gravity pulled more and more material in. Eventually, the pressure in the core was so great that hydrogen atoms began to combine and form helium, releasing a tremendous amount of energy. With that, our Sun was born, and it eventually amassed more than 99% of the available matter.

Matter farther out in the disk was also clumping together. These clumps smashed into one another, forming larger and larger objects. Some of them grew big enough for their gravity to shape them into spheres, becoming planets, dwarf planets, and large moons. In other cases, planets did not form: the asteroid belt is made of bits and pieces of the early solar system that could never quite come together into a planet. Other smaller leftover pieces became asteroids, comets, meteoroids, and small, irregular moons.

Structure

The order and arrangement of the planets and other bodies in our solar system is due to the way the solar system formed. Nearest to the Sun, only rocky material could withstand the heat when the solar system was young. For this reason, the first four planets Mercury, Venus, Earth, and Mars are terrestrial planets. They are all small with solid, rocky surfaces.

Meanwhile, materials we are used to seeing as ice, liquid, or gas settled in the outer regions of the young solar system. Gravity pulled these materials together, and that is where we find gas giants Jupiter and Saturn, and the ice giants Uranus and Neptune.

Formation of Our Solar System

The Sun and the planets formed together, 4.6 billion years ago, from a cloud of gas and dust called the solar nebula. A shock wave from a nearby supernova explosion probably initiated the collapse of the solar nebula. The Sun formed in the center, and the planets formed in a thin disk orbiting around it. In a similar manner, moons formed orbiting the gas giant planets. Comets condensed in the outer solar system, and many of them were thrown out to great distances by close gravitational encounters with the giant planets. After the Sun ignited, a strong solar wind cleared the system of gas and dust. The asteroids represent the rocky debris that remained.

Size and Time Scales of the Solar System

- The Earth revolves around the Sun at a distance of 150 million kilometers (93 million miles).
- The orbits of the planets are nearly circular, and measure from one-third to 30 times the size of Earth's orbit.
- Mercury, the innermost planet, orbits the Sun in about three months, while Neptune takes 165 years.
- The Sun contains about 99.9 percent of all the mass of the solar system as display in Figure 3.

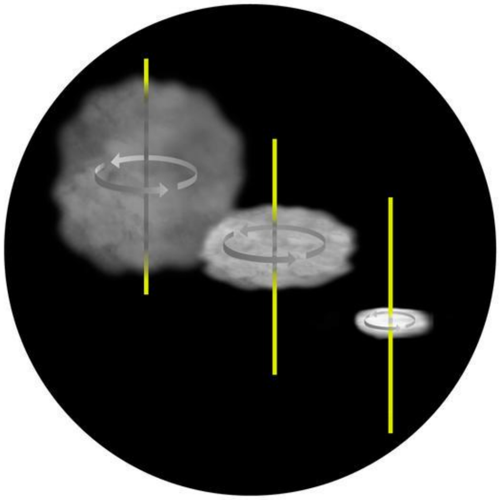

Figure 3: Represented that the Size and Time Scales of the Solar System

Forming Of Solar System

Solar system formation as display in below figure began approximately 4.5 billion years ago, when gravity pulled a cloud of dust and gas together to form our solar system as mention in Figure 4. Scientists can't directly study how our own solar system formed, but combining observations of young stellar systems in a range of wavelengths with computer simulations has led to models of what could have happened so many years ago.

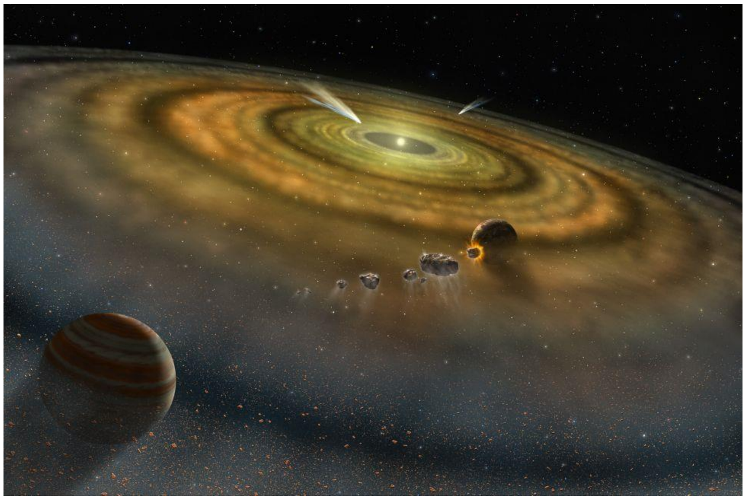

Figure 4: Represented that the Forming of the Solar System.

The solar system is anchored by our sun. Before the solar system existed, a massive concentration of interstellar gas and dust created a molecular cloud that would form the sun's birthplace. Cold temperatures caused the gas to clump together, growing steadily denser. The densest parts of the cloud began to collapse under their own gravity, perhaps with a nudge from a nearby stellar explosion, forming a wealth of young stellar objects known as proto-stars.

Gravity continued to collapse the material onto the infant solar system, creating a star and a disk of material from which the planets would form. Eventually, the newborn sun encompassed more than 99% of the solar system's mass, according to NASA. When pressure inside the star grew so powerful that fusion kicked in, turning hydrogen to helium, the star began to blast a stellar wind that helped clear out the debris and stopped it from falling inward. Although gas and dust shroud young stars in visible wavelengths, infrared telescopes have probed many clouds in the Milky Way galaxy to study the environment of other newborn stars. Scientists have applied what they've seen in other systems to our own star.

The planets, moons, asteroids and everything else in the solar system formed from the small fraction of material in the region that wasn't incorporated in the young sun. This material formed a massive disk around the baby star, which surrounded it for about 100 million years an eye blink in astronomical terms.During that time, planets and moons formed out of the disk. Among the planets, Jupiter likely formed first, perhaps as soon as a million years into the solar system's life, scientists have argued.

Scientists have developed three different models to explain how planets in and out of the solar system may have formed. The first and most widely accepted model, core accretion, works well with the formation of the rocky terrestrial planets but has problems with giant planets. The second, pebble accretion, could allow planets to quickly form from the tiniest materials. The third, the disk instability method, may account for the creation of giant planets.

The Core Accretion Model

Approximately 4.6 billion years ago, the solar system was a cloud of dust and gas known as a solar nebula. Gravity collapsed the material in on itself as it began to spin, forming the sun in the center of the nebula.

With the rise of the sun, the remaining material began to clump together. Small particles drew together, bound by the force of gravity, into larger particles, according to the core accretion model. The solar wind swept away lighter elements, such as hydrogen and helium, from the closer regions, leaving only heavy, rocky materials to create terrestrial worlds. But farther away, the solar winds had less impact on lighter elements, allowing them to coalesce into gas giants. In this way, asteroids, comets, planets and moons were created.

Some exoplanet observations seem to confirm core accretion as the dominant formation process. Stars with more "metals" a term astronomer’s use for elements other than hydrogen and helium in their cores have more giant planets than their metal-poor cousins. According to NASA(opens in new tab), core accretion suggests that small, rocky worlds should be more common than the large gas giants.

The 2005 discovery of a giant planet with a massive core orbiting the sun-like star HD 149026 is an example of an exoplanet that helped strengthen the case for core accretion. The planet's core is about 70 times more massive than Earth, scientists found; they believe that is too large to have formed from a collapsing cloud, according to a NASA statement about the research(opens in new tab).

Pebble Accretion

The biggest challenge to core accretion is time building massive gas giants fast enough to grab the lighter components of their atmosphere. Research published in 2015 probed how smaller, pebble-size objects fused together to build giant planets up to 1,000 times faster than earlier studies."This is the first model that we know about that you start out with a pretty simple structure for the solar nebula from which planets form, and end up with the giant-planet system that we see," study lead author Harold-Levison, an astronomer at SwRI, told Space.com at the time.

In 2012, researchers Michiel Lambrechts and Anders Johansen of Lund University in Sweden proposed that tiny rubble, once written off, held the key to rapidly building giant planets. "They showed that the leftover pebbles from this formation process, which previously were thought to be unimportant, could actually be a huge solution to the planet-forming problem," Levison said.

In simulations that Levison and his team developed, larger objects acted like bullies, snatching away pebbles from the mid-size masses to grow at a far faster rate. "The bigger guy basically bullies the smaller one so they can eat all the pebbles themselves, and they can continue to grow up to form the cores of the giant planets," study co-author Katherine Kretke, also from SwRI, told Space.com.

The Disk Instability Model

Other models struggle to explain the formation of the gas giants. According to core accretion models, the process would take several million years, longer than the light gases were available in the early solar system.

"Giant planets form really fast, in a few million years," Kevin Walsh, a researcher at the Southwest Research Institute (SwRI) in Boulder, Colorado, told Space.com. "That creates a time limit because the gas disk around the sun only lasts 4 to 5 million years."

A relatively new theory called disk instability addresses this challenge. In the disk instability model of planet formation, clumps of dust and gas are bound together early in the life of the solar system. Over time, these clumps slowly compact into a giant planet.Planets can form in this way in as little as 1,000 years, the models suggest, allowing them to trap the rapidly vanishing lighter gases. They also quickly reach an orbit-stabilizing mass that keeps them from death-marching into the sun. As scientists continue to study planets inside of the solar system, as well as around other stars, they will better understand how gas giants formed. Originally, scientists thought that planets formed in their current locations in the solar system. But the discovery of explants shook things up, revealing that at least some of the most massive worlds could migrate through their neighborhoods.

In 2005, a trio of papers published in the journal Nature outlined an idea the researchers called the Nice model, after the city in France where they first discussed it. This model proposes that in the early days of the solar system, the giant planets were bound in near-circular orbits much more compact than they are today. A large disk of rocks and ices surrounded them, stretching out to about 35 times the Earth-sun distance, just beyond Neptune's present orbit.

As the planets interacted with smaller bodies, they scattered most of these objects toward the sun. The process caused the massive planets to trade energy with the smaller objects, sending the Saturn, Neptune and Uranus farther out into the solar system. Eventually the small objects reached Jupiter, which sent them flying to the edge of the solar system or completely out of it.

Movement between Jupiter and Saturn drove Uranus and Neptune into even more eccentric orbits, sending the pair through the remaining disk of ices. Some of the material was flung inward, where it crashed into the terrestrial planets during the Late Heavy Bombardment. Other material was hurled outward, creating the Kuiper Belt.

As they moved slowly outward, Neptune and Uranus traded places. Eventually, interactions with the remaining debris caused the pair to settle into more circular paths as they reached their current distance from the sun.

Along the way, our solar system may have lost members: It's possible that one or even two other giant planets were kicked out of the neighborhood by all this movement. Astronomer David Nesvorny of SwRI has modeled the early solar system in search of clues that could lead toward understanding its early history. “In the early days, the solar system was very different, with many more planets, perhaps as massive as Neptune, forming and being scattered to different places”.

Even after the planets had formed, the solar system itself wasn't quite recognizable. Earth stands out from the planets because of its high water content, which many scientists suspect contributed to the evolution of life. But the planet's current location was too warm for it to collect water in the early solar system, suggesting that the life-giving liquid may have been delivered after Earth formed. Just one hitch: scientists still don't know where that water might have come from. Originally, researchers suspected comets carried it to Earth, but several missions, including six that flew by Halley’s Comet in the 1980s and the European Space Agency's more recent Rosetta spacecraft, revealed that the composition of the icy material from the outskirts of the solar system didn't quite match Earth's.

The asteroid belt is another potential source of water. Several meteorites have shown evidence of alteration, changes made early in their lifetimes that hint that water in some form interacted with their surface. Impacts from meteorites could be another source of water for the planet.

Recently, some scientists have even challenged the notion that the early Earth was too hot to collect water. They argue that, if the planet formed fast enough, it could have collected the necessary water from icy grains before they evaporated.

Whatever process brought water to Earth likely did so to Venus and Mars as well. But rising temperatures on Venus and a thinning atmosphere on Mars kept these worlds from retaining their water, resulting in the dry planets we know today.

Water Formation

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From Core to Crust: Defining Earth's Layers

Before learning about earthquakes, let's look at the inside of our planet. What happens on Earth's surface is directly related to its interior. About 4.6 billion years ago, Earth formed from a hot cloud of dust orbiting a blazing sun. As the planet cooled, dense elements became concentrated in the core of the planet, while lighter elements formed the mantle. A thin, rigid crust formed at the surface. A constant heating and cooling cycle in the mantle drives plate movement on Earth's surface. Heat working its way out from the core of the planet fractured the crust into irregular tectonic plates that are constantly in motion.

- **Inner Core**: The innermost part of Earth is the core and is about 1500 miles (2414 km) thick. Both the inner and outer cores consist primarily of iron and nickel. They're extremely hot, with temperatures ranging from 7200–9000°F (4000–5000°C). The inner core is under intense pressure, which keeps it solid despite high temperatures.
- **Outer Core**: The outer core, which is liquid, is about 1300 miles (2092 km) thick. Both the inner and outer cores consist primarily of iron and nickel and are extremely hot with temperatures ranging from 7200–9000°F (4000–5000°C).
- **Mantle**: Most of Earth's volume is in the mantle. This layer is about 1800 miles (2880 km) thick. It's composed of dark, dense rock, similar to oceanic basalt. The deeper you go inside the Earth, the hotter it gets. Mantle material near the cold outer crust is about 1300°F (700°C) while rock near the Earth's core heats up to about 7200°F (4000°C).
- **Crust**: Two types of crust make up Earth's outermost layer: continental and oceanic. Continental crust is composed of silica-rich rocks and is an average of 44 miles (70 km) thick. Ocean crust is made of dark, silica-poor rocks like basalt. It is thinner and more flexible than the continents, only about 3 miles (5 km) thick.

Earth formed about 4.6 billion years ago during the birth of our solar system. This date comes from meteorites and moon rocks. For several hundred million years after the formation of the solar system the planets were continuously bombarded by meteoric debris thus the surface of the Earth probably remitted repeatedly by the impacts of large asteroids. This early bombardment continued until about 3.8 billion years ago. During the next major phase of earth's formation cooling and differentiation of the Earth's layers occurred, which is mentioned in Figure 5. Dense materials sank to the center, forming an iron-nickel rich core. Lighter buoyant silicate-rich magma rose to the surface. The remaining material between the core and the magma formed Earth's thickest layer, called the mantle,which is composed mainly of iron, magnesium, calcium-rich silicate minerals as mention in below figure.

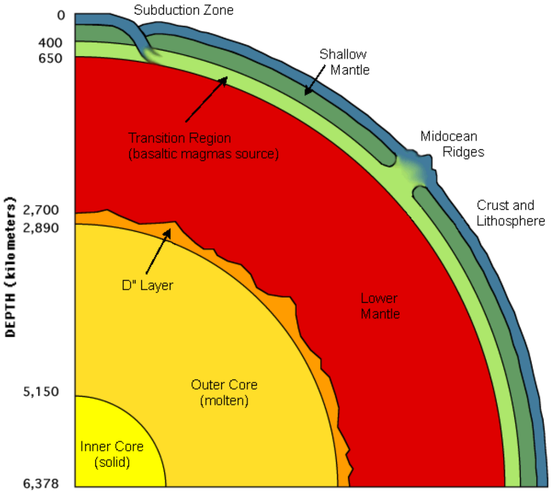

Figure 5: Display that the Earth's Layers.

Eventually, the magma cooled to form a thin layer of silica/aluminum-rich crust. Oceanic crust is composed of dense basalt and gabbro. Continental crust is less dense and has a granitic composition overall. The division of the Earth's interior into 3 distinct layers called the core, mantle, and crust is based on chemical composition. Earth's interior is commonly further differentiated into 5 layers based on physical properties. Starting from the Earth's surface, the interior is divided into the lithosphere, asthenosphere, mesosphere, outer core, and inner core.

The rock cycle is a fundamental concept describing dynamic transitions of minerals and materials through three main rock types: sedimentary, metamorphic, and igneous. Igneous rock forms from the crystallization of molten material (magma) from the lithosphere. Igneous rock may be classified as intrusive if the magma cools and solidifies underground. When magma reaches Earth's surface through a volcanic eruption, the resulting rock is known as extrusive igneous rock.

Once exposed to atmospheric conditions at the surface of the earth, weathering processes cause rocks to disintegrate or decompose into loose sediment and dissolved ions. Sediment can be transported by rivers, wave action, wind, gravity, or glacial ice, be deposited, and become buried whereby the loose grains may be compacted and cemented and converted into classic sedimentary rock. Chemical sedimentary rock is deposited by chemical precipitation of minerals held in solution. Sedimentary rock may also be classified as organic such as coal that forms from the compaction of plant material.

If buried deep enough, rock can be subjected to high temperature intense pressure causing it to change into the third rock group called metamorphic rock. If metamorphic rock undergoes additional heating or still higher pressure it may completely melt and once again become magma, completing the rock cycle.

As illustrated in the diagram to the right, other pathways exist in the rock cycle as display in given figure. Over the course of Earth's long history rocks have been formed, changed, and reformed again and again.

Geologic Time

There are two types of geologic age determinations: relative age and numerical age. Geologists in the late 18th and early 19th century studied rock layers and the fossils in them to determine relative age. It wasn't until well into the 20th century that enough information had accumulated about the rate of radioactive decay that the age of rocks and fossils in number of years could be determined through radiometric age dating.

Relative age dating means to place events in a proper sequence or order, without knowing the age in years. Deciphering a sequence of geologic events is done by applying four fundamental principles:

i. Law of Original Horizontality:

Sedimentary rock layers, and large lava flows, are initially deposited in a horizontal or nearly horizontal orientation due to gravity as display in below Figure 6.

Figure 6: Represented that the Original Horizontality.

Therefore if rock layers appear tilted to the horizon we can assume the rocks have been moved into that position by some crustal disturbance sometime after their deposition as shown in below Figure 7.

Figure 7: Represented That the Crustal Disturbance.

ii. Law of Superposition:

In an undisturbed sequence of sediments and lava flows, the layer above is younger than the layer.

iii. Law of Lateral Continuity:

Sediments and lava flows are generally laterally continuous; if not then they are usually cut by faults. Original sedimentary layers extend to the edges of a depositional environment (such as a lake or ocean basin) until they thin or taper off or until one type of sediment laterally interfingers with another as the depositional environments change.

iv. Law of Cross-Cutting Relationships:

Any sediment or lava flow that is cut by a fault, another igneous body, or an erosional surface is older than the cross-cutting feature is display in below Figure 8.

Figure 8: Represented that theLaw of Cross-Cutting Relationships.

Earth's Inner Core Contradiction

It is widely accepted that the Earth's inner core formed about a billion years ago when a solid, super-hot iron nugget spontaneously began to crystallize inside a 4,200-mile-wide ball of liquid metal at the planet's center.

One problem: That's not possible or, at least, has never been easily explained according to a new paper published in Earth and Planetary Science Letters from a team of scientists at Case Western Reserve University.

The research team composed of postdoctoral student Ludovic Huguet; Earth, Environmental, and Planetary Sciences Professors James Van Orman and Steven Hauck II; and Materials Science and Engineering Professor Matthew Willard refer to this enigma as the "inner-core nucleation paradox." That paradox goes like this: Scientists have *known* for more than 80 years that a crystallized inner core exists. But the Case Western Reserve team asserts that this widely accepted idea neglects one critical point one that, once added, would suggest the inner core shouldn't exist.

While it is well known that a material must be at or below its freezing temperature to be solid, it turns out that making the first crystal from a liquid takes extra energy. That extra energy the nucleation barrier is the ingredient that models of Earth's deepest interior have not included until now.

To overcome the nucleation barrier and start to solidify, however, the liquid has to be cooled well below its freezing point–what scientists call "supercoiling." Alternatively, something different has to be added to the liquid metal of the core at the center of the planet that substantially reduces the amount of required supercoiling.

But the nucleation barrier for metal at the extraordinary pressures at the center of the Earth—is enormous. "Everyone, ourselves included, seemed to be missing this big problem that metals don't start crystallizing instantly unless something is there that lowers the energy barrier a lot," Hauck said.

The Case Western Reserve team contends the most obvious solutions are suspect:

- That the inner core was somehow subjected to a massive supercoiling of about 1,800 degrees Fahrenheit (1,000 Kelvin) well beyond the amount of cooling scientists have concluded. If the Earth's center had reached this temperature, nearly the entire core should be crystallizing rapidly, but the evidence indicates that it is not.

- That something happened to lower the nucleation barrier, allowing crystallization to occur at a higher temperature. Scientists do this in the lab by adding a piece of solid metal to a slightly supercoiled liquid metal, causing the now-heterogeneous material to quickly solidify.

- But it's difficult to figure on an earth-sized scale how this could have happened, how a nucleation enhancing solid could have found its way to the center of the planet to allow for the hardening (and expansion) of the inner core.

Earth's Layers

- The interior of the earth is made up of several concentric layers of which the crust, the mantle, the outer core and the inner core are significant because of their unique physical and chemical properties as display in below Figure 9.
- The crust is a silicate solid, the mantle is a viscous molten rock, the outer core is a viscous liquid, and the inner core is a dense solid.
- Mechanically, the earth's layers can be divided into lithosphere, asthenosphere, mesospheric mantle (part of the Earth's mantle below the lithosphere and the asthenosphere), outer core, and inner core.
- Chemically, Earth can be divided into the crust, upper mantle, lower mantle, outer core, and inner core.

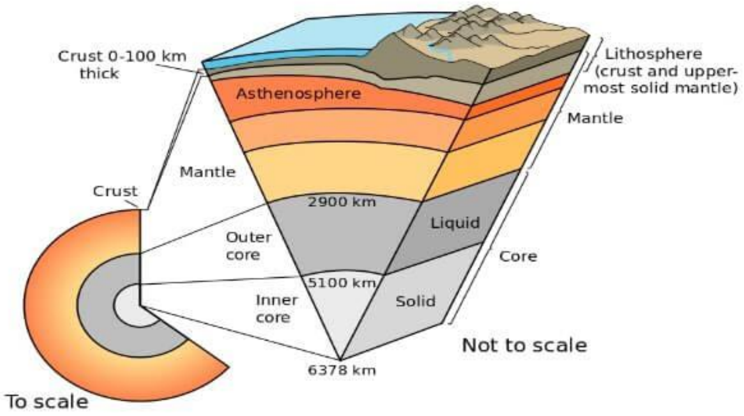

Figure 9: Represented that the Different Earth's Layers.

The Crust

1. The crust is the outermost layer of the earth making up 0.5-1.0 per cent of the earth's volume and less than 1 per cent of Earth's mass.
2. Density increases with depth, and the average density is about 2.7 g/cm^3 (average density of the earth is 5.51 g/cm^3).
3. The thickness of the crust varies in the range of range of 5-30 km in case of the oceanic crust and as 50-70 km in case of the continental crust.
4. The continental crust can be thicker than 70 km in the areas of major mountain systems. It is as much as 70-100 km thick in the Himalayan region.
5. The temperature of the crust increases with depth, reaching values typically in the range from about 200 °C to 400 °C at the boundary with the underlying mantle.
6. The temperature increases by as much as 30 °C for every kilometre in the upper part of the crust.
7. The outer covering of the crust is of sedimentary material and below that lie crystalline, igneous and metamorphic rocks which are acidic in nature.
8. The lower layer of the crust consists of basaltic and ultra-basic rocks.
9. The continents are composed of lighter silicates silica + aluminum (also called **sial**) while the oceans have the heavier silicates silica + magnesium (also called sima).
10. The continental crust is composed of lighter (felsic) sodium potassium aluminium silicate rocks, like granite.
11. The oceanic crust, on the other hand, is composed of dense (mafic) iron magnesium silicate igneous rocks, like basalt.

Chemical Composition of Earth

The layers found inside Earth are divided by composition into core, mantle, and crust or by mechanical properties into lithosphere and asthenosphere. Scientists use information from earthquakes and computer modeling to learn about Earth's interior.

The layers scientists recognize are pictured in below Figure 10:

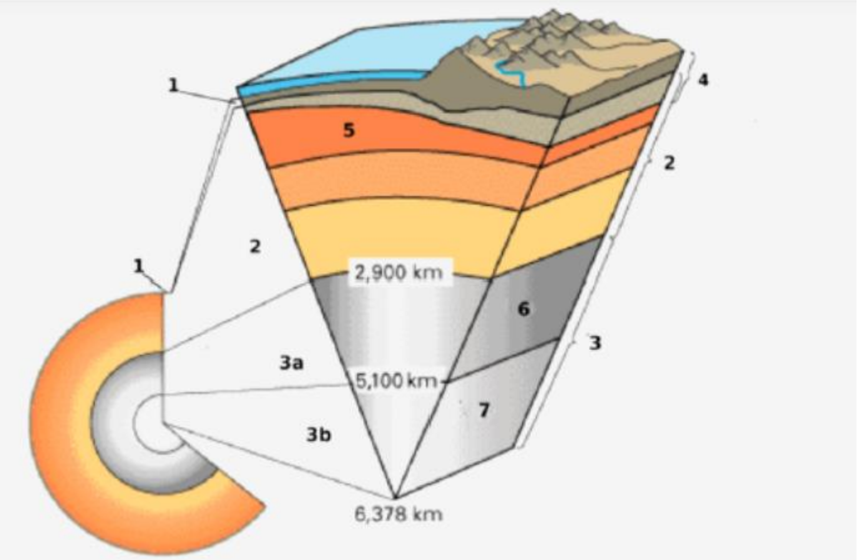

Figure 10: Represented that the Chemical Composition of Earth

According to the figure the Cross section of Earth showing the following layers: (1) crust (2) mantle (3a) outer core (3b) inner core (4) lithosphere (5) asthenosphere (6) outer core (7) inner core.

CHAPTER 2

CORE, MANTLE, AND CRUST AND DIVISIONS OF EARTH

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Three distinct layers the crust, mantle, and core make up the earth's interior. The earth's crust is its outermost layer, while its core, which is situated at a depth of 2900 kilometers, is its deepest layer. These three distinct inner layers of the planet are briefly explained in this article.

- **Crust**

The Earth's surface is the crust. Generally speaking, the crust is predominately silicon oxide and aluminum oxide. Continental crust is thicker and less dense than oceanic crust. Earth's crust varies in thickness from less than 5 km (under mid-ocean spreading ridges) to more than 70 km (beneath the highest mountain range).

- **Mantle**

The next layer down chemically is the mantle. The mantle has an ultramafic composition – it contains more iron, magnesium, less aluminum and somewhat less silicon than the crust. The mantle is roughly 2,900 km thick. In terms of volume, the mantle is the largest of earth's three chemical layers.

- **Core**

The final layer is the core, which is mostly iron and nickel. The core is about 3,500 km thick as mention in Table 1.

Table 1: Represented that the Chemical Layers of Earth.

Sr. No.	Core	Crust	Mantle
1.	Thickness: 3,500 km	Thickness: 5 to 70 km	Thickness: 2,900 km
2.	Composition: Fe & Ni	Composition: high Si, Al, & O	Composition: moderate Si, high Mg & Fe

And Table 2, provides the elemental composition of the Earth's crust.

Table 2: Represented that the he Elements of Earth's Crust

Sr. No.	Most Abundant Elements of Earth's Crust	Approximate % by weight
1.	Mg	1.5
2.	K	2.6
3.	Na	2.8
4.	Ca	3.6

5.	Fe	5.0
6.	Al	8.1
7.	Si	27.7
8.	O	46.6

Lithosphere and asthenosphere are divisions based on mechanical properties:

- The lithosphere is composed of both the crust and the portion of the upper mantle that behaves as a brittle, rigid solid.
- The asthenosphere is partially molten upper mantle material that behaves plastically and can flow.

Crust and Lithosphere

Earth’s outer surface is its crust; a cold, thin, brittle outer shell made of rock. The crust is very thin, relative to the radius of the planet. There are two very different types of crust, each with its own distinctive physical and chemical properties, which are summarized in Table 3.

Table 3: Represented that the Physical and Chemical Properties of Oceanic and Continental Crust.

Crust	Thickness	Density	Rock types	Composition
Continental	Avg. 35 km (22 mi)	2.7 g/cm3	All types	Felsic
Oceanic	5-12 km (3-8 mi)	3.0 g/cm3	Basalt and gabbro	Mafic

Oceanic crust is composed of mafic magma that erupts on the seafloor to create basalt lava flows or cools deeper down to create the intrusive igneous rock gabbro as mention in below figure.

Figure 1: Represented that the Igneous Rock.

Sediments, primarily muds and the shells of tiny sea creatures, coat the sea floor. Sediment is thickest near the shore where it comes off the continents in rivers and on wind currents.Continental crust is made up of many different types of igneous, metamorphic, and sedimentary rocks as dislay in Figure 2. The average composition is granite, which is much less dense than the mafic rocks of the oceanic crust which is display in below figure. Because it is thick and has relatively low density, continental crust rises higher on the mantle than oceanic crust, which sinks into the mantle to form basins. When filled with water, these basins form the planet's oceans.

Figure 2: Represented that the Sedimentary Rocks.

The lithosphere is the outermost mechanical layer, which behaves as a brittle, rigid solid. The lithosphere is about 100 kilometers thick. Can you find where the crust and the lithosphere are located? How are they different from each other?

The definition of the lithosphere is based on how earth materials behave, so it includes the crust and the uppermost mantle, which are both brittle. Since it is rigid and brittle, when stresses act on the lithosphere, it breaks. This is what we experience as an earthquake.

Mantle

The two most important things about the mantle are:

- It is made of solid rock,
- It is hot.

Scientists know that the mantle is made of rock based on evidence from seismic waves, heat flow, and meteorites. The properties fit the ultramafic rock peridotite, which is made of the iron- and magnesium-rich silicate minerals as like below Figure 3. Peridotite is rarely found at Earth's surface. Scientists know that the mantle is extremely hot because of the heat flowing outward from it and because of its physical properties.

Figure 3: Represented that the Magnesium-Rich Silicate Minerals.

Core

At the planet's center lies a dense metallic core. Scientists know that the core is metal because:

- The density of Earth's surface layers is much less than the overall density of the planet, as calculated from the planet's rotation. If the surface layers are less dense than average, then the interior must be denser than average. Calculations indicate that the core is about 85% iron metal with nickel metal making up much of the remaining 15%.
- Metallic meteorites are thought to be representative of the core. The 85% iron/15% nickel calculation above is also seen in metallic meteorites as display in below Figure 4.

Figure 4: Represented that the Metallic Meteorites.

If Earth's core were not metal, the planet would not have a magnetic field. Metals such as iron are magnetic, but rock, which makes up the mantle and crust, is not.

Interior Structure: Core, Mantle, Crust

The interior of Earth is not subject to direct investigation, but its properties must be indirectly deduced from the study of earthquake waves that propagate through the interior rocks as mention in below table. From an earthquake near the surface, both pressure or compression waves and transverse that is side-to-side waves move outwards in all directions. Wave energy moving into the interior, however, has its path slowly changed by refraction as the wave moves through regions of slowly changing properties. These waves reach the surface after a time that depends on the length of the path and the velocity of propagation at each point along that path. Careful analysis at seismographic stations of the time of arrival of earthquake waves over the surface of Earth yields information about the densities, temperatures, and pressures of Earth's interior. A thin crust (at its thickest only 30 kilometers deep), which contains the continental masses and the ocean floors, overlies a denser outer mantle. The uppermost layer of the mantle acts as solid material, a lithosphere no more than about 80 kilometers deep. Most of the mantle slowly flows under pressure and acts as a plastic, or malleable, asthenosphere.

In an annulus about the surface of Earth, opposite an earthquake, exists the shadow zone, in which you cannot observe pressure waves. The path of pressure waves is significantly affected by a sharp refraction that astronomers interpret as the point of transition between the mantle and an interior core that is substantially different from the outer part of the planet. The shadow zone for transverse waves, however, covers the whole of Earth opposite the earthquake source. No transverse wave energy apparently passes through the core, indicating that its physical state, in the outer regions at least, must be liquid. The innermost core, however, though at higher temperatures, is likely solid because of an even higher pressure there. As the center of Earth continues to slowly cool over time, this inner core must be slowly growing in size at the expense of the liquid outer core. Evidence also shows that this inner core is rotating faster than the rest of the planet, completing one full turn in two-thirds of a second less time than at the surface.

Table 4: Represented that the Interior Properties of Earth

Sr. No.	Property	Crust	Mantle	Core
1.	Fraction of Earth	<1% of mass	~70.0%	~30.0%
2.	State	“Broken Rock”	Plstic	(Semi-) Liquid
3.	Depth (Kilometers)	0-30	30-3030	3030-6370
4.	Density (grams/cubic centimeter)	2.7	3.5-5.5	10-12
5.	Representative Chemical Composition	SiO_2	(Fe, Mg)SiO_2	Fe, Ni
6.	Temperature (Kelvin)	300-500	500-3000	3000-5300
7.	Pressure (atmosphere)	1-1000	10^3-10^6	10^6-10^7

The Age of the Earth

The age of Earth (and by inference, the age of most other objects in the solar system) is also not directly known. But related evidence can be studied, in this case, by the technique of radioactive dating. Various elements (the parent element) are unstable and decay to produce another (the daughter) element. The time in which one-half of a parent sample decays into its daughter product is known as the half-life ($t_{1/2}$): it takes 4.5 billion years, for example, for one-half of a sample of uranium-238 (the form of uranium with 238 nuclear particles) to become lead-206. Alternatively, uranius-235 decays much quicker, with one-half of a sample becoming lead-207 in 710 million years.

After one half-life, the parent/daughter ratio is one-half; after two half-lives, the ratio is $(1/2)^2$ = 1/4, three half-lives, $(1/2)^3$ = 1/8, and so forth. Chemical analysis of a rock sample thus yields the present abundance ratios and an age for the formation of the rock. The oldest Earth rocks (which are rare due to the recycling of surface materials by plate tectonics) have an age of 3.8×10^9 years, which is a lower limit to the age of the planet and the solar system. A more correct estimate of the age of the solar system is based on materials that have been unaltered since their original formation. Applying radioactive dating to a specific class of meteorites believed to be unaltered since their formation yields consistent dates for their origin of $4.6 \pm\text{-}\ 0.1 \times 10^9$ years. This solution is adopted as the age of Earth and the solar system.

Geological Time Scale

The geological time scale is based on the the geological rock record, which includes erosion, mountain building and other geological events. Over hundreds to thousands of millions of years, continents, oceans and mountain ranges have moved vast distances both vertically and horizontally. For example, areas that were once deep oceans hundreds of millions of years ago are now mountainous desert regions.

Measuring Geological Time

The earliest geological time scales simply used the order of rocks laid down in a sedimentary rock sequence (stratum) with the oldest at the bottom. However, a more powerful tool was the fossilized remains of ancient animals and plants within the rock strata. After Charles Darwin's publication Origin of Species (Darwin himself was also a geologist) in 1859, geologists realized that particular fossils were restricted to particular layers of rock. This built up the first generalized geological time scale.

Once formations and stratigraphic sequences were mapped around the world, sequences could be matched from the faunal successions. These sequences apply from the beginning of the Cambrian period, which contains the first evidence of macro-fossils. Fossil assemblages 'fingerprint' formations, even though some species may range through several different formations.

This feature allowed William Smith (an engineer and surveyor who worked in the coal mines of England in the late 1700s) to order the fossils he started to collect in south-eastern England in 1793. He noted that different formations contained different fossils and he could map one formation from another by the differences in the fossils. As he mapped across southern England, he drew up a stratigraphic succession of rocks although they appeared in different places at different levels.

By matching similar fossils in different regions throughout the world, correlations were built up over many years. Only when radioactive isotopes were developed in the early 1900s did stratigraphic correlations become less important as igneous and metamorphic rocks could be dated for the first time.

Divisions in the geological time scales still use fossil evidence and mark major changes in the dominance of particular life forms. For example, the Devonian Period is known as the 'Age of Fishes', as fish began to flourish at this stage. However, the end of the Devonian was marked by the predominance of a different life form, plants, which in turn denotes the beginning of the Carboniferous Period. The different periods can be further subdivided (e.g. Early Cambrian, Middle Cambrian and Late Cambrian).

Major Changes on the Earth's Surface

Despite our tendency to consider Earth as static, it is actually a dynamic and ever-changing planet. Wind, water, and ice erode and shape the land. Volcanic activity and earthquakes alter the landscape in a dramatic and often violent manner. And on a much longer timescale, the movement of earth's plates slowly reconfigures oceans and continents.

Each one of these processes plays a role in the Arctic and Antarctica. We'll discuss each in general and specifically in the Polar Regions.

Erosion

Wind, water, and ice are the three agents of erosion, or the carrying away of rock, sediment, and soil. Erosion is distinguished from weathering the physical or chemical breakdown of the minerals in rock. However, weathering and erosion can happen simultaneously. Erosion is a natural process, though it is often increased by humans' use of the land. Deforestation, overgrazing, construction, and road building often expose soil and sediments and lead to increased erosion. Excessive erosion leads to loss of soil, ecosystem damage, and a buildup of sediments in water sources. Building terraces and planting trees can help reduce erosion.

Glaciers

In the Arctic and sub-Arctic, glacial erosion has shaped much of the landscape. Glaciers primarily erode through plucking and abrasion. Plucking occurs as a glacier flows over bedrock, softening and lifting blocks of rock that are brought into the ice. The intense pressure at the base of the glacier causes some of the ice to melt, forming a thin layer of subglacial water. This water flows into cracks in the bedrock. As the water refreezes, the ice acts as a lever loosening the rock by lifting it. The fractured rock is thus incorporated into the glacier's load and is carried along as the glacier slowly moves.

Abrasion happens when the glacier's ice and rock fragments act as sandpaper, crushing the rock into finely grained rock flour and smoothing the rock below. Meltwater streams of many glaciers are grayish in color due to high amounts of rock flour. Glacial erosion is evident through the U-shaped valleys and fjords that are located throughout the Arctic and sub-Arctic regions. Glacial moraines are formed as a glacier recedes, leaving behind large piles of rock, gravel, and even boulders. Moraines may form at the foot (terminal moraine) or sides (lateral moraine) of the glacier or in the middle of two merging glaciers (medial moraine).

Coastal erosion has become a major issue in recent years in the Arctic, with Alaska's North Slope losing as much as 30 meters (100 feet) per year! Climate change is thought to be the underlying cause. As the climate warms and sea ice melts, more of the sun's energy is absorbed by ocean water. As this heat is transferred to the land, the permafrost (frozen soil) thaws, making the coast vulnerable to erosion from wave action and storms (which are more frequent due to warmer temperatures and open water).

Wind

In Antarctica, katabatic winds play a large role in erosion. This type of wind occurs when high-density cold air builds up at high elevations (on the ice sheets, for example) and moves downhill under the force of gravity. The winds in Antarctica carry small grains of sand that scour and erode the exposed rocks, resulting in unusual shapes and formations. These oddly shaped, eroded rocks are called ventrifacts.

Plate Tectonics

The theory of plate tectonics describes the motions of earth's *lithosphere*, or outermost layer of hard, solid rock, over geologic time. Plate tectonics provides scientists with a great deal of information about the polar region's past. Earth's lithosphere is broken into seven major and many minor tectonic plates. These plates move in relation to each other, slowly changing the location of earth's continents and oceans.

Geological evidence from Antarctica supports the theory that North America and Antarctica were connected approximately one billion years ago in the global supercontinent Rodinia. The continents eventually broke apart, merging again approximately 200 million years ago in the supercontinent Pangaea. Fossil evidence from this time period confirms that Antarctica was connected to Australia and South America and much warmer than it is today.

The movement of the tectonic plates also means that they are associated with much of the world's volcanic and seismic activity.

Volcanoes

A volcano is simply an area where magma, or molten rock, from the earth's mantle reaches the earth's surface, becoming lava. Most volcanoes occur at plate boundaries, where two plates are moving away (diverging) or together (converging). A few volcanoes like the Hawaiian Islands form from a *hot spot*, or a weak spot in earth's crust, where magma forces its way to the surface.

Volcanic eruptions may be explosive (violent) or effusive (passive), depending on the lava chemistry (amounts of silica and dissolved gases). Silica is a mineral found in nature as sand or quartz. High levels of silica mean very viscous (thick) lava, and low levels mean more fluid lava. Dissolved gases build up inside the volcano, much like a can of soda or other carbonated beverage. The higher the level of gas, the more pressure that builds – and the more violent an explosion. The combination of silica and dissolved gas levels determines the type of eruption and shape of the volcano.Volcanoes are classified into four types, based on their lava chemistry and shape, which explain below:

- **Shield Volcano**:

A shield volcano has low levels of dissolved gas and silica in its magma. Its eruptions are effusive, and the very fluid lava moves quickly away from the vent, forming a gently sloping volcano. Mauna Loa in Hawaii is an example given in Figure 5 below.

Figure 5: Represented that the Shield Volcano.

- **Cinder Cone Volcano**:

A cinder cone volcano has low silica levels and high levels of dissolved gas, resulting in fluid lava that erupts explosively as a result of the immense pressure built in the magma chamber. A cinder cone volcano erupts by shooting fountains of fiery lava high in the air, which cools and forms a steep-sided conical structure. Lava Butte in Oregon is an example mention in Figure 6 below.

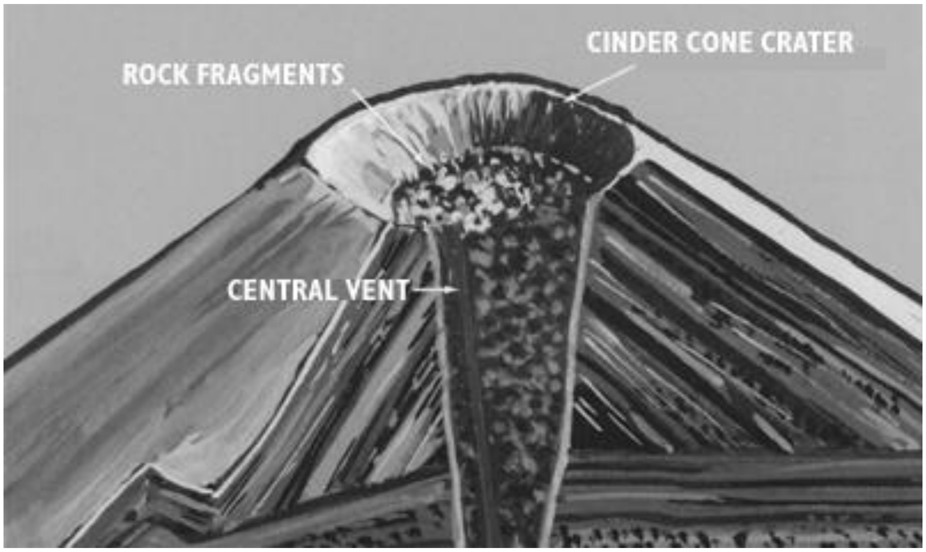

Figure 6: Represented that the Cinder Cone Volcano.

- **Lava Dome Volcano**:

A lava dome volcano has high silica levels and low dissolved gases in its magma which is display in Figure 7. This results in effusive, viscous lava that forms a rounded, steep-sided mound. Lava domes are often created after an explosive eruption, which released much of the dissolved gas in the magma as mention in below figure. The lava slowly continues to flow out of the volcano, forming a rounded, steep-sided mound. Since the 1981 eruption of Mt. St. Helens, a lava dome has been forming inside the crater of the volcano.

Figure 7: Represented that theLava Dome Volcano

- **Composite Volcano**:

A composite volcano has high levels of dissolved gas and silica and erupts explosively as mention in below Figure 8. Composite volcanoes often resemble steep-sided mountains before erupting. During violent eruptions, it can seem as if the whole top of the mountain has been blown off. Eruptions often include pyroclastic material (ash and lava fragments), leaving the volcano to collapse inward and form a crater. Mt. St. Helens and Mt. Rainier in Washington are examples.

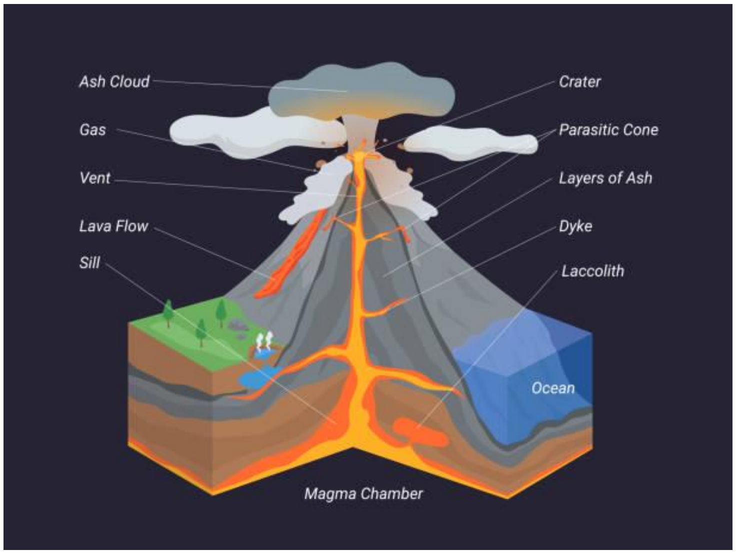

Figure 8: Represented that theComposite Volcano

Holocene and the Emergence of Humans

The Holocene Epoch is the current period of geologic time. Another term that is sometimes used is the Anthropogenic Epoch, because its primary characteristic is the global changes caused by human activity. This term can be misleading, though; modern humans were already well established long before the epoch began. The Holocene Epoch began 12,000 to 11,500 years ago at the close of the Paleolithic Ice Age and continues through today.

As Earth entered a warming trend, the glaciers of the late Paleolithic retreated. Tundra gave way to forest. As the climate changed, the very large mammals that had adapted to extreme cold, like mammoth and wooly rhinoceros, became extinct. Humans, once dependent on these “mega mammals” for much of their food, switched to smaller game and increased their gathering of plant materials to supplement their diet.

Evidence indicates that about 10,800 years ago, the climate underwent a sharp cold turn lasting for several years. The glaciers did not return, but game and plant materials would have been scarce. As temperatures began to rebound, human population began to increase and we began inventing the processes that would change the planet forever.

Agriculture Takes Root

Agriculture is one of the primary ways in which human activity has impacted the planet. By 8000 B.C., the cultivation of wheat, barley and other plants had spread from its origins in the Fertile Crescent through much of the Indo/European world. Domestication of sheep, goats and cattle began at about the same time. In Central and South America, the most commonly domesticated plants were maize, bottle gourds, squash and beans. Farming seems to have gotten a later start in Asia. Current evidence suggests that it may have been introduced to China by trade with Indo/European tribes, although it appears to have been common by the time of the start of the Shang Dynasty in about 1675 B.C.

Until the advent of agriculture and urbanization, the human population was largely limited by the same factors that limit other living organisms. Limiting factors in the environment, such as availability of food, water and shelter, evolutionary relationships like predator/prey ratios or presence of pathogens provide natural balances to populations. A population will generally expand until it reaches the carrying capacity, the maximum number of individuals an environment can support without detrimental effects, at which time it will level off. Continued expansion beyond the carrying capacity generally results in a crash (a rapid decline to a level far below the carrying capacity). If enough genetic diversity remains the population may recover; it may also become extinct.

Beginning about the first century A.D., humans began to sidestep these restraints. Agriculture had increased the number of people that could be supported by the environment; we were the first animals to increase the carrying capacity of our existing habitat. Population slowly began to rise. There were approximately 170 million people on Earth at the end of the first century; by 1800, the population was over 1 billion. The Industrial Revolution of the 19th century allowed human populations to grow exponentially. Industrialization, improved sanitation and medical care caused death rates to decline, while birth rates continued to climb in most parts of the world. Science has continued to help us increase the carrying capacity of the planet, but not the size of the planet.

Holocene Extinction

Pressure from the human population has had far-reaching effects on the biodiversity of the planet. Earth has undergone at least five major mass extinction events (times when at least 60 percent of extant genera became extinct within a span of no more than a few hundred thousand years.) Most people are familiar with the last mass extinction that closed the Cretaceous Period 65 million years ago and resulted in the extinction of the dinosaurs. Many scientists believe we are in the midst of a sixth mass extinction event caused by ourselves. Based on population numbers required to maintain genetic viability; it is estimated that as many as 30 percent of plant and animal species may become extinct within the next 100 years. Habitat destruction is the leading cause of species extinction today.

We have also had significant impacts on the geophysical characteristics of Earth. Monoculture has affected the composition and fertility of the soil in most arable parts of the world. This effect has been ameliorated by use of chemical fertilizers, but has not been eliminated. Depletion of aquifers has reduced the availability of free fresh water.

We base our division of geologic time on evidence of changes in the life forms present on Earth in different times. In the past, global climate change has often been synchronous with mass extinction. Although there is some controversy about whether humans are part of the cause for the current global warming trend, there is no doubt that Earth is experiencing climate change. We may be nearing the end of the Holocene Epoch.

CHAPTER 3

EARTH’S LAYERS

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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 kilometers 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 i.e. 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 center 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 means 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 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.

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 meters (2,750 feet), while the average depth of oceanic crust is 3,790 meters (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.

During the late 20th and early 21st 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 as display in Figure 1. 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.

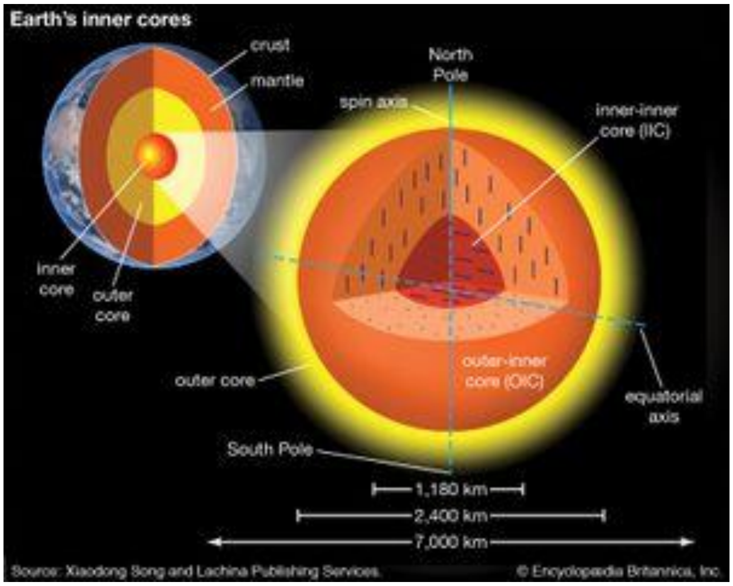

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Figure 1: Represented that the Core Properties of Earth.

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 behaviours 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.

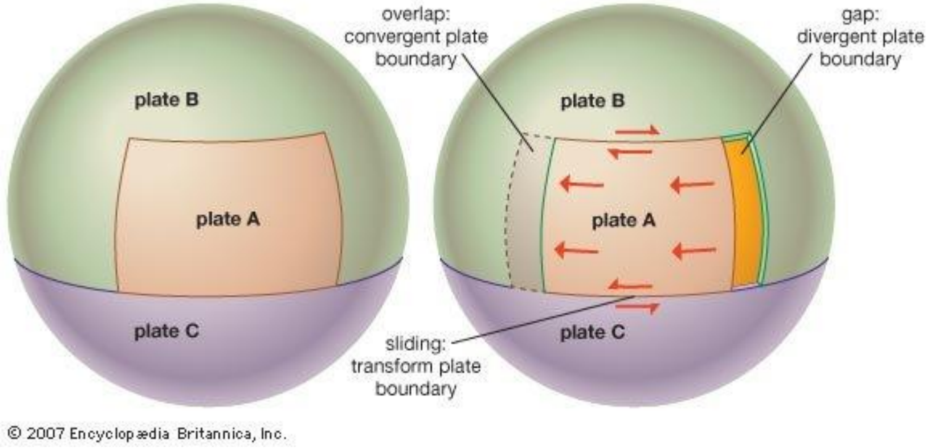

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Figure 2: Represented that the Earth's Boundaries.

In a simplified example of plate as mention in above figure; 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.

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 drift. Consequently, diverging plate boundaries, even if they originate within continents, eventually come to lie in ocean basins of their own making.

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 center important evidence in favors 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.

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 sub ducted 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 sub duct, 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).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.

Where two oceanic plates meet, the older, denser plate is preferentially sub-ducted 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 sub-ducted. 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 sub-ducted. 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 as mention in below figure.

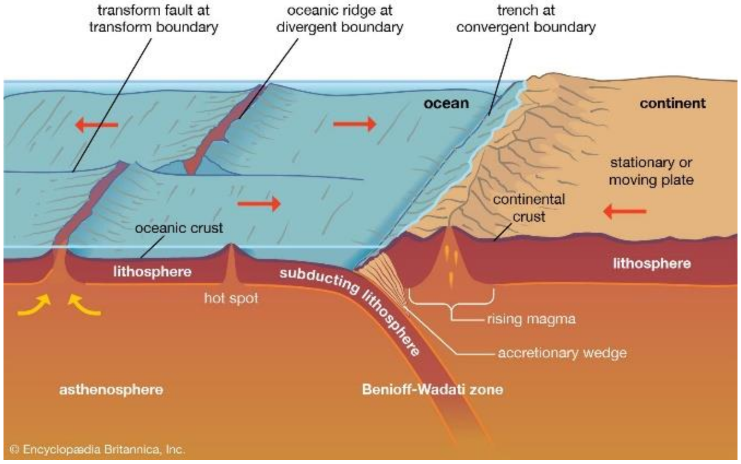

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Figure 3: Represented that the Himalayas Range.

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 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 sub horizontalthat is, they sub duct 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.

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. (*See also* metamorphic rock.) 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 blue schist is accompanied by a significant increase in density and has been recognized as an important additional factor that facilitates the subduction process.

Island Arcs

When the downward-moving slab reaches a depth of about 100 km (60 miles), it gets sufficiently warm to drive off its most volatile components, thereby stimulating partial melting of mantle in the plate above the subduction zone (known as the mantle wedge). Melting in the mantle wedge produces magma, which is predominantly basaltic in composition. This magma rises to the surface and gives birth to a line of volcanoes in the overriding plate, known as a volcanic arc, typically a few hundred kilometers behind the oceanic trench. The distance between the trench and the arc, known as the arc-trench gap, depends on the angle of subduction. Steeper subduction zones have relatively narrow arc-trench gaps. A basin may form within this region, known as a fore-arc basin, and may be filled with sediments derived from the volcanic arc or with remains of oceanic crust.

If both plates are oceanic, as in the western Pacific Ocean, the volcanoes form a curved line of islands, known as an island arc, that is parallel to the trench, as in the case of the Mariana Islands and the adjacent Mariana Trench. If one plate is continental, the volcanoes form inland, as they do in the Andes of western South America. Though the process of magma generation is similar, the ascending magma may change its composition as it rises through the thick lid of continental crust, or it may provide sufficient heat to melt the crust. In either case, the composition of the volcanic mountains formed tends to be more silicon-rich and iron- and magnesium-poor relative to the volcanic rocks produced by ocean-ocean convergence.

Back-arc Basins

Where both converging plates are oceanic, the margin of the older oceanic crust will be subducted because older oceanic crust is colder and therefore denser. As the dense slab collapses into the asthenosphere, however, it also may “roll back” ocean ward and cause extension in the overlying plate. This results in a process known as back-arc spreading, in which a basin opens up behind the island arc. The crust behind the arc becomes progressively thinner, and the decompression of the underlying mantle causes the crust to melt, initiating seafloor-spreading processes, such as melting and the production of basalt; these processes are similar to those that occur at ocean ridges as display in Figure 4. The geochemistry of the basalts produced at back-arc basins superficially resembles that of basalts produced at ocean ridges, but subtle trace element analyses can detect the influence of a nearby sub ducted slab.

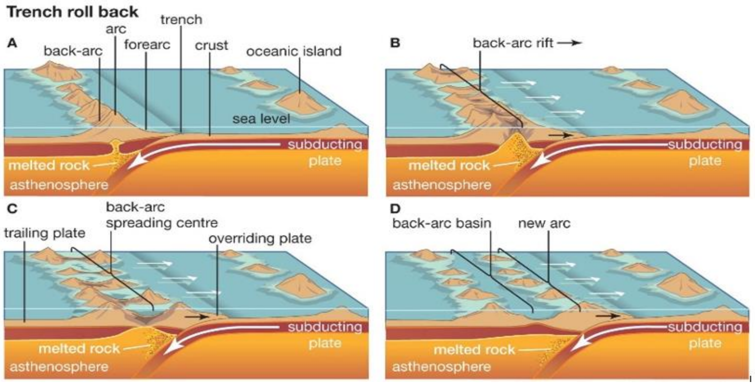

Figure 4: Represented that the Back-arc Basins.

This style of subduction predominates in the western Pacific Ocean, in which a number of back-arc basins separate several island arcs from Asia. Examples include the Mariana Islands, the Kuril Islands, and the main islands of Japan. However, if the rate of convergence increases or if anomalously thick oceanic crust possibly caused by rising mantle plume activity is conveyed into the subduction zone, the slab may flatten as display in Figure 5. Such flattening causes the back-arc basin to close, resulting in deformation, metamorphism, and even melting of the strata deposited in the basin.

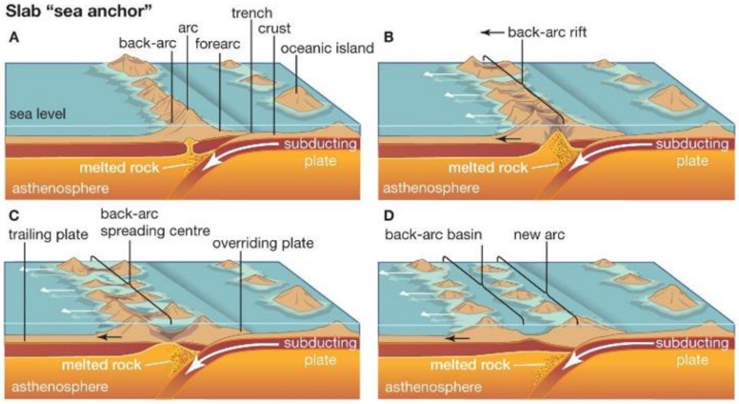

Figure 5: Represented that the Slab See Anchor.

Mountain Building

If the rate of subduction in an ocean basin exceeds the rate at which the crust is formed at oceanic ridges, a convergent margin forms as the ocean initially contracts. This process can lead to collision between the approaching continents, which eventually terminates subduction. Mountain building can occur in a number of ways at a convergent margin: mountains may rise as a consequence of the subduction process itself, by the accretion of small crustal fragments (which, along with linear island chains and oceanic ridges, are known as terranes), or by the collision of two large continents.

Many mountain belts were developed by a combination of these processes. For example, the Cordilleran mountain belt of North America which includes the Rocky Mountains as well as the Cascades, the Sierra Nevada, and other mountain ranges near the Pacific coast developed by a combination of subduction and terrane accretion. As continental collisions are usually preceded by a long history of subduction and terrane accretion, many mountain belts record all three processes. Over the past 70 million years the subduction of the Neo-Tethys Sea, a wedge-shaped body of water that was located between Gondwana and Laurasia, led to the accretion of terranes along the margins of Laurasia, followed by continental collisions beginning about 30 million years ago between Africa and Europe and between India and Asia. These collisions culminated in the formation of the Alps and the Himalayas.

Mountains by Subduction

Mountain building by subduction is classically demonstrated in the Andes Mountains of South America. Subduction results in voluminous magmatism in the mantle and crust overlying the subduction zone, and, therefore, the rocks in this region are warm and weak. Although subduction is a long-term process, the uplift that results in mountains tends to occur in discrete episodes and may reflect intervals of stronger plate convergence that squeezes the thermally weakened crust upward. For example, rapid uplift of the Andes approximately 25 million years ago is evidenced by a reversal in the flow of the Amazon River from its ancestral path toward the Pacific Ocean to its modern path, which empties into the Atlantic Ocean.

In addition, models have indicated that the episodic opening and closing of back-arc basins have been the major factors in mountain-building processes, which have influenced the plate-tectonic evolution of the western Pacific for at least the past 500 million years.

Mountains by Terrane Accretion

As the ocean contracts by subduction, elevated regions within the ocean basin terranes are transported toward the subduction zone, where they are scraped off the descending plate and added accreted to the continental margin. Since the late Devonian and early Carboniferous periods, some 360 million years ago, subduction beneath the western margin of North America has resulted in several collisions with terranes. The piecemeal addition of these accreted terranes has added an average of 600 km (400 miles) in width along the western margin of the North American continent, and the collisions have resulted in important pulses of mountain building.

During these accretionary events, small sections of the oceanic crust may break away from the subducting slab as it descends. Instead of being subducted, these slices are thrust over the overriding plate and are said to be abducted. Where this occurs, rare slices of ocean crust, known as ophiolites, are preserved on land. They provide a valuable natural laboratory for studying the composition and character of the oceanic crust and the mechanisms of their emplacement and preservation on land. A classic example is the Coast Range ophiolite of California, which is one of the most extensive ophiolite terranes in North America. These ophiolite deposits run from the Klamath Mountains in northern California southward to the Diablo Range in central California. This oceanic crust likely formed during the middle of the Jurassic Period, roughly 170 million years ago, in an extensional regime within either a back-arc or a forearc basin. In the late Mesozoic, it was accreted to the western North American continental margin.

Because preservation of oceanic crust is rare, the recognition of ophiolite complexes is very important in tectonic analyses. Until the mid-1980s, ophiolites were thought to represent vestiges of the main oceanic tract, but geochemical analyses have clearly indicated that most ophiolites form near volcanic arcs, such as in back-arc basins characterized by subduction roll-back (the collapse of the subducting plate that causes the extension of the overlying plate). The recognition of ophiolite complexes is very important in tectonic analysis, because they provide insights into the generation of magmatism in oceanic domains, as well as their complex relationships with subduction processes.

Mountains by Continental Collision

Continental collision involves the forced convergence of two buoyant plate margins that results in neither continent being subducted to any appreciable extent. A complex sequence of events ensues that compels one continent to override the other. These processes result in crustal thickening and intense deformation that forces the crust skyward to form huge mountains with crustal roots that extend as deep as 80 km (about 50 miles) relative to Earth’s surface, in accordance with the principles of isostasy.

The subducted slab still has a tendency to sink and may become detached and founder (submerge) into the mantle. The crustal root undergoes metamorphic reactions that result in a significant increase in density and may cause the root to also founder into the mantle. Both processes result in a significant injection of heat from the compensatory upwelling of asthenosphere, which is an important contribution to the rise of the mountains.Continental collisions produce lofty landlocked mountain ranges such as the Himalayas. Much later, after these ranges have been largely leveled by erosion, it is possible that the original contact, or suture, may be exposed.

The balance between creation and destruction on a global scale is demonstrated by the expansion of the Atlantic Ocean by seafloor spreading over the past 200 million years, compensated by the contraction of the Pacific Ocean, and the consumption of an entire ocean between India and Asia (the Tethys Sea). The northward migration of India led to collision with Asia some 40 million years ago. Since that time India has advanced a further 2,000 km (1,250 miles) beneath Asia, pushing up the Himalayas and forming the Plateau of Tibet. Pinned against stable Siberia, China and Indochina were pushed sideways, resulting in strong seismic activity thousands of kilometers from the site of the continental collision.

Transform Faults

Along the third type of plate boundary, two plates move laterally and pass each other along giant fractures in Earth’s crust. Transform faults are so named because they are linked to other types of plate boundaries. The majority of transform faults link the offset segments of oceanic ridges. However, transform faults also occur between plate margins with continental crust—for example, the San Andreas Fault in California and the North Anatolian fault system in Turkey. These boundaries are conservative because plate interaction occurs without creating or destroying crust. Because the only motion along these faults is the sliding of plates past each other, the horizontal direction along the fault surface must parallel the direction of plate motion. The fault surfaces are rarely smooth, and pressure may build up when the plates on either side temporarily lock. This buildup of stress may be suddenly released in the form of an earthquake.

Many transform faults in the Atlantic Ocean are the continuation of major faults in adjacent continents, which suggests that the orientation of these faults might be inherited from preexisting weaknesses in continental crust during the earliest stages of the development of oceanic crust. On the other hand, transform faults may themselves be reactivated, and recent geodynamic models suggest that they are favorable environments for the initiation of subduction zones.

Continental Drift Theory

According to the Continental Drift Theory, part of the crust are capable of horizontal movement round the globe causing the continents to slowly change their positions in relation to one another.The fact that South America is a mirror image of Africa is presented as a proof of the continental drift theory see video below for an animation showing the migration of both of these continents.

For hundreds of millions of years, all the land of Earth was joined together in one large mass or super continent. Scientists call it Pangaea (meaning “all lands” in Greek). Then about 200 million years ago the land began to drift apart. It broke into two pieces, and scientists have called the continent in the north Laurasia and the continent in the south Gondwanaland (named by Eduard Suess, an Austrian geologist).The two large continents continued to break apart into the smaller continents that exist today. Scientists call this movement ‘continental drift’ which is shown in Figure 6.

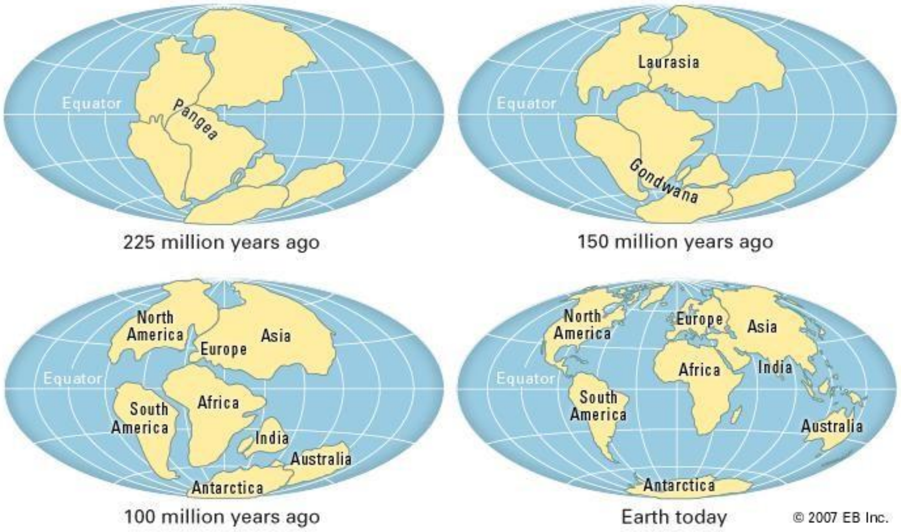

Figure 6: Represented that the Evolution of the Earth.

According to Wegener, the drift was in two directions:

- Towards the equator 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.
- 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.
- The evidences in support of the continental drift theory:

Jigsaw Fit

The similarity in outline of the coastlines of eastern South America and West Africa had been noted for some time. The best fit is obtained if the coastlines are matched at a depth of 1,000 meters below current sea level. As display in Figure 7 below:

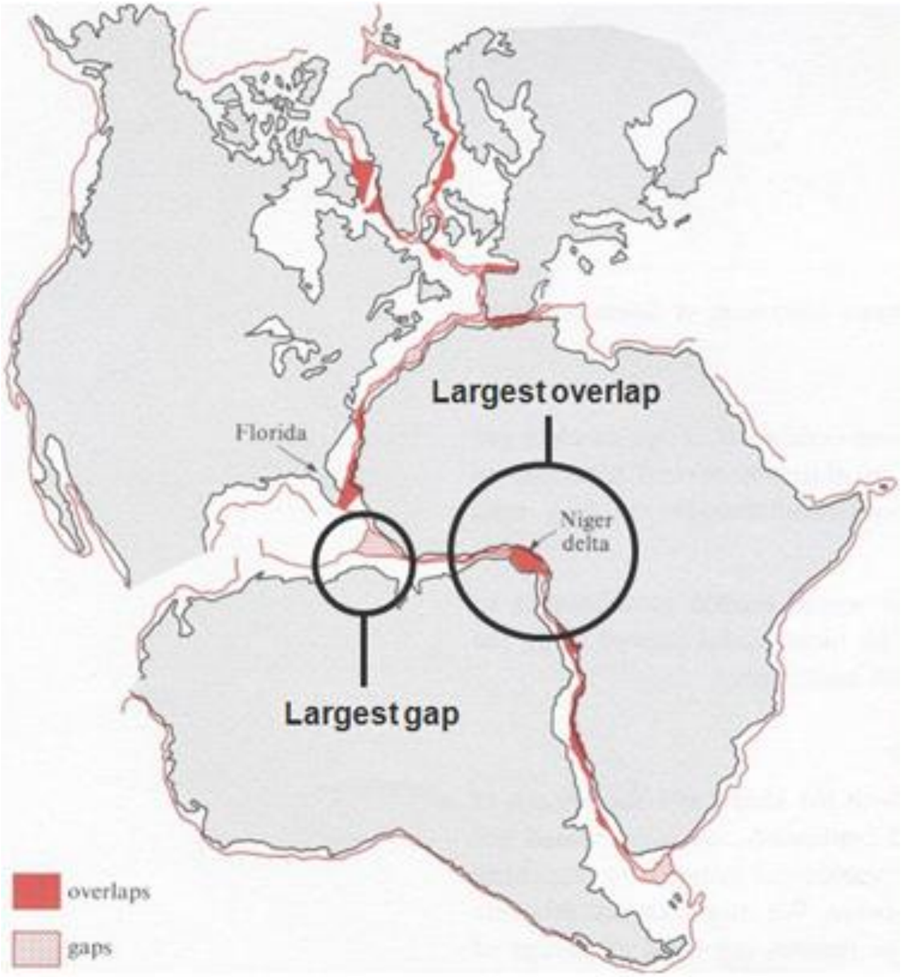

Figure 7: Represented that the Jigsaw Fit.

Geological Fit

When the geology of eastern South America and West Africa was mapped it revealed that ancient rock outcrops over 2,000 million years old were continuous from one continent to the other as mention in Figure 7.

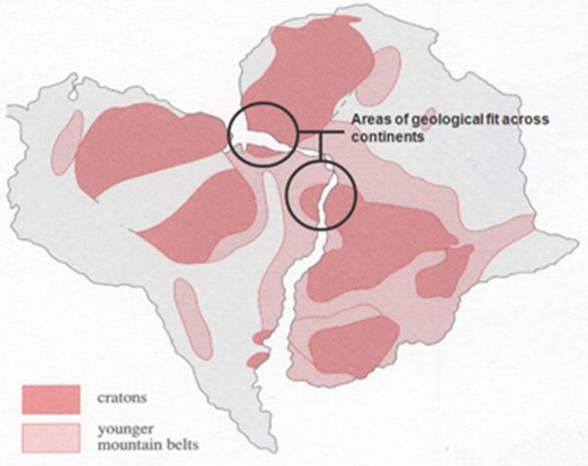

Figure 8: Represented that the Geological Fit.

Tectonic Fit

- Fragments of an old fold mountain belt between 450 and 400 million years ago are found on widely separated continents today.
- Pieces of the Caledonian fold mountain belt are found in Greenland, Canada, Ireland, England, Scotland and Scandinavia. When these land masses are re-assembled the mountain, belt forms a continuous linear features as display in Figure 9.

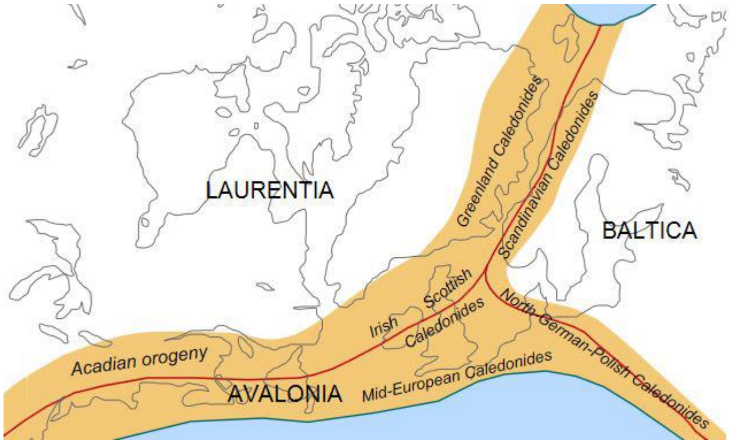

Figure 9; Represented that the Tectonic Fit on Earth.

Glacial Deposits

- Today, glacial deposits formed during the Permo-Carboniferous glaciation (about 300 million years ago) are found in Antarctica, Africa, South America, India and Australia.
- If the continents haven’t moved, then this would suggest an ice sheet extended from the South Pole to the equator at this time – which is unlikely as the UK at this time was also close to the equator and has extensive coal and limestone deposits.
- If the continents of the southern hemisphere are re-assembled near the South Pole, then the Permo-Carboniferous ice sheet assumes a much more reasonable size

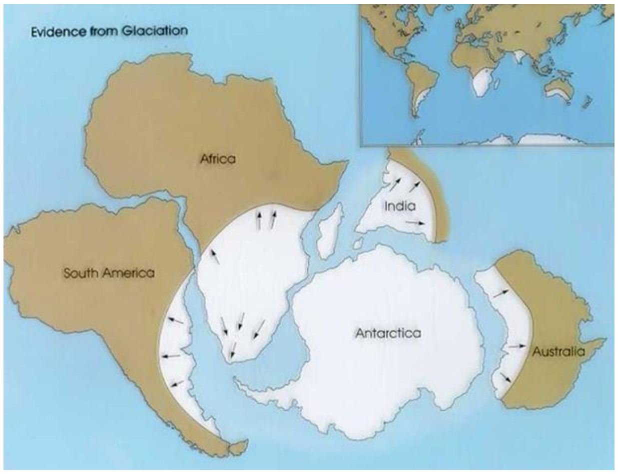

Figure 10: Represented that theGlacial Deposits.

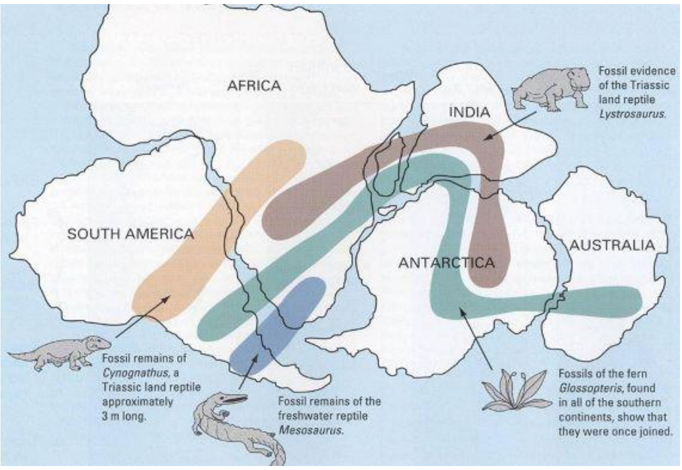

Figure 11: Represented that theFossil Evidence on the Earth.

Fossil Evidence

There are many examples of fossils found on separate continents and nowhere else, suggesting the continents were once joined which is shown in Figure 11. If Continental Drift had not occurred, the alternative explanations would be:

- The species evolved independently on separate continents contradicting Darwin’s theory of evolution.
- They swam to the other continent/s in breeding pairs to establish a second population.

CHAPTER 4

CONTINENTAL COLLISION AND FORMATION OF HIMALAYA

The Himalayan mountain range and Tibetan plateau have formed as a result of the collision between the Indian Plate and Eurasian Plate which began 50 million years ago and continues today. 225 million years ago (Ma) India was a large island situated off the Australian coast and separated from Asia by the Tethys Ocean. The supercontinent Pangea began to break up 200 Ma and India started a northward drift towards Asia. 80 Ma India was 6,400 km south of the Asian continent but moving towards it at a rate of between 9 and 16 cm per year. At this time Tethys Ocean floor would have been subduction northwards beneath Asia and the plate margin would have been a Convergent oceanic-continental one just like the Andes today.

As seen in the animation above not all of the Tethys Ocean floor was completely sub ducted; most of the thick sediments on the Indian margin of the ocean were scraped off and accreted onto the Eurasian continent in what is known as an accretionary wedge (link to glossary). These scraped-off sediments are what now form the Himalayan mountain range. From about 50-40 Ma the rate of northward drift of the Indian continental plate slowed to around 4-6 cm per year. This slowdown is interpreted to mark the beginning of the collision between the Eurasian and Indian continental plates, the closing of the former Tethys Ocean, and the initiation of Himalayan uplift.

The Eurasian plate was partly crumpled and buckled up above the Indian plate but due to their low density/high buoyancy neither continental plate could be sub-ducted. This caused the continental crust to thicken due to folding and faulting by compressional forces pushing up the Himalaya and the Tibetan Plateau. The continental crust here is twice the average thickness at around 75 km. The thickening of the continental crust marked the end of volcanic activity in the region as any magma moving upwards would solidify before it could reach the surface.

The Himalayas are still rising by more than 1.00 cm per year as India continues to move northwards into Asia, which explains the occurrence of shallow focus earthquakes in the region today. However the forces of weathering and erosion are lowering the Himalayas at about the same rate. The Himalayas and Tibetan plateau trend east-west and extend for 2,900 km, reaching the maximum elevation of 8,848 metres (Mount Everest – the highest point on Earth).

Mantle

The mantle is the 1,802 miles (2,900 km) thick layer between the Earth's crust and outer core as mention in below figure. Its temperature varies from 1,832°F near the crust-mantle boundary to 6,692°F close to the mantle-core boundary. The mantle is almost entirely solid but behaves as a highly viscous fluid, although scientists predict that small portions of melt may occur near the surface and at depth. Its movement is extremely slow to be observable within a human life but becomes significant over geologic time spans.

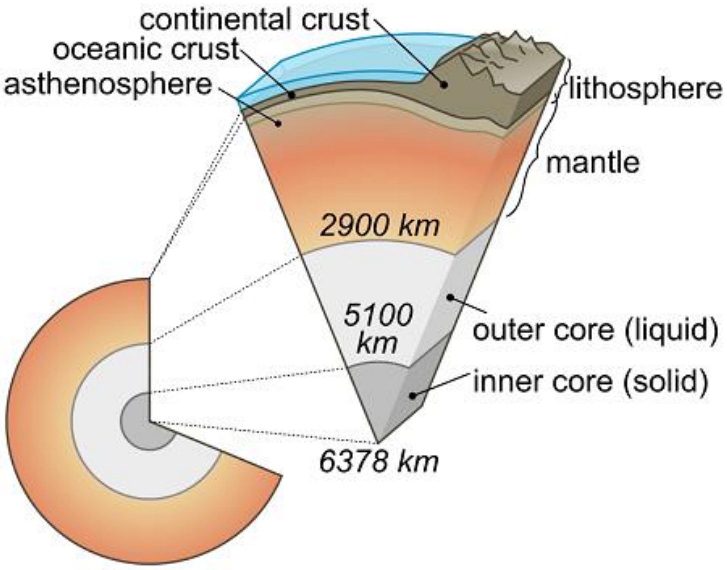

Figure 1: Represented that the Earth's Crust and Outer Core.

Most current information about the mantle comes from analyzing seismic waves produced during earthquakes and studying mantle rocks and silicate minerals (e.g., pyroxene, olivine, and garnet) extruded from volcanic eruptions. Data suggests that it has distinct layers or transitions, as follows:

- **Upper Mantle:**

It is about 255 miles thick (410 km) and is composed of the lithosphere and the asthenosphere. The lithosphere is the solid and rigid outer layer of the Earth, while the asthenosphere is a denser and weaker layer beneath the lithosphere. The asthenosphere is primarily solid but contains small amounts of semi-molten rock, making it more ductile and viscous than other mantle regions.

- **Transition Zone:**

It has an average thickness of about 155 miles (249 km), located at a depth of 250 to 400 miles (410 and 660 km) beneath the Earth's surface. Rocks in these zones are denser and do not melt or disintegrate. Several studies suggest it influences mantle convection by limiting extensive material exchange between the upper and lower mantles.

- **Lower Mantle:**

It is about 1,349 miles thick (2,171 km), much hotter and denser than the upper mantle. The intense pressure at these depths keeps it solid.

- **D double-Prime (D")**

It is a thin boundary, about 124 miles (200 km), between the mantle and the core. It has a thick assemblage of iron and silicates, while a few regions may also contain melts. Some scientists suggest that this is where deep mantle plumes originate and where subducting slabs terminate.

<u>Convection in Geology</u>

Convection in geology refers to the mass movement of a material due to density differences caused by a variation in either composition or temperature. Thermal boundary layers in the Earth's mantle cause hot material to rise and cold material to sink. Furthermore, convection is one of the methods of heat transfer that helps Earth gradually cool. Most importantly, it governs the movement of tectonic plates, which also relates to earthquakes, volcanoes, seafloor spreading, and mountain building.

Examples of Convection in the Earth

Convection also occurs in the Earth's oceans and atmosphere through thermohaline circulation and cloud formation. Thermohaline circulation involves the movement of deep-ocean currents driven by the difference in densities due to temperature and salinity. Water in the Polar Regions becomes cold enough to form sea ice, leaving behind its salt content. Consequently, the surrounding water becomes saltier and denser, making it sink. Surface water eventually replaces the sinking water, which undergoes a similar process until it becomes salty and cold enough to sink. The cycle continues and primarily drives the mechanism of how heat and nutrients move across the globe.

Mantle Convection

Mantle convection is characterized by rising hot mantle material and sinking colder material, forming convection currents. It is the primary driver of plate tectonic movement, influencing tectonic processes such as earthquakes and volcanic eruptions and contributing to the planet's gradual cooling. Unlike the typical examples of convection involving liquids or gas, mantle convection involves changing mantle material from a very viscous fluid slowly rising to the surface to a brittle solid cooling and becoming dense enough to sink back to the mantle.

The solid silicate mantle of Earth moves extremely slowly as a result of convection currents that transfer heat from the planet's core to its surface. This process is known as mantle convection. The asthenosphere and the lithosphere at the surface of the Earth together make up the upper mantle.

Heat driving the mantle convection comes from two sources—(1) the excess heat from the Earth's formation and (2) heat generated by unstable isotopes such as uranium-238, thorium-232, and potassium-40. These sources produce *internal heating*, heat from the bulk of the fluid and the base near the Earth's core. Consequently, the mantle's interior temperature is closer to the hot temperature at the bottom but further from the cold temperature near the surface, causing stronger down welling and weaker upwelling of mantle material.

Convection Currents in the Mantle

Convection currents in the mantle occur due to density differences caused by variations in temperature and composition. It consists of hotter and less dense mantle material rising while colder, denser material sinks. These convection currents govern the tectonic plate movement and influence various tectonic processes on the planet.

Although not yet fully understood, scientists have created several approaches to investigate the mechanisms of mantle convection and relate them to plate tectonics. Two of the well-studied methods are layered convection and whole-mantle convection.

Layered Convection

The layered convection model suggests that mantle convection occurs in separate layers above and below the 660-km discontinuity (lower boundary of the transition zone). The chemical analysis of basalts extruded from different tectonic settings supports this layered convection model. For example, basalts from the mid-oceanic ridges have depleted trace elements, suggesting that they come from the mantle region that has already melted. On the other hand, analysis of basalts from hot spots volcanoes indicates that they originated from areas with less melting and trace element depletion. These observations imply that at least two distinct chemical reservoirs in the mantle occur and are not homogeneously mixed up. Moreover, earthquakes recorded in the subduction zones stop at the 660-km discontinuity, suggesting that the sinking slab experiences resistance from further subduction.

Whole-Mantle Convection

Whole-mantle convection proposes that convection involves the entire mantle, except for some regions that may be too viscous to move. Modern seismic tomography a technique used to produce subsurface images of Earth supports this model. Results showed that most descending plates penetrate the 660-km discontinuity and continue to sink. It supports computer models showing the difficulty of maintaining an impermeable boundary at the 660-km discontinuity or any region in the mantle. Moreover, models show that any difference between the upper and lower mantle would eventually disappear in a few hundred million years as long as tectonic slabs continue to penetrate the 660-km boundary.

Earthquake

An earthquake is what happens when two blocks of the earth suddenly slip past one another. The surface where they slip is called the fault or fault plane. The location below the earth’s surface where the earthquake starts is called the hypocenter, and the location directly above it on the surface of the earth is called the epicenter.

Sometimes an earthquake has foreshocks. These are smaller earthquakes that happen in the same place as the larger earthquake that follows. Scientists can’t tell that an earthquake is a foreshock until the larger earthquake happens. The largest, main earthquake is called the mainshock. Mainshocks always have aftershocks that follow. These are smaller earthquakes that occur afterwards in the same place as the mainshock. Depending on the size of the mainshock, aftershocks can continue for weeks, months, and even years after the mainshock.

Causes Earthquakes

The earth has four major layers: the inner core, outer core, mantle and crust. The crust and the top of the mantle make up a thin skin on the surface of our planet. But this skin is not all in one piece it is made up of many pieces like a puzzle covering the surface of the earth. Not only that, but these puzzle pieces keep slowly moving around, sliding past one another and bumping into each other. We call these puzzle pieces tectonic plates, and the edges of the plates are called the plate boundaries. The plate boundaries are made up of many faults, and most of the earthquakes around the world occur on these faults. Since the edges of the plates are rough, they get stuck while the rest of the plate keeps moving. Finally, when the plate has moved far enough, the edges unstick on one of the faults and there is an earthquake. Earthquakes happen every day all over the world, along both tectonic plate edges and interiors. Earthquakes occur along faults, which are fractures between blocks of rock that allow the blocks to move relative to one another. Faults are caused by the bumping and sliding that plates do and are more common near the edges of the plates.

Plates, Motion, Faults, Energy Release

The Earth's crust (the outer layer of the planet) is made up of several pieces called tectonic plates and most earthquakes occur along their edges. The plates under the oceans are called oceanic plates. Plates that are not under the ocean are continental plates**.** The plates are moved around by the motion of a deeper part of the earth (the mantle) that lies underneath the crust, and by the weight of oceanic plates that pulls them down below oceanic plates. These plates are always moving apart, bumping, or sliding past each other at about the same speed that your fingernails grow. Earthquakes usually occur where two plates are running into each other or sliding past each other.

Earthquakes Can Happen Along Interpolate Faults

Earthquakes can occur along faults far from the edges of plates. Although these earthquakes are much less common, they are due to the same forces that cause earthquakes along plate boundaries.

Types of Faults

Faults are defined by the kind of motion that happens where they are. Normal faults show cracks where one block of rock is sliding down and away from another block of rock. These faults usually occur in areas where the crust is very slowly stretching or where two plates are pulling away from each other. A normal fault is defined by the hanging wall (a term that comes from mining) moving down relative to the footwall (where the miner would stand), which is moving up.

- **Normal Fault**

The "footwall" is on the "upthrown" side of the fault, moving upwards. The "hanging wall" is on the "downthrown" side of the fault, moving downwards.

- **Reverse Faults**

Reverse faults are formed where the Earth’s crust is under compression. They also occur where the crust is folding up because it's being compressed by another plate pushing against it. At these faults, one block of rock is sliding underneath another block or one block is being pushed up over the other. A reverse fault is defined by the hanging wall moving up relative to the footwall, which is moving down.

- **Strike-slip Faults**

Strike-slip faults lie between two sides of the crust that slide past each other and are common in places like California where the Pacific Plate is moving northwest relative to the North American Plate. In a pure strike-slip fault, there is no motion up or down along the fault. The well-known San Andreas Fault is predominantly strike-slip.

- **Strike-slip Fault**

The motion shows a left-lateral strike-slip fault. No matter which side of the fault you are on, the other side is moving to the left. For a right lateral strike-slip fault (not shown), no matter which side of the fault you are on, the other side is moving to the right.

Volcanism

A volcano is an opening or rupture in the earth’s surface that allows magma (hot liquid and semi-liquid rock), volcanic ash and gases to escape. They are generally found where tectonic plates come together or separate but they can also occur in the middle of plates due to volcanic hotspots. A volcanic eruption is when lava and gas are released from a volcano—sometimes explosively. The most dangerous type of eruption is called a 'glowing avalanche' which is when freshly erupted magma flows down the sides of a volcano. They can travel quickly and reach temperatures of up to 1,200 degrees Fahrenheit. Other hazards include ash fall, and lahars (mud or debris flows). Volcanoes often cause population displacement and food shortages.

Volcanoes are ruptures in the crust of our planet Earth that allow hot gases, molten lava and some rock fragments to erupt by opening and exposing the magma inside. In this piece of article, we will be discussing how and why volcanoes erupt. Volcanism is the eruption of molten rock from inside the Earth to the surface.Volcanism occurs because of Earth’s internal heat, and is associated with tectonic processes and a part of the rock cycle.

Volcanism can both increase and decrease temperature. Volcanism can cause long term increases in average temperatures by releasing greenhouse gases, but at a very slow rate over millions of years.

By comparison, human activities that release greenhouse gases have increased Earth’s average temperature just over the last few decades. Volcanic events can also cause short term cooling by increasing the amount of airborne particles that reflect sunlight in the atmosphere. Although volcanic events have not caused the recent increase in Earth’s average temperature, eruptions have occurred throughout history and influence the Earth system in a variety of ways on various scales. Some of these ways include:

1. Affecting the reflectivity of the atmosphere by releasing airborne particles, which can result in short-term cooling of the atmosphere.
2. Airborne particles that affect air quality.
3. Releasing greenhouse gases, including carbon dioxide and water vapor, although not enough to account for current warming trends.
4. Affecting mountain building and formation of new land (distribution of continents and oceans).
5. The displacement of human populations that live near volcanoes due to the release of lava, ash, and airborne particles.

Volcanoes Eruption

It is so hot deep within the earth that some rocks slowly melt and turn into a thick flowing matter known as magma. Since it is lighter than solid rock, the magma rises and collects in magma chambers. Eventually, some magma pushes through fissures and vents on the earth’s surface. Hence, a volcanic eruption occurs, and the erupted magma is known as lava.

We need to understand the Earth’s structure to know how volcanoes erupt. At the top lies the lithosphere, the outermost layer that consists of the upper crust and mantle. The thickness of the crust ranges from 10km to 100km in mountainous locations and mainly consists of silicate rock.

The Earth’s mantle within the crust is classified into different sections depending on individual seismology. These include the upper mantle, which ranges between 8-35 km to 410 km; the transition zone ranges from 400 to 660 km; the lower mantle lies between 660 – 2891 km.The conditions change dramatically from the crust to the mantle location. The pressures rise drastically and temperatures rise up to 1000 ^{o}C. This viscous and molten rock gets collected into large chambers within the Earth’s crust.

Since magma is lighter than surrounding rock, it floats up towards the surface and seeks out cracks and weakness in the mantle. It finally explodes from the peak point of a volcano after reaching the surface. When it is under the surface, the melted rock is known as magma and erupts as ash when comes up.

Rocks, lava and ash are built across the volcanic vent with every eruption. The nature of the eruption mainly depends on the viscosity of the magma. The lava travels far and generates broad shield volcanoes when it flows easily. When it is too thick, it makes a familiar cone volcano shape. If the lava is extremely thick, it can build up in the volcano and explode, known as lava domes.

Causes of Volcanic Eruption

We know that the mantle of the Earth is too hot, and the temperature ranges from 1000° Celsius to 3000° Celsius. The rocks present inside melt due to high pressure and temperature. The melted substance is light in weight. This thin lava comes up to the crust since it can float easily. Since the density of the magma between the area of its creation and the crust is less than the enclosed rocks, the magma gets to the surface and bursts.The magma is composed of andesitic and rhyolitic components along with water, sulfur dioxide, and carbon dioxide in dissolved form. By forming bubbles, excess water is broken up with magma. When the magma comes closer to the surface, the level of water decreases and the gas/magma rises in the channel. When the volume of the bubbles formed is about 75%, the magma breaks into pyroclasts and bursts out. The three main causes of volcanic eruptions are:

1. The buoyancy of the magma.
2. Pressure from the extoled gases in the magma.
3. Increase in pressure on the chamber lid.

Orogeny

An event that leads to the compositional differentiation and structural deformation of the lithosphere at the margins of the convergent plate is called orogeny. It is also known as an orogenic belt. When the continental plate is crumpled and uplifted to form one or more mountain ranges then the development of the orogeny takes place. This series of geological processes are called orogenesis. During the development of orogeny, the synergic plate is formed. Orogeny is the primary mechanism through which the mountains are built on the continents. The word orogeny was derived from Greek, where oros means mountain, genesis means to create. Orogeny takes place due to the convergence of tectonic plates. This may take the form of subduction. It is the process where a continent rides forcefully over an oceanic plate to form an accretionary orogeny or continental collision where the convergence of two or more continents takes place to form a collisional orogeny.

Physiography of Orogeny

Orogenic belts are typically produced by orogeny, which are elongated regions of bordering continental cartons where the deformation occurs. The process of subduction remains continued during the young orogenic belts and these are characterized by frequent volcanic activity and earthquakes. Older orogenic belts are typically deeply eroded to show displaced and deformed strata. These are often highly metamorphosed and include vast bodies of intrusive rock called batholiths.

Orogenic belts are related to subduction zones, which consume crust, thicken lithosphere, produce earthquakes and volcanoes, and sometimes build island arcs. These island arcs could also be added to a continental margin during an accretionary orogeny. The orogeny may culminate with continental crust from the other side of subducting oceanic plates; these plates arrive at the subduction zone. This ends the subduction and transforms the accretional orogeny into a collisional orogeny. The collisional orogeny may produce extremely high mountains, as has been happening within the Himalayas for the last 65 million years.

The processes of orogeny can take tens of many years and build mountains from what were once sedimentary basins. Activity along an orogenic belt is often extremely long-lived. For example, much of the basement underlying us belongs to the Transcontinental Proterozoic Provinces, which accreted to Laurentia over the course of 200 million years within the Paleoproterozoic. The Yavapai and Mazatzal orogenies were peaks of orogenic activity during this point. An identical sequence of orogenies has taken place on the region of the West Coast of North America. It is the region where it began within the late Devonian with the Antler orogeny. It was then continued with the Sevier orogeny and Sonoma orogeny and these were culminating with the help of Laramide orogeny. The Laramide orogeny alone lasted from 75 million to 35 million years ago for about 40 million years.

The topographic height of orogenic mountains is said to be the principle of isostasy, that's, a balance of the downward gravity upon an upthrust range that is composed of sunshine. The continental crust material and the buoyant upward forces are exerted by the dense underlying mantle. Erosion of overlying strata that is present in the orogenic belts and isostatic adjustment is involved in the removal of this overlying mass of rock, which can bring deeply buried strata to the surface. The erosional process is named unroofing and therefore the resulting exposure of formerly deeply buried strata is named exhumation.

Types of Orogeny

Even though in the process of orogeny the tectonic plates are involved, there are several tectonic forces or sequence of events that occur in the formation of the orogeny. These sequence of events are the deformation of crustal, thickening of crustal, thinning of crustal, and melting of crustal. Along with these events, it includes processes such as magmatism, metamorphism, and the process of mineralization. There are two main types of orogeny, and they are:

- **Accretionary Orogens:**

These orogens are produced by the subduction of one oceanic plate under the other continental plate. This results in the formation of the accretion of island arc terranes or the continental arc magmatism to the margins of the continent.

- **Collisional Orogens:**

When the collision between the two continental blocks takes place then the subduction of one of the continental blocks over the other continental block occurs leading to the formation of the collisional orogens.

Orogenic events can be studied with the help of tectonic structural events, geographical events, and chronological events. These events can cause the following:

- It can cause structural phenomena that are related to the tectonic plates.
- In particular regions, it can affect rocks and crust.

- It will happen in a specified period of time.

Alleghanian Orogeny

The Alleghanian orogeny or Appalachian orogeny meaning is one of the geological mountain-forming events that formed the Appalachians and Alleghenies. H.P. Woodward in 1957 originally proposed the term and spelling of Alleghany orogeny. The Alleghanian orogeny occurred approximately 325 million to 260 million years ago over a minimum of five deformation events within the Carboniferous to Permian. When Africa collided with North America then orogeny was caused. At the time, these continents didn’t even exist in their current forms: North America was a part of the Euramerica super-continent, while Africa was a part of Gondwana. Super-continent Pangaea formed by this collision, which contained all major continental landmasses.

The collision provoked the orogeny: it exerted massive stress on what's today the Eastern Seaboard of North America, forming a good and high range. Evidence for the Alleghanian orogeny stretches for several many miles on the surface from Alabama to New Jersey and may be traced further to the southwest. In the north, the Alleghanian deformation extends northeast to Newly found land.

This subsequent erosion had led to the spread of the sediments to both directions to the east and to the west. The immense region is involved within the continental collision, the vast temporal length of the orogeny and hence the thickness of the pile of sediments and igneous rocks are known to possess been involved are the evidence that at the peak of the building process of the mountain, the Appalachians likely once reached these elevations that are similar to those of the Alps and the Rocky Mountains before they were eroded.

Hercynian Orogeny

The Variscan orogeny or Hercynian orogeny definition is a geologic mountain-building event that is caused by the Late Paleozoic continental collision between Euramerica and Gondwana in order to make the supercontinent of Pangaea. The name Variscan comes from the Medieval Latin name the Varisci. Eduard Suess is a professor of geology at the University of Vienna, coined the term in 1880.

Hercynian, on the opposite hand, derives from the Hercynian Forest. Both words were descriptive terms of strike directions observed by geologists within the field, variscan for southwest to northeast, Hercynian for northwest to southeast. The Hercynian direction has reflected the direction of the ancient fold belts that are cropping out throughout Germany and adjacent countries and therefore the meaning shifted from direction to the fold belt. German geologist Franz Kossmat is one of the pioneers in research on the Variscan fold belt, establishing a still valid division of the ecu Variscides in 1927.

The other direction, Variscan, for the direction of the Harz Mountains in Germany, saw a similar shift. Today, Hercynian is usually used as another name for Variscan but is somewhat less used than the latter. It's used just for European orogenies, the existing and genetically linked mountain-building phases within the Appalachians have different names.

Since the 1960s, the regional term Hercynian underwent a further meaning shift. Geologists generally began to use it to characterize late Paleozoic fold-belts and orogenic phases having an age of roughly 380 to 280 Ma. Some publications use the term Variscan for fold belts of even younger age, deviating from the meaning as a term for the North American and European orogeny associated with the Gondwana-Laurasia collision.

Pan African Orogeny

A series of major Neoproterozoic orogenic events had led to the formation of the Pan-African orogeny that is related to the formation of the supercontinents such as Gondwana and Pannotia that are about 600 million years ago. This orogeny is also referred to as the Pan-Gondwanan or Saldanian Orogeny.

The most important known systems of orogenies on Earth are Pan-African orogeny and therefore the Grenville orogeny. The sum of the continental crust formed within the Pan-African orogeny and the Grenville orogeny makes the Neoproterozoic the amount of Earth's history that has produced most continental crust.

Kennedy in 1964 has termed the word Pan-African for a tectonic-thermal event at about 500 Ma when a series of mobile belts in Africa are formed in between much older African cratons. At the time, other terms were used for similar orogenic events on other continents, such as Brasiliano that is present in South America, Adelaidean present in Australia, and Beardmore that is present in Antarctica.

When the tectonics became accepted generally, the term Pan-African was extended to all the supercontinent of Gondwana. Because the formation of Gondwana encompassed several continents and extended from the Neoproterozoic to the first Palaeozoic, Pan-African could not be considered one orogeny, but rather an orogenic cycle that included the opening and shutting off several large oceans and therefore the collisions of several continental blocks.

Furthermore, the Pan-African events exist with the Caweredomian orogeny that is present in Europe. Therefore, in Asia, the crust from these areas was probably a part of Pannotia during the Precambrian. Attempts to correlate the African Pan-African belts with the South American Brasiliano belts on the opposite side of the Atlantic have in many cases been problematic.

Cordilleran Orogeny

The Cordilleran orogeny meaning is the belt that is present in North America and is formed during the process of an orogeny that had occurred mainly in Cretaceous and Paleocene times. This belt is marked by a zone of thrust faulting and strong folding that extends from the region of Alaska to Guatemala. However, the belt is so obscured in between southern Nevada and northeastern Chihuahua, that some of the geologists doubt its continuity.

A recent study of a part of the Nevada-Chihuahua interval provides evidence that the belt is continuous, without major interruption; the complications are the results of pre-orogenic and post-orogenic tectonic events. With due in regard to these complicating factors, a structure section through the region of south-eastern Arizona and south-western New Mexico that closely resembles the sections through south-western Canada, regions near Salt Lake City, and Las Vegas in the United States, and northern Mexico.

In each region, supracrustal rocks were tectonically transported east-northeastward a distance of probably quite 100 km. Those features that vary between the regions are able to reflect the differences that are present in tectonic position within the belt, in anisotropy of preorogenic rocks, or in subsequent geologic history.

Andean Orogeny

The Andean orogeny definition is as follows, it is an ongoing process of orogeny that began within the Early Jurassic and is liable for the increase of the Andes mountains. The orogeny is driven by a reactivation of a long-lived subduction system along the western margin of South America. On a continental scale, the Cretaceous and Oligocene were periods of re-arrangements within the orogeny. Locally the small print of the character of the orogeny varies counting on the segment and therefore the period considered.

The Paleozoic Pampean, Famatinian, and Gondwanan orogenies are the immediate precursors to the later Andean orogeny.

The primary phases of Andean orogeny within the Jurassic and Early Cretaceous were characterized by extensional tectonics, rifting, the event of back-arc basins, and therefore the emplacement of huge batholiths. This development is presumed to have been linked to the subduction of the cold oceanic lithosphere.

During the mid to Late Cretaceous, the Andean orogeny changed significantly in character. Warmer and younger oceanic lithosphere is believed to have begun to be subducted beneath South America around this point.

Such quite subduction is held responsible not just for the extreme contractional deformation that different lithologies were subject to, but also the uplift and erosion that are known to have occurred from the Late Cretaceous onward. Plate tectonic reorganization since the mid-Cretaceous may additionally be linked to the opening of the South Atlantic Ocean.

Isostasy

Isostasy is a term that means equal standstill. This translates to pieces of the Earth's crust floating on the top of the Earth's mantle in an equilibrium position. It is an application of Archimede's Law of buoyancy, or the tendency of an object to float on a fluid. An example of this principle would be wooden blocks floating on water.

When a block is placed on the water, it will sink until the amount of water becomes equal to the mass of the block. As the wood is less dense than the water, part of it will float above the water. Different thicknesses of blocks will displace different amounts of water.

Isostasy Definition

As mentioned above, isostasy applies buoyancy in the Earth's crust, floating on the mantle. To explain how this works, it is first important to understand the different layers of the Earth. What are the crust and mantle, and how are they related to each other? The Earth has three distinct layers that are further divided into sub layers. The top layer is the crust is the solid outer layer where human life exists. Beneath the crust is the mantle and below the mantle is the core as mention in below Figure. 2

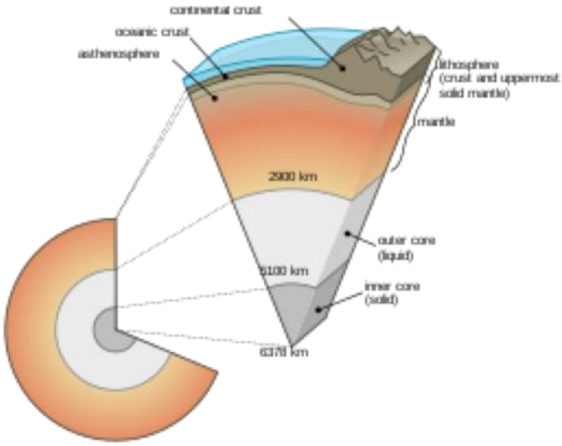

Figure 2: Represented that the Isostasy Definition.

Gravitational Field of the Earth

A gravitational field is a model used to explain the influence that a massive body extends into the space around itself, producing a force on another massive body. The earth is considered a uniform sphere radius R. So, its total mass M is assumed to be concentrated at the centre. So, intensity of a distance from the centre of the earth ($r > R$) will be, $E = GM/r_1^2$. Force of gravity a body of mass m is mg. So on the earth’s surface or near to it intensity,

$$\mathbf{E = mg/m = g.}$$

Hence, on the earth’s surface or near to it field intensity of the earth is equal to the acceleration due to gravity.

Intensity due to a point mass: In order to find the intensity at a distance r from a point mass of M a unit mass is placed at that point. Now according to Newton’s gravitational law, force acting on the unit mass, i.e., intensity at that point,

$$\mathbf{E = G\ (M \times 1)/r^2 = GM/r^2}$$

A field is something that has a magnitude and a direction at every point in space. Gravity is a good example – we know there is acceleration due to gravity of about 9.8 m/s^2 down at every point in the room. Another way of saying this is that the magnitude of the Earth’s gravitational field is 9.8 m/s^2 down at all points in room.

Gravitational field: $g = F/m$

Where, F is the force of gravity.

We can draw a field-line pattern to reflect that, near the Earth’s surface, the field is uniform. The strength of a field is reflected by the density of field lines – a uniform field has equally-spaced field lines.

Earth's Magnetic Field

Earth's magnetic field (and the surface magnetic field) is approximately a magnetic dipole, with the magnetic field S pole near the Earth's geographic north pole and the other magnetic field N pole near the Earth's geographic south pole as display in below Figure 3. This makes the compass usable for navigation. The cause of the field can be explained by dynamo theory. A magnetic field extends infinitely, though it weakens with distance from its source. The Earth's magnetic field, also called the geomagnetic field, which effectively extends several tens of thousands of kilometers into space, forms the Earth's magnetosphere. A pale magnetic study of Australian red dacite and pillow basalt has estimated the magnetic field to be at least 3.5 billion years old.

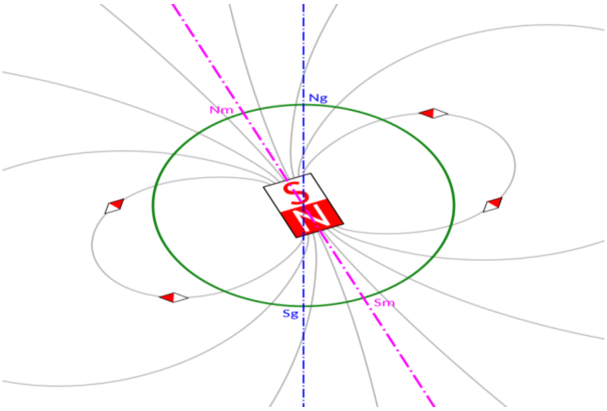

Figure 3: Represented that the Earth's Magnetic Field.

Earth is largely protected from the solar wind, a stream of energetic charged particles emanating from the Sun, by its magnetic field, which deflects most of the charged particles. Some of the charged particles from the solar wind are trapped in the Van Allen radiation belt. A smaller number of particles from the solar wind manage to travel, as though on an electromagnetic energy transmission line, to the Earth's upper atmosphere and ionosphere in the auroral zones. The only time the solar wind is observable on the Earth is when it is strong enough to produce phenomena such as the aurora and geomagnetic storms. Bright auroras strongly heat the ionosphere, causing its plasma to expand into the magnetosphere, increasing the size of the plasma geosphere, and causing escape of atmospheric matter into the solar wind. Geomagnetic storms result when the pressure of plasmas contained inside the magnetosphere is sufficiently large to inflate and thereby distort the geomagnetic field.

The solar wind is responsible for the overall shape of Earth's magnetosphere, and fluctuations in its speed, density, direction, and entrained magnetic field strongly affect Earth's local space environment. For example, the levels of ionizing radiation and radio interference can vary by factors of hundreds to thousands; and the shape and location of the magnetopause and bow shock wave upstream of it can change by several Earth radii, exposing geosynchronous satellites to the direct solar wind. These phenomena are collectively called space weather. The mechanism of atmospheric stripping is caused by gas being caught in bubbles of magnetic field, which are ripped off by solar winds. Variations in the magnetic field strength have been correlated to rainfall variation within the tropics.

Magnetic Poles and Magnetic Dipole

The positions of the magnetic poles can be defined in at least two ways.

Often, a magnetic (dip) pole is viewed as a point on the Earth's surface where the magnetic field is entirely vertical. Another way of saying this is that the inclination of the Earth's field is

90° at the North Magnetic Pole and -90° at the South Magnetic Pole. At a magnetic pole, a compass held in the horizontal plane points randomly, while otherwise it points nearly to the North Magnetic Pole or away from the South Magnetic Pole, though local deviations exist. The two poles wander independently of each other and are not at directly opposite positions on the globe. Magnetic dip pole can migrate rapidly, observation of up to 40 km per year have been made for the North Magnetic Pole.

The Earth's magnetic field can be closely approximated by the field of a magnetic dipole positioned near the center of the Earth. A dipole's orientation is defined by an axis. The two positions where the axis of the dipole that best fits the geomagnetic field intersect the Earth's surface are called the North and South geomagnetic poles. For best fit the dipole representing the geomagnetic field should be placed about 500 km off the center of the Earth. This causes the inner radiation belt to skim lower in Southern Atlantic Ocean, where the surface field is the weakest, creating what is called the South Atlantic Anomaly.

If the Earth's magnetic field were perfectly dipolar, the geomagnetic and magnetic dip poles would coincide. However, significant non-dipolar terms in an accurate description of the geomagnetic field because the position of the two pole types to be in different places.

Field Characteristics

The strength of the field at the Earth's surface ranges from less than 30 microteslas (0.3 gauss) in an area including most of South America and South Africa to over 60 microteslas (0.6 gauss) around the magnetic poles in northern Canada and south of Australia, and in part of Siberia. The average magnetic field strength in the Earth's outer core was measured to be 25 Gauss, 50 times stronger than the magnetic field at the surface.[9][10]

The field is similar to that of a bar magnet. The Earth's magnetic field is mostly caused by electric currents in the liquid outer core. The Earth's core is hotter than 1043 K, the Curie point temperature above which the orientations of spins within iron become randomized. Such randomization causes the substance to lose its magnetization.

Convection of molten iron within the outer liquid core, along with a Coriolis Effect caused by the overall planetary rotation, tends to organize these "electric currents" in rolls aligned along the north-south polar axis. When conducting fluid flows across an existing magnetic field, electric currents are induced, which in turn creates another magnetic field. When this magnetic field reinforces the original magnetic field, a dynamo is created that sustains itself. This is called the Dynamo Theory and it explains how the Earth's magnetic field is sustained.

Another feature that distinguishes the Earth magnetically from a bar magnet is its magnetosphere. At large distances from the planet, this dominates the surface magnetic field. Electric currents induced in the ionosphere also generate magnetic fields. Such a field is always generated near where the atmosphere is closest to the Sun, causing daily alterations that can deflect surface magnetic fields by as much as one degree. Typical daily variations of field strength are about 25 nanoteslas (nT) (i.e. ~ 1:2,000), with variations over a few seconds of typically around 1 nT (i.e. ~ 1:50,000).

Magnetic Field Variations

The currents in the core of the Earth that create its magnetic field started up at least 3,450 million years ago.Magnetometers detect minute deviations in the Earth's magnetic field caused by iron artifacts, kilns, some types of stone structures, and even ditches and middens in archaeological geophysics. Using magnetic instruments adapted from airborne magnetic anomaly detectors developed during World War II to detect submarines, the magnetic variations across the ocean floor have been mapped. The basalt the iron-rich, volcanic rock making up the ocean floor contains a strongly magnetic mineral (magnetite) and can locally distort compass readings. The distortion was recognized by Icelandic mariners as early as the late 18th century. More important, because the presence of magnetite gives the basalt measurable magnetic properties, these magnetic variations have provided another means to study the deep ocean floor. When newly formed rock cools, such magnetic materials record the Earth's magnetic field.

Frequently, the Earth's magnetosphere is hit by solar flares causing geomagnetic storms, provoking displays of aurorae. The short-term instability of the magnetic field is measured with the K-index.Recently, leaks have been detected in the magnetic field, which interact with the Sun's solar wind in a manner opposite to the original hypothesis. During solar storms, this could result in large-scale blackouts and disruptions in artificial satellites.

Magnetic Field Reversals

Based upon the study of lava flows of basalt throughout the world, it has been proposed that the Earth's magnetic field reverses at intervals, ranging from tens of thousands to many millions of years, with an average interval of approximately 300,000 years.[15] However, the last such event, called the Brunhes–Matuyama reversal, is observed to have occurred some 780,000 years ago.There is no clear theory as to how the geomagnetic reversals might have occurred. Some scientists have produced models for the core of the Earth wherein the magnetic field is only quasi-stable and the poles can spontaneously migrate from one orientation to the other over the course of a few hundred to a few thousand years. Other scientists propose that the geodynamo first turns itself off, either spontaneously or through some external action like a comet impact, and then restarts itself with the magnetic "North" pole pointing either North or South. External events are not likely to be routine causes of magnetic field reversals due to the lack of a correlation between the age of impact craters and the timing of reversals. Regardless of the cause, when the magnetic pole flips from one hemisphere to the other this is known as a reversal, whereas temporary dipole tilt variations that take the dipole axis across the equator and then back to the original polarity are known as excursions.

Studies of lava flows on Steens Mountain, Oregon, indicate that the magnetic field could have shifted at a rate of up to 6 degrees per day at some time in Earth's history, which significantly challenges the popular understanding of how the Earth's magnetic field works.[16]Paleomagnetic studies such as these typically consist of measurements of the remnant magnetization of igneous rock from volcanic events. Sediments laid on the ocean floor orient themselves with the local magnetic field, a signal that can be recorded as they solidify. Although deposits of igneous rock are mostly paramagnetic, they do contain traces of ferri- and antiferromagnetic materials in the form of ferrous oxides, thus giving them the ability to possess remnant magnetization. In fact, this characteristic is quite common in numerous other types of rocks and sediments found throughout the world. One of the most common of these oxides found in natural rock deposits is magnetite.

As an example of how this property of igneous rocks allows us to determine that the Earth's field has reversed in the past, consider measurements of magnetism across ocean ridges. Before magma exits the mantle through a fissure, it is at an extremely high temperature, above the Curie temperature of any ferrous oxide that it may contain. The lava begins to cool and solidify once it enters the ocean, allowing these ferrous oxides to eventually regain their magnetic properties, specifically, the ability to hold a remnant magnetization. Assuming that the only magnetic field present at these locations is that associated with the Earth itself, this solidified rock becomes magnetized in the direction of the geomagnetic field. Although the strength of the field is rather weak and the iron content of typical rock samples is small, the relatively small remnant magnetization of the samples is well within the resolution of modern magnetometers. The age and magnetization of solidified lava samples can then be measured to determine the orientation of the geomagnetic field during ancient eras.

Magnetic Field Detection

The Earth's magnetic field strength was measured by Carl Friedrich Gauss in 1835 and has been repeatedly measured since then, showing a relative decay of about 10% over the last 150 years. The Magsat satellite and later satellites have used 3-axis vector magnetometers to probe the 3-D structure of the Earth's magnetic field. The later Ørsted satellite allowed a comparison indicating a dynamic geodynamo in action that appears to be giving rise to an alternate pole under the Atlantic Ocean west of S. Africa.

Governments sometimes operate units that specialise in measurement of the Earth's magnetic field. These are geomagnetic observatories, typically part of a national Geological Survey, for example the British Geological Survey's Eskdalemuir Observatory. Such observatories can measure and forecast magnetic conditions that sometimes affect communications, electric power, and other human activities. (See magnetic storm.)

The International Real-time Magnetic Observatory Network, with over 100 interlinked geomagnetic observatories around the world has been recording the earth’s magnetic field since 1991.The military determines local geomagnetic field characteristics, in order to detect anomalies in the natural background that might be caused by a significant metallic object such as a submerged submarine. Typically, these magnetic anomaly detectors are flown in aircraft like the UK's Nimrod or towed as an instrument or an array of instruments from surface ships.

Commercially, geophysical prospecting companies also use magnetic detectors to identify naturally occurring anomalies from ore bodies, such as the Kursk Magnetic Anomaly.Animals including birds and turtles can detect the Earth's magnetic field, and use the field to navigate during migration. Cows and wild deer tend to align their bodies north-south while relaxing, but not when the animals are under high voltage power lines, leading researchers to believe magnetism is responsible.

CHAPTER 5

MINERALS AND ROCKS

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Minerals and Important Rock Forming

Rocks are composed of minerals. A mineral is a naturally occurring substance which is usually solid, crystalline, stable at room temperature and inorganic.There are almost 5000 known mineral species, yet the vast majority of rocks are formed from combinations of a few common minerals, referred to as "rock-forming minerals". The rock-forming minerals are: feldspars, quartz, amphiboles, micas, olivine, garnet, calcite, pyroxenes.

Minerals occurring within a rock in small quantities are referred to as "accessory minerals". Although accessory minerals are present in only small amounts, they may provide valuable insight into the geological history of a rock, and are often used to ascertain the age of a rock. Common accessory minerals are: zircon, monazite, apatite, titanite, tourmaline, pyrite and other opaques.

The abundance and diversity of minerals depend on the abundance in the Earth's crust of the elements of which they are composed. Eight elements make up 98% of the Earth's crust: oxygen, silicon, aluminium, iron, magnesium, calcium, sodium and potassium. The composition of minerals formed by igneous processes is directly controlled by the chemistry of the parent body. For example, a magma rich in iron and magnesium will form minerals such as olivine and pyroxene (as found in basalt). Magma richer in silicon will form more silica-rich minerals such as feldspar and quartz (as found in granite). It is unlikely that a mineral will be found in a rock with dissimilar bulk chemistry unlike its own; thus it is unlikely that andalusite ($A_{l2}SiO_5$) would be found in an aluminium-poor rock such as a quartzite.

Scientists have identified over 4,000 different minerals. A small group of these minerals make up almost 90% of the rocks of Earth's crust. These minerals are known as the common rock-forming minerals.To be considered a common rock-forming mineral, a mineral must:

A. Be one of the most abundant minerals in Earth's crust;

B. Be one of the original minerals present at the time of a crustal rock's formation;

C. Be an important mineral in determining a rock's classification.

Minerals that easily meet these criteria include: plagioclase feldspars, alkali feldspars, quartz, pyroxenes, amphiboles, micas, clays, olivine, calcite and dolomite.

Minerals of the Oceanic Crust

As an example of the influence of just a few minerals, let's consider the rocks of the oceanic crust. The oceanic crust is mainly composed of basalt and gabbro. These two rock types are made up of mainly of plagioclase feldspar and pyroxenes, with smaller amounts of olivine, micas and amphiboles. This small group of minerals makes up most of the rocks of the oceanic crust.

Minerals of the Continental Crust

As a second example, let’s consider the rocks of the continental crust. The continental crust is made up mainly of rocks with a granitic to andesitic composition. These rocks are composed mainly of alkali feldspar, quartz, and plagioclase feldspar, with smaller amounts of amphiboles and micas. This small number of minerals makes up most of the continental crust.

Minerals in the Sedimentary Cover

Both the oceanic and continental crusts are partly covered with a thin layer of sedimentary rocks and sediments. These consist mainly of clastic rocks such as sandstone, siltstone and shale, along with carbonate rocks such as dolostone and limestone. These clastic rocks are composed of mainly quartz, clay minerals, and a small amount of micas and feldspar minerals. The carbonate rocks consist primarily of calcite and dolomite. A small number of materials, composed of a small number of minerals, make up most of the sediment and sedimentary rocks that cover the continents and ocean basins.

Physical Properties of Minerals

Some minerals are easily identifiable; others can only be recognized only by the use of a petrographic microscope or by complex analytical techniques. The following criteria are used to differentiate minerals in hand sample. Most minerals cannot be identified from one particular property, and so it is advisable to use several of the diagnostic criteria outlined below. A hand lens will assist you greatly.

Color

Color is one of the most obvious characteristic of a mineral, but generally not the most useful diagnostic feature. Depending on impurities, individual mineral types may come in a vast variety of colors. For example, ruby and sapphire are differently colored types of the mineral corundum (Al_2O_3). The red color of ruby is due to the presence of the element chromium. Sapphires may come is a vast variety of colors; blue is the most familiar color, but yellow, orange, green, pink, orange and brown varieties are also known. Garnets may also come in a large range of colours, depending on their composition. They can be found with virtually any colour, although blue garnets are exceptionally rare. It is therefore advisable not to rely on colour alone to identify a mineral.

Crystal Habit

Crystal habit refers to the characteristic shape of a mineral unit (either an individual crystal or an aggregate of crystals). Crystals with well-developed faces are referred to as “euhedral”; for example garnet crystals are often euhedral. Minerals may also occur as aggregates of crystals; for example, asbestos is usually found as an aggregate of very fine fibers.

Hardness

Hardness is a measure of how resistant a mineral is to scratching. This physical property is controlled by the chemical composition and structure of the mineral. Hardness is commonly measured on the Mohs scale. This is defined by ten minerals, where each mineral can scratch those with a lower scale number as mention in below table. Diamond (hardness 10) can scratch everything below it on the Mohs scale, but cannot itself be scratched, whereas quartz (hardness 5) can scratch calcite (hardness 3) but not corundum (hardness 9).

Table 5: Represented that the Hardness Scale of Indicator Mineral.

Scale Number	Indicator Mineral	Common Objects
1	Talc	
2	Gypsum	Fingernail
3	Calcite	Copper coin
4	Fluorite	
5	Apatite	Knife blade
6	Orthoclase	Window glass
7	Quartz	Steel file
8	Topaz	
9	Corundum	
10	Diamond	

Streak

The streak of a mineral refers to the color of the mark it leaves behind after being rubbed against a piece of unglazed porcelain.

Hematite provides a good example of how streak works. While this mineral is usually black, silver or brown-red in hand sample, its streak is always a dark blood-red. Chalcopyrite is usually golden-brown in hand sample, but has a green-black streak. Streak can be used only for minerals with a Mohs hardness of 7 or less, as minerals with a hardness greater than 7 will themselves scratch the streak plate.

Cleavage

Minerals are composed of atoms, which, for each mineral, have a characteristic arrangement. Weaknesses in the chemical bonds between these atoms cause planes of weakness in the crystal structure. Cleavage is an indication of how well a mineral breaks along these planes of weakness, and may be a good diagnostic characteristic.

Cleavage may be described as “perfect”, ”good”, “distinct” or ”poor”. In transparent minerals or in thin sections viewed though a microscope, cleavage may be seen as a series of parallel lines.

The number of cleavage planes in a mineral may also aid its identification. Cleavage typically occurs in either one, two, three, four or six directions. Micas easily split along their one plane of cleavage to form thin sheets. Amphiboles exhibit two cleavage planes. Iceland spar, a variety of calcite, cleaves readily along three planes of weakness into distinctive rhombs. Galena breaks along three cleavage planes producing cubic fractions. Fluorite and diamond show cleavage in four directions.

Sphalerite exhibits cleavage in six directions. Not every mineral displays cleavage. For example, quartz does not have a weakness in its crystal structure, and therefore does not exhibit cleavage. When a quartz specimen is broken with a hammer, it displays conchoidal (shell-like) fracture.

Rock Cycle

The rock components of the crust are slowly but constantly being changed from one form to another and the processes involved are summarized in the rock cycle as mention below Figure 4. The rock cycle is driven by two forces:

A. Earth's internal heat engine, which moves material around in the core and the mantle and leads to slow but significant changes within the crust,

B. The hydrological cycle, which is the movement of water, ice, and air at the surface, and is powered by the sun.

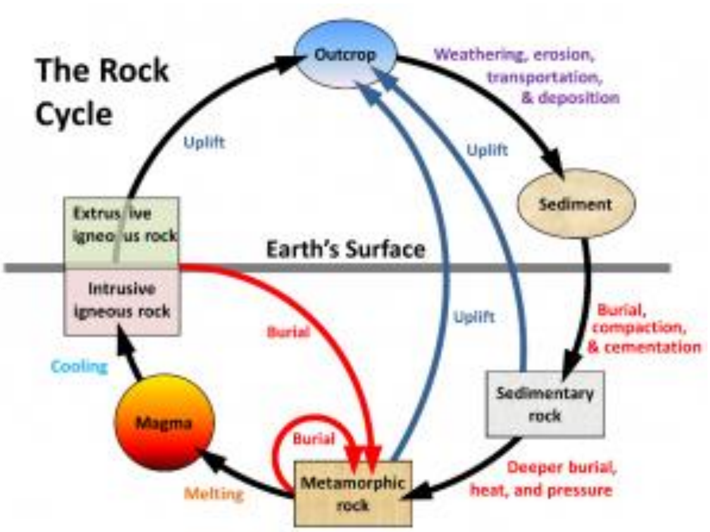

Figure 4: Display that the Rock Cycle.

The rock cycle is still active on Earth because our core is hot enough to keep the mantle moving, our atmosphere is relatively thick, and we have liquid water. On some other planets or their satellites, such as the Moon, the rock cycle is virtually dead because the core is no longer hot enough to drive mantle convection and there is no atmosphere or liquid water.There are three main types of rocks:

A. Sedimentary,

B. Igneous,

C. Metamorphic.

Each of these rocks are formed by physical changes such as melting, cooling, eroding, compacting, or deforming that are part of the rock cycle.

Igneous rocks (derived from the Latin word for fire) are formed when molten hot material cools and solidifies. Igneous rocks can also be made a couple of different ways. When they are formed inside of the earth, they are called intrusive, or plutonic, igneous rocks. If they are formed outside or on top of Earth's crust, they are called extrusive, or volcanic, igneous rocks.

Granite and diorite are examples of common intrusive rocks. They have a coarse texture with large mineral grains, indicating that they spent thousands or millions of years cooling down inside the earth, a time course that allowed large mineral crystals to grow.

Alternatively, rocks like basalt and obsidian have very small grains and a relatively fine texture. This happens because when magma erupts into lava, it cools more quickly than it would if it stayed inside the earth, giving crystals less time to form. Obsidian cools into volcanic glass so quickly when ejected that the grains are impossible to see with the naked eye.

In describing the rock cycle, we can start anywhere we like, although it's convenient to start with magma. As we'll see in more detail below, magma is rock that is hot to the point of being entirely molten. This happens at between about 800° and 1300°C, depending on the composition and the pressure, onto the surface and cool quickly (within seconds to years) forming extrusive igneous rock as display below Figure 5.

Figure 5: Represented that the Igneous Rocks.

Metamorphic Rocks

Metamorphic rocks are rocks that have been changed from their original form by immense heat or pressure. Metamorphic rocks have two classes: foliated and nonaffiliated. When a rock with flat or elongated minerals is put under immense pressure, the minerals line up in layers, creating foliation. Foliation is the aligning of elongated or platy minerals, like hornblende or mica, perpendicular to the direction of pressure that is applied. An example of this transformation can be seen with granite, an igneous rock. Granite contains long and platy minerals that are not initially aligned, but when enough pressure is added, those minerals shift to all point in the same direction while getting squeezed into flat sheets. When granite undergoes this process, like at a tectonic plate boundary, it turns into gneiss.

Nonaffiliated rocks are formed the same way, but they do not contain the minerals that tend to line up under pressure and thus do not have the layered appearance of foliated rocks. Sedimentary rocks like bituminous coal, limestone, and sandstone, given enough heat and pressure, can turn into nonfoliated metamorphic rocks like anthracite coal, marble, and quartzite. Nonfoliated rocks can also form by metamorphism, which happens when magma comes in contact with the surrounding rock. Unless they are re-eroded and moved along, sediments will eventually be buried by more sediments. At depths of hundreds of metres or more, they become compressed and cemented into sedimentary rock as display in below figure. Again through various means, largely resulting from plate-tectonic forces, different kinds of rocks are either uplifted, to be re-eroded, or buried deeper within the crust where they are heated up, squeezed, and changed into metamorphic rock as display in Figure 6**.**

Figure 6: Represented that the MetamorphicRock.

Igneous Rocks

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Extrusive igneous rocks can also have a vesicular, or "holey" texture. This happens when the ejected magma still has gases inside of it so when it cools, the gas bubbles are trapped and end up giving the rock a bubbly texture. An example of this would be pumice.

Natural Resource with its Problems

Human population is growing day-by-day. Continuous increase in population caused an increasing demand for natural resources. Due to urban expansion, electricity need and industrialization, man started utilizing natural resources at a much larger scale. Non-renewable resources are limited. They cannot be replaced easily. After some time, these resources may come to an end. It is a matter of much concern and ensures a balance between population growth and utilization of resources. This overutilization creates many problems. In some regions there are problems of water logging due to over irrigation. In some areas, there is no sufficient water for industry and agriculture. Thus, there is need for conservation of natural resources. There are many problems associated with natural resources:

Resources of Forest and it Problems

A. Use and over-exploitation.

B. Deforestation.
C. Timber extraction.
D. Mining and its effects on forest.
E. Dams and their effects on forests and tribal people.

Resources of Water and Related Problems

A. Use and overutilization of water.
B. Floods, droughts etc.
C. Conflicts over water
D. Dams and problems.

Resources of Mineral and Related Problems

A. Use and exploitation.
B. Environmental effects of extracting and using minerals.

Food Resources and Associated Problems

A. World food problems.
B. Changes caused by agriculture and over grazing.
C. Effects of modern agriculture.
D. Fertilizer-pesticide problems.
E. Water logging and salinity.

Resources of Energy and Related Problems

- Growing energy needs.

Land Resources and Related Problems

A. Land degradation.
B. Man-induced landslides.
C. Soil erosion and desertification.

Forest Resources

Forests are one of the most important natural resources and a part of biosphere since these are natural assets on this earth. Forests predominantly composed of trees, shrubs, woody vegetation etc… Approximately 1/3rd of the earth's total land area is covered by forests. Forests are important ecologically and economically. Ecologically forests are to be considered as earth's lungs because they consume CO_2 and release O_2which is required for sustaining the life on this earth. The poisonous gas CO_2 is absorbed by the trees of forests and reduces the global warming and helps to continue hydrological cycle, reduce soil erosion. Forest ecosystems are extremely good and hold a good quantity of water. Economically forests provide timber, fodder to grazing animals, firewood (conventional fuel), bamboos, rubbers, medicines, gums, resins, food items etc.

Different Uses of Forest

- **In Market as Productive use:**
- Most of the above products used for consumptive purposes are also sold as source of income for supporting the livelihoods of forest dwelling people.
- Minor forest produce (non-wood products): Fuel wood, fruit, gum, fiber, etc. Which are Collected and sold in local markets as a source of income for forest dwellers.
- Major timber extraction construction, industrial uses, paper pulp, etc. Timber extraction is done in India by the Forest Department, but illegal logging continues in many of the forests of India and the world.
- **Atmospheric Regulation:**
- Absorption of solar heat during evapo-transpiration.
- Maintaining carbon dioxide levels for plant growth.
- Maintaining the local climatic conditions.
- **Watershed Protection:**
- Reduce the rate of surface run-off of water.
- Prevent flash floods and soil erosion.
- Produces prolonged gradual run-off and thus prevent effects of drought.
- **Erosion Control:**
- Holding soil.

Forest has been known to possess huge potential for human use and they have been exploited since early times for their vast potential. Exploitation of forest has taken place to meet human demands in the following ways:

- Due to wood cutting and large scale logging for raw materials like timber, pulp wood, fuel wood etc.
- Deforestation due to road construction.
- Clearing of forest to create more agricultural lands to meet the food needs of growing population.
- Encroachment of forests leading to destruction of about 19.57 lakh hectares (2013)of forest in the country.
- About 78% of forest area is under heavy grazing.
- Mining activities leads to clearing of forests.
- Big hydroelectric projects result in large scale destruction of forest.

In India, Joint forest management has come up as innovative approach involving community participation so that the rural economy is strengthened as well as forest resources are conserved through public involvement.

Deforestation

Deforestation is the permanent destruction of indigenous forests and woodlands. The term does not include the removal of industrial forests such as plantations of gums or pines. Deforestation has resulted in the reduction of indigenous forests to four-fifths of their pre-agricultural area. Indigenous forests now cover 21% of the earth's land surface. Deforestation refers to the loss of forest cover (or) the aimless destruction of trees. The clearing of forests across the earth has been occurring on a large scale basis for many centuries. This process involves the cutting down, burning and damaging of forests. Currently 12 million hectares of forests are cleared annually and the current rate of deforestation continues, the world’s forests will vanish within the next 100 years about 80% of the original forests on the earth have already been cleared.

Major causes of Deforestation:

i. Shifting Cultivation

There are an estimated 300 million people living as shifting cultivators who practice slash and burn agriculture and are supported so clear more than 5 lakh ha of forests for shifting cultivation annually. In India, we have this practice of North-East and to some extent in Andhra Pradesh, Bihar and M.P. which contribute to nearly half of the forest clearing annually.

ii. Fuel Requirements

Increasing demands for fuel wood by the growing population in India alone has shooted up to 300-500 million tons in 2001 as compared to just 65 million tons during independence, thereby increasing the pressure on forests.

iii. Raw Materials for Industrial Use

Wood for making boxes, furniture, railway-sleepers, plywood, match boxes, pulp for paper industry etc. have exerted tremendous pressure on forests. Plywood 10 is in great demand for packing tea for Tea industry of Assam while fir tree wood is exploited greatly for packing apples in J & K.

iv. Development Projects

Massive destruction of forests occurs for various development projects like hydroelectric projects, big dams, road construction, mining etc.

v. Growing food Needs

In developing countries this is the main reason for deforestation. To meet the demands of rapidly growing population, agricultural lands and settlements are created permanently by clearing forests.

vi. Overgrazing

The poor in the tropics mainly rely on wood as a source of fuel leading to loss of tree cover and the cleared lands are turned into the grazing lands. Overgrazing by the cattle leads to further degradation of these lands.

vii. Conversion of forests and woodlands to agricultural land to feed growing numbers of people.

Major activities and threats toForests resources

i. Timber Extraction

Logging for valuable timber, such as teak and Mahogany not only involves a few large trees per hectare but about a dozen more trees since they are strongly interlocked with each other a by vines etc. Also road construction for making approach to the trees causes further damage to the forests. The steps in timber extraction are:

i. Clear felling
ii. Mechanized logging
iii. Manual logging
iv. Selective logging

ii. Mining

Mining operations for extracting minerals and fossil fuels like coal often involves vast forest areas. Mining from shallow deposits is done by surface mining while that from deep deposits is done by sub-surface mining. More than80000 ha of land of the country is presently under the stress of mining activities. Mining and its associated activities require removal of vegetation along with underlying soil mantle and overlying rock masses. This results in defacing the topography and destruction of the landscape in the area. Large scale deforestation has been reported in Mussorie and Dehradun valley due to indiscriminating mining of various minerals over a length of about 40 Km.

Dams and Other Effects on Forest and Tribal People

Forest are directly are indirectly effected by the forest. Hydro-electric dams are main cause for deforestation. About 40,000 large dams are currently obstructing Workloads Rivers. Destruction of forest occurs for constructing big dams, which alters ecological balance. In these way landslides, droughts and floods conditions may rise in area. Socio-economic problems related to tribal and native people results from big dam construction Dam construction produces a number of health hazards. Thousands of workers who build the dams attacked by the diseases like AIDS, measles, tuberculosis, syphilis etc. Dam building has resulted in wide range human rights violations. Rehabilitation policy of the government is important and typical when most of the displaced persons are tribal people. Tribal life and culture are mostly associated with forest.

Water Resources

Water resources are sources of water that are useful or potentially useful. Uses of water includeagricultural, industrial, household, recreational and environmental activities. Virtually all ofthese human uses require fresh water.

Distribution of Water on Earth:

- 97% of the water on the Earth is salt water. Only three percent is fresh water; slightly over two thirds of this is frozen in glaciers and polar ice. The remaining unfrozen freshwater is found mainly as groundwater, with only a small fraction present above ground or in the air.

Fresh water occurs mainly in two forms:

- Ground water
- Surface water

Groundwater: About 9.86% of the total fresh water resources is in the form of groundwater and it is about 35-50 times that of surface water supplied

Uses of Water

- **Domestic Use**

Water used in the houses for the purposes of drinking, bathing, washing Clothes, cooking, sanitary & other needs. The recommended value according to Indian standard specification for domestic use is 135 liters/day

- **Industrial Use**

Water is required for various industries such as cement, mining, textile, leather industries.

- **Public Use**

This includes water used for public utility purpose such as watering parks, Flushing streets, jails etc.

- **Fire Use**

Water is used in case of accidents and to prevent the fire issues.

- **Irrigation**

To grow crops which is the main sources for food

- **Other Uses**

Hydroelectric power generation requires water.

Over Utilization of Ground Water and Surface Water

Over use of groundwater has following effects.

i. Lowering of Water Table

Excessive use of ground water for drinking, irrigation and Domestic purposes has resulted in rapid depletion of ground water in various regions leading to lowering of water table & drying of wells. The reasons for shortage of water are:

- Increase in population,
- Increasing demand of water for various purposes.
- Unequal distribution of fresh water.
- Increasing pollution of water sources cause over exploitation.

ii. Ground subsidence

When ground water withdrawal is greater than its recharge rate, the sediments in the aquifer become compacted. This is called ground subsidence which may cause damage of buildings, destroy water supply systems etc.

iii. Drought:

A drought is an extended period of months or years when a region notes a deficiency in its water supply whether surface or underground water. Generally, this occurs when a region receives consistently below average precipitation. We can define drought in four main ways:

- Meteorological Drought: Related to rainfall amounts,
- Hydrological drought: determined by water levels in reservoirs,
- Agricultural drought: related to the availability of water for crops,
- Socioeconomic Drought: related to demand and supply of economic goods.

a. **Meteorological Drought:**

Meteorological drought is generally defined by comparing the rainfall in a particular place and at a particular time with the average rainfall for that Place. The definition is, therefore, specific to a particular location. Meteorological drought leads to a depletion of soil moisture and this almost always has an impact on crop production.

b. Hydrological Drought:

Hydrological drought is associated with the effect of low rainfall on water levels in rivers, reservoirs, lakes and aquifers. Hydrological droughts usually are noticed some time after meteorological droughts. First precipitation decreases and, Sometime after that, water levels in rivers and lakes drop.

c. Agricultural Drought:

Agricultural drought mainly effects food production and farming. Agricultural drought and precipitation shortages bring soil water deficits, reduced ground water or reservoir levels, and so on. Deficient topsoil moisture at planting may stop germination, leading to low plant populations.

d. Socioeconomic Drought:

Socioeconomic drought occurs when the demand for an economic good exceeds supply as a result of a weather-related shortfall in water supply. The supply of many economic goods, such as water, forage, food grains, fish, and hydroelectric power, depends on weather. Due to variability of climate, water supply is sufficient in some years but not satisfactory to meet human and environmental needs in other year.

Floods

A flood is an overflow of water that submerges land which is normally dry. The European Union (EU) Floods Directive defines a flood as a covering by water of land not normally covered by water.

Flooding may occur as an overflow of water from water bodies, such as a river or lake, in which the water overtops or breaks, resulting in some of that water escaping its usual boundaries, or it may occur due to an accumulation of rainwater on saturated ground in an area flood. Floods can also occur in rivers when the flow rate exceeds the capacity of the river channel, particularly at bends in the waterway. Floods often cause damage to homes and businesses if they are in the natural flood plains of rivers.

Conflicts over Water

Water conflict is a term describing a conflict between countries, states, or groups over an access to water resources. The United Nations recognizes that water disputes result from opposing interests of water users, public or private. A wide range of water conflicts appear throughout history, though rarely are traditional wars waged over water alone. Instead, water has historically been a source of tension and a factor in conflicts that start for other reasons. However, water conflicts arise for several reasons, including territorial disputes, a fight for resources, and strategic advantage.

These conflicts occur over both freshwater and saltwater, and between international boundaries. However, conflicts occur mostly over freshwater; because freshwater resources are necessary, yet limited, they are the center of water disputes arising out of need for potable water. As freshwater is a vital, yet unevenly distributed natural resource, its availability often impacts the living and economic conditions of a country or region. The lack of cost-effective water desalination techniques in areas like the Middle East, among other elements of water crises can put severe pressures on all water users.

According to the 1992 International Conference on Water and the Environment, Water is a vital element for human life, and any human activity relates somehow to water. Unfortunately, it is not a renewable resource and in the future it "might get worse with climate change.

Water conflicts occur because the demand for water resources and potable water extend far beyond the amount of water actually available. Elements of a water crisis may put pressures on affected parties to obtain more of a shared water resource, causing diplomatic tension or outright conflict.

CHAPTER 6

THE CAUVERY WATER DISPUTE

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Out of Indias 18 major rivers, 17 are shared between different states. In all these cases, there are intense conflicts over these resources which badly seem to resolve. The Cauvery river water is a born of contention between tamilnadu and Karnataka and the problem is almost hundred years old. Tamilnadu occupying the downstream region of the river wants water-use regulated in the upstream state Karnataka refuses to do so and claims its privacy over the river as upstream user. The river water is almost fully utilized and both the 14 states having increasing demands for agriculture and industry.

The consumption is more in Tamilnadu than Karnataka where the catchment area is rockier. On June 2, 1990, the Cavery Water dispute tribunal was set up which through an interim award directed Karnataka to ensure that 205 TMCF of water was made available in Tamilnadus mettur dam every year, till a settlement was reached. In 1991-92 due to good monsoon, there was no disputr as there was good stock of water in Mettur , but in 1995, the situation turned into a crisis due to delayed rains and an expert committee was set up to look into the matter which found there was a complex cropping pattern in Cauvery basin.

Sambra paddy in winter, Kurvai paddy in summer and some cash crops demanded intensive water, thus aggravating the water crisis. Proper selection of crop varieties, optimum use of water, better rationing and rational sharing patterns, and pricing of water are suggested as some measures to solve the problem.

Advantages of Dams and Its Problems

Today there are more than 45,000 large dams around the world, which play an important role in communities and economies that harness these water resources for their economic development. Current estimates suggest some 30-40% of irrigated land worldwide relies on dams.

Hydropower, another contender for the use of stored water, currently supplies 19% of the world’s total electric power supply and is used in over 150 countries. The world’s two most populous countries – China and India – have built around 57% of the world’s large dams.

Advantages of Dams

River valley projects with big dams have usually been considered to play a key role in the development process due to their multiple uses. India has the distinction of having the largest number of river valley projects. The tribal’s living in the area pin big hopes on these projects as they aim at providing employment and raising the standard and quality of life. The dams have tremendous potential for economic upliftment and growth. They can help in checking floods and famines, generate electricity and reduce water and power shortage, provide irrigation water to lower areas, provide drinking water in remote areas and promote navigation, fishery etc

Problems

i. Fragmentation and physical transformation of rivers.
ii. Serious impacts on riverine ecosystems.
iii. Social consequences of large dams due to displacement of people.
iv. Water logging and Stalinization of surrounding lands.
v. Dislodging animal populations, damaging their habitat and cutting off their migration routes.
vi. Fishing and travel by boat disrupted.

Large dams have had serious impacts on the lives, livelihoods, cultures and spiritual existence of indigenous and tribal peoples. They have suffered disproportionately from the negative Impacts of dams and often been excluded from sharing the benefits. In India, of the 16 to 18 million people displaced by dams, 40 to 50% were tribal people, who account for only 8% of our nation's one billion people.

Mineral Resources

A mineral is a naturally occurring substance of definite chemical composition and identifiable physical properties. An ore is a mineral or combination of minerals from which a useful substance, such as a metal, can be extracted and used to manufacture a useful product. The geological processes are caused for the formation of the minerals over millions of years ago in the earth's crust. Minerals are generally localized in occurrence and the deposits are very sporadic in distribution. Mineral resources are nonrenewable and the mineral /ore is extracted by the process of mining. Iron, aluminum, zinc, manganese and copper are important raw materials for industrial use. Important non-metal resources include coal, salt, clay, cement and silica. Stone used for building material, such as granite, marble, limestone, constitute another category of minerals. Minerals with special properties that humans value for their aesthetic and ornamental value are gems such as diamonds, emeralds and rubies. The luster of gold, silver and platinum is used for ornaments. Minerals in the form of oil, gas and coal were formed when ancient plants and animals were converted into underground fossil fuels.

Uses of Minerals

Minerals are used in a large number of ways for domestic, industrial, commercial Sectors etc.

- Generation of energy by using coal (lignite / anthracite); uranium, gold, silver, platinum, diamond are used in jewellery. Copper, aluminum etc are used as cables for transmission of power.
- Some of the minerals are used in ayurvedam as medicine. Gold is reputed to strengthen the heart muscle and increase energy and stamina.

Mining and its Process

Minerals and their ores need to be extracted from the earth's interior so that they can be used. This process is known as mining. Mining is the extraction of valuable minerals or other geological materials from the earth, from an ore body, lode, vein, (coal) seam or reef, which forms the mineralized horizon and package of economic interest to the miner. Mining operations generally progress through four stages:

i. **Prospecting:** Searching for minerals.
ii. **Exploration:** Assessing the size, shape, location,
iii. **Development:** Work of preparing access to the deposit so that the minerals can be extracted from it.
iv. **Exploitation:** Extracting the minerals from the mines.

Types of Mining

The method of mining has to be determined depending on whether the ore or mineral deposit is nearer the surface or deep within the earth. The topography of the region and the Physical nature of the ore deposit is studied. Mines are of two types:

- Surface (open cut or strip mines)
- Deep or shaft mines.

a. Surface Mining

Surface mining is used to obtain mineral ores that are close to Earth’s Surface. The soil and rocks over the ore are removed by blasting. Typically, the remaining ore is drilled or blasted so that large machines can fill trucks with the broken rocks. The trucks take the rocks to factories where the ore will be separated from the rest of the rock. Surface mining includes open-pit mining, quarrying, and strip mining.

- Open-pit mining creates a big pit from which the ore is mined. The size of the pit grows until it is no longer profitable to mine the remaining ore.
- Strip mines are similar to pit mines, but the ore is removed in large strips.
- A quarry is a type of open-pit mine that produces rocks and minerals that are used to make buildings.

b. Underground Mining

Underground mining is used for ores that are deep in Earth's surface. For deep ore deposits, it can be too expensive to remove all of the rocks above the ore. Underground mines can be very deep. The deepest gold mine in South Africa is more than 3,700 meters deep (that is more than 2 miles)! There are various methods of underground mining. These methods are more expensive than surface mining because tunnels are made in the rock so that miners and equipment can get to the ore. Underground mining is dangerous work. Fresh air and lights must also be brought in to the tunnels for the miners. Miners breathe in lots of particles and dust while they are underground. The ore is drilled, blasted, or cut away from the surrounding rock and taken out of the tunnel.

Environmental Effects

Mineral extraction and processing in mines involves a negative impact on environment. Much risk is involved in mining process because of high temperature, pressure Variations, fire hazards and lack of ventilation in mines.

1. Mining process involves removal of over burden of soil, ore extraction & transportation, crushing & grinding of ore, water treatment of ore, and storage of waste material. As a result of these activities cause air pollution, noise pollution, water pollution, loss of

habitat of wildlife, concentration of toxic substances in tailing ponds and spreading of dust.

2. People working in mines often suffer from serious respiratory system and skin diseases.
3. Mining often causes ground subsidence which results in tilting of buildings, cracks in houses, buckling of roads, bending of rail tracks etc.
4. Exploration process before a mining involves, geochemical, geophysical surveys Drilling activities which causes for air pollution, noise pollution etc.
5. In addition, disturbance of all vegetation (flora) and fauna (animals) from that a region.
6. Acid mine drainage (AMD), or acid rock drainage (ARD): The outflow of acidic water from (usually abandoned) metal mines or coal mines. However, other areas where the earth has been disturbed (e.g. construction sites, subdivisions, transportation corridors, etc.) may also contribute acid rock drainage to the environment.

CHAPTER 7

EROSION: PHYSICAL PROCESSES OF EROSION

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Erosion, 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 as given in below figure; 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 as mention in below Figure 1, 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.

Figure 1: Represented that thePhysical Processes of Erosion

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 in below Figure 2.

Figure 2: Represented that the Water Erosion.

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 rectangular 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 alongshore currents. These transportation movements lead to deposition and the formation of programed, or advancing, shorelines, bars, spits, bay head beaches a bay head beach is formed between two headlands, and barrier beaches a barrier beach parallels the shore.

Figure 3: Represented that the 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 when river and tidewater combine in their erosive action. This scouring action of the moving water entrains 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 as shown in above Figure 3. 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 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 as display in figure 4.

Figure 4: Represented that the Glacial Erosion.

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.

Factors Affecting Erosion

Erosion- Factors Affecting Soil Erosion

The factors that influence erosion are:

1. The amount and intensity of rainfall and wind velocity.
2. Topography with special reference to slope of land.
3. Physical and chemical properties of soil.
4. Ground cover its nature and extent.

Soil erosion is the wearing away detachment and transportation of soil from one place and its deposition at another place by moving water blowing wind or any other cause.

i. The Amount and Intensity of Rainfall and Wind Velocity

Rainfall is the most forceful factor causing erosion through splash and excessive run off. Rain drop erosion is splash, which results from the impact of water drops, directly on soil. Although the impact of rain drops on water in shallow streams may not splash soil, it does cause turbulence, providing a greater sediment carrying capacity. Large drop may increase the sediment carrying capacity of run off as much as 12 times.

If rain falls gently, it will enter the soil where it strikes and some will slowly run off, but if it occurs in torrents, as usually the monsoon rains doe, there is not enough time for the water to soak through the soil and it runs off causing erosion. Run off that causes erosion, therefore, depends upon intensity, duration, amount and frequency of rainfall. It is observed that rains in excess of 5 cm. per day always caused run off whereas those below 1.25 cm. usually do not.

(The results of soil and runoff losses from air dry deep black and later tic soils with 2 p.e., slope under a rainfall simulator with a constant rainfall immensity of 8.75 cm. per hour indicate that soil loss per 2.5 cm. of siuautated ram) in case of latertic soil is 0.25 tons per hectare. Thus the soil loss in case of deep black soil which is heavier than latertic soil is ten times more.

ii. Topography will Special Reference to Slope of Lands:

Slope accelerates erosion as it increases the velocity of flowing water. Small differences in slope make big difference in damage. According to the laws of hydraulics, a four – time increase in slope doubles the velocity of flowing water. This doubled velocity can increase the erosive power four times and the carrying capacity by 32 times. In one of the experiments in United States of America, it was observed that the loss of soil per hectare due to erosion in a maize plot was 12 tons when the slope was 5 p.c., but it was as high as 44.5 tons under 9 p.c., slope.

iii. Physical and Chemical Properties of Soil:

Some soils erode more readily than other under the same conditions. The crodibility of the soil is influenced by its texture, structure, and organic matter, nature of day and the amount and kind of salts present. There is less erosion in sandy soil because water is absorbed readily due to high permeability.

More organic manure in the soil improves granular structure and water holding capacity. As organic matter decreases, the crodibility of soil increases. Fine textured and alkaline soils are more crodible.

In general, soil detachability increases as the size of the particle increases but soil transportability increases with the decrease in particle size. Clay particles are more difficult to detach than sand, but are easily transported on a level land and much more rapidly on slopes.

iv. Ground Cover, its Nature and Extent:

The presence of vegetation ground cover retards erosion. Forests and grasses are more effective in providing cover than cultivated crops.

Vegetation intercepts the erosive beating action of falling raindrops retards the amount and velocity of surface fun off, permits more water flow into the soil and creates more storage capacity in the soil. It is the lack of vegetation that creates erosion permitting condition.

Other factors Affecting Soil & Water Erosion

i. For Soil Erosion

Factors such as rainfall, runoff, wind soil, slope, plant cover and presence or absence of conservation measures are responsible for soil erosion. But mainly three following factors affect the erosion.

- **Energy:**

It include The potential ability of rainfall, runoff and wind to course erosion and other factor which affects the power of erosive agents such as reduction in length of runoff or wind blow through construction of terrace, bunds etc. in case of water erosion and wind breaks or shelter belts in case of wind erosion.

- **Resistance:**

It is referred to that factors which affect soil erodibility and soil erosion. Mechanical and chemical properties of soil are responsible for infiltration rate of soil which reduces runoff and decreases soil erodibility. Cultivation decreases the erodibility of clay but increases erodibility of sandy soils.

- **Protection:**

It refers to plant covers which intercept the raindrop falling on ground surface reducing their impact on soil. Plant cover also reduces the runoff and wind velocity, there by soil erosion. Different plant cover offers different protection so suitable cover can be developed to control erosion.

ii. Factors affecting Water Erosion

Water erosion is due to dispersive and transporting power of water. Factors affecting are:

- **Climatic Factors:**

This includes rainfall characteristics, atmospheric temperature and wind velocity

- **Soil Characteristic:**

This affect infiltration rate of soil, Infiltration rate depends upon permeability of soil, surface condition and presence of moisture in it.

- **Vegetation:**

It creates the obstacle for raindrops as well as glowing runoff. A good vegetative cover completely reduces the effect of rainfall on soil erosion.

- **Topographic Effect:**

The land slope, length of slope and shape of slope are main factors which influences soil erosion. As slope of land increases from mild to steep, erosion increases

Agents of Erosion

i. Erosion by Water

a) Liquid water is the major agent of erosion on Earth. Rain, rivers, floods, lakes, and the ocean carry away bits of soil and sand and slowly wash away the sediment.

b) Rainfall produces four types of soil erosion: splash erosion, sheet erosion, rill erosion, and gully erosion.

   1. Splash erosion describes the impact of a falling raindrop, which can scatter tiny soil particles as far as 6 meters (2 feet).
   2. Sheet erosion describes erosion caused by runoff.
   3. Rill erosion describes erosion that takes place as runoff develops into discrete streams (rills).
   4. Gully erosion is the stage in which soil particles are transported through large channels. Gullies carry water for brief periods of time during rainfall or snowmelt but appear as small valleys or crevasses during dry seasons.

c) Valley erosion is the process in which rushing streams and rivers wear away their banks, creating larger and larger valleys. The Fish River Canyon, in southern Namibia, is the largest canyon in Africa and a product of valley erosion.

d) The ocean is a huge force of erosion.

   1. Coastal erosion: the wearing a way of rocks, earth, or sand on the beach—can change the shape of entire coastlines. During the process of coastal erosion, waves pound rocks into pebbles and pebbles into sand. Waves and currents sometimes transport sand away from beaches, moving the coastline farther inland.
   2. Coastal erosion can have a huge impact on human settlement as well as coastal ecosystems.
   3. The battering force of ocean waves also erodes seaside cliffs.
   4. The action of erosion can create an array of coastal landscape features.
   5. For example, erosion can bore holes that form caves.
   6. When water breaks through the back of the cave, it can create an arch. The continual pounding of waves can cause the top of the arch to fall, leaving nothing but rock columns called sea stacks.
   7. The seven remaining sea stacks of Twelve Apostles Marine National Park, in Victoria, Australia, are among the most dramatic and well-known of these features of coastal erosion.

ii. **<u>Erosion by Wind</u>**

   1. Wind is a powerful agent of erosion. Aeolian (wind-driven) processes constantly transport dust, sand, and ash from one place to another.
   2. Wind can sometimes blow sand into towering dunes. Some sand dunes in the Badain Jaran section of the Gobi Desert in China, for example, reach more than 400 meters (1,300 feet) high.
   3. In dry areas, windblown sand can blast against a rock with tremendous force, slowly wearing away the soft rock. It polishes rocks and cliffs until they are smooth giving the stone a so-called “desert varnish.”

4. Wind is responsible for the eroded features that give Arches National Park, in the U.S. state of Utah, its name.
5. Wind can also erode material until little remains at all.
6. Ventfacts are rocks that have been sculpted by wind erosion.
7. The enormous chalk formations in the White Desert of Egypt are ventifacts carved by thousands of years of wind roaring through the flat landscape.
8. Some of the most destructive examples of wind erosion are the dust storms that characterized the "Dust Bowl" of the 1930s in North America. Made brittle by years of drought and agricultural mismanagement, millions of tons of valuable topsoil were eroded away by strong winds in what came to be known as "black blizzards." These dust storms devastated local economies, forcing thousands of people who depended on agriculture for their livelihoods to migrate.

iii. Erosion by Ice

1. Ice, usually in the form of glaciers, can erode the earth and create dramatic landforms.
2. In frigid areas and on some mountaintops, glaciers move slowly downhill and across the land. As they move, they transport everything in their path, from tiny grains of sand to huge boulders.
3. Rocks carried by glaciers scrape against the ground below, eroding both the ground and the rocks.
4. In this way, glaciers grind up rocks and scrape away the soil. Moving glaciers gouge out basins and form steep-sided mountain valleys.
5. Eroded sediment called moraine is often visible on and around glaciers.
6. Ice Age glaciers scoured the ground to form what are now the Finger Lakes in the U.S. state of New York, for example. They carved fjords, deep inlets along the coast of Scandinavia.
7. Today, in places such as Greenland and Antarctica, glaciers continue to erode the earth. Ice sheets there can be more than a mile thick, making it difficult for scientists to measure the speed and patterns of erosion. However, ice sheets do erode remarkably quickly as much as half a centimeter (0.2 inch) every year.

Aeolian Transportation

Aeolian processes, in the study of geology and weather, pertain to wind activity and specifically to the wind's ability to shape the surface of the Earth. Winds may erode, transport, and deposit materials, and are effective agents in regions with sparse vegetation and a large supply of unconsolidated sediments.Aeolian Transport is the first process of coastal dune formation and involves the movement and weathering of sand particles behind and parallel to the shoreline as display in below Figure 5.

Figure 5: Represented that the Aeolian Transportation.

There are three main processes involved in Aeolian Transport:

- **Suspension**

The finer sand particles are moved by the wind, high in the air. They are not affected by gravity and therefore can travel thousands of kilometers before they land on earth again. When they land, it is often because they have combined with raindrops and fall with the rain.

- **Saltation**

When the wind hits the ground, it causes turbulence, disturbing the sand particles. If the wind has enough velocity, it will cause the particles to start moving (initially just along the ground). The required velocity is called critical velocity and varies depending on grain size, vegetation present and the moisture levels of the sand (which holds the sand down, requiring the critical velocity to be greater). As the sand moves, it hits other grains which cause them to bounce up in the air. The wind then picks these airborne particles up and carries them. Gravity causes them to fall back down. If sand lands on a hard surface (e.g., rock), the sand particle will bounce off again, being carried further. If it lands on a sandy surface, it will cause other particles to be disturbed, bounce up and they too will be carried, thus starting off a chain reaction.

- **Surface Creep**

The larger particles are too heavy to be picked up and carried by the wind so instead, they move along the ground. When they become dislodged by the falling ones, they roll along the ground. Through this process, they are not only moved but by moving against other particles, they erode into smaller particles which can be moved by saltation or suspension.

Glacial Transportation

The term load is used for all drift that's in transport by a glacier at a given time. As with fluvial sediment transport, keep in mind the distinction between the load and the transport rate. The transport rate of a glacier is the time rate of passage of sediment past some cross section through the glacier that's stationary relative to the underlying bedrock.

The load is generally classified on the basis of where it's transport in the glacier:

- **Supraglacial Load:**

Load transported on the surface of the glacier. It gets there by falling onto the glacier. It's thus restricted mainly to valley glaciers. But near the terminus of the glacier, drift can reach the surface by ablation of the ice, and also by upthrusting.

- **Englacial Load:**

Load transported within the glacier. The quantities of englacial drift are always much smaller than of supraglacial drift and subglacial drift, because the load is obtained by the glacier at the bottom and the top of the glacier. Solids deposited on the surface of the glacier in the area of accumulation are buried and thus become englacial drift.

- **Subglacial Load:**

Load transported at the base of the glacier. This constitutes most of the load, just because most material is entrained at the base. Cold-based glaciers have little subglacial load. The dirtiest warm- based glaciers might have concentrations of up to tens of percent by volume, for thicknesses of a few meters above the base. The way this is known is by examination of now-dead ice at a stagnant terminus.

Processes of Glacial Transportation

Glaciers move very slowly. As they move, they transport material from one place to another:

1. As freeze-thaw weathering occurs along the edge of the glacier pieces of rock, which break off larger rocks, fall onto the glacier and are transported.
2. Rocks plucked from the bottom and sides of the glacier are moved downhill with the ice.
3. Bulldozing is when rocks and debris, found in front of the glacier, are pushed downhill by the sheer force of the moving ice.
4. Rotational slip is the circular movement of the ice in the corrie.

Any material carried or moved by a glacier is called moraine. There are three different types of moraine:

1. Lateral moraine - material deposited along both sides of the glacier. This moraine is usually made up of weathered material that has fallen from the valley sides above the glacier.
2. Medial moraine - material deposited in the middle of the glacier. This is caused by the lateral moraines of two glaciers when they meet.
3. Terminal moraine - material deposited at the end of the glacier.

CHAPTER 8

EROSION AND DEPOSITION: ACTION OF RUNNING WATER AND GROUNDWATER

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In the previous, we were discussing various types of endogenic and exogenic processes. We have also seen that erosion and deposition are some of the exogenic processes. In this post, we are dealing with the geomorphic agents running water and groundwater**,** which causes erosion and deposition. They form various erosional (destructional) and depositional (constructional) landforms.Even though we are considering the erosional and depositional activities and their landform creation, it should be kept in mind that they are always aided by weathering and mass movements. There are some other independent controls like

1. Stability of sea level;
2. Tectonic stability of landmass;
3. Climate etc. which influence the evolution of these landforms.

Running Water

1. Running water, which doesn't need any further explanation, has two components: one is overland flow on the general land surface as a sheet and the other is linear flow as streams and rivers in valleys.
2. The overland flow causes sheet erosion and depending upon the irregularities of the land surface, the overland flow may concentrate into narrow to wide paths.
3. During the sheet erosion, minor or major quantities of materials from the surface of the land are removed in the direction of flow and gradual small and narrow rills will form.
4. These rills will gradually develop into long and wide gullies, the gullies will further deepen, widen and lengthen and unite to give rise to a network of valleys. (Note: A valley can be formed in various ways like faulting, but here we are dealing only with the formation by means of exogamic geomorphic agent).
5. Once a valley is formed, it later develops into a stream or river as display ion Figure 1.

Courses of a River

A river, which is the best example of the linear flow of running water through a valley, can be divided into three, on the basis of its course – upper course, middle course and lower course.

Upper Course / Stage of Youth (Erosion dominates)

6. It starts from the source of the river in hilly or mountainous areas.
7. The river flows down the steep slope and, as a result, its velocity and eroding power are at their maximum.

8. Streams are few, with poor integration.
9. As the river flows down with high velocity, vertical erosion or downward cutting will be high which results in the formation of V-Shaped Valleys**.**
10. Waterfalls, rapids, and gorges exist where the local hard rock bodies are exposed.

Figure 1: Represented that the Running water Source

<u>Middle Course/ Stage of Maturity (Transportation dominates):</u>

1. In this stage, vertical erosion slowly starts to replace with lateral erosion or erosion from both sides of the channel.
2. Thus, the river channel causes the gradual disappearance of its V-shaped valley (not completely).
3. Streams are plenty at this stage with good integration.
4. Wider flood plains start too visible in this course and the volume of water increases with the confluence of many tributaries.
5. The work of river predominantly becomes transportation of the eroded materials from the upper course (little deposition too).
6. Landforms like alluvial fans, piedmont alluvial plains, meanders etc. can be seen at this stage.

<u>Lower Course/ Stage of Old (Deposition Dominates):</u>

1. The river starts to flow through a broad, level plain with heavy debris brought down from upper and middle courses.
2. Vertical erosion has almost stopped and lateral erosion still goes on.
3. The work of the river is mainly deposition, building up its bed and forming an extensive flood plain.
4. Landforms like braided channels, floodplains, levees, meanders, oxbow lakes, deltas etc. can be seen at this stage as display the Figure 2.

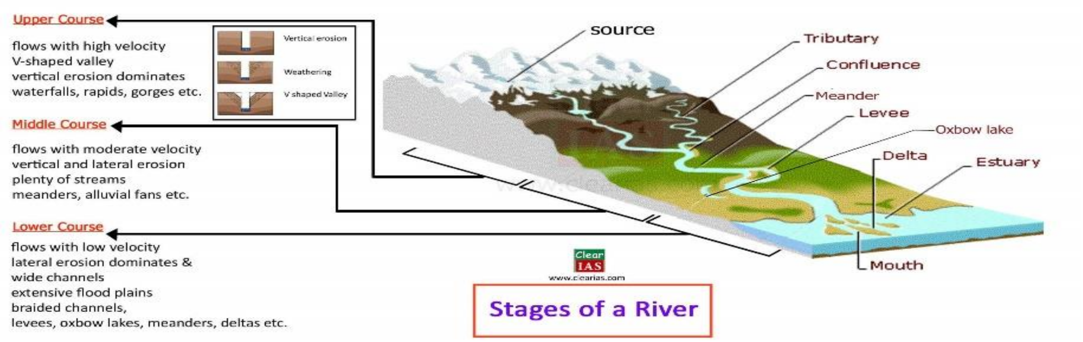

Figure 2: Represented that the Lower Course

Running water: erosion, transportation, and deposition

1. Erosion occurs when overland flow moves soil particles downslope.
2. The rock materials carried by erosion is the load of the river.
3. This load acts as a grinding tool helping in cutting the bottom and sides of the river bed, resulting in deepening and widening of the river channel.

Erosion Types

The work of river erosion is accomplished in different ways, all of which may operate together. They are corrasion, corrosion, hydraulic action etc.

1. **Corrasion or Abration:** As the rock particles bounce, scrape and drag along the bottom and sides of the river, they break off additional rock fragments. This form of erosion is called corrasion or abration. They are two types: vertical corrosion which acts downward and lateral corrosion which acts on both sides.
2. **Corrosion or Solution:** This is the chemical or solvent action of water on soluble or partly soluble rocks with which the river water comes in contact.
3. **Hydraulic Action:** This is the mechanical loosening and sweeping away of material by the sheer force or river water itself. No load or material is involved in this process.

Transportation Types

After erosion, the eroded materials get transported with the running water. This transportation of eroded materials is carried in four ways**:**

i. Traction:

The heavier and larger rock fragments like gravels, pebbles etc are forced by the flow of the river to roll along its bed. These fragments can be seen rolling, slipping, bumping and being dragged. This process is called as traction and the load transported in this way are called traction load.

ii. Saltation:

Some of the fragments of the rocks move along the bed of a stream by jumping or bouncing continuously. This process is called as saltation.

iii. Suspension:

The holding up of small particles of sand, silt and mud by the water as the stream flows is called suspension.

iv. Solution:

Some parts of the rock fragments dissolved in the river water and transported. This type of transportation is called solution transportation as mention in Figure 3.

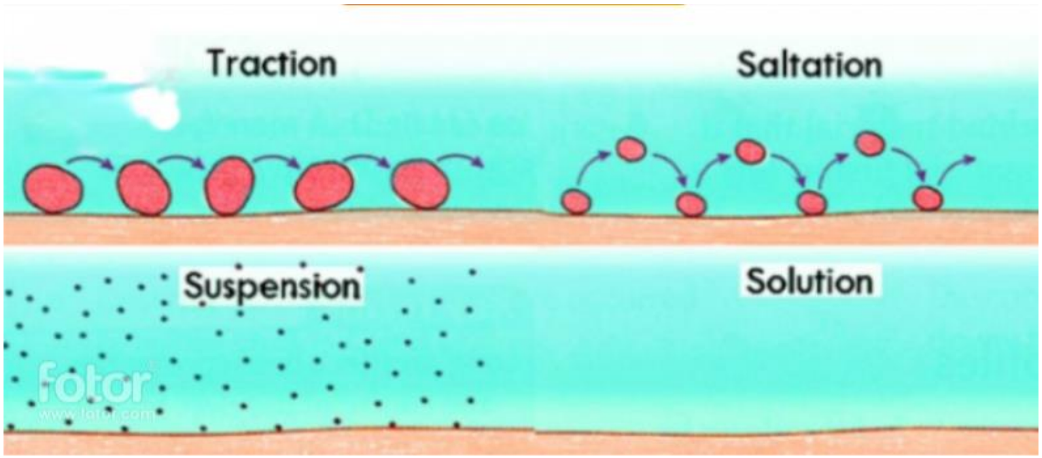

Figure 3: Display that the Water Transportation

1. When the stream comes down from the hills to plain areas with the eroded and transported materials, the absence of slope/gradient causes the river to lose it energy to further carry those transported materials.
2. As a result, the load of the river starts to settle down which is termed as deposition.
3. Erosion, transportation, and deposition continue until the slopes are almost completely flattened leaving finally a lowland of faint relief called peneplains with some low resistant remnants called monadnocks.

Erosional Landforms due to Running Water

- **Valleys, Gorges, Canyon**

1. As we discussed above, valleys are formed as a result of running water.
2. The rills which are formed by the overland flow of water later develop into gullies.
3. These gullies gradually deepen and widen to form valleys.
4. A gorge is a deep valley with very steep to straight sides.
5. A canyon is characterized by steep step-like side slopes and may be as deep as a gorge.
6. A gorge is almost equal in width at its top as well as bottom and is formed in hard rocks while a canyon is wider at its top than at its bottom and is formed in horizontal bedded sedimentary rocks.

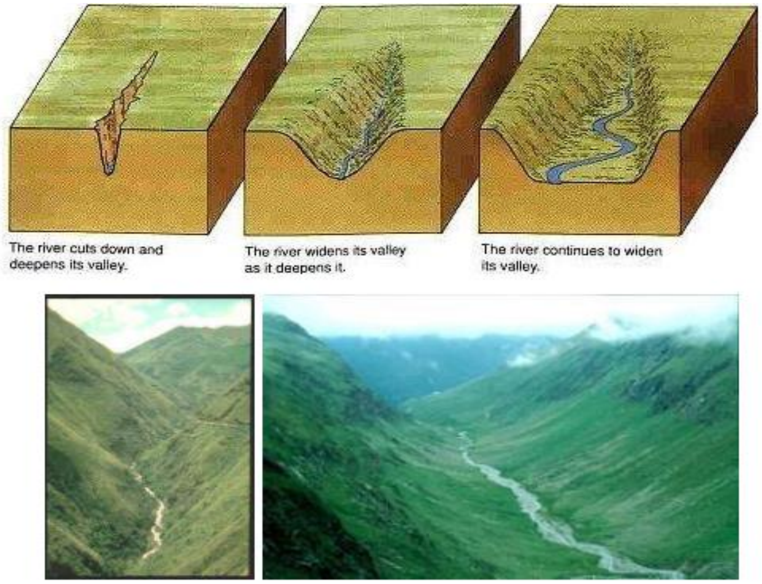

Figure 4: Represented the Erosional Landforms due to Running Water.

Potholes, Plunge pools

1. Potholes are more or less circular depressions over the rocky beds of hills streams.
2. Once a small and shallow depression forms, pebbles and boulders get collected in those depressions and get rotated by flowing water. Consequently, the depressions grow in dimensions to form potholes.
3. Plunge pools are nothing but large, deep potholes commonly found at the foot of a waterfall.
4. They are formed because of the sheer impact of water and rotation of boulders.

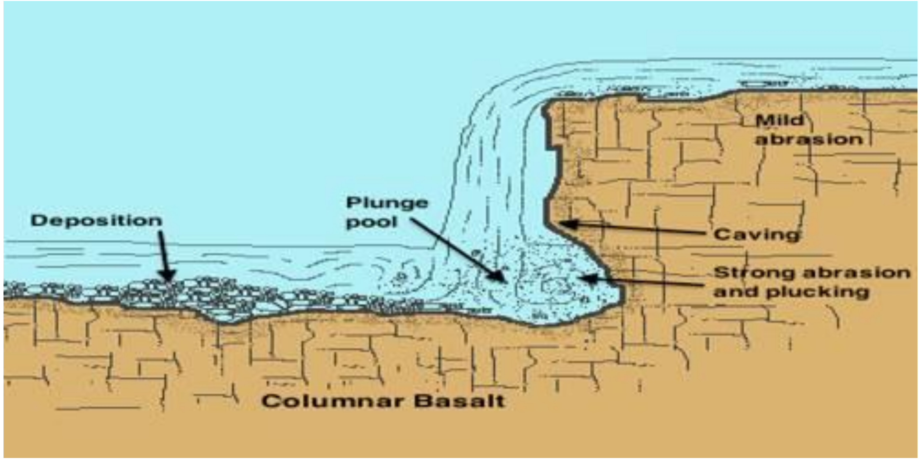

Figure 5: Display the Potholes, Plunge pools

Incised or Entrenched Meanders

1. They are very deep wide meanders (loop-like channels) found cut in hard rocks.
2. In the course of time, they deepen and widen to form gorges or canyons in hard rock.

3. The difference between a normal meander and an incised/entrenched meander is that the latter found on hard rocks as mention in Figure 6.

Figure 6: Shows the Incised or Entrenched Meanders

River Terraces

1. They are surfaces marking old valley floor or flood plains.
2. They are basically the result of vertical erosion by the stream.
3. When the terraces are of the same elevation on either side of the river, they are called as paired terraces.
4. When the terraces are seen only on one side with none on the other or one at quite a different elevation on the other side, they are called as unpaired terraces, which is mentioned in Figure 7.

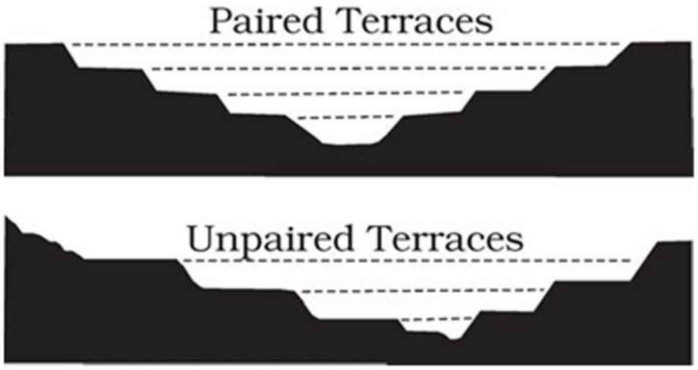

Figure 7: Represented that the River Terraces.

Depositional Landforms due to Running Water

Alluvial Fans

- They are found in the middle course of a river at the foot of slope/ mountains.
- When the stream moves from the higher level break into foot slope plain of low gradient, it loses its energy needed to transport much of its load.
- Thus, they get dumped and spread as a broad low to the high cone-shaped deposits called an alluvial fan.

- The deposits are not roughly very well sorted as mention in Figure 8.

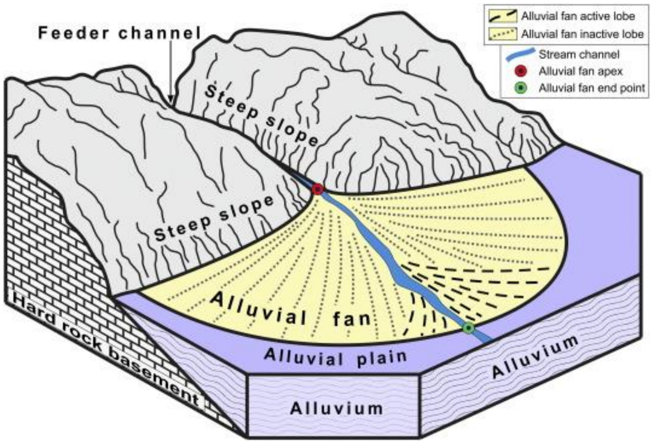

Figure 8: Shows theAlluvial Fans

Deltas

- Deltas are like an alluvial fan but develop at a different location.
- They are found in the mouth of the river, which is the final location of depositional activity of a river.
- Unlike alluvial fans, the deposits making up deltas are very well sorted with clear stratification.
- The coarser material settle out first and the finer materials like silt and clay are carried out into the sea as shown in Figure 8.

Figure 8: Display the Deltas.

Flood Plains, Natural Levees

- According to the Figure 9 the deposition develops a flood plain just as erosion makes valleys.

- A riverbed made of river deposits is the active flood plain and the flood plain above the bank of the river is the inactive flood plain.
- Natural levees are found along the banks of large rivers. They are low, linear and parallel ridges of coarse deposits along the banks of a river.
- The levee deposits are coarser than the deposits spread by flood water away from the river.

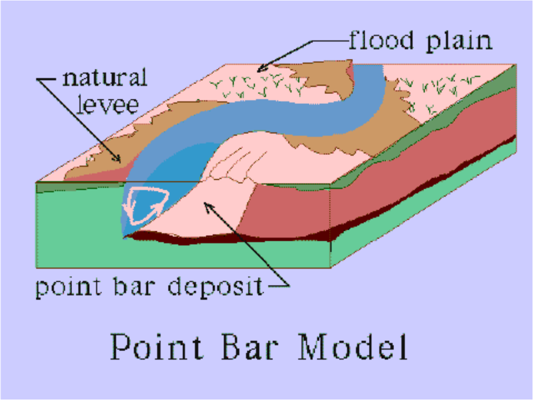

Figure 9: Illustrated that theFlood Plains, Natural Levees.

- **Meanders and oxbow lakes**

- Meanders are loop-like channel patterns develop over the flood and delta plains.
- They are actually not a landform but only a type of channel pattern formed as a result of deposition.
- They are formed basically because of three reasons: (i) propensity of water flowing over very gentle gradient to work laterally on the banks; (ii) unconsolidated nature of alluvial deposits making up the bank with many irregularities; (iii) Coriolis force acting on fluid water deflecting it like deflecting the wind.
- The concave bank of a meander is known as cut-off bank and the convex bank is known as a slip-off
- As meanders grow into deep loops, the same may get cut-off due to erosion at the inflection point and are left as oxbow lakes.
- For large rivers, the sediments deposited in a linear fashion at the depositional side of a meander are called as Point Bars or Meander Bars as mention in Figure 10.

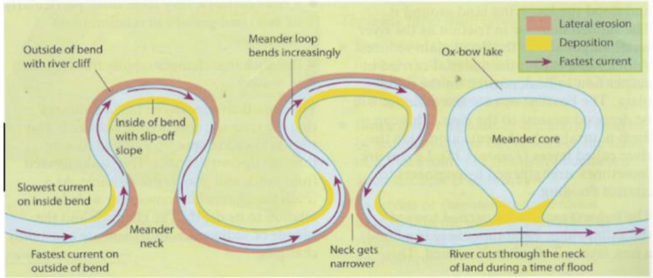

Figure 10: Represented that the Meanders and Oxbow Lakes.

  - Braided Channels
- When selective deposition of coarser materials causes the formation of a central bar, it diverts the flow of river towards the banks, which increases lateral erosion.
- Similarly, when more and more such central bars are formed, braided channels are formed.
- Riverine Islands are the result of braided channels.

Groundwater Working

- The part of rain or snow-melt water which accumulates in the rocks after seeping through the surface is called underground water or simply groundwater.
- The rocks through which water can pass easily are called as permeable rocks while the rocks which do not allow water to pass are called as impermeable rocks.
- After vertically going down to some depth, the water under the ground flows horizontally through the bedding planes, joints or through the materials themselves.
- Although the amount of groundwater varies from place to place, its role in shaping the surface features of the earth is quite important.
- The works of groundwater are mainly seen in rocks like limestone, gypsum or dolomite which are rich in calcium carbonate.
- Any limestone, dolomite or gypsum region showing typical landforms produced by the action of groundwater through the process of solution and deposition is called as Karst Topography (Karst region in the Balkans)
- The zones or horizons of permeable and porous rocks which are fully filled with water are called as the Zones of Saturation.
- The marks which show the upper surface of these saturated zones of the groundwater are called as the Water Tables.
- And these rocks, which are filled with underground water, are called as aquifers.
- The water table is generally higher in the areas of high precipitation and also in areas bordering rivers and lakes.
- They also vary according to seasons. On the basis of variability, water tables are of two types:
  - i. Permanent water table, in which the water will never fall below a certain level and wells dug up to this depth provide water in all seasons;
  - ii. Temporary water tables, which are seasonal water tables.
- Springs: They are the surface outflow of groundwater through an opening in a rock under hydraulic pressure.
- When such springs emit hot water, they are called as Hot Springs. They generally occur in areas of active or recent volcanism.
- When a spring emits hot water and steam in the form of fountains or jets at regular intervals, they are called as geysers.

- In a geyser, the period between two emissions is sometimes regular (Yellowstone National Park of USA is the best example).

Erosional Landforms due to Groundwater

Sinkholes and caves are erosional landforms formed due to the action of ground water as display in Figure 11.

i. Sinkholes

- Small to medium sized rounded to sub-rounded shallow depressions called swallow holes forms on the surface of rocks like limestone by the action of the solution.
- A sinkhole is an opening more or less circular at the top and funnel-shaped towards the bottom.
- When as sinkhole is formed solely through the process of solution, it is called as a **solution sink**.
- Some sinkhole starts its formation through the solution process but later collapse due to the presence of some caves or hollow beneath it and becomes a bigger sinkhole. These types are called as **collapse sinks**.
- The term **Doline** is sometimes used to refer collapse sinks.
- Solution sinks are more common than collapse sinks.
- When several sink holes join together to form valley of sinks, they are called as valley sinks or **Uvalas**.
- **Lapies** are the irregular grooves and ridges formed when most of the surfaces of limestone are eaten by solution process.

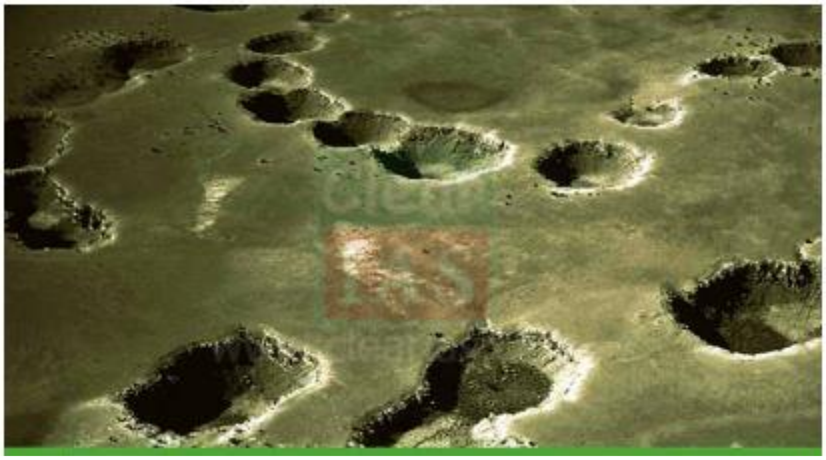

Figure 11: Represented the Erosional Landforms due to Groundwater

ii. Caves

- In the areas where there are alternative beds of rocks (non-soluble) with limestone or dolomite in between or in areas where limestone are dense, massive and occurring as thick beds, cave formation is prominent.
- Caves normally have an opening through which cave streams are discharged

- Caves having an opening at both the ends are called tunnels.

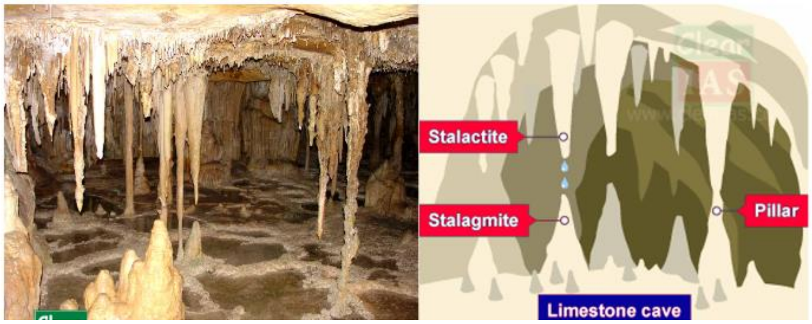

Figure 12: Display the Depositional Landforms of Groundwater

Depositional Landforms of Groundwater

Stalactites and Stalagmites

1. They are formed when the calcium carbonates dissolved in groundwater get deposited once the water evaporates.
2. These structures are commonly found in limestone caves.
3. Stalactites are calcium carbonate deposits hanging as icicles while Stalagmites are calcium carbonate deposits which rise up from the floor.
4. When a stalactite and stalagmite happened to join together, it gives rise to pillars or columns of different diameters.

CHAPTER 9

ATMOSPHERE: EVOLUTION OF EARTH'S ATMOSPHERE

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Evolution of the atmosphere, the development of Earth's atmosphere across geologic time. The process by which the current atmosphere arose from earlier conditions is complex; however, evidence related to the evolution of Earth's atmosphere, though indirect, is abundant. Ancient sediments and rocks record past changes in atmospheric composition due to chemical reactions with Earth's crust and, in particular, to biochemical processes associated with life as display in Figure 1.

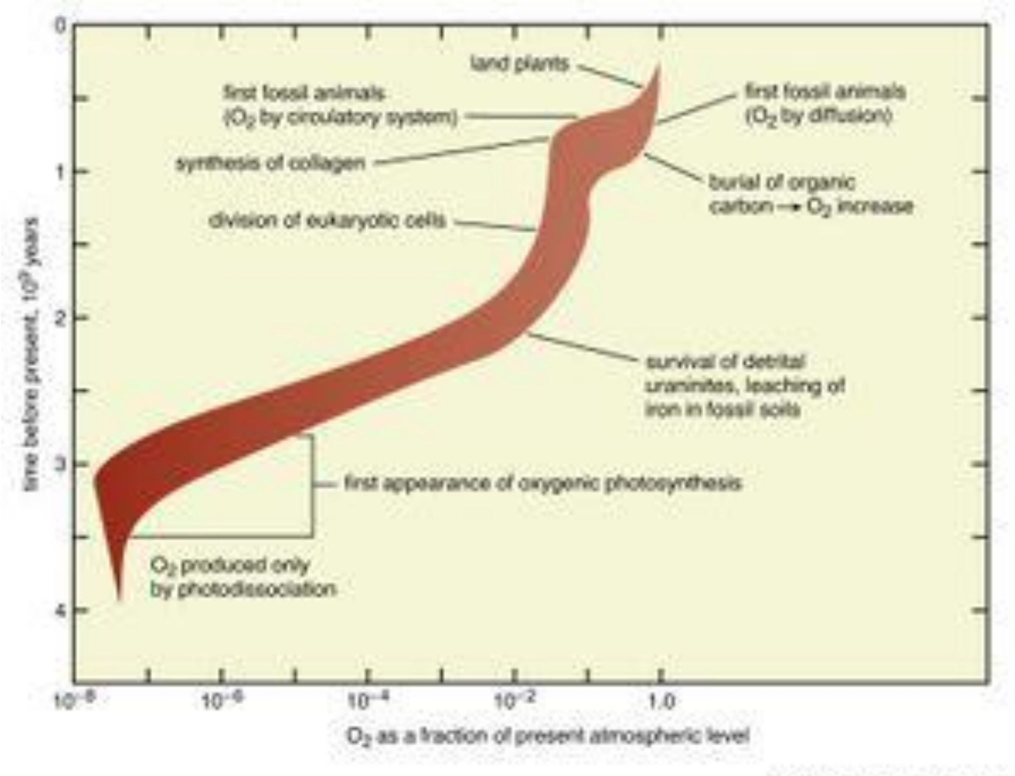

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Figure 1: Represented the Earth's Atmosphere

Earth's original atmosphere was rich in methane, ammonia, water vapour, and the noble gas neon, but it lacked free oxygen. It is likely that hundreds of millions of years separated the first biological production of oxygen by unicellular organisms and its eventual accumulation in the atmosphere.

The composition of the atmosphere encodes a great deal of information bearing on its origin. Furthermore, the nature and variations of the minor components reveal extensive interactions between the atmosphere, terrestrial environment, and biota.

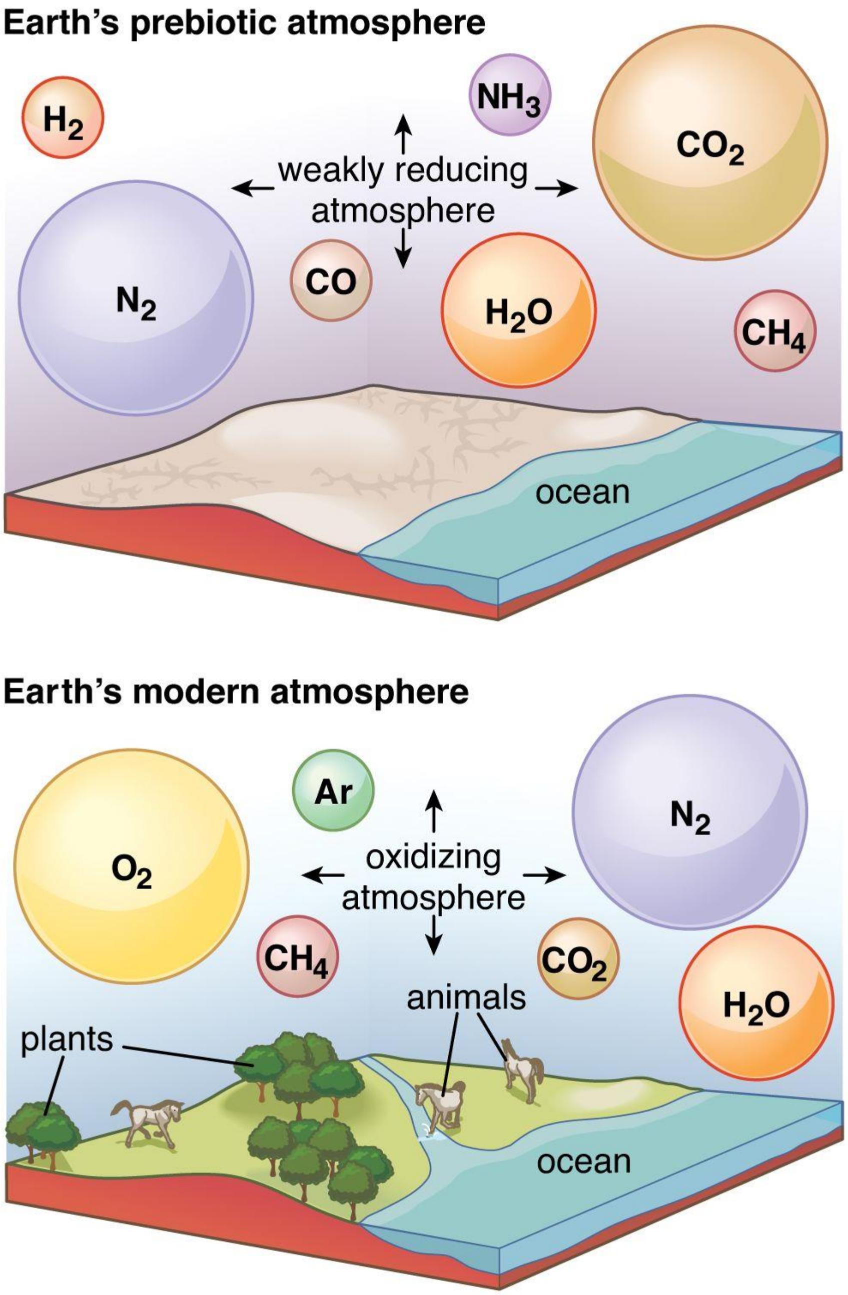

Figure 2: Represented that the Earth's Modern Atmosphere.
(Figure Source: Encyclopedia Britannica, Inc.)

The development of the atmosphere and such interactions are discussed in this article, with particular attention given to the rise of biologically produced molecular oxygen, O_2, as a major component of air.

Concepts Related to Atmospheric Development

A complete reconstruction of the origin and development of the atmosphere would include details of its size and composition at all times during the 4.5 billion years since Earth's formation. This goal could not be achieved without knowledge of the pathways and rates of supply and consumption of all atmospheric constituents at all times. Information regarding these particular processes, however, is incomplete even for the present atmosphere, and there is almost no direct evidence regarding atmospheric constituents and their rates of supply and consumption in the past.

The contrast with related fields of Earth's history is notable. Fossils and other structural and chemical details of ancient rocks provide information useful to evolutionary biologists and historical geologists, but ancient atmospheres, "mere vapours," have not left such substantial remnants. These vapours are, however, the stuff of stars and the moving force of storms and erosion.

The Atmosphere as Part of the Crust

To the Earth scientist, the crust includes not only the top layer of solid material (soil and rocks to a depth of 6 to 70 km [4 to 44 miles], separated from the underlying mantle by differences in density and by susceptibility to surficial geologic processes) but also the hydrosphere (oceans, surface waters on land, and groundwater beneath the land surface) and the atmosphere. Interactions among these solid, liquid, and gaseous portions of the crust are so frequent and thorough that considering them separately introduces more complexities than it eliminates. As a result, a description of the history of the atmosphere must concern itself with all volatile components of the crust.

Materials

Volatile compounds as well as elements important in present and past atmospheres or in interactions between the atmosphere, biosphere, and other portions of the crust include the following:

1. Present major components: molecular nitrogen (N_2) and molecular oxygen (O_2)
2. Noble gases: helium (He), neon (Ne), argon (Ar), krypton (Kr), and xenon (Xe)
3. Abundant variable components: water vapour (H_2O) and carbon dioxide (CO_2)
4. Other components: molecular hydrogen (H_2), methane (CH_4), carbon monoxide (CO), ammonia (NH_3), nitrous oxide (N_2O), nitrogen dioxide (NO_2), hydrogen sulfide (H_2S), dimethyl sulfide [$(CH_3)_2S$], sulfur dioxide (SO_2), and hydrogen chloride (HCl).

Some elements appear in multiple form—for example, carbon as carbon dioxide, methane, or dimethyl sulfide. It is useful to consider the occurrence of the elements before focusing on the more specific aspects of atmospheric chemistry (the forms in which the elements are present). One can speak of Earth's "inventory of volatiles," recognizing that the components of the inventory may be reorganized from time to time, but also that it is always composed primarily of the compounds of hydrogen, carbon, nitrogen, and oxygen, along with the noble gases.

Processes

A process that delivers a gas to the atmosphere is termed a source for the gas. Depending on the question under consideration, it can make sense to speak in terms of either an ultimate source the process that delivered a component of the volatile inventory to Earth or an immediate source the process that sustains the abundance of a component of the present atmosphere. Any process that removes gas either chemically, as in the consumption of oxygen during the process of combustion, or physically, as in the loss of hydrogen to space at the top of the atmosphere, is called a sink.

Throughout the history of the atmosphere, sources and sinks have often been simultaneously present. While one process consumes a particular component, another produces it, and the concentration of that component in the atmosphere will rise or fall depending on the relative strengths of the sources and sinks.

If those strengths are balanced (or nearly so), the composition of the atmosphere will not change (or will change only very slowly, perhaps imperceptibly); however, the molecules of the gas in question are passing through the atmosphere and are not permanently resident. The rate of the resulting turnover of molecules in the atmosphere is expressed in terms of the residence time, the average time spent by a molecule in the atmosphere after it leaves a source and before it encounters a sink.

Processes Affecting the Composition of the Early Atmosphere

The material from which the solar system formed is often described as a gas cloud or, at a later stage, a solar nebula. The cloud was rich in volatiles (termed primordial gases) and must have been the ultimate source of the atoms in the present atmosphere. What is of primary concern, however, is the sequence of events and processes by which the volatiles present in the initial gas cloud were transferred to Earth’s inventory and the efficiency with which this was accomplished.

The formation of the solar system began when one portion of the gas cloud became dense enough due to compression by some external force—a shock wave from the explosion of a nearby supernova, perhaps—to gravitationally attract the material around it. This material “fell” into the region of higher density, making it even denser and attracting other material from still further away. As gravitational collapse continued, the centre of the cloud became very dense and hot, because the kinetic energy of the incoming material was released as heat. Thermonuclear reactions began at the core of the central object, the Sun.

Capture and Retention of Primordial Gases

Far from the central point, the material in the gas cloud tended to settle to an extensive equatorial plane around the Sun. As the material in this disk cooled, chunks of rock grew and accreted to form the planets. The planets are much less massive than the Sun, but if they grew large enough and if the gases around them were cool enough, they could accumulate an atmosphere from the volatile components of the gas cloud. This direct capture is the first of three source mechanisms that can be described.

A planetary atmosphere accumulated in this way would consist of primordial gases, but the relative abundances of the individual components would differ from those in the gas cloud if the gravitational field of the new planet were strong enough to hold some, but not all, of the gases around it. It is convenient to express the strength of a gravitational field in terms of escape velocity, the speed at which any particle (a molecule or spacecraft) must be traveling in order to overcome the force of gravity. For Earth, this velocity is 11.3 km (7.0 miles) per second, and it follows that, once the solid material had accumulated, gas molecules passing Earth at lower speeds would have been captured and accumulated to form an atmosphere.

Outgassing of the Solid Planet

The speed at which a gas molecule moves is proportional to $(T/M)^{1/2}$, where T is absolute temperature in kelvins (K) and M is molecular mass. The uppermost layers of the present atmosphere are still very hot and might have been much hotter early in Earth's history. At temperatures below 2,000 K, however, molecules of any compound with a molecular weight greater than about 10 will have an average velocity of less than 11.3 km per second (7.0 miles per second). On this basis, it has long been thought that Earth's earliest atmosphere must have been a mixture of the primordial gases with molecular weights greater than 10. Hydrogen and helium, with molecular weights of 2 and 4, should have been able to escape. Because hydrogen is the most abundant element in the solar system, it is thought that the most abundant forms of the other volatile elements were their compounds with hydrogen. If so, methane, ammonia, and water vapour, together with the noble gas neon, would have been the most abundant volatiles with molecular weights greater than 10 and, thus, the major constituents of Earth's primordial atmosphere. The atmospheres of the four giant outer planets (Jupiter, Saturn, Uranus, and Neptune) are rich in such components, as well as in molecular hydrogen and, presumably, helium, which those more massive and colder bodies were apparently able to retain as mention in Figure 3.

Figure 3: Represented the Outgassing of the Solid Planet.

Mount Pinatubo

The release of gases during volcanic eruptions is one example of outgassing; releases at submarine hydrothermal vents are another. Although the gas in modern volcanic emanations commonly derives from rocks that have picked up volatiles at Earth's surface and then have been buried to depths at which high temperatures remobilize the volatile material, a very different situation must have prevailed at the earliest stages of Earth's history.

The planet accreted from solid particles that formed as the primordial gas cloud cooled. Long before the volatile components of the cloud began to condense to form massive solid phases (that is, long before water vapour condensed to form ice), their molecules would have coated the surfaces of the solid particles of rocky material that were forming. As these solid particles continued to grow, a portion of the volatiles coating their surfaces would have been trapped and carried thereafter by the particles. If the solids were not remelted by impact as they collected to form the planet, the volatiles they carried would have been incorporated in the solid planet. In this way, even without collecting an enveloping gaseous atmosphere, a newly formed planet could include as material occluded in its constituent grains a substantial inventory of volatiles.

At some point in its early history, Earth became so hot that much of the iron dispersed among the solid particles melted, became mobile, and collected to form the core. Related events led to the formation of rocky layers that were the precursors of Earth's present-day mantle and crust. As part of this process of differentiation, volatiles present in the particles would have been released through outgassing. The outgassing must have occurred on a colossal scale if the accreting particles had retained their volatiles right up to the time of differentiation.

An atmosphere created by retention of these outgassing products would derive ultimately from nebular gases. Its chemical composition, however, would be expected to differ in two principal respects from that of an atmosphere formed by the capture of primordial gases: (1) whereas the captured atmosphere would contain all gases that were moving slowly enough (that is, that were sufficiently cold and/or of sufficient molecular weight) so that it was possible for the planet to retain them gravitationally, the outgassed atmosphere would contain only those gases "sticky" enough to have been significantly retained in the rocky particles from which the planet formed; and (2) methane and ammonia, two presumed components of a captured atmosphere, would probably not be stable under the conditions involved in outgassing. Thus, the noble gases, which would be poorly held by particles, would be of low abundance relative to gases derived from chemically active elements. Further, the principal forms of carbon and nitrogen in an outgassed atmosphere would be carbon monoxide or carbon dioxide together with molecular nitrogen.

Importation

A compromise between the extremes of direct capture and outgassing proposes that Earth's inventory of volatiles was delivered to the planet late in its accretionary history—possibly after differentiation was nearly complete—by impact of a "last-minute" crop of solid bodies that were very strongly enriched in volatile materials (these were the last substances to condense as the solar nebula cooled).

Such bodies might have had compositions similar to those of comets that still can be observed in the solar system. These last-minute condensates may have coated the planet as a surface veneer that yielded gases only when heated during differentiation, or they may have released their volatiles on impact. Because such bodies would have been relatively small, they would not have been able to retain primordial gases by means of a substantial gravitational field. Their complement of volatiles, retained by cold trapping in ices and on particle surfaces, would be expected to resemble the "sticky" (that is, polar and reactive) gases occluded by solid particles at earlier stages of cooling of the gas cloud but possibly lost during earlier higher temperature phases of Earth's accretion.

Sinks

The dominant pathways by which gases are removed from the present atmosphere are discussed below in the section on biogeochemical cycles. Apart from those processes, three other sinks merit attention and are described here.

Photochemical reactions

Sunlight can provide the energy required to drive chemical reactions that consume some gases. Due to a rapid and efficient photochemical consumption of methane (CH_4) and ammonia (NH_3), a methane–ammonia atmosphere, for example, would have a maximum lifetime of about one million years. This finding is of interest because it has been suggested that life originated from mixtures of organic compounds synthesized by nonbiological reactions starting from methane and ammonia. Recognition of the short atmospheric lifetimes of these materials poses grave difficulties for such a theory. Water, too, is not stable against sunlight that has not been filtered by overlying layers containing ozone or molecular oxygen, which very strongly absorb much of the Sun's ultraviolet radiation. Water molecules that rise above these layers are degraded to yield, among other products, hydrogen atoms (H·).

Escape

Hydrogen molecules (H_2) and helium, or products like H·, tend to have velocities high enough so that they are not bound by Earth's gravitational field and are lost to space from the top of the atmosphere. The importance of this process extends beyond the very earliest stages of Earth's history because continuous sources exist for these light gases. Helium is continually lost as it is produced by the decay of radioactive elements in the crust.

A combination of photochemical reactions and the subsequent escape of products can serve as a source for molecular oxygen (O_2), a major component of the modern atmosphere that, because of its reactivity, cannot possibly have derived from any of the other sources so far discussed. In this process, water vapour is broken up by ultraviolet light and the resulting hydrogen is lost from the top of the atmosphere, so that the products of the photochemical reaction cannot recombine. The residual oxygen-containing products then couple to form O_2.

Solar-wind Stripping

The Sun emits not only visible light but also a continuous flow of particles known as the solar wind. Most of these particles are electrically charged and interact only weakly with the atmosphere, because the Earth's magnetic field tends to steer them around the planet. Prior to the formation of Earth's iron core and consequent development of the geomagnetic field, however, the solar wind must have struck the top layers of the atmosphere with full force. It is postulated that the solar wind was much more intense at that time than it is today and, further, that the young Sun emitted a powerful flux of extreme ultraviolet radiation. In such circumstances, much gas may have been carried away by a kind of atomic sandblasting that may have had a marked effect on the earliest phases of atmospheric development.

Biogeochemical Cycles

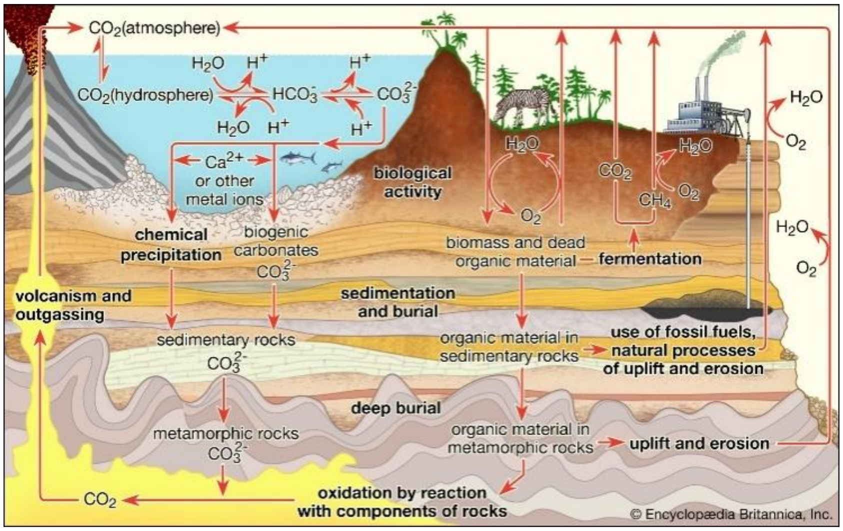

Figure 4: Represented the Biogeochemical Cycles

Interactions with the crust and, in particular, with living things—the biosphere—can strongly affect the composition of the atmosphere. These interactions, which form the most important sources and sinks for atmospheric constituents, are viewed in terms of biogeochemical cycles, the most prominent and central being that of carbon. The carbon cycle includes two major sets of processes: biological and geologic as display in the Figure 4.

Atmosphere Composition and Structure

The earth's atmosphere is a life-supporting atmosphere. Questions can sometimes be asked in UPSC prelims regarding the composition of the earth's atmosphere.

Salient Facts about Earth's Atmosphere

The atmosphere is described as the air that surrounds the earth.

1. The thickness of the earth's atmosphere is about 480 km. 99 percent of the thickness lies up to the height of 32 km from the earth.
2. With increasing altitude, the air pressure decreases.
3. The atmosphere has a mixture of gases that sustains life on earth.
4. The earth's gravity helps hold the atmosphere in place.
5. The major role of the atmosphere is to contain the entry of ultraviolet rays.

As per NASA, the composition of the earth's atmosphere is as mentioned below:

1. Nitrogen-78 percent
2. Oxygen-21 percent
3. Argon-0.93 percent
4. Carbon dioxide-0.04 percent
5. Trace amounts of neon, helium, methane, krypton and hydrogen, as well as water vapor

Composition of the Atmosphere

The atmosphere is a layer of gas or layers of gases that envelope a planet and is held in place by the gravity of the planetary body. A planet retains an atmosphere when the gravity is great and the temperature of the atmosphere is low.

1. The atmosphere of earth is composed of nitrogen (78%), oxygen (21%), argon (0.9%), carbon dioxide (0.04%) and trace gases. A variable amount of water vapour is also present in the atmosphere (approx.1% at sea level) and it decreases with altitude.
2. Carbon dioxide gas is largely responsible for the greenhouse effect. It is transparent to the incoming solar radiation but is opaque to the outgoing terrestrial radiation. It absorbs a part of terrestrial radiation and reflects back some of it towards the earth's surface.
3. Dust particles are also present in the atmosphere. They originate from different sources like fine soil, smoke-soot, pollen, dust and disintegrated particles of meteors. Dust and salt particles act as hygroscopic nuclei around which water vapour condenses to produce clouds.

4. The atmosphere is a mixture of many gases. In addition, it contains huge numbers of solid and liquid particles, collectively called ‘aerosols’.
5. Some of the gases may be regarded as permanent atmospheric components which remain in fixed proportion to the total gas volume.
6. Other constituents vary in quantity from place to place and from time to time. If the suspended particles, water vapour and other variable gases were excluded from the atmosphere, then the dry air is very stable all over the earth up to an altitude of about 80 kilometers.
7. The proportion of gases changes in the higher layers of the atmosphere in such a way that oxygen will be almost in negligible quantity at the height of 120 km. Similarly, carbon dioxide and water vapour are found only up to 90 km from the surface of the earth.
8. Nitrogen and oxygen make up nearly 99% of the clean, dry air. The remaining gases are mostly inert and constitute about 1% of the atmosphere.
9. Besides these gases, large quantities of water vapour and dust particles are also present in the atmosphere. These solid and liquid particles are of great climatic significance.

The details of different gases of the atmosphere are given in the table below:

Sr. No.	Constituent	Formula	% by Value
1.	Hydrogen	H2	0.00005
2.	Xenon	Xe	0.00009
3.	Krypto	Kr	0.001
4.	Heltum	Ne	0.0005
5.	Neon	He	0.002
6.	Carbon dioxide	CO2	0.036
7.	Argon	Ar	0.93
8.	Oxygen	O2	20.95
9.	Nitrogen	N2	78.08

Composition of the Atmosphere: Ozone Gas

- Present around 10-50 km above the earth’s surface and acts as a sieve, absorbing UV (ultraviolet rays) from the sun.
- Ozone averts harmful rays from reaching the surface of the earth.

Composition of the Atmosphere: Water Vapor

- Water vapour is a variable gas, declines with altitude.
- It also drops towards the poles from the equator.
- It acts like a blanket letting the earth from becoming neither too hot nor too cold.
- It also contributes to the stability and instability in the air.

Composition of the Atmosphere: Dust Particles

- Dust particles are in higher concentrations in temperate and subtropical regions due to dry winds in contrast to the polar and equatorial regions.

- They act as hygroscopic nuclei over which water vapour of the atmosphere condenses to create clouds.

Composition of the Atmosphere: Nitrogen

- The atmosphere is composed of 78% nitrogen.
- Nitrogen cannot be used directly from the air.
- Biotic things need nitrogen to make proteins.
- The Nitrogen Cycle is the way of supplying the required nitrogen for living things.

Composition of the Atmosphere: Oxygen

- The atmosphere is composed of 21% oxygen.
- It is used by all living things and is essential for respiration.
- It is obligatory for burning.

Oxygen Cycle

The oxygen cycle, along with the carbon and nitrogen cycles, is crucial to the maintenance of life on Earth. The oxygen cycle is a biochemical process that works its way and through earth's three primary sectors, assisting in maintain the oxygen level.

1. Atmosphere

2. Lithosphere

3. Biosphere

The flow of oxygen throughout atmosphere, ecosystem, biosphere, and lithosphere is understood by this biogeochemical cycle. The burning of fossil fuels and the oxygen exchange are linked.

The layer of gases flowing above the earth's surface is classified as the atmosphere. A biosphere is mainly composed of all the ecosystems on Earth. The biggest resource of oxygen is found in the lithosphere, which includes the solid outer layer of the globe alongside the crust.

Production of Oxygen

i. Plants:

The leading creators of oxygen are plants by the process of photosynthesis. Photosynthesis is a biological process by which all green plants synthesize their food in the presence of sunlight. During photosynthesis, plants use sunlight, water, carbon dioxide to create energy and oxygen gas is liberated as a by-product of this process.

ii. Sunlight:

Sunlight also produces oxygen. Some oxygen gas is produced when the sunlight reacts with water vapor in the atmosphere.

Uses of Oxygen

The four main processes that use atmospheric oxygen are:

i. Breathing:

It is the physical process, through which all living organisms, including plants, animals and humans inhale oxygen from the outside environment into the cells of an organism and exhale carbon dioxide back into the atmosphere.

ii. Decomposition:

It is one of the natural and most important processes in the oxygen cycle and occurs when an organism dies. The dead animal or plants decay into the ground, and the organic matter along with the carbon, oxygen, water and other components are returned into the soil and air. This process is carried out by the invertebrates, including fungi, bacteria and some insects which are collectively called as the decomposers. The entire process requires oxygen and releases carbon dioxide.

iii. Combustion:

It is also one of the most important processes which occur when any of the organic materials, including fossil fuels, plastics and wood, are burned in the presence of oxygen and releases carbon dioxide into the atmosphere.

iv. Rusting:

This process also requires oxygen. It is the formation of oxides which is also called oxidation. In this process, metals like iron or alloy rust when they are exposed to moisture and oxygen for an extended period of time and new compounds of oxides are formed by the combination of oxygen with the metal.

Importance of Oxygen Cycle

As we all know, oxygen is one of the most essential components of the earth's atmosphere. It is mainly required for:

1. Breathing
2. Combustion
3. Supporting aquatic life
4. Decomposition of organic waste.

Oxygen is an important element required for life, however, it can be toxic to some anaerobic bacteria (especially obligate anaerobes).

The oxygen cycle is mainly involved in maintaining the level of oxygen in the atmosphere. The entire cycle can be summarized as, the oxygen cycle begins with the process of photosynthesis in the presence of sunlight, releases oxygen back into the atmosphere, which humans and animals breathe in oxygen and breathe out carbon dioxide, and again linking back to the plants. This also proves that both the oxygen and carbon cycle occur independently and are interconnected to each other.

Composition of the Atmosphere: Argon

- The atmosphere is composed of 0.9% argon.
- They are mainly used in light bulbs.

Composition of the Atmosphere: Carbon Dioxide

- The atmosphere is composed of 0.03% carbon dioxide.
- Plants use it to make oxygen.
- It is significant as it is opaque to outgoing terrestrial radiation and transparent to incoming solar radiation.
- It is also one of the gases responsible for the greenhouse effect.

Structure of the Atmosphere

The atmosphere is divided into five different layers depending upon the temperature conditions – troposphere, stratosphere, mesosphere, thermosphere and exosphere.The atmosphere can be divided into five layers according to the diversity of temperature and density. They are:

1. Troposphere
2. Stratosphere
3. Mesosphere
4. Thermosphere (Ionosphere)
5. Exosphere

Troposphere

1. It is the lowermost layer of the atmosphere.
2. The average height of the troposphere is 13 km; its height is about 8 km near the poles and about 18 km at the equator. At the equator, its thickness is greatest because heat is transported to great heights by strong convection currents.
3. All the climatic and weather changes take place in this layer of the atmosphere.
4. The temperature decreases with the increase in height; for every 165 m of height, the temperature decreases by 1°C (normal lapse rate).
5. Tropopause is a zone that separates the troposphere from the stratosphere. The temperature in this zone is nearly constant (-80°C over the equator and about -45°C over the poles) and hence, it is called the tropopause.

Stratosphere

1. It is the second layer of the atmosphere, just above the troposphere and extends up to a height of 50 km.
2. This layer of the atmosphere contains the ozone layer which absorbs ultraviolet radiation from the sun and protects life from harmful forms of energy. The UV radiations absorbed by the ozone layer gets converted into heat that is why the stratosphere gets warmer with increasing altitude (unlike the troposphere).
3. Weather-related phenomena are absent in this layer of the atmosphere, that is why aero planes fly in the stratosphere for a smooth ride.

4. Stratopause separates the stratosphere and mesosphere.

Mesosphere

1. Mesosphere is the third layer of the atmosphere which extends up to a height of 80 km.
2. In this layer, temperature decreases with increasing altitude and drops down to minus 100°C at the height of 80 km.
3. Meteorites burn in this layer on entering the atmosphere from outer space.
4. Its upper limit is menopause which separates the mesosphere and thermosphere.

Thermosphere

1. The ionosphere lies within the thermosphere. It is located between 80 and 400 km above the mesosphere and contains electrically charged particles called ions, hence the name ionosphere.
2. In this layer of the atmosphere, temperature increases with increasing height.
3. Radio Waves transmitted from the earth are reflected back to the earth by this layer.
4. Satellites orbit in the upper part of the thermosphere s mention in Figure 5.

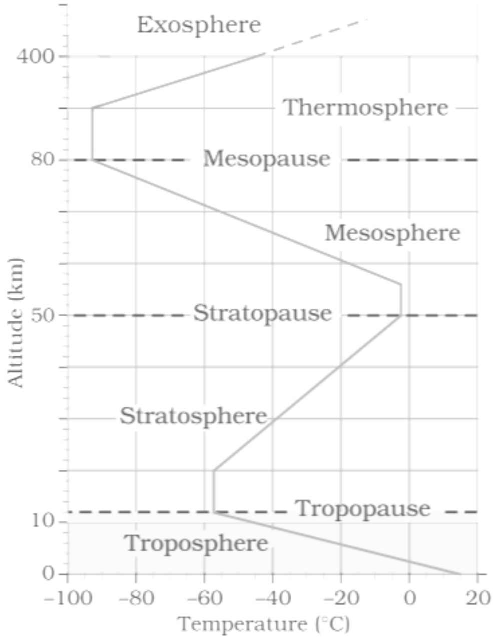

Figure 5: Represented the Thermosphere Graph.

Exosphere

1. The uppermost layer of the atmosphere above the thermosphere is called the exosphere.
2. This layer gradually merges with outer space.

CHAPTER 10

OPTICAL AND PHYSICAL PROPERTIES OF MINERALS ON EARTH

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Physical Properties of Minerals:

Colour:

The colour of any object is a light dependent property- it is the appearance of the particular object in light. A particular color is produced by reflection of some and absorption of other components of white light. A mineral shows colour of that wavelength of the white light which is not absorbed by it by virtue of its composition and atomic structure. In nature, minerals of all perceivable colours are known to occur. Quite a few common minerals generally occur in characteristics colours so that they can be easily identified from their colours.

On the basis of color, a mineral may belong to any one of the three types:

1. Idiochromatic having a characteristic, fairly constant colour related primarily to the composition of mineral. Metallic minerals (e.g. of copper group) belong to this category.
2. Allochromatic having a variable colour; the variety in colour is generally due to minute quantities of colouring impurities thoroughly dispersed in the mineral composition. Many non-metallic minerals like quartz, calcite, fluorite and tourmaline etc. may occur in more than two colours depending on the nature of impurities.
3. Pseudochromatic showing a false colour. Such an effect generally happens when a mineral is rotated in hand; it is then seen to show a set of colours in succession. This change or play of colours is attributed to simultaneous reflection and refraction from the mineral surface due to minute inclusions of impurities in the mineral at different locations.

Some of the peculiar phenomena connected with colour in minerals are briefly explained below:

- **Play of Colours:**

It is the development of a series of prismatic colours shown by some minerals on turning about in light. The colours change in rapid succession on rotation and their effect is quite brilliant and appealing to the eye. These are caused by the interference of light reflected from numerous cleavage surfaces of the mineral. Example- diamond.

- **Change of Colours:**

It is similar to play of colours except that the rate of change of colours on rotation and their intensity is rather low. Each colour continues over a larger space in the mineral before the other takes over. Example- labradorite.

- **Iridescence:**

Some minerals show rainbow colours (similar to those appearing in drops of oil spilled over water) either in their interior or on the exterior surface. This is called iridescence. It is also related to reflections from inclusions. Example- Limonite and hematite.

- **Tarnish:**

This may be described as a phenomenon of change of original colours of a mineral to some secondary colours at its surface due to its oxidation at the surface. Some minerals tarnish very quickly so that their exterior colour is quite different from the interior colour. Example- Bornite and Chalcopyrite.

Although colour is never taken as a diagnostic or conclusive property in the final identification of minerals, it is invariably studied first of all and is generally very helpful. In fact, some minerals have typical colours associated with them such as- Lazurite (deep blue), Pyrite (brass yellow), Cinnabar (carmine red), and magnetite (black) and so on. Quite a few minerals may be colorless and transparent when absolutely pure, e.g. quartz, calcite, diamond and gypsum.

Lustre:

Simply defined, it is the shine of a mineral.

Technically speaking, it is intensity of reflection of light from the mineral surface and depends at least on three factors:

1. The refractive index of the mineral.
2. The absorption (of light) capacity of the mineral.
3. The nature of reflecting surface.

The same mineral may show a poor lustre on rough surface and brilliant lustre on a cleavage face.

Broadly speaking, lustre may be classified into metallic and non-metallic types. Metallic lustres are characteristic of high density, high refractive index and opaque minerals like galena, pyrite and chalcopyrite.

In the non-metallic luster the reflection may vary from very brilliant shine as that of diamonds to very feeble greasy luster of olivine and nepheline.

While studying lustre of the minerals, one may make use of following qualitative terms:

1. Metallic- shine resembles to known metals; example- galena
2. Adamantine- luster of diamonds; very brilliant; example- diamond
3. Vitreous- shine typical of glass, ice etc.; example- quartz
4. Pearly- resembling shine of pearls; example- labradorite
5. Silky- like the shine of pure silk; example- gypsum
6. Resinous- shine is oily, waxy or greasy; example- nepheline.
7. Dull or earthy, where shine is almost absent because no light is reflected due to highly porous nature of the mineral; example- chalk, clay, bauxite.

It may be mentioned that lustre is entirely independent of colour of the mineral. A deeply coloured mineral may be lusterless and vice versa.

Streak:

It is an important and diagnostic property of many coloured minerals. Simply defined, streak is the colour of the finely powdered mineral as obtained by scratching or rubbing the mineral over a rough unglazed porcelain plate. The plate is often named as a streak plate in a geology laboratory.

Colourless and transparent minerals will always give a colourless streak that has no significance. The coloured and opaque minerals, especially of ore groups, give typically characteristic streaks quite different from other similarly looking minerals. For instance, chromite and magnetite resemble closely in their other physical properties- both are almost black. These may be at once distinguished by their streaks: brown for chromite and black for magnetite.

It follows that the colour of a mineral may or may not be the same as its streak. For identification, streak is relied upon more than the colour of the mineral.

Hardness:

It is a fairly constant and diagnostic property of minerals. Hardness may be defined as the resistance, which a mineral offers to an external deformation action such as scratching, abrasion, rubbing or indentation. Hardness of a mineral depends on its chemical composition and atomic constitution.

Broadly speaking hardness of minerals as determined conventionally is a qualitative property determined in relative terms. It was in 1822 that Austrian mineralogist F. Mohs proposed a relative, broadly quantitative “scale of hardness” of minerals assigning values between 1 and 10. Since then, the Mohs’ Scale of Hardness for Minerals has been universally adopted. All minerals, when pure, have been found to have a fairly constant hardness value on this scale and hence the importance of hardness as a diagnostic property.

Cleavage:

It is defined as the tendency of a crystallized mineral to break along certain definite directions yielding more or less smooth, plane surfaces. In other words, cleavage planes are the planes of easiest fractures, and are essentially indicative of directions of least cohesion in the atomic constitution of a mineral.

A mineral may have cleavage in one, two or three directions. Further, the degree of ease in splitting along cleavage directions may vary in the same mineral. As such cleavage is described both in terms of number of directions in which it is observed on a mineral and also in terms of degree of perfect splitting.

Since cleavage directions are always parallel to certain crystal faces in a mineral, these may be described as such. For instance, cubic cleavage (galena and haylite), rhombohedral cleavage (calcite) and prismatic cleavage, basal cleavage and octahedral cleavage.

In terms of perfection, the cleavage is described as: eminent, perfect, good, distinct and indistinct in that order. In eminent cleavage, the mineral can be spilt very easily yielding extremely smooth surfaces e.g. in mica. Perfect cleavages are seen in orthoclase and calcite.

Parting:

It is a property of minerals by virtue of which it can split easily along certain secondary planes. Although it may be confused at first with cleavage but its true nature can be established by careful study.

Parting is actually due to the presence of secondary twin-planes and gliding planes along which the mineral may split easily. These (parting surfaces) are not necessarily related to the mineral as a species, that is, they may be present in one specimen and absent in the other specimen of the same mineral.

Parting is attributed to the presence of a substance of different composition along the parting planes or to the stresses that might have operated during or after the formation of the particular crystals. Best example of parting can be seen in corundum where cleavage may be absent but parting may be very prominent.

Fracture:

The appearance of the broken surface of a mineral in a direction other than that of cleavage is generally expressed by the term fracture. In some cases fracture becomes a characteristic property of a mineral.

Common types of fractures are:

- **Even:**

When the broken surface is smooth and flat. Example- chert.

- **Uneven:**

When the mineral breaks with an irregular surface which is full of minute ridges and depressions. It is a common fracture of many minerals. Example- Fluorite.

- **Conchoidal:**

The broken surface of the mineral shows broadly concentric rings or concavities which may be deep or faint in outline. In the latter case, the fracture may be termed as subconchoidal. Example: Quartz.

- **Splintery:**

When the mineral breaks with a rough woody fracture resulting in rough projection at the surface. Example- kyanite.

- **Hackly:**

The broken surface is highly irregular with numerous sharp, fine, pinching projections. Example- Native Copper.

- **Earthy:**

The surface is smooth, soft and porous. Example- Chalk

- **Tenacity**:

The behaviours of a mineral towards the forces that tend to break, bend, cut or crush it is described by the term tenacity. Thus, when a mineral can be cut with a knife, it is described as sectile. If the slices cut out of it can be flattened under a hammer, it is said to be malleable. Most minerals exhibit the property of brittleness, by virtue of which they change into fine grains or powder when scratched with a knife or when brought under the hammer.

A mineral is said to be flexible when it can be bent, especially in thin sheets. Chlorites are flexible. Some minerals are not only flexible but elastic, that is, they regain their shape when the force applied on them is removed. Micas are best example. The flexible and elastic fibres of asbestos can be woven into fire-proof fabric.

As such, in terms of tenacity mineral may be sectile, brittle, flexible, plastic and elastic, the last two qualities being of diagnostic importance.

Structure:

Minerals often occur in characteristic body forms or physical shapes. The physical make up of a mineral is expressed by the term structure and is often helpful in identifying a particular mineral. In reality, structure merely shows the habit in which the crystal or crystalline substance making a mineral tends to occur in nature. Following are a few common structural forms (habits) observed in minerals.

- **Tabular:**

The mineral occurs in the form of a flattened, square, rectangular or rhombohedral shape. In other words, flattening is conspicuous compared to lengthwise elongation. Examples- Calcite, orthoclase, barite etc.

- **Elongated:**

When the mineral is in the form of a thin or thick elongated, column-like crystals. Examples- Beryl, quartz, hornblende. It is also commonly referred as a columnar structure.

- **Bladed:**

The mineral appears as if composed of thin, flat, blade-like overlapping or juxtaposed parts. Example- Kyanite

- **Lamellar:**

The mineral is made up of relatively thick, flexible, leaf-like sheets. Example- Vermiculite.

- **Foliated:**

The structure is similar to lamellar in broader sense but in this case the individual sheets are paper thin, even thinner and can be easily separated. Example- Muscovite (mica).

- **Fibrous:**

When the mineral is composed of fibres, generally separable, either quite easily (example- asbestos) or with some difficulty (example- gypsum).

- **Radiating:**

The mineral is made up of needle like or fibrous crystals which appear originating from a common point thereby giving a radiating appearance. Example- Iron pyrites. When needles are pointed and not necessarily radiating, the structure is called acicular.

- **Granular:**

The mineral occurs in the form of densely packed mass of small grain-like crystals. Example- Chromite.

- **Globular:**

Globular or botroiydal, when the mineral surface is in the form of rounded, bulb-like overlapping globules or projections. Example- Hematite.

- **Reniform:**

It is similar to globular but the shape of the bulbs or projections resembles to human kidneys. Example- Hematite.

- **Mammillary:**

It is similar to globular but the projections are conspicuous in size, overlapping in arrangement and rounded in shape. Example- Malachite.

Specific Gravity:

The density of a substance is a fundamental property of great significance and is defined as the mass per unit volume of the substance. For minerals, it is expressed in g/cc.

In mineralogy, the term specific gravity is used more frequently than density and signifies "the ratio between the density of a mineral and that of water at 4° Celsius".

Since it is a ratio, it has no units. Specific gravity of quartz is, for instance, 2.65. The specific gravity is also termed relative density.

Density (hence specific gravity) of minerals depends primarily on:

- **Composition:**

The non-metallic minerals have low values, ranging between 2.5 to 4.5 g/cc, whereas metallic minerals and ores have densities as high as 20 g/cc.

- **Atomic Constitution:**

Minerals with atoms of greater atomic radii show less density values compared with those made of atoms of smaller atomic radii.

Since temperature and pressure are both known to change volume of a substance, it follows that density will also show a change when a mineral is subjected to elevated temperature or high pressures.

Specific gravity of some common minerals is: quartz (2.65); calaite (2.60); fluorite (3.18); hematite (5.2); chalcopyrite (4.2); galena (7.5); native gold (19.3).

- **Determination:**

Many methods and instruments are available for determination of specific gravity of minerals. All of them involve weighing the mineral specimen in air and then in a liquid (generally water), wherefrom the loss in weight of the mineral is obtained which is due to the displacement of an equal volume of the liquid.

Specific gravity is calculated by the following relationship:

Sp.Gr. = (Weight of the mineral in air/Loss of weight in liquid) × d

Where d = density of the liquid used. (In the case of water it is 1)

The Jolly's balance, the Beam balance and the Walker's Steelyard Balance are commonly used in the geological laboratories for determination of specific gravity of minerals.

These are all very simple yet delicate instruments and require:

- Careful selection of the sample from the mineral; the grain should be small in weight, free from dust and other impurities;
- Careful handling, as a slight error in adjustment and observation can give rise to incorrect values.

Air-Sea Interface

Air-Sea interface, boundary between the atmosphere and the ocean waters. The air-sea interface is one of the most physically and chemically active environments on Earth. Its neighborhood supports most marine life.

The atmosphere gains much of its heat at the interface in tropical latitudes by back radiation from the heated ocean. In turn, the atmosphere heats the ocean surface in higher latitudes. Atmospheric motion at the interface generates waves and currents. The atmosphere acquires most of its moisture and additional energy in the form of latent heat from the evaporation of water at the interface. Enormous quantities of oxygen and carbon dioxide are exchanged between the atmosphere and the ocean at the interface; this exchange aids and benefits from marine life processes.

The impact of climate at the interface controls the salinities and temperatures of surface ocean waters. The density of seawater is determined by these parameters and, in turn, controls to which depths in the ocean the water masses flow.

Photosynthesis, the fundamental basis for oceanic life, takes place just below the interface, where the necessary ingredients of solar energy, carbon dioxide, and nutrient seawater salts are all available.

Atmospheric science, interdisciplinary field of study that combines the components of physics and chemistry that focus on the structure and dynamics of Earth's atmosphere. Mathematical tools, such as differential equations and vector analysis, and computer systems are used to evaluate the physical and chemical relations that describe the workings of the atmosphere.

The atmospheric sciences are traditionally divided into three topical areas—meteorology (the study and forecasting of weather), climatology (the study of long-term atmospheric patterns and their influences), and aeronomy (the study of the physics and chemistry of the upper atmosphere). In meteorology, the focus of study concerns day-to-day and hour-to-hour changes in weather within the lower stratosphere and troposphere. Climatology, on the other hand, concentrates more on longer time periods ranging from a single month to millions of years and attempts to describe the interaction of the atmosphere with the oceans, lakes, land, and glaciers. For example, of the three topical areas, climatology would be the best equipped to provide a farmer with the most likely date of the first frost in the autumn. The focus of aeronomy is on the atmosphere from the stratosphere outward. This field also considers the role the atmosphere plays in the propagation of electromagnetic communications, such as shortwave radio transmissions.

Within these three major topical areas, the broad nature of the atmospheric sciences has spawned practitioners who specialize in several distinct subfields. Scientists who investigate the physics associated with atmospheric flow are called dynamic meteorologists or simply dynamicists. When the investigation procedure involves the application of large computer models of atmospheric structure and dynamics, the scientists are called numerical modelers. Scientists and technicians who specifically investigate procedures of weather forecasting are called synoptic meteorologists, while those who investigate the physical mechanisms associated with the growth of cloud droplets and ice crystals and related precipitation processes are called cloud physicists. Researchers who study atmospheric optical effects are referred to as physical meteorologists, while individuals who investigate the dynamics and observations of climate are called climatologists or climate scientists. Pale climatologists are researchers who concentrate on ancient climate patterns. Scientists who investigate atmospheric structure and dynamics within the boundary layer are referred to as boundary layer meteorologists or micrometeorologists.

Sea Level

Sea level, position of the air-sea interface, to which all terrestrial elevations and submarine depths are referred. The sea level constantly changes at every locality with the changes in tides, atmospheric pressure, and wind conditions. Longer-term changes in sea level are influenced by Earth's changing climates. Consequently, the level is better defined as mean sea level, the height of the sea surface averaged over all stages of the tide over a long period of time.

Global mean sea level rose at an average rate of about 1.2 mm (0.05 inch) per year over much of the 20th century, with shorter terms during which the rise was significantly faster (5.5 mm [0.2 inches] per year during the period from 1946 to 1956). This variable rise has been shown to have occurred for a very long time. The sea level appears to have been very close to its present position 35,000 years ago. It dropped 130 meters (426 feet) or more during the interval from 30,000 to 15,000 years ago and has been rising ever since. Fluctuations of equivalent magnitude probably have accompanied the alternate growth and melting of continental glaciers during the Pleistocene Epoch (from 2.6 million to 11,700 years ago) because the ocean's waters are the ultimate source of glacial ice. Slower changes in the shapes and sizes of the ocean basins have less effect.

CHAPTER 11

GLACIERS

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A glacier is a large, perennial accumulation of crystalline ice, snow, rock, sediment, and often liquid water that originates on land and moves down slope under the influence of its own weight and gravity. Typically, glaciers exist and may even form in areas where:

1. Glaciers are a mass of ice moving under its own weight. They are commonly found in the snow-fields.
2. We know that the landmass on the earth is not entirely the same as we see around. Some areas are covered by thick green forests, some with dry hot deserts, some with permanent ice covers etc. Among these varied landmasses, the permanently ice-covered regions on the earth surface are called as snow-fields. The lowest limit of permanent snow or snow-field is called as the snowline.
3. A Glacier forms in areas where the accumulation of snow exceeds its ablation (melting and sublimation) over many years, often centuries.
4. They form features like crevasses, seracs etc. A crevasse is a deep crack, or fracture, found in an ice sheet or glacier, as opposed to a crevice that forms in rock. A **serac** is a block or column of glacial ice, often formed by intersecting crevasses on a glacier.
5. ***Ogives*** are alternating wave crests and valleys (troughs) that appear as dark and light bands of ice on glacier surfaces. They are linked to seasonal motion of glaciers; the width of one dark and one light band generally equals the annual movement of the glacier.
6. Glaciers cover about 10 percent of Earth’s land surface and they are the largest freshwater reservoirs on earth.
7. Mean annual temperatures are close to the freezing point
8. Winter precipitation produces significant accumulations of snow
9. Temperatures throughout the rest of the year do not result in the complete loss of the previous winter’s snow accumulation

Types of Glaciers

There are two main types of glaciers: continental glaciers and alpine glaciers. Latitude, topography, and global and regional climate patterns are important controls on the distribution and size of these glaciers.

Continental Glaciers

Continental glaciers cover vast areas of land. Today, continental glaciers are only present in extreme Polar Regions: Antarctica and Greenland as mention in below figure. Historically, continental glaciers also covered large regions of Canada Europe, and Asia, and they are responsible for many distinctive topographic features in these regions.

Continent glaciers can form and grow when climate conditions in a region cool over extended periods of time. Snow can build up over time in regions that do not warm up seasonally, and if the snow accumulates in vast amounts, it can compact under its own weight and form ice.

Earth's two current continental glaciers, the Antarctic and Greenland Ice Sheets, comprise about 99% of Earth's glacial ice, and approximately 68% of Earth's fresh water. The Antarctic Ice Sheet is vastly larger than the Greenland Ice Sheet and contains about 17 times as much ice. If the entire Antarctic Ice Sheet melted, sea level would rise by about 80 m and most of Earth's major coastal cities would be submerged as mention in Figure 1.

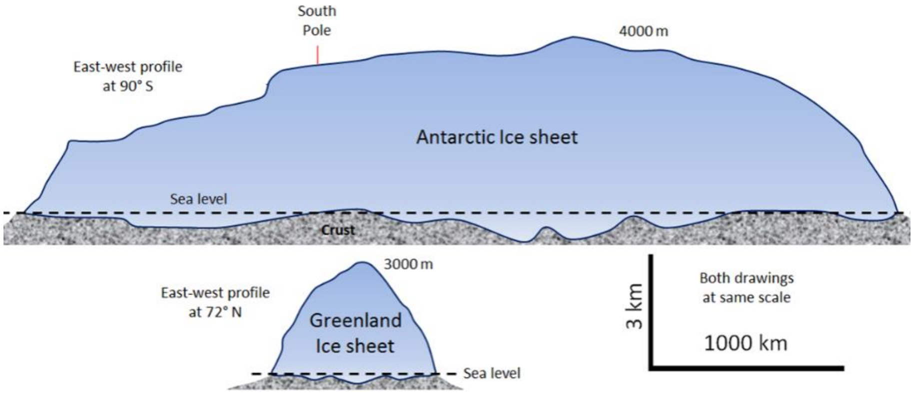

Figure 1: Represented theContinental Glaciers.

Continental glaciers generally cover areas that are flat, but the force of gravity still acts on them and causes them to flow. Continental glacier ice flows from the region where it is thickest toward the edges where it is thinner as display in below figure. In the central thickest parts, the ice flows almost vertically down toward the base, while at the edges of the glacier, it flows horizontally out toward the margins. In continental glaciers like the Antarctic and Greenland Ice Sheets, the thickest parts (4,000 m and 3,000 m thick, respectively) are the areas where the rate of snowfall, and therefore of ice accumulation, are greatest. In Antarctica, the ice sheet flows out over the ocean, forming ice shelves Figure 2. Ice shelves can slow the flow of continental glaciers outward. Conversely, if ice shelves break down continental glacier flow can speed up.

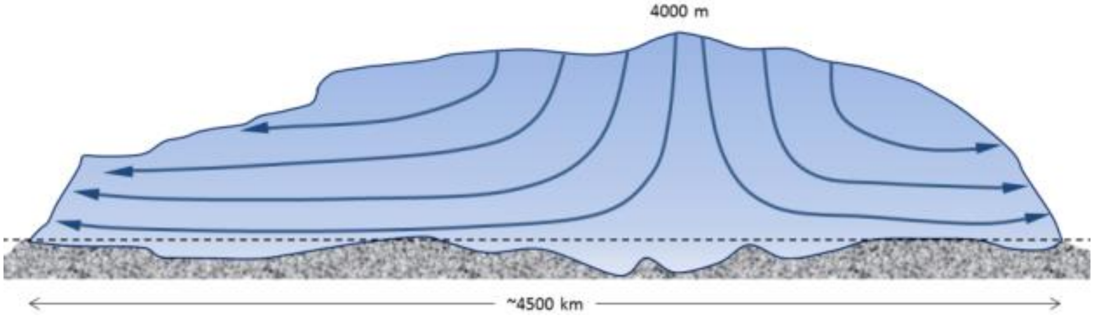

Figure 2: Represented that the flow of Continental Glaciers Outward

Alpine Glaciers

Alpine glaciers (aka valley glaciers) originate high up in the mountains, mostly in temperate and Polar Regions, but also in tropical regions in high mountains. E.g. in the Andes Mountains of South America). The flow of alpine glaciers is driven by gravity, and primarily controlled by the slope of the ice surface as represented in below figure. Alpine glaciers grow due to accumulation of snow over time. In the zone of accumulation, the rate of snowfall is greater than the rate of melting. In other words, not all of the snow that falls each winter melts during the following summer, and the ice surface in the zone of accumulation does not lose its annual accumulation of snow cover over the course of the year as mention in Figure 3. In the zone of ablation**,** the rate of melting exceeds accumulation. The equilibrium line marks the boundary between the zones of accumulation (above) and ablation.

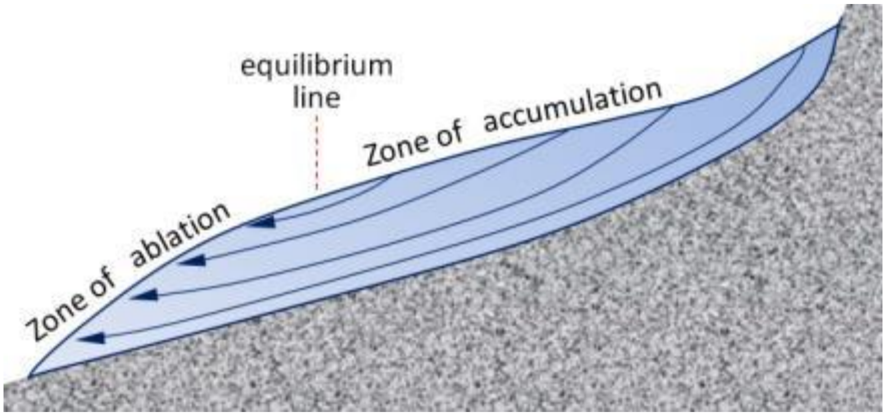

Figure 3: Represented the Alpine Glaciers.

Above the equilibrium line of a glacier, winter snow will remain even after summer melting, so snow gradually accumulates on the glacier over time. The snow layer from each year is covered and compacted by subsequent snow, and it is gradually compressed and converted to firn as shown in below Figure 4.

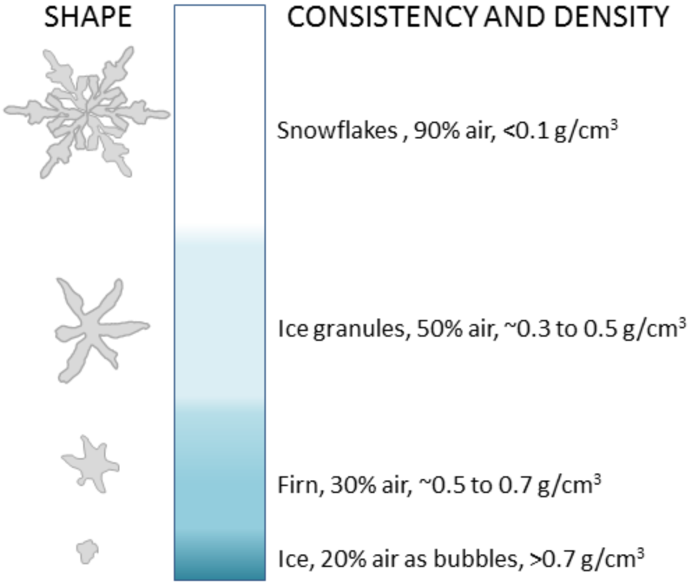

Figure 4: Represented the Equilibrium Line of a Glacier.

Firn is a form of ice that forms when snowflakes lose their delicate shapes and become granules due to compression. With more compression, the granules are squeezed together, and air is forced out. Eventually the granules are "welded" together to create glacial ice. Downward percolation and freezing of water from melting contributes to the process of ice formation. The equilibrium line of a glacier near Whistler, BC, is shown in below Figure 5. Below this line is the zone of ablation. In the zone of ablation, bare ice is exposed because the previous winter's snow has all melted. Above this line the ice is still mostly covered with snow from the previous winter.

Figure 5: Represented the Equilibrium Line of a Glacier.

The position of the equilibrium line changes from year to year as a function of the balance between snow accumulation in the winter, and snow and ice melt during the summer. If there is more winter snow and less summer melting, this favors the advance of the equilibrium line down the glacier and ultimately increases the size of the glacier and between accumulation and melting, the summer melt matters most to a glacier's ice budget. Cool summers promote an increase in glacier size, and thus lead to advance of the equilibrium line. Warm summers promote melting, and retreat of the equilibrium line.

Alpine glaciers move because they are heavy, and the force of gravity acts on the ice in the glacier to pull it down the slope of the mountains where they form. The movement of the glacier generates stress in the ice, which is proportional to the slope of the glaciers surface features of the underlying rock surface, and to the depth within the glacier.

As shown in below figure, the stresses are relatively small near the ice surface but much larger at depth. Stresses are greater in areas where the ice surface is relatively steep.

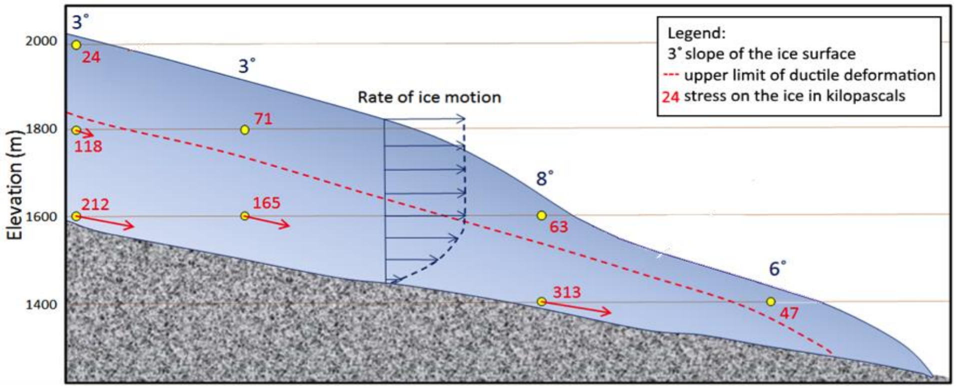

Figure 6: Represented the Rate Ice Surface Motion.

According to the above figure Stress within an alpine glacier red numbers as determined from the slope of the ice surface and the depth within the ice. The ice will deform and flow where the stress is greater than about 100 kilopascals, and regions with higher rates of deformation are depicted by the red arrows. Any motion of the lower ice will be transmitted to the ice above it, so although the red arrows get shorter toward the top, the ice is still moving blue arrows in center of diagram inset illustrate rate of ice motion. The upper ice above the red dashed line does not flow plastically, but it is carried along with the lower ice as mention in Figure 6.

Like rock, ice behaves in a brittle fashion under low pressure conditions (shallow depths in the glacier), and plastically at higher pressures deeper in the glacier. Stress also affects how ice deforms; at high stress ice will either break or deform plastically ductile deformation depending on the pressure conditions. Under brittle deformation conditions (low pressures, shallow depths in the glacier), stress is released when the ice cracks, so does not build up to high values. Within the upper 50-100 m of ice, flow is brittle: the ice is rigid and will crack in response to stress. Under ductile deformation conditions (higher pressures deeper in the glacier), stress can accumulate, and the ice will flow plastically in response to that stress. Ice deforms plastically if deeper than about 100 m in the glacier, and in this region stress levels can accumulate to high values (100 kilopascals or greater..

When the lower ice of a glacier flows, it moves the upper ice along with it. It may seem from the stress patterns that the lower ice moves more or faster than the upper ice, but this is not the case. The lower ice deforms (flows) and the upper part is carried along and deforms through brittle deformation if subjected to sufficient stress. The upper part of the glacier moves faster than the base of the glacier because there is friction between the base of the glacier and the surface beneath it that slows the movement of the ice at the base.The plastic lower ice of a glacier can flow over irregularities in the rocks under the glacier. However, the upper rigid ice cannot flow in this way, and because it is being carried along by the lower ice, it tends to crack in locations when the lower ice flows over changes in the topography below the glacier. This leads to formation of crevasses in areas where the rate of flow of the deeper, plastic ice is changing. In the area shown in figure below, for example, the glacier is accelerating over the steep terrain, and the rigid surface ice cracks to release stress that accumulates due to the change in velocity and tension in the ice.

In addition to deformation, another important aspect of glacier flow is basal sliding, which is sliding movement between the base of the glacier and the underlying material. The base of a glacier can be cold below the freezing point of water or warm above the freezing point. If it is warm, a film of water can form between the ice and the material underneath, and the ice will be able to slide over this surface as display in figure below, which is describe the Differences in glacial ice motion with basal sliding (left) and without basal sliding (right). The dashed red line indicates the upper limit of plastic internal flow. If the base is cold, the ice will be frozen to the material underneath and it will be stuck unable to slide along its base. In this case, all the movement of the ice will be by internal flow as mention in Figure 7.

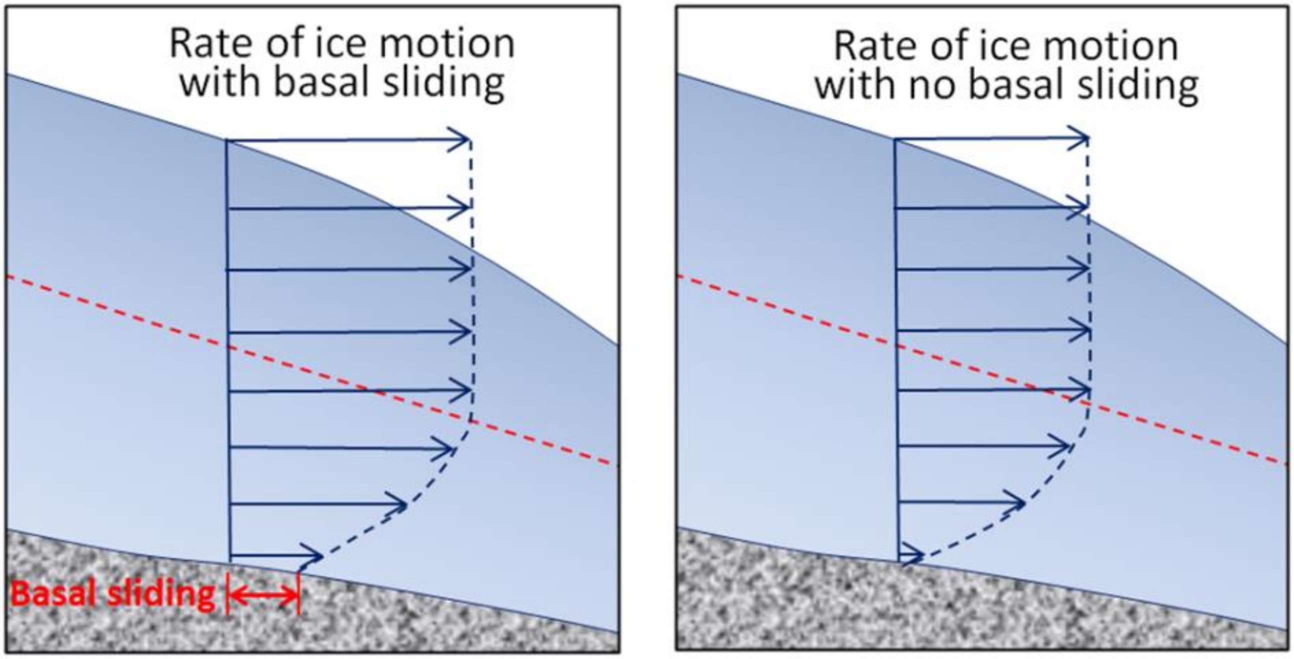

Figure 7: Represented that the Rate of Ice Motion.

There are several factors that can influence warming of the ice and basal flow at the base of an alpine glacier. Friction between the base of the glacier and the surface underneath generates heat and can lead to melting of the ice at the base of the glacier. Rainwater and meltwater from upper regions of the glacier can percolate down and transfer heat to warm the base of the glacier and enhance basal sliding, particularly in warmer seasons. Geothermal heat from below also contributes to melting at the base of glaciers in regions with high heat flow due to volcanic activity.

Another factor that controls the temperature at the base of a glacier is the thickness of the ice. The force of gravity acting on thicker ice can enhance friction and melting at the base. Ice is also a good insulator so can prevent accumulated heat from escaping. The leading edge of an alpine glacier is typically relatively thin, so it is common for this part to be frozen to its base while the rest of the glacier is still sliding. Since the leading edge of the glacier is frozen to the ground, and the rest of the glacier behind continues to slide forward, this causes the trailing ice to be pushed (or thrust) over top of the leading edge, forming thrust faults in the ice.

Just as the base of a glacier moves slower than the surface, the edges, which are more affected by friction along the channel walls, also move slower. If we were to place a series of markers across an alpine glacier and come back a year later, we would see that the ones in the middle had moved further forward than the ones near the edges as display in figure Below 8. Which is shows that the Markers on an alpine glacier move forward at different rates over a period of time.

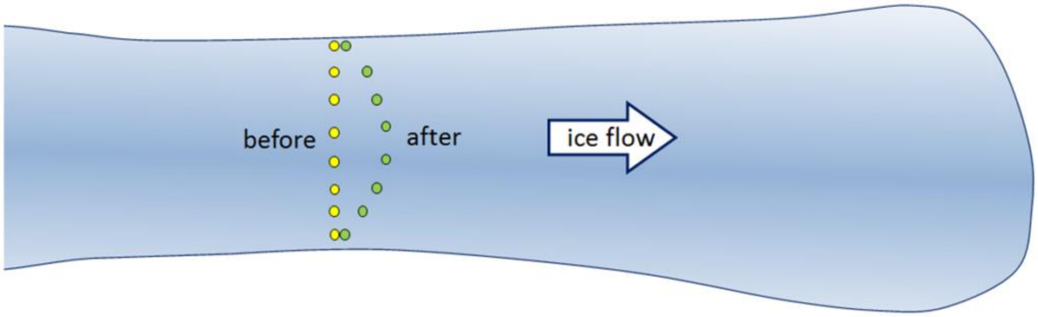

Figure 8: Represented the Ice Flow in different Phase.

Alpine glacial ice continuously moves down the slope of the ice in response to gravity, but it may not appear to be moving because the front edge of a glacier is also continuously losing volume. It either melts or, if they glacier terminates at a lake or ocean, the front edge will calve into the water (break off pieces of the front edge of the glacier that become icebergs). If the rate of forward motion of the glacier is faster than the rate of ablation (melting), the leading edge of the glacier advances (moves forward). If the rate of forward motion is about the same as the rate of ablation, the leading edge remains stationary, and if the rate of forward motion is slower than the rate of ablation, the leading-edge retreats (moves backward).

Calving of icebergs is an important process for glaciers that terminate in lakes or oceans. An example of such a glacier, which sheds small icebergs into Berg Lake. The Berg Glacier also lose mass by melting, evaporation, and sublimation. In the below figure Mt. Robson, the tallest peak in the Canadian Rockies, hosts the Berg Glacier (centre), and Berg Lake. Although there were no icebergs visible when this photo was taken, the Berg Glacier loses mass by shedding icebergs into Berg Lake.

Erosional landforms due to Glaciers

- **Cirque or Corris**

  1. They are deep, long and wide troughs or basins with very steep concave to vertically dropping high walls at its head as well as sides.
  2. They are simply a bowl-shaped depression formed due to the erosional activity of glaciers.
  3. When these depressions are filled with water, they are called as Cirque lake or Corrie Lake or Tarn Lakes**.**

- **Hanging Valleys or U-shaped Valleys, Fjords/fiords**

  1. The Glacier doesn’t create a new valley like a river does but deepens and widens a pre-existing valley by smoothening away the irregularities.
  2. These valleys, which are formed by the glacial erosions assume the shape of letter ‘U’ and hence are called as U-shaped Valleys or Hanging Valleys.
  3. A fjord is a very deep glacial trough filled with sea water and making up shorelines.
  4. A fjord is formed when a glacier cuts a U-shaped valley by ice segregation and abrasion of the surrounding bedrock and this valley gradually gets filled with the seawater (formed in mountains nearby sea).

- **Horns and Aretes**

1. Horns are sharp pointed and steep-sided peaks.
2. They are formed by headward erosion of cirque wall.
3. When the divide between two cirque walls gets narrow because of progressive erosions, it results in the formation of a saw-toothed ridge called Arete.

Depositional Landforms due to Glaciers

Glacial deposits are of two types:

- **Glacial Till:** Unsorted coarse and fine debris;
- **Outwash:** Assorted roughly stratified deposits.

i. Moraines

1. Moraines are long ridges of deposits of glacial till.
2. When these deposits are at the end of a glacier, they are called as Terminal moraines and when they are deposited on both sides, they are called as Lateral moraines.
3. When lateral moraines of two glaciers join together, they form Medial moraines.
4. When the lateral moraines of both sides of a glacier join together, it forms a horse-shoe shape.
5. Ground moraines are deposits left behind in areas once covered by glaciers as mention in Figure 9.

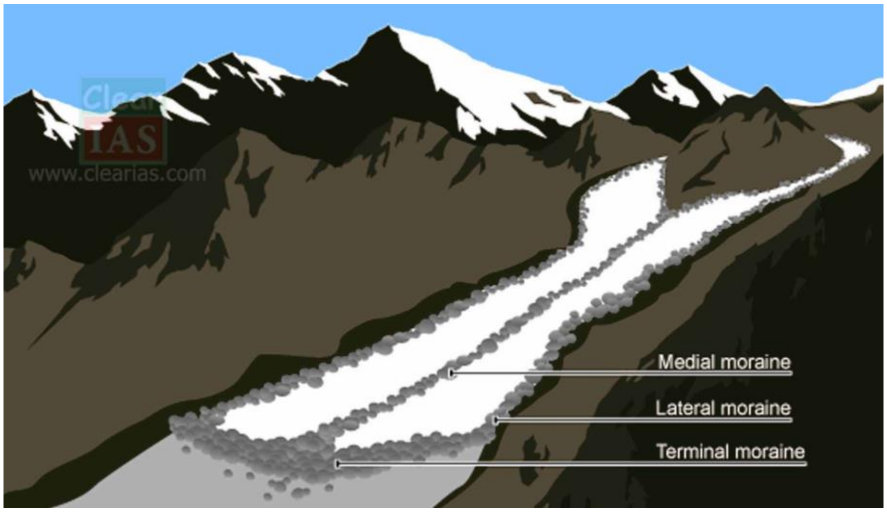

Figure 9: Showed the Moraines.

ii. Eskers

1. When glaciers melt in summer, the water which formed as a result of melting accumulates beneath the glacier and flows like streams in channels beneath that ice.
2. Very coarse material like boulders, blocks and some minor fractions of rock debris are carried away by these streams.

3. They later get deposited in the valleys itself and once the ice melts completely, they are visible to the surface as sinuous ridges.
4. These ridges are called as Eskers.

iii. **Drumlins**

1. They are smooth oval-shaped ridge-like structures composed mainly of glacial till.
2. It shapes like an inverted spoon with the highest part is called as Stoss End and the lowest narrow part is called as Tail End.
3. They are formed as a result of glacial movement over some minor obstruction like small surface rocks.
4. The glacial till gets deposited in those obstructions and the movement of glacier shapes these deposits like an inverted spoon.

CHAPTER 12

COASTAL PROCESSES

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The coastal zone is that part of the land surface influenced by marine processes. It extends from the landward limit of tides, waves, and windblown coastal dunes, and seaward to the point at which waves interact significantly with the seabed. The coastal zone is a dynamic part of the Earth's surface where both marine and atmospheric processes produce rocky coasts, as well as beaches and dunes, barriers and tidal inlets, and shape deltas. The atmospheric processes include temperature, precipitation, and winds, while the major marine processes are waves and tides, together with water temperature and salinity. The coast also supports rich ecosystems, including salt marshes, mangroves, seagrass, and coral reefs. The diverse coastal ecology is favored by the shallow waters, abundant sunlight, terrestrial and marine nutrients, tidal and wave flushing, and a range of habitat types.

Wave’s Generation and Types

Waves provide about half the energy to do work at the coast. Ocean waves are generated by wind blowing over the ocean surface. The stronger the wind, the longer it blows and the longer the fetch, or stretch of ocean over which it blows, the larger the waves (Figure 1). The world's greatest wave factories are in the zone of sub-polar lows centered on 40–60° N and S latitudes, the so-called roaring 40's and screaming 60's. The strong westerly winds produce the world's biggest waves which initially head west, and are deflected equatorward by the Coriolis effect, arriving from the northwest in the northern hemisphere and southwest in the southern hemisphere as mention in Figure 1. Other major wave climates are the easterly waves produced by the expansive but moderate velocity northeast and southeast Trade winds and lesser seasonal waves produced by the monsoons and even the polar easterlies, together with occasional hurricanes that can produce massive waves as well as storm surges.

When waves are being generated they are called a sea and consist of short, steep, high, slower waves, which tend to topple over and break, and have a broad spectrum of direction. Once the wind stops blowing, and/or the waves leave the area of generation, they quickly transform into swell lower, longer, faster and uniform in direction. Swell waves can theoretically travel around the world with minimal loss of energy, while in reality they eventually break on some distant shore. Waves are a form of potential energy that can be transported across hundreds to thousands of kilometers of ocean to be released as kinetic energy when they shoal and break. Waves are defined by their height (H) (trough to crest), length (L) (crest to crest) and period (T) (time between successive crests). The longer the period the longer and faster the waves, as wave length $L=1.56\ T$, and wave velocity $C = 1.56\ T^2$. When waves enter shallow water their velocity is controlled by the water depth (d) such that $C=\sqrt{g}d$ where g is the gravitational constant. For this reason waves slowly down as they move towards the shore, with a 10 sec wave traveling at 56 km/hr (35 mph) in deep water slowed to 7 km/hr (4 mph) in 5 m water depth.

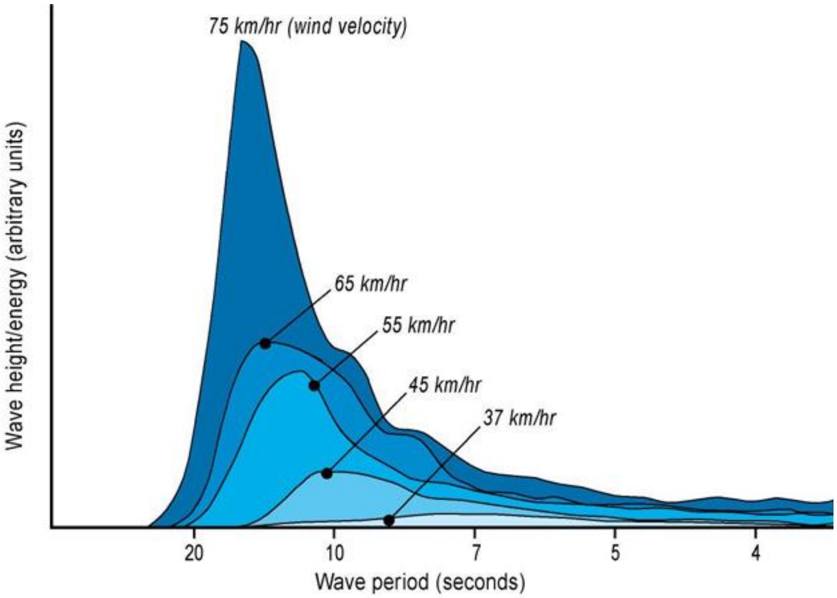

Figure 1: Represented the Wave Height or Energy.

Tides and Tidal Currents

Tides are produced by the gravitational pull of the Moon and Sun acting on a rotating Earth. This pull produces a very slight bulge in the ocean, which we know as tide. The tides and the currents they generate are responsible for about 50% of the marine energy delivered to the coast. The major impact of tides is to shift the shoreline between high and low tide, and to generate tidal currents either parallel to the coast, or at tidal inlets and estuaries, currents flowing into the inlets and perpendicular to the coast as see in below Figure 2.

Figure 2: Represented the Different Coast.

Wind and Currents

Winds blowing over the oceans are responsible for generating ocean waves. Nearer the coast they can generate local seas they can move the ocean surface and generate locally wind driven currents which in places can result in upwelling and down welling. Finally, when blowing over the beach, they can transport sand inland to build coastal sand dunes.

Fluvial-deltaic Systems

Fluvial systems deliver sediment to the coast where it is deposited in estuaries and deltas. Depending on their location, deltas are also acted on by waves, tides, and other currents, and shaped to suit the prevailing processes. Sediment can also be moved longshore to supply beach and barrier systems.

Sea level

Sea level determines the position of the shoreline. During the last glacial maxima (ice age) 18,000 years ago, sea level was 120 m below present, and the continental shelves were exposed. It then rose, reaching present sea level around 6,000 years ago, after which it was relatively stable. Now, with climate change, it is beginning to rise again, and may rise as much as 1 m over the next 100 years, triggering shoreline retreat, inundation, and erosion.

Beach Systems

Beaches are wave-deposited accumulations of sediment located at the shoreline. They require a base to reside on, usually the bedrock geology, waves to shape them, sediment to form them, and most are also affected by tides. The beach extends from wave base where waves begin to feel bottom and shoal, across the near shore zone, though the surf zone to the upper limit of wave swash as display in below Figure 3. In the coastal zone ocean waves are transformed by shoaling, breaking, and swash. In doing so they interact with the seabed, and determine the beach morphology or shape, a process called beach morph dynamics.

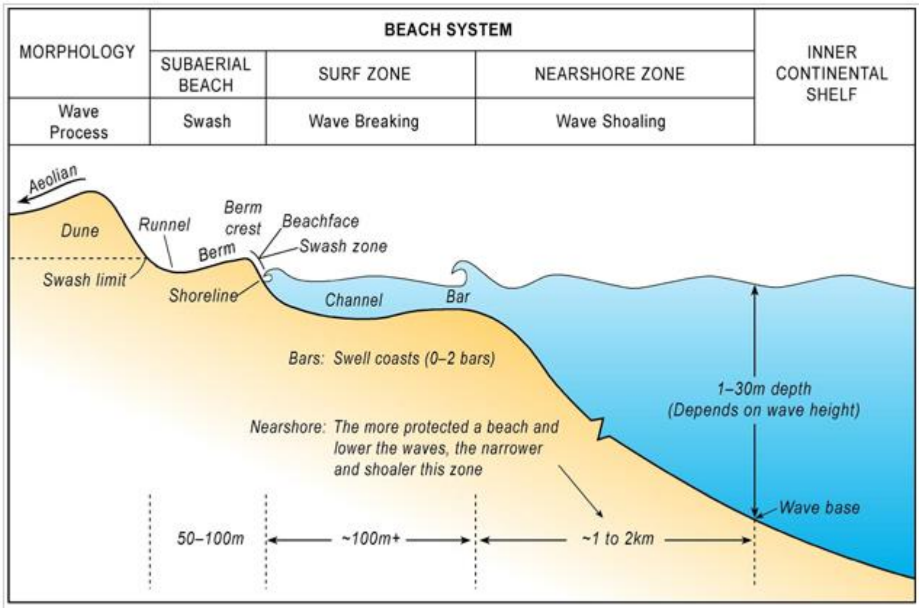

Figure 3: Represented that the Beaches System.

Beach Sediment types & Sources

All beaches consist of sediment, which can range in size from sand up to cobbles and boulders. The finer sand result in very low gradient (~1°) beaches while cobbles may be stacked as steep as 20°. Most beaches with fine to medium sand have a swash zone gradient between 1–8°.

In the mid-latitudes most beaches are composed of siliceous or quartz sand grains derived from erosion. In the topics, coral reef detritus and shells known as 'carbonate sediment' tend to dominate, while in higher latitudes physical weathering produces coarse rock fragments and gravel.

Beach Sub-systems.

At the beach the three zones of wave transformation (shoaling, breaking, and swash) produce three morphologically distinct sub-systems. The shoaling wave zone builds a low gradient (~1°) concave upward profile, smooth in outline, with small wave-generated ripples and generally onshore sediment movement. As they shoal they interact with the seabed, slowing down and increasing in steepness and height.

The surf zone is the most dynamic part of the beach and extends from the breaker zone to the shore. Waves break when the water depth is approximately 1.5 times the wave height. They can break as a spilling breaker on low gradient slopes, a plunging wave on moderate gradients, or a surging wave on steep slopes. In breaking, waves transform their potential energy to kinetic energy, which is initially manifest as the broken wave of translation, or wave bore, which moves shoreward as broken white water. At the shoreline the currents can be deflected longshore and water may return seaward as a rip current.

Surf zone currents can transport sediment onshore, long shore and offshore and build the (sand) bars and troughs that occupy the surf zone. The number and location of the bars is a product of infragravity waves, a low frequency (greater 30 sec period) wave produced by sets of higher and lower waves and which is enhanced by wave breaking across the surf zone. The longer the infragravity wave period the more widely spaced the bar(s). Another form of infragravity wave called edge waves also influence the long shore spacing of rip currents and channels, which are typically 200–300 m apart on ocean beaches. Rip currents are narrow, seaward moving currents that move seaward though the surf zone, often in a deeper rip channel in below figure. They are a mechanism for returning the water back out to sea, and a conduit to transport seaward eroded beach sediment during high seas. They are also a major hazard to beach goers and responsible for most beach rescues and drowning.

When the broken wave reaches the base of the wet beach it collapses and runs up the beach face as swash or uprush in the swash zone in below figure. The uprush stops toward the top of the slope, some percolates into the beach, the remainder flows back down the beach as backwash. Both actions produce a relatively steep seaward sloping swash zone or beach face, which can range from 1 to 20°. As sediment is deposited in the swash zone it can build a berm, a near horizontal to slightly landward-dipping sand surface, the area where most people sit when they go to the beach. The swash zone may also contain beach cusps, spaced about every 20 to 30 m and produced by another form of edge wave.

CHAPTER 13

HILLS OF PENINSULAR INDIA: ARAVALIS, VINDHYAS, SATPURAS, WESTERN & EASTERN GHATS HILL RANGES OF THE PENINSULAR PLATEAU

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1. Most of the hills in the peninsular region are of the relict type (residual hills).
2. They are the remnants of the hills and horsts formed many million years ago (horst: uplifted block; graben: subsided block).
3. The plateaus of the peninsular region are separated from one another by these hill ranges and various river valleys as display in Figure 1.

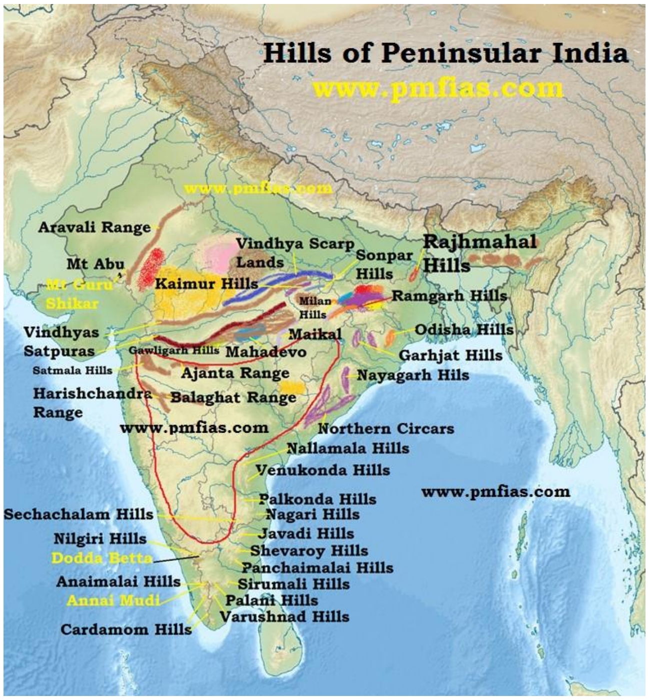

Figure 1: Represented that the Hill Ranges of the Peninsular Plateau

Aravali Range

- **i.** They are aligned in north-east to south-west direction.
- **ii.** They run for about 800 km between Delhi and Palanpur in Gujarat.
- **iii.** They are one of the oldest (very old) fold mountains of the world and the oldest in India. {Fold Mountains – Block Mountains}

iv. After its formation in Archaean Era (several 100 million years ago), its summits were nourishing glaciers and several summits were probably higher than the present day Himalayas.

v. Now they are relict (remnants after severe weathering and erosion since millions of years) of the world's oldest mountain formed as a result of folding (Archaean Era).

vi. They continue up to Hariddwar buried under the alluvium of Ganga Plains.

vii. The range is conspicuous in Rajasthan (continuous range south of Ajmer where it rises to 900 m.) but becomes less distinct in Haryana and Delhi (characterized by a chain of detached and discontinuous ridges beyond Ajmer).

viii. According to some geographers, one Branch of the Aravalis extends to the Lakshadweep Archipelago through the Gulf of Khambhat and the other into Andhra Pradesh and Karnataka.

ix. It's general elevation is only 400-600 m, with few hills well above 1,000 m.

x. At the south-west extremity the range rises to over 1,000 m. Here Mt. Abu (1,158 m), a small hilly block, is separated from the main range by the valley of the Banas. Guru Sikhar (1,722 m), the highest peak, is situated in Mt. Abu.

xi. Pipli Ghat, Dewair and Desuri passes allow movement by roads and railways.

<u>Vindhyan Range</u>

i. The Vindhyan Range, overlooking (have a view of from above) the Narmada valley, rises as an escarpment (a long, steep slope at the edge of a plateau or separating areas of land at different heights) flanking (neighboring on one side) the northern edge of the Narmada-Son Trough (the rift through which the Narmada river flows)(trough is opposite of ridge. It is a narrow depression).

ii. It runs more or less parallel to the Narmada Valley in an east-west direction from Jobat in Gujarat to Sasaram in Bihar for a distance of over 1,200 km.

iii. The general elevation of the Vindhyan Range is 300 to 650 m.

iv. Most parts of the Vindhayan Range are composed of horizontally bedded sedimentary rocks of ancient age. {Rock System}

v. The Vindhyas are continued eastwards as the Bharner and Kaimur hills.

vi. This range acts as a watershed between the Ganga system and the river systems of south India.

vii. The rivers Chambal, Betwa and Ken rise within 30 km of the Narmada.

<u>Satpura Range</u>

i. Satpura range is a series of seven mountains ('Sat' = seven and 'pura' = mountains)

ii. It runs in an east-west direction south of the Vindhyas and in between the Narmada and the Tapi, roughly parallel to these rivers.

iii. It stretches for a distance of about 900 km.

iv. Parts of the Satpuras have been folded and upheaved. They are regarded as structural uplift or 'horst'.

v. Dhupgarh (1,350 m) near Pachmarhi on Mahadev Hills is the highest peak.

vi. Amarkantak (1,127 m) is another important peak.

Western Ghats (or The Sahyadris)

i. They form the western edge of the Deccan tableland.

ii. Run from the Tapi valley (21° N latitude) to a little north of Kanniyakumari (11° N latitude) for a distance of 1,600 km.

iii. The Western Ghats are steep-sided, terraced, flat-topped hills presenting a stepped topography facing the Arabian Sea coast.

iv. This is due to the horizontally bedded lavas, which on weathering, have given a characteristic 'landing stair aspect' to the relief of this mountain chain.

v. The Western Ghats abruptly rise as a sheer wall to an average elevation of 1,000 m from the Western Coastal Plain.

vi. But they slope gently on their eastern flank and hardly appear to be a mountain when viewed from the Deccan tableland.

vii. South of Malabar, the Nilgiris, Anamalai, etc. present quite different landscape due to the difference in geological structure.

The Northern Section

i. The northern section of the Ghats from Tapi valley to a little north of Goa is made of horizontal sheets of Deccan lavas (Deccan Traps).

ii. The average height of this section of the Ghats is 1,200 m above mean sea level, but some peaks attain more heights.

iii. Kalasubai (1,646 m) near Igatpuri, Salher (1,567 m) about 90 km north of Nashik, Mahabaleshwar (1,438 m) and Harishchandragarh (1,424 m) are important peaks.

iv. Thal ghat and Bhor ghat are important passes which provide passage by road and rail between the Konkan Plains in the west and the Deccan Plateau in the east.

The Middle Sahyadri

i. The Middle Sahyadri runs from 16°N latitude upto Nilgiri hills.

ii. This part is made of granites and gneisses.

iii. This area is covered with dense forests.

iv. The western scarp is considerably dissected by headward erosion of the west flowing streams.

v. The average height is 1200 m but many peaks exceed 1500 m.

vi. The Vavul Mala (2,339 m), the Kudremukh (1,892 m) and Pashpagiri (1,714 m) are important peaks.

- **vii.** The Nilgiri Hills which join the Sahyadris near the trijunction of Karnataka, Kerala and TN, rise abruptly to over 2,000 m.
- **viii.** They mark the junction of the Western Ghats with Eastern Ghats.
- **ix.** Doda Betta (2,637 m) and Makurti (2,554 m) are important peaks of this area.

The Southern Section

- **i.** The southern part of the Western Ghats is separated from the main Sahyadri range by Pal ghat Gap [Palakkad Gap].
- **ii.** The high ranges terminate abruptly on either side of this gap.
- **iii.** Pal ghat Gap it is a rift valley. This gap is used by a number of roads and railway lines to connect the plains of Tamil Nadu with the coastal plain of Kerala.
- **iv.** It is through this gap that moist-bearing clouds of the south-west monsoon can penetrate some distance inland, bringing rain to Mysore region.
- **v.** South of the Pal ghat Gap there is an intricate system of steep and rugged slopes on both the eastern and western sides of the Ghats.
- **vi.** Anai Mudi (2,695 m) is the highest peak in the whole of southern India.
- **vii.** Three ranges radiate in different directions from Anai Mudi. These ranges are the Anaimalai (1800-2000 m) to the north, the Palani (900-1,200 m) to the north-east and the Cardamom Hills or the Ealaimalai to the south.

Eastern Ghats

- **i.** Eastern Ghats run almost parallel to the east coast of India leaving broad plains between their base and the coast.
- **ii.** It is a chain of highly broken and detached hills starting from the Mahanadi in Odisha to the Vagai in Tamil Nadu. They almost disappear between the Godavari and the Krishna.
- **iii.** They neither have structural unity nor physiographic continuity. Therefore these hill groups are generally treated as independent units.
- **iv.** It is only in the northern part, between the Mahanadi and the Godavari that the Eastern Ghats exhibit true mountain character. This part comprises the Maliya and the Madugula Konda ranges.
- **v.** The peaks and ridges of the Maliya range have a general elevation of 900-1,200 m and Mahendra Giri (1,501 m) is the tallest peak here.
- **vi.** The Madugula Konda range has higher elevations ranging from 1,100 m and 1,400 m with several peaks exceeding 1,600 m. Jindhagada Peak (1690 m) in Araku Valley Arma Konda (1,680 m), Gali Konda (1,643 m) and Sinkram Gutta (1,620 m) are important peaks.
- **vii.** Between the Godavari and the Krishna rivers, the Eastern Ghats lose their hilly character and are occupied by Gondwana formations (KG Basin is here).

viii. The Eastern Ghats reappear as more or less a continuous hill range in Cuddapah and Kurnool districts of Andhra Pradesh where they are called as Nallamalai Range [Naxalite hideout in AP] with general elevation of 600-850 m.

ix. The southern part of this range is called the Palkodna range.

x. To the south, the hills and plateaus attain very low altitudes; only Javadi Hills and the Shevroy-Kalrayan Hills form two distinct features of 1,000 m elevation.

xi. The Biligiri Rangan Hills in Karnataka (at its border with Tamil Nadu) attain a height of 1,279 m.

xii. Further south, the Eastern Ghats merge with the Western Ghats.

Significance of the Peninsular Plateau

i. There are huge deposits of iron, manganese. copper, bauxite, chromium, mica, gold, etc.

ii. 98 per cent of the Gondwana coal deposits of India are found in the Peninsular Plateau.

iii. Besides there are large reserves of slate, shale, sandstones, marbles, etc.

iv. A large part of north-west plateau is covered with fertile black lava soil which is extremely useful for growing cotton.

v. Some hilly regions in south India are suitable for the cultivation of plantation crops like tea, coffee, rubber, etc..

vi. Some low lying areas of the plateau are suitable for growing rice.

vii. The highlands of the plateau are covered with different types of forests which provide a large variety of forest products.

viii. The rivers originating in the Western Ghats offer great opportunity for developing hydroelectricity and providing irrigation facilities to the agricultural crops.

ix. The plateau is also known for its hill resorts such as Udagamangalam (Ooty), Panchmarhi, Kodaikanal, Mahabaleshwar, Khandala, Matheron, Mount Abu, etc.

CHAPTER 14

FORMATION OF THE HIMALAYA

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The Himalayan mountain range and Tibetan plateau have formed as a result of the collision between the Indian Plate and Eurasian Plate which began 50 million years ago and continues today.225 million years ago (Ma) India was a large island situated off the Australian coast and separated from Asia by the Tethys Ocean. The supercontinent Pangea began to break up 200 Ma and India started a northward drift towards Asia. 80 Ma India was 6,400 km south of the Asian continent but moving towards it at a rate of between 9 and 16 cm per year. At this time Tethys Ocean floor would have been sub ducting northwards beneath Asia and the plate margin would have been a Convergent oceanic-continental one just like the Andes today.

As seen in the animation above not all of the Tethys Ocean floor was completely sub-ducted; most of the thick sediments on the Indian margin of the ocean were scraped off and accreted onto the Eurasian continent in what is known as an accretionary wedge (link to glossary). These scraped-off sediments are what now form the Himalayan mountain range.

From about 50-40 Ma the rate of northward drift of the Indian continental plate slowed to around 4-6 cm per year. This slowdown is interpreted to mark the beginning of the collision between the Eurasian and Indian continental plates, the closing of the former Tethys Ocean, and the initiation of Himalayan uplift.

The Eurasian plate was partly crumpled and buckled up above the Indian plate but due to their low density/high buoyancy neither continental plate could be sub ducted. This caused the continental crust to thicken due to folding and faulting by compressional forces pushing up the Himalaya and the Tibetan Plateau. The continental crust here is twice the average thickness at around 75 km. The thickening of the continental crust marked the end of volcanic activity in the region as any magma moving upwards would solidify before it could reach the surface.

The Himalayas are still rising by more than 1 cm per year as India continues to move northwards into Asia, which explains the occurrence of shallow focus earthquakes in the region today. However the forces of weathering and erosion are lowering the Himalayas at about the same rate. The Himalayas and Tibetan plateau trend east-west and extend for 2,900 km, reaching the maximum elevation of 8,848 metres (Mount Everest – the highest point on Earth).

The geology of the Himalayas is a record of the most dramatic and visible creations of the immense mountain range formed by plate tectonic forces and sculpted by weathering and erosion. The Himalayas, which stretch over 2400 km between the Namcha Barwa syntaxis at the eastern end of the mountain range and the Nanga Parbat syntaxis at the western end, are the result of an ongoing orogeny the collision of the continental crust of two tectonic plates, namely, the Indian Plate thrusting into the Eurasian Plate. The Himalaya-Tibet region supplies fresh water for more than one-fifth of the world population, and accounts for a quarter of the global sedimentary budget. Topographically, the belt has many superlatives: the highest rate of uplift (nearly 10 mm/year at Nanga Parbat), the highest relief (8848 m at Mt. Everest Chomolangma), among the highest erosion rates at 2–12 mm/yr,[4] the source of some of the greatest rivers and the highest concentration of glaciers outside of the polar regions. This last feature earned the Himalaya its name, originating from the Sanskrit for "the abode of the snow".

From south to north the Himalaya (Himalaya orogen) is divided into 4 parallel tectonostratigraphic zones and 5 thrust faults which extend across the length of Himalaya orogen. Each zone, flanked by the thrust faults on its north and south, has stratigraphy (type of rocks and their layering) different from the adjacent zones. From south to north, the zones and the major faults separating them are the Main Frontal Thrust (MFT), Subhimalaya Zone (also called Sivalik), Main Boundary Thrust (MBT), Lesser Himalaya (further subdivided into the "Lesser Himalayan Sedimentary Zone (LHSZ) and the Lesser Himalayan Crystalline Nappes (LHCN)), Main Central thrust (MCT), Higher (or Greater) Himalayan crystallines (HHC), South Tibetan detachment system (STD), Tethys Himalaya (TH), and the Indus-Tsangpo Suture Zone (ISZ).[5] North of this lies the transhimalaya in Tibet which is outside the Himalayas. Himalaya has Indo-Gangetic Plain in south, Pamir Mountains in west in Central Asia, and Hengduan Mountains in east on China–Myanmar border.

Making of Himalayas

During Late Precambrian and the Paleozoic, the Indian subcontinent, bounded to the north by the Cimmerian Super terranes, was part of Gondwana and was separated from Eurasia by the Paleo-Tethys Ocean as mention in Figure below. During that period, the northern part of India was affected by a late phase of the Pan-African orogeny which is marked by an unconformity between Ordovician continental conglomerates and the underlying Cambrian marine sediments. Numerous granitic intrusions dated at around 500 Ma are also attributed to this event.

In the Early Carboniferous, an early stage of rifting developed between the Indian subcontinent and the Cimmerian Super terranes. During the Early Permian, this rift developed into the Neotethys ocean. From that time on, the Cimmerian Superterranes drifted away from Gondwana towards the north. Nowadays, Iran, Afghanistan and Tibet are partly made up of these terranes.

In the Norian (210 Ma), a major rifting episode split Gondwana in two parts. The Indian continent became part of East Gondwana, together with Australia and Antarctica. However, the separation of East and West Gondwana, together with the formation of oceanic crust, occurred later, in the Callovian (160-155 Ma). The Indian plate then broke off from Australia and Antarctica in the Early Cretaceous (130-125 Ma) with the opening of the "South Indian Ocean".

In the Late Cretaceous (84 Ma), the Indian plate began its very rapid northward drift covering a distance of about 6000 km, with the oceanic-oceanic subduction continuing until the final closure of the oceanic basin and the obduction of oceanic ophiolite onto India and the beginning of continent-continent tectonic interaction starting at about 65 Ma in the Central Himalaya. The change of the relative speed between the Indian and Asian plates from very fast (18-19.5 cm/yr) to fast (4.5 cm/yr) at about 55 Ma is circumstantial support for collision then. Since then there has been about 2500 km of crustal shortening and rotating of India by 45° counterclockwise in the Northwestern Himalayato 10°-15° counterclockwise in North Central Nepal relative to Asia as mention in Figure 1.

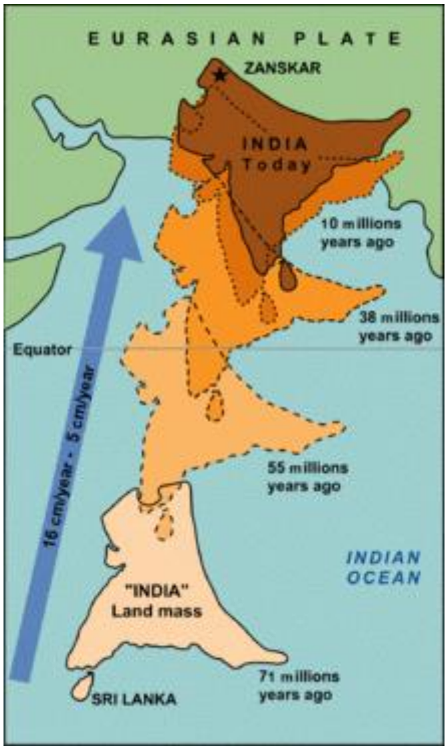

Figure 1: Represented that the Evolution of Himalyas.

While most of the oceanic crust was "simply" sub ducted below the Tibetan block during the northward motion of India, at least three major mechanisms have been put forward, either separately or jointly, to explain what happened, since collision, to the 2500 km of "missing continental crust".

The first mechanism also calls upon the subduction of the Indian continental crust below Tibet.

Second is the extrusion or escape tectonics mechanism (Molnar & Tapponnier 1975) which sees the Indian plate as an indenter that squeezed the Indochina block out of its way.

The third proposed mechanism is that a large part (~1000 km (Dewey, Cande & Pitman 1989) or ~800 to ~1200 km[15]) of the 2500 km of crustal shortening was accommodated by thrusting and folding of the sediments of the passive Indian margin together with the deformation of the Tibetan crust.

Even though it is more than reasonable to argue that this huge amount of crustal shortening most probably results from a combination of these three mechanisms, it is nevertheless the last mechanism which created the high topographic relief of the Himalaya.

Developments of Glaciers

Glaciers are massive bodies of slowly moving ice. Glaciers form on land, and they are made up of fallen snow that gets compressed into ice over many centuries. They move slowly downward from the pull of gravity.Most of the world’s glaciers exist in the Polar Regions, in areas like Greenland, the Canadian Arctic, and Antarctica. Glaciers also can be found closer to the Equator in some mountain regions. The Andes Mountain range in South America contains some of the world’s largest tropical glaciers. About 2 percent of all the water on Earth is frozen in glaciers.

Glaciers can range in age from a couple hundred to thousands of years old. Most glaciers today are remnants of the massive ice sheets that covered Earth during the Ice Age. The Ice Age ended more than 10,000 years ago. During Earth's history, there have been colder periods when glaciers formed and warmer periods when glaciers melted.Scientists who study glaciers are called glaciologists. Glaciologists began studying glaciers during the 19th century in order to look for clues about past ice ages. Today, glaciologists study glaciers for clues about global warming. Old photographs and paintings show that glaciers have melted away from mountain regions over time. Indeed, glaciers worldwide have been shrinking and even disappearing at an accelerated rate for the past several decades.

Among the scientists studying the changes in glaciers is Erin Christine Pettit, a glaciologist at the University of Alaska Fairbanks. Pettit observes and measures the flow, fracture, and retreat of glaciers. She uses this information to study how much water enters the oceans from melting glaciers. Melting glaciers are one factor contributing to the global sea-level rise.

CHAPTER 15

THE MAJOR INDIAN RIVER SYSTEMS

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The Rivers of India play a significant role in the lives of Indian society. The river systems provide irrigation, drinking water, economical transportation, power, as well as grant livelihoods to a large number of population. This straightforwardly demonstrates why all the major cities of India are positioned by the banks of the river.

List of Major Indian River Systems, Rivers and their Origin

Most of the rivers discharge their waters into the Bay of Bengal. Some of the rivers flow through the western part of the country and merge into the Arabian Sea. The northern parts of the Aravalli range, some parts of Ladakh, and arid regions of the Thar Desert have inland drainage. All major rivers of India originate from one of the three main watersheds-

1. The Himalaya and the Karakoram range
2. The Chota Nagpur plateau and Vindhya and Satpura range
3. The Western Ghats

Given below are the major river systems in India:

Sr. No.	River System	Total length	Length in India
1.	Mahanadi River System	851 km	851 km
2.	Brahmaputra River System	2900 km	916 km
3.	Cauvery River System	805 km	805 km
4.	Godavari River System	1465 km	1465 km
5.	Krishna River System	1400 km	1400 km
6.	Tapi River System	724 km	724 km
7.	Narmada River System	1312 km	1312 km
8.	Yamuna River System	1376 km	1376 km
9.	Ganga River System	2510 km	2510 km
10.	Indus River System	3180 km	1114 km

Major River System:

i. The Indus River System

The Indus arises from the northern slopes of the Kailash range in Tibet near Lake Mansarovar.

1. It has a large number of tributaries in both India and Pakistan and has a total length of about 2897 km from the source to the point near Karachi where it falls into the Arabian Sea out of which approx 700km lies in India.

2. It enters the Indian Territory in Jammu and Kashmir by forming a picturesque gorge.
3. In the Kashmir region, it joins with many tributaries – the Zaskar, the Shyok, the Nubra and the Hunza.
4. It flows between the Ladakh Range and the Zaskar Range at Leh.
5. It crosses the Himalayas through a 5181 m deep gorge near Attock, which is lying north of Nanga Parbat.

The major tributaries of the Indus River in India are Jhelum, Ravi, Chenab, Beas, and Sutlej.

ii. The Brahmaputra River System

The Brahmaputra originates from Mansarovar Lake, which is also a source of the Indus and Sutlej.

1. It is 3848kms long, a little longer than the Indus River.
2. Most of its course lies outside India.
3. It flows parallel to the Himalayas in the eastward direction. When it reaches Namcha Barwa, it takes a U-turn around it and enters India in the state of Arunachal Pradesh.
4. Here it is known as the Dihang River. In India, it flows through the states of Arunachal Pradesh and Assam and is connected by several tributaries.
5. The Brahmaputra has a braided channel throughout most of its length in Assam.
6. The river is known as the Tsangpo in Tibet. It receives less volume of water and has less silt in the Tibet region. But in India, the river passes through a region of heavy precipitation, and as such, the river carries large amounts of water during rainfall and a significant amount of silt. It is considered one of the largest rivers in India in terms of volume. It is known for creating calamities in Assam and Bangladesh.

Similar to major river systems in India, you can check more static GK topics for UPSC exams on the linked page.

iii. Ganga River System

1. The Ganga originates as the Bhagirathi from the Gangotri glacier.
2. Before it reaches Devprayag in the Garhwal Division, the Mandakini, Pindar, the Dhauliganga and the Bishenganga rivers merge into the Alaknanda and the Bheling drain into the Bhagirathi.
3. The Pindar River rises from East Trishul and Nanda Devi unite with the Alaknanda at Karan Prayag. The Mandakini meets at Rudraprayag.
4. The water from both Bhagirathi and the Alaknanda flows in the name of the Ganga at Devprayag.

iv. The concept of Panch Prayag

1. Vishnuprayag: where the river Alaknanda meets river Dhauli Ganga
2. Nandprayag: where river Alaknanda meets river Nandakini

3. Karnaprayag: where river Alaknanda meets river Pinder
4. Rudraprayag: where river Alaknanda meets river Mandakini
5. Devprayag: where river Alaknanda meets river Bhagirathi -GANGA
6. The principal tributaries of the Ganga are Yamuna, Damodar, Sapta Kosi, Ram Ganga, Gomati, Ghaghara, and Son. The river after travelling a distance of 2525 km from its source meets the Bay of Bengal.

v. Yamuna River System

- The Yamuna River is the largest tributary of the Ganga River.
- It originates from the Yamunotri glacier, at the Bandarpoonch peak in Uttarakhand.
- The main tributaries joining the river include the Sin, Hindon, Betwa Ken, and Chambal.
- The Tons is the largest tributary of the Yamuna.
- The catchment of the river extends to the states of Delhi, Himachal Pradesh, Uttar Pradesh, Haryana, Rajasthan, and Madhya Pradesh.

vi. The Narmada River System

- The Narmada is a river located in central India.
- It rises to the summit of the Amarkantak Hill in Madhya Pradesh state.
- It outlines the traditional frontier between North India and South India.
- It is one of the major rivers of peninsular India. Only the Narmada, the Tapti, and the Mahi rivers run from east to west.
- The river flows through the states of Madhya Pradesh, Gujarat, and Maharashtra.
- It drains into the Arabian Sea in the Bharuch district of Gujarat.

vii. The Tapi River System

- It is a central Indian river. It is one of the most important rivers of peninsular India with the run from east to west.
- It originates in the Eastern Satpura Range of southern Madhya Pradesh state.
- It flows in a westward direction, draining some important historic places like Madhya Pradesh’s Nimar region, East Vidarbha region and Maharashtra’s Khandesh in the northwest corner of the Deccan Plateau and South Gujarat before draining into the Gulf of Cambay of the Arabian Sea.
- The River Basin of Tapi River lies mostly in eastern and northern districts Maharashtra state.
- The river also covers some districts of Madhya Pradesh and Gujarat as well.
- The principal tributaries of Tapi River are Waghur River, Aner River, Girna River, Purna River, Panzara River and Bori River.
-

viii. The Godavari River System

- The Godavari River is the second-longest course in India with brownish water.
- The river is often referred to as the Dakshin (South) Ganga or Vriddh (Old) Ganga.
- It is a seasonal river, dried during the summers, and widens during the monsoons.
- This river originates from Trimbakeshwar, near Nasik in Maharashtra.
- It flows southeast across south-central India through the states of Madhya Pradesh, Telangana, Andhra Pradesh, and Orissa, and drains into the Bay of Bengal.
- The river forms a fertile delta at Rajahmundry.
- The banks of this river have many pilgrimage sites, Nasik(MH), Bhadrachalam(TS), and Trimbak. Some of its tributaries include Pranahita (Combination of Penuganga and Warda), Indravati River, Bindusara, Sabari, and Manjira.
- Asia's largest rail-cum-road bridge which links Kovvur and Rajahmundry is located on the river Godavari.

ix. The Krishna River System

- Krishna is one of the longest rivers of India, which originates from Mahabaleshwar in Maharashtra.
- It flows through Sangli and drains the sea in the Bay of Bengal.
- The river flows through the states of Maharashtra, Karnataka, Telangana and Andhra Pradesh.
- Tungabhadra River is the main tributary which itself is formed by the Tunga and Bhadra rivers that originate in the Western Ghats.
- Dudhganga Rivers, Koyna, Bhima, Mallaprabha, Dindi, Ghataprabha, Warna, Yerla, and Musi are some of the other tributaries.

x. The Cauvery River System

- It originates from Talakaveri located in the Western Ghats.
- It is a famous pilgrimage and tourist place in the Kodagu district of Karnataka.
- The headwaters of the river are in the Western Ghats range of Karnataka state, and from Karnataka through Tamil Nadu.
- The river drains into the Bay of Bengal. The river supports irrigation for agriculture and is considered as a means of support of the ancient kingdoms and modern cities of South India.
- The river has many tributaries called Arkavathy, Shimsha, Hemavati, Kapila, Shimsha, Honnuhole, Amaravati, Lakshmana Kabini, Lokapavani, Bhavani, Noyyal, and Tirtha.

xi. The Mahanadi River System

- The Mahanadi originates from the Satpura Range of central India and it is a river in eastern India.

- It flows east to the Bay of Bengal. The river drains of the state of Maharashtra, Chhattisgarh, Jharkhand, and Orissa.
- The largest dam, the Hirakud Dam is built on the river.

CHAPTER 16

FORMATION OF INDO-GANGETIC PLAINS

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a. Indo-Gangetic Plains

i. The 300m contour line divides the Himalayas and the Gangetic Basin.

ii. The southern boundary is demarcated by the edge of the peninsula which coincides with 75m contours in most of its length and 35m in the northeastern section, towards the delta.

iii. The plains are extremely flat with a slope of nearly 1:1000 to 1:2000

iv. The plains are flat and are rolling with monotonous character as display the displayed the Indo-Gangetic plains.

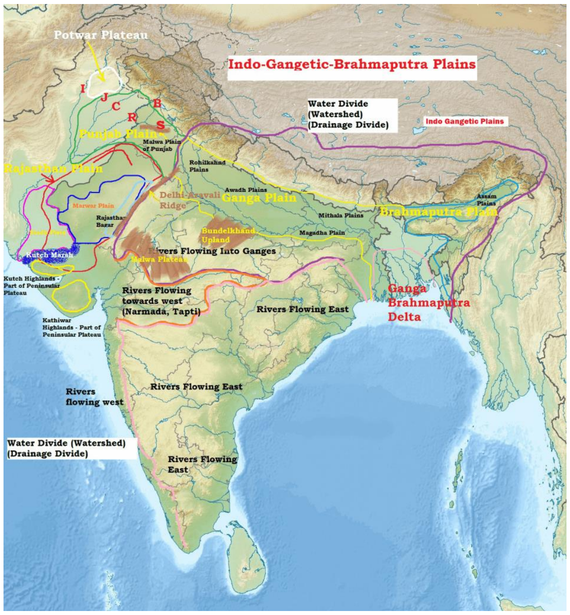

Figure 1: **Displayed the Indo-Gangetic Plains**

b. Formation of Indo–Gangetic–Brahmaputra Plain

i. The formation of Indo-Gangetic plain is closely related to the formation of Himalayas.

ii. The rivers which were previously flowing into the Tethys Sea that is Before Indian Plate collided with Eurasian Plate continental drift, plate tectonics) deposited a huge amount of sediments in the Tethys Geosyncline.

- **iii.** The Himalayas are formed out of these sediments which were uplifted, folded, and compressed due to the northern movement of the Indian Plate.
- **iv.** The northern movement of the Indian Plate also created a trough to the south of the Himalayas.

c. Depositional Activity

- During the initial stages of upliftment of sediments, the already existing rivers changed their course several times and they were rejuvenated each time (perpetual youth stage of rivers.
- The rejuvenation is associated with intense headword and vertical down cutting of the soft strata overlying the harder rock stratum.
- Headword erosion and vertical erosion of the river valley in the initial stages, lateral erosion in later stages contributed a huge amount of conglomerates (detritus)(rock debris, silt, clay, etc.) which were carried downslope.
- Headword erosion Erosion at the origin of a stream channel, which causes the origin to move back away from the direction of the stream flow, and so causes the stream channel to lengthen**.**
- These conglomerates were deposited in the depression (Indo-Gangetic Trough or Indo-Gangetic syncline) (the base of the geosyncline is hard crystalline rock) between peninsular India and the convergent boundary (the region of present-day Himalayas).

d. New rivers and more alluvium

- **i.** The raising of the Himalayas and the subsequent formation of glaciers gave rise to many new rivers. These rivers along with glacial erosion supplied more alluvium which intensified the filling of the depression.
- **ii.** With the accumulation of more and more sediments (conglomerates), the Tethyssea started receding.
- **iii.** With the passage of time, the depression was completely filled with alluvium, gravel, rock debris (conglomerates) and the Tethys completely disappeared leaving behind a monotonous aggradation plain.

  Monotonous = = featureless topography;

  Aggradational plain = = plain formed due to depositional activity.
- **iv.** Indo-Gangetic plain is a monotonous aggradational plain formed due to fluvial depositions.
- **v.** Upper peninsular rivers have also contributed to the formation of plains, but to a very small extent.
- **vi.** During recent times (since few million years), depositional work of three major river systems viz., the Indus, the Ganga, and the Brahmaputra have become predominant.

vii. Hence this arcuate (curved) plain is also known as Indo-Gangetic-Brahmaputra Plain as display in Figure 2.

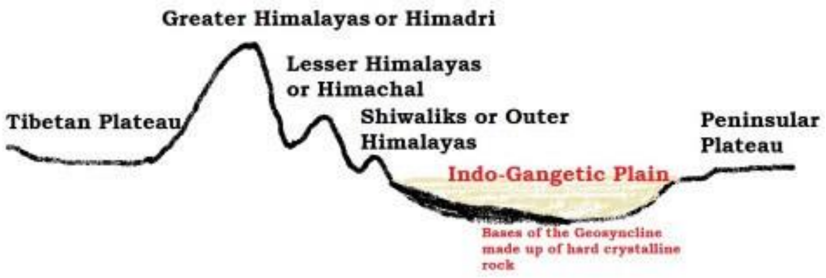

Figure 2: Represented that theNew Rivers and more Alluvium.

e. Indo Gangetic Plains

i. Longitudinal Profile- Indo Gangetic Plains

ii. Bhabhar

iii. Tarai

iv. Bangar

v. Khadar

f. Bhabhar Region

- Adjacent to Shiwalik foothills, coarser materials like cobbles, pebbles, gravels, boulders with coarse sand.
- It is a narrow, porous, northernmost stretch of the Indo-Gangetic plain.
- It is about 8-16 km wide running in an east-west direction along the foothills (alluvial fans) of the Shiwaliks.
- They show a remarkable continuity from the Indus to the Tista.
- Rivers descending from the Himalayas deposit their load along the foothills in the form of alluvial fans.
- These alluvial fans have merged together to build up the bhabar belt.
- The porosity of bhabar is the most unique feature.
- The porosity is due to the deposition of a huge number of pebbles and rock debris across the alluvial fans.
- The streams disappear once they reach the bhabar region because of this porosity.
- Therefore, the area is marked by dry river courses except in the rainy season.
- The Bhabar belt is comparatively narrow in the east and extensive in the western and north-western hilly region.
- Bhabhar zones stretches from Punjab to Assam Himalayas.

- It has a complex profile and general slope of 1:6000.
- The area is not suitable for agriculture and only big trees with large roots thrive in this belt.

g. Terai Plains

- **i.** Marshy near the Bhabhar zone, extremely flat marshy lands, densely deforested and parallel to the mountains from Punjab to Assam.
- **ii.** Terai is an ill-drained, damp (marshy) and thickly forested narrow tract to the south of Bhabar running parallel to it.
- **iii.** The Terai is about15-30 km wide.
- **iv.** Widest along Bihar and eastern UP and the narrowest in the east.
- **v.** The underground streams of the Bhabar belt re-emerge in this belt.
- **vi.** The Terai is more marked in the eastern part than in the west because the eastern parts receive a comparatively higher amount of rainfall.
- **vii.** Most part is deforested for agriculture.
- **viii.** Tarai soils are Nitrogen-rich and have a humus content.
- **ix.** Most of the Terai land, especially in Punjab, Uttar Pradesh, and Uttarakhand, has been turned into agricultural land which gives good crops of sugarcane, rice, and wheat.

h. Bangar Region

- **i.** It extends over the whole Gangetic plain.
- **ii.** The Bhangar is the older alluvium along the river beds forming terraces higher than the flood plain.
- **iii.** The terraces are often impregnated with calcareous concretions known as ‘KANKAR’.
- **iv.** ‘The Barind plains’ in the deltaic region of Bengal and the ‘bhur formations’ in the middle Ganga and Yamuna doab are regional variations of Bhangar.
- **v.** Bhur denotes an elevated piece of land situated along the banks of the Ganga river especially in the upper Ganga-Yamuna Doab. This has been formed due to the accumulation of wind-blown sands during the hot dry months of the year.
- **vi.** Bhangar contains fossils of animals like rhinoceros, hippopotamus, elephants, etc.
- **vii.** It has Kankar deposits which are fragments of Limestone, thus natural supplements of bases to the soil.

i. Barind Tract (Barind Plains)

- Barind Tract (alternately called the Varendra Tract in English and Borendro Bhumi in Bengali) is the largest Pleistocene era physiographic unit in the Bengal Basin. Barind Tract is the geographic region in parts of northwestern Bangladesh and north-central West Bengal state, India.

- It lies northwest of the confluence of the upper Padma (Ganga) and Jamuna (the name of the Brahmaputra in Bangladesh) rivers and is bordered by the floodplains of the Mahananda River to the west and the Karatoya River to the east tributaries of the upper Padma and of the Jamuna, respectively.
- Barind is a comparatively high, undulating region, with reddish and yellowish clay soils.
- It has long been recognized as a unit of old alluvium.
- Khadar Region
- The Khadar is composed of newer alluvium and forms the flood plains along the river banks.
- A new layer of alluvium is deposited by river flood almost every year.
- This makes them the most fertile soils of Ganges.

j. Reh or Kollar

i. Reh or Kollar comprises saline efflorescence's of drier areas in Haryana.

ii. Reh areas have spread in recent times with an increase in irrigation (capillary action brings salts to the surface).

k. Transverse Profile-Indo Gangetic Plains

- Rajasthan Plains
- Punjab Plains
- Gangetic Plain
- Assam Plain (Brahmaputra Plain)
- Divisions of Indo-Gangetic-Brahmaputra Plains

l. Rajasthan Plain

i. The Ghaghar basin in North, Aravallis in East

ii. It is a part of the Thar desert but it has alluvial deposits of Indus and its tributaries

iii. In the wake of the Himalayas' upliftment, these channels shifted to west.

iv. This plain is an undulating plain (wave-like) whose average elevation is about 325 m above mean sea level.

v. 25cm isohyte divides the plain into marusthali in the west and Rajasthan Bagar in the east.

vi. Marusthali is a desert with shifting sand dunes called Dhrian.

vii. This entire Marushatli region receives a rainfall of 25cm and the only tree is Khejri (the Bishnoi tribe is associated with it).

viii. Rajasthan Bagar – It is semi-arid fertile tracts or green patches called ROHI.

ix. In the north of Luni, a sandy desert is known as THALI.

m. Saline Lakes

- **i.** North of the Luni, there is inland drainage having several saline lakes. They are a source of common salt and many other salts.
- **ii.** Sambhar, Didwana, Degana, Kuchaman, etc. are some of the important lakes. The largest is the Sambhar lake near Jaipur.

n. Punjab Plain

- **i.** This plain is formed by five important rivers of the Indus system.
- **ii.** The plain is primarily made up of 'doabs' the land between two rivers.
- **iii.** There are 5 doabs (Chaj, Rechna, Bist, Bari and Sindsagar).
- **iv.** The depositional process by the rivers has united these doabs giving a homogenous appearance.
- **v.** Punjab literally means "(The Land of) Five Waters" referring to the following rivers: the Jhelum, Chenab, Ravi, Sutlej, and Beas.
- **vi.** Extremely fertile plains but poor drainage and flood-prone.
- **vii.** The total area of this plain is about 1.75 lakh sq km.
- **viii.** The average elevation of the plain is about 250 m above mean sea level.
- **ix.** It is bounded by 291m contour line running parallel to Delhi–Ambala ridge which separates it from the Gangetic basin.
- **x.** The eastern boundary of the Punjab Haryana plain is marked by subsurface Delhi-Aravali ridge.
- **xi.** The northern part of this plain has been intensively eroded by numerous streams called Chos. This has led to enormous gullying.
- **xii.** To the south of the Satluj river, there is Malwa plain of Punjab.
- **xiii.** The area between the Ghaggar and the Yamuna rivers lies in Haryana and often termed as 'Haryana Tract'. It acts as a water-divide between the Yamuna and the Satluj rivers.
- **xiv.** The only river between the Yamuna and the Satluj is the Ghaggar which is considered to be the present-day Successor of the legendary Saraswati River.

o. Gangetic Plain

- **i.** This is the largest unit of the Great Plain of India stretching from Delhi to Kolkata (about 3.75 lakh sq km).
- **ii.** The Ganga along with its large number of tributaries originating in the Himalayans have brought large quantities of alluvium from the mountains and deposited it here to build this extensive plain.
- **iii.** The peninsular rivers such as Chambal, Betwa, Ken, Son, etc. joining the Ganga river system have also contributed to the formation of this plain.
- **iv.** The general slope of the entire plain is to the east and south east.

- **v.** Rivers flow sluggishly in the lower sections of Ganges as a result of which the area is marked by local prominences such as levees, bluffs, oxbow lakes, marshes, ravines, etc. {Fluvial Landforms, Arid Landfroms}
- **vi.** Almost all the rivers keep on shifting their courses making this area prone to frequent floods. The Kosi river is very notorious in this respect. It has long been called the 'Sorrow of Bihar'.

p. Divisions of Ganga plains

- **i.** Upper Gangetic Plain
- **ii.** Middle Gangetic Plain
- **iii.** Lower Gangetic Plain

q. Upper Gangetic Plain

- **i.** 291m contour in the west, 300m contour in the North, 75m in South and 100m contour in east forms the boundary.
- **ii.** It includes
- **iii.** Rohilkhand Plains:

Rohila Tribe (Afghan), Bareilly, Muzaffarnagar. It is very fertile. It has Sharda and Ramganga doabs

- Ganga-Yamuna Doab:

Largest doab of India. It has fine dust deposits by the aeolian process. It is famous for sugarcane cultivation.

- Yamuna -Chambal Basin:

Badland region because of gully erosions, ravines. The worst soil degraded area of India and largest degraded area.

r. Middle Gangetic Plain

- **i.** It is transitional plain par excellence. It is the most fertile tract of the world, which alone can sustain the major population of India.
- **ii.** It includes 3 sections :
- **iii.** Awadh Plain: B/w Ghaghra and Gomti, east UP, Flood Prone
- **iv.** Mithila Plain: B/w Gandak and Kosi, Flood Prone
- **v.** Magadh Plain: Located east of R.Son, not flood-prone
- **vi.** These transitional plains have perfect loam deposits and the groundwater level is very high

s. Lower Gangetic Plain

- i. Paradelta in North which is erosion bound looks like an inverted triangle, North part of WB

ii. Rarh Plains: Western section adjacent to Chota Nagour plateau, Laterite deposits. 35m contour line separates it from Chota Nagar Plateau

iii. Delta Plains: Most Extensive part of Sunderbans(1/3 in India). The braided channel, lakes, and marshes. It is famous for inland fishing and it is known for Jute cultivation. Sunderbans or Mangrove forests or Tidal Forests are located towards the coastline.

t. Ganga-Brahmaputra Delta

i. This is the largest delta in the world.

ii. The Ganga River divides itself into several channels in the delta area. The slope of the land here is a mere 2 cm per km. Two-thirds of the area is below 30 m above mean sea level. [Highly vulnerable to sea-level changes]

iii. The seaward face of the delta is studded with a large number of estuaries, mud flats, mangrove swamps, sandbanks, islands, and forelands.

iv. A large part of the coastal delta is covered tidal forests. These are called the Sunderbans because of the predominance of the Sundri tree here.

u. Brahmaputra Plain

- This is also known as the Brahmaputra valley or Assam Valley or Assam Plain as most of the Brahmaputra valley is situated in Assam as show in Figure 3.
- Its western boundary is formed by the Indo-Bangladesh border as well as the boundary of the lower Ganga Plain. Its eastern boundary is formed by Purvanchal hills.
- It is an aggradational plain built up by the depositional work of the Brahmaputra and its tributaries.
- The innumerable tributaries of the Brahmaputra River coming from the north form a number of alluvial fans. Consequently, the tributaries branch out in many channels giving birth to river meandering leading to the formation of the bill and ox-bow lakes.
- There are large marshy tracts in this area. The alluvial fans formed by the coarse alluvial debris have led to the formation of terai or semi-terai conditions.

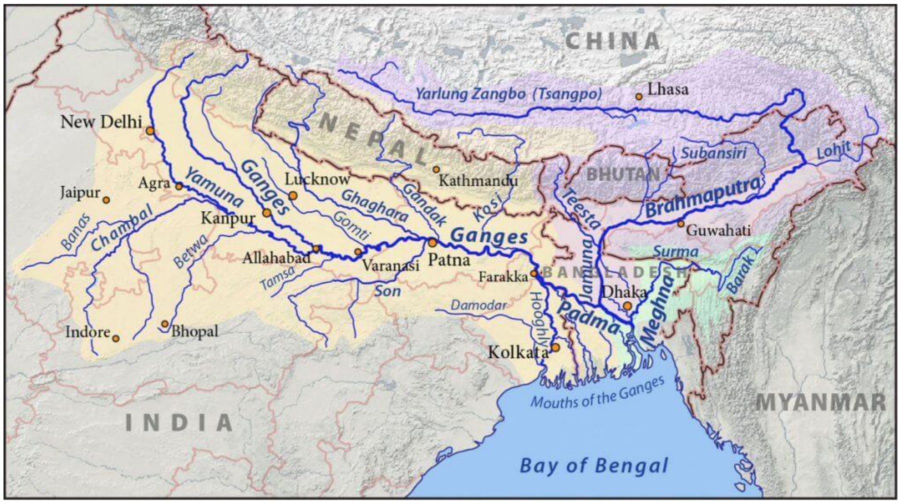

Figure 3: Represented that the Brahmaputra Plain.

v. Significance of the Plain

i. This one-fourth of the land of the country hosts half of the Indian population.

ii. Fertile alluvial soils, flat surface, slow-moving perennial rivers, and favorable climate facilitate intense agricultural activity.

iii. The extensive use of irrigation has made Punjab, Haryana, and the western part of Uttar Pradesh the granary of India (Prairies are called the granaries of the world).

iv. The entire plain except the Thar Desert has a close network of roads and railways which has led to large-scale industrialization and urbanization.

v. Cultural tourism: There are many religious places along the banks of the sacred rivers like the Ganga and the Yamuna which are very dear to Hindus. Here flourished the religions of Budha and Mahavira and the movements of Bhakti and Sufism.

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CHAPTER 17

FOOD RESOURCES

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The main sources of human food are plants and animals. Human beings consume almost all parts of plants in the form of cereals (wheat, barley, millet, rye, oats, maize, corn, rice etc.); pulses (peas, red grams, green grams); vegetables (carrot, cauliflower, beans); fruits (banana, orange, grapes, pineapple) and spices (pepper, cloves). Also a number of products such as milk, butter, egg and meat supplement the requirements.

World Food Problems

Since world's population is growing every year and the demand of food is also increasing continuously. Although world's food production has increased almost three times during the last. 50 years, but at the same time rapid population growth outstripped the food production. So, the world food problem is a complex one depending on food production, population increase, the prevalence of poverty and environmental impacts. Famines are due to lack of access to food but not lack of food. Modern agriculture is largely based upon technological factors like the use of improved seeds, chemical fertilizers, synthetic pesticides etc.

The green revolution however changed traditional agricultural practices with a rapid increase in food production in developing countries. An American agricultural scientist, Norman Borlaug developed a high yielding variety of wheat through new concepts in plant breeding. By the mid

1960's, the green revolution was fully adopted in India.

Changes Caused by Agriculture and Over Grazing

Changes Caused By Agriculture

There are two types of agricultural systems:

1. Traditional system
2. Modern and Industrialized system

i. Traditional system

The traditional system is again subdivided into two types namely:

- Traditional Subsistence Agriculture (TSA)

In this system, only enough crops or livestock are produced for the use of family and a little surplus to sell to meet the needs.

- Traditional Intensive Agriculture(TIA)

Farmers increase their inputs of human labor, Water fertilizers to get higher yields for the use of their families and to sell small quantities for getting income.

ii. Modern and industrialized system

In the system of modern and industrialize agriculture, a large extent of land will be brought under agriculture and huge quantities of fuel, energy, water, chemical fertilizers, pesticides used to produce large quantities of single crops purely for sale. This system is spreading in India in the name of Green revolution. But this modern agricultural system has its own adverse effects on environment.

1. Excessive use of chemical fertilizers to boost up the crop yield, contaminate groundwaterwith nitrate. The presence of excess of nitrate in drinking water is dangerous for human Health.Excess Nitrate reacts with hemoglobin and causes for "Blue Baby Syndrome" which kill theinfants.
2. The excessive N P K fertilizers in agriculture fields are often washed off with water andleads to algal blooming and Eutrophication. Phosphates have been accumulating in soils, lakesediments for decades change the ecology. Increased levels of phosphates in water bodies causeEutrophication (growth of unwanted plants).
3. The excessive use of pesticides enters the food chain and become hazardous to human life.
4. A large area of fertile land has become saline in recent years due to excessive irrigation
5. Consumption of fuel energy is more when shifting of human and animal labour agriculture machinery. Use of fuel leads to air pollution.
6. Continuing to increase input of fertilizers, water and pesticides eventually produces additional increase in crop yield but slows down the productivity of the crop.
7. Due to increased irrigation, the underground aquifers are slowly and constantly becomedry. The rate at which they are being depleted is much faster than its recharge.
8. Excessive application of chemical fertilizers can increase soil salt content. The percolationof domestic and industrial sewage also increase the salinity of soil.
9. The stagnation of water in the soil in the upper layers causes for water logging which causes for less oxygen availability for respiration of plants.

Modern, intensive agriculture causes many problems, including the following:

1. Artificial fertilizers and herbicides are easily washed from the soil and pollute rivers, lakes and Water courses.
2. The prolonged use of artificial fertilizers results in soils with a low organic matter content which is easily eroded by wind and rain.
3. Dependency on fertilizers. Greater amounts are needed every year to produce the same y ieldsof crops.
4. Artificial pesticides can stay in the soil for a long time and enter the food chain where theybuild up in the bodies of animals and humans, causing health problems.
5. Artificial chemicals destroy soil micro-organisms resulting in poor soil structure an aerationand decreasing nutrient availability.
6. Pests and diseases become more difficult to control as they become resistant to artificial

7. Pesticides. The numbers of natural enemies decrease because of pesticide use and habitat loss.

Water Logging

Water logging refers to the saturation of soil with water. Soil may be regarded as waterlogged when the water table of the groundwater is too high to conveniently permit an anticipated activity, like agriculture. In agriculture, various crops need air (specifically, oxygen) to a greater or lesser depth in the soil. Water logging of the soil stops air getting in. How near the water table must be to the surface for the ground to be classed as waterlogged varies with the purpose in view. A crop's demand for freedom from water logging may vary between seasons of the year, as with the growing of rice (Oryza sativa).

In irrigated agricultural land, water logging is often accompanied by soil salinity as waterlogged soils prevent leaching of the salts imported by the irrigation water

Salinity

Soil salinity is the salt content in the soil; the process of increasing the salt content is known as salinization. Salt is a natural element of soils and water. Salinization can be caused by natural processes such as mineral weathering or the gradual withdrawal of an ocean. It can also be caused by artificial processes such as irrigation.

Salinization is a process that results from:

1. High levels of salt in the water.
2. Landscape features that allow salts to become mobile(movement of water table).
3. Climatic trends that favors accumulation.
4. Human activities such as land clearing, aquaculture activities and the salting of icy roads.

Changes Caused by Over Grazing

Overgrazing occurs when plants are exposed to intensive grazing for extended periods of time, or without sufficient recovery periods. It can be caused by either livestock in poorly managed agricultural applications, or by overpopulations of native or native wild. Overgrazing reduces the usefulness, productivity, and biodiversity of the land and is one cause of desertification and erosion. Overgrazing is also seen as a cause of the spread of invasive species of non-native plants and of weeds. Overgrazing typically increases soil erosion. Reduction in soil depth, soil organic matter and soil fertility impair the land's future natural and agricultural productivity. Soil fertility can sometimes be mitigated by applying the appropriate lime and organic fertilizers. However, the loss of soil depth and organic matter takes centuries to correct. Their loss is critical in determining the soil's water-holding capacity and how well pasture plants do during dry weather.

Energy Resources

Energy is defined by physicists as the capacity to do work. Energy is found on ourplanet in a variety of forms, some of which are immediately useful to do work, while others require a process of transformation. Energy can neither be created nor destroyed but transformed from one form to other. Energy is closely related to force. When a force causes an object to move, energy is being transferred from the force to kinetic energy. Energy is present in a number of forms suchas mechanical, thermal, chemical, biological energy etc.. Energy production and utilization have become essential to carry out many activities in modern life. Energy is one of the important requirements that a country needs for its economic growth. At the same time, energy production has its impact on environment due to pollution and finally affects the quality of life of people.

Growing Energy Needs

Energy plays a key role in the process of economic growth of a nation. The industrialdevelopment of any country is dependent on the organized development of its power resources'.

Energy is also indispensable for agriculture, transport, business and domestic requirements. In fact, electricity has such a wide range of applications in modern economic development that its per capita consumption is, to a great extent, an index of the material advancement of the country.

Energy is the capacity for doing useful work. It is an essential input for economic growth. This energy is used in the form of electrical energy, thermal energy, light, mechanical energy and chemical energy etc. Energy is measured in joules in Si units. The annual per capita energy consumption in developed countries ranges from 5 to 11 kW whereas in the developing countries it is between 1 to 1.5 KW only.

Uses of Energy

1. Energy is a primary input in any industrial operation.
2. It is also a major input in sectors such as commerce, transport, tele-communications etc.
3. The wide range of services required in the household and industrial sectors.
4. Owing to the far-reaching changes in the forms of energy and their respective roles in supporting human activities, research and training on various aspects of energy and environment have assumed great significance.

Types of Energy

There are three main types of energy;

1. Non-renewable
2. Renewable
3. Nuclear energy

i. Non-renewable energy resources

Fossil fuels: Fossil means the remains of an animal or a plant which have become hard and turned into rock. All these, which is mention below figure found in earth’s crusts which have been formed in the past by the geological processes. Fossil fuels are solid coal (lignite), liquid (crude oil / petroleum) and gases (natural gas).

- **Coal:**

Huge quantity of plant materials buried under earth’scrust and altered by geological process and converted into carbon rich fuel. It is a non-renewable source because it takes a very long period (millions of years) for its formation.

Coal is extracted by the process of mining and involves accidents due to mine collapse, ground water pollution, accumulation of poisonous material, explosive gases etc cause diseases. CO2Pollution leads to greenhouse effect (global warming).

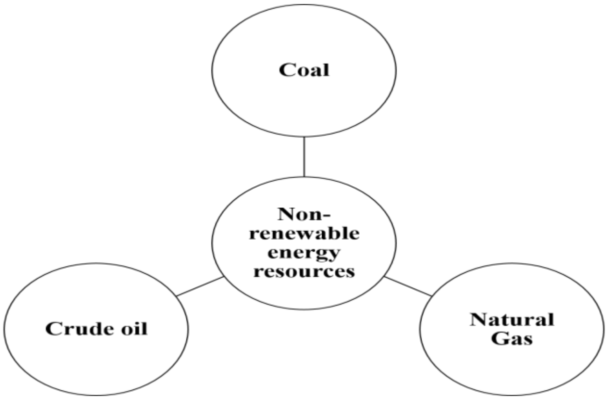

Figure 1: Represented the Non-renewable Energy Resource.

- **Crude Oil:**

It is obtained in the form of liquid. The crude oil is heated up to 600oC in the oil Refinery and condense the vapours of hydro – carbons. Petrol another petroleum products arerefined fuels from crude oil. Petroleum products are used in large quantities in the manufactureof detergents, plastics, fertilizers, pharmaceuticals, synthetic rubber etc. The transport sectorconsumes about 40% of diesel; 25% industries and 19%household and rest 16% agriculture and other sectors. .

- **Natural Gas:**

Gas deposits are trapped from the sedimentary formations by means drilling holes into the rock formations. While burning of natural gas, the emission of CO2 is less and thus reduces greenhouse effect and global warming. A total of 734 billion cubic mts of gas is estimated as proven reserves.

ii. Renewable energy resources:

Renewable energy systems use resources that are constantly replaced and are usually less polluting. Examples include hydropower, solar, wind, and geothermal (energy from the heat inside the earth).

- **Solar energy:**

The energy which is derived from the sun is known as solar energy. It can be used for direct heating or sun’s heat is converted into electricity. Photo voltaic cells convert direct solar energy into electricity.

A number of solar equipment’s have been developed to utilize sun rays to heat water, to cook food, to pump water and to run certain machines and used for street lighting, railway signals etc.

But the major problem with solar energy is that during cloudy weather it is available in less quantity than on sunny days.

Working of Solar Power

The sun's energy can be captured to generate electricity or heat through a system of panels ormirrors.

- Solar, or photovoltaic, cells convert sunlight directly into electricity. Most photovoltaic cellsare made primarily of silicon, the material used in computer semiconductor chips, andarranged on rectangular panels. When sunlight hits a cell, the energy knocks electrons free oftheir atoms, allowing them to flow through the material. The resulting DC (direct current)electricity is then sent to a power inverter for conversion to AC (alternating current).
- Solar thermal collectors use heat absorbing panels and a series of attached circulation tubes to heat water or buildings.
- Solar concentration systems use mirrors usually arranged in a series of long, parabolictroughs, a large round dish, or a circle surrounding a "power tower" -- to focus the sun'sreflected rays on a heat-collecting element. The concentrated sunlight heats water or a heat transferring fluid such as molten salt to generate steam, which is then used conventionally tospin turbines and generate electricity.
- Passive solar design is the creative use of windows, skylights and sunrooms, building site andorientation, and thermal construction materials to heat and light buildings, or to heat water,the natural way.

Hydro-Power Energy:

Electrical power is generated by hydro-electric projects in which dams are constructed across the river as display in Figure 2. The kinetic energy of water is converted into mechanical energy by means of turbines and in turn, the mechanical energy is transferred into electrical energy by generators. The figure mention below. Hydro power projects lead to several environmental problems like destruction of animal habitats, deforestation, migration of people etc.

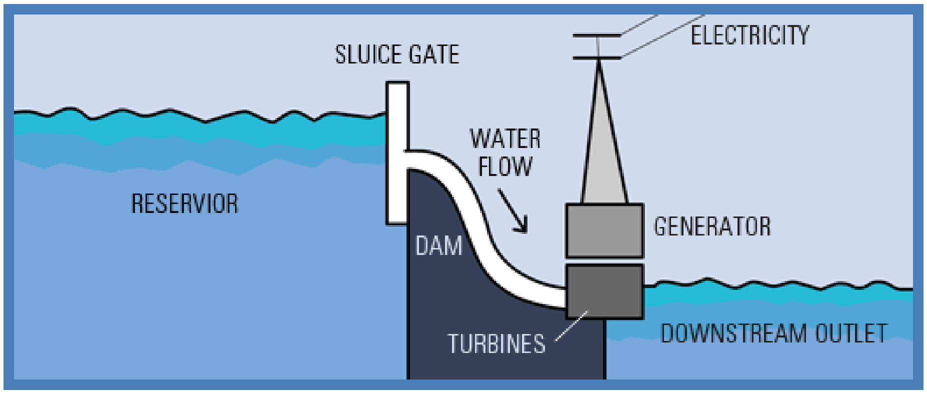

Figure 2: Represented that the Hydro-Power Energy

Geothermal Energy:

Geothermal energy found within rock formations. Inside the earth the temperature rises with depth .The temperature in earth's crust is around 4000o C.

Geysers (anatural spring that emits hot water) and hot springs are examples for geothermal energy as display in Figure 3, where the steam and hot water come to the surface, in areas where the steam is tapped by drilling. The obtained steam is then used to generate power. Air pollution results in case of geothermal energy where the gases like H2S, NH3, and CO2 present in the steam coming out of the geothermal sources.

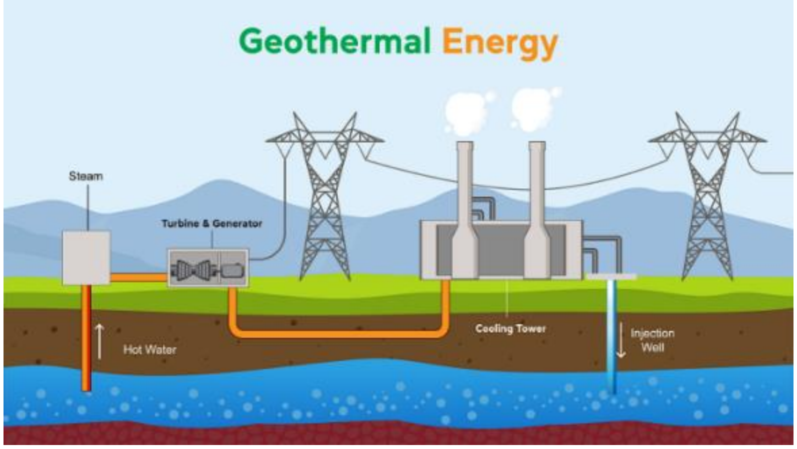

Figure 3: Represented that the Geothermal Energy

The overall efficiency for power production is low (15%) as compared to fossil fuels (40%).

Wind Energy:

According to the Figure 4, Wind energy is the kinetic energy associated with the movement of atmospheric air which is display in below figure. Wind mills convert the wind energy into electrical energy. On an average wind mills can convert 30-40 % of available wind energy into electrical energy at a steady wind speed of 8.5mts / sec. The efficiency of wind mill is increased with the speed of wind and length of rotor blade.

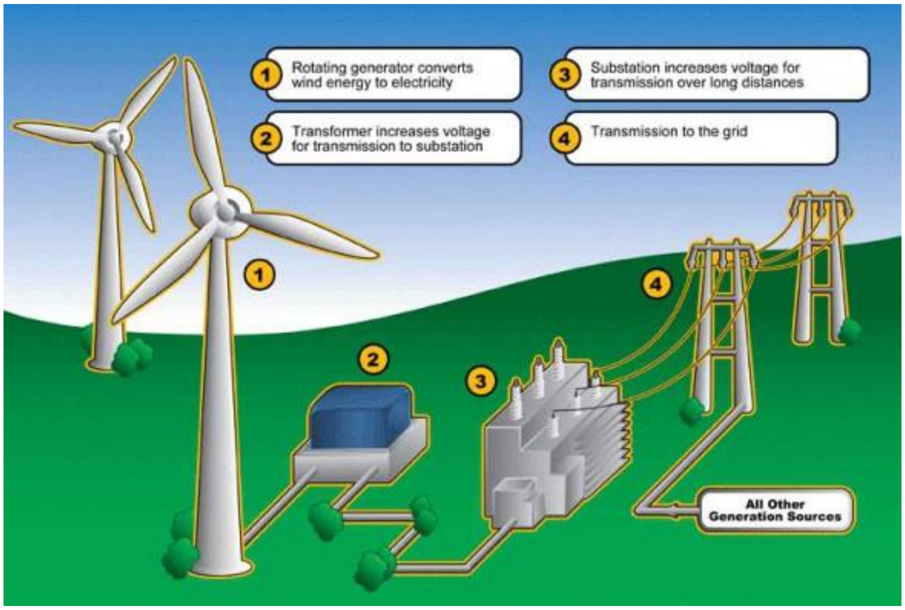

Figure 4: Represented that the Wind Energy.

The total wind energy potential in India's estimate is 25,000 MW of this about6000 MW is locatedin Tamil Nadu; 5000 MW in Gujarat and contribute the states of Andhra Pradesh, Maharashtra, Uttar Pradesh and Rajasthan for balance quantity.

Related Question for Revision

1. Explain the formation of Himalayas.
2. Correlate the Himalayas formation process with a fold mountain.
3. Correlate the timeline of Himalaya's formation with a young mountain
4. What is the main function to the formation of the Himalayas?
5. Which of the layers of the atmosphere consists of the ozone layer that is responsible for absorbing the Ultra-Violet (UV) light?
6. Which of the essential non-metallic minerals?
7. What is the estimated percentage of forest land that India should ideally have?
8. Which of the elements is considered to be the largest source of commercial energy consumption in the world?
9. Which is does not constitute to be a reason for the loss of forests?
10. How many total numbers of biodiversity hotspots are there in the world?
11. Which of these elements is present in the drinking water that can lead to numerous fatal diseases?

Reference of Book for Further Reading

1. Paryavaran Adhyayan “Textbook of Environmental Studies”
2. Elizabeth Kolbert “The Sixth Extinction: An Unnatural History”
3. James Lovelock “Gaia: A New Look at Life on Earth”
4. Mark Lynas “Our Final Warning: Six Degrees of Climate Emergency”
5. Edward O. Wilson “Half-Earth: Our Planet’s Fight for Life”
6. Alan Weisman “The World Without Us”
7. Aldo Leopold “A Sand County Almanac and Sketches”
