Physical Geology

Unit I.

Introduction to geology.

Geology is an Earth science concerned with the solid Earth, the rocks of which it is composed, and the processes by which they change over time. Geology can also include the study of the solid features of any terrestrial planet or natural satellite such as Mars or the Moon. Modern geology significantly overlaps all other Earth sciences, including hydrology and the atmospheric sciences, and so is treated as one major aspect of integrated Earth system science and planetary science.

Geology describes the structure of the Earth on and beneath its surface, and the processes that have shaped that structure. It also provides tools to determine the relative and absolute ages of rocks found in a given location, and also to describe the histories of those rocks.[3] By combining these tools, geologists are able to chronicle the geological history of the Earth as a whole, and also to demonstrate the age of the Earth. Geology provides the primary evidence for plate tectonics, the evolutionary history of life, and the Earth's past climates.

Branch and application of geology

The word "Geology" is derived from the Greek word "geo" means globe and "logos" means logical discourse. Hence, geology is defined as the logical study of all of the globe. Today, geology does not restrict its domain to the study of the planet earth alone. It also includes the study of the other planets and moons of the entire solar system. Geology is a very vast subject. It has several branches. In the olden days, people divided it into two broad areas, as physical geology and historical geology. The subject of Physical geology deals with the study of Earth's materials, such as minerals and rocks, as well as the processes that are operating on and within the Earth and on its surface. The subject of Historical geology focuses on the origin and evolution of life on the Earth, its continents, oceans, atmosphere, and the life of all ecosystems. Historical geology is more than just concentrating on the past events in geological history. It is the study of the sequential changes that have happened and evolved continuously during the past 4.6 billion years on the planet. Geology is a grand parent subject comprising four levels of grand children branches. Some of the notable ones are only discussed in this report.

1.Pysical geology.

Physical geology may be defined as the branch of geology which deals with the study of physical forces and processes that bring about changes in the earth's crust or to the surface of the earth on account of their prolonged existence and action .

2.Structural geology.

The study of the deformation of the rocks in the earth's lithosphere is the subject matter of the branch of geology known as structural geology.

3.Sedimentology.

Sedimentology deals with the study sediments, their formation, transportation and deposition.

4.mineralogy

The branch of geology which deals with the study of minerals, their formation, analysis, association, physical and chemical properties and classification is called mineralogy

5.Crytallography

The branch dealing with the study of crystal of minerals is known as crystallography. Crystals are solid geometric figures and have well defined, more or less plane, faces which bound the solid.

6.Optical mineralogy.

The branch which deals the optical properties of the minerals and the behaviour of light through the minerals.

7.Petrology.

The branch of geology which is concerned with the study of rocks is called petrology. It is further subdivided into igneous, sedimentary and metamorphic petrology depending upon the rock group studied under the particular heading.

8.Paleontology.

The study of the past life on the earth is called paleontology. It is studied with the help of fossil records that is preserved in the sedimentary.

9.Historical geology(or) Stratigraphy.

Historical Geology is that branch of geology that studies the evolutionary history of the earth in a chronological manner. Historical geology is further subdivided into stratigraphy (the study of the stratified rocks of the earth).

10.Economic geology.

The branch of geology which that deals with the study of the earth materials that are used for economic and/or industrial purposes such as petroleum, coal, ores, building stones, salt, gemstones, etc., is known as economic geology.

Application of geology

Exploration for energy and mineral sources: Over the past century, industries have developed rapidly, populations have grown dramatically, and standards of living have improved, resulting in an ever-growing demand for energy and mineral resources. Geologists and geophysicists have led the exploration for fossil fuels (coal, oil, natural gas, etc.) and concentrations of geothermal energy, for which applications have grown in recent years. They also have played a major role in locating deposits of commercially valuable minerals.

Coal: The Industrial Revolution of the late 18th and 19th centuries was fueled by coal. Though it has been supplanted by oil and natural gas as the primary source of energy in most modern industrial nations, coal nonetheless remains an important fuel.

The U.S. Geological Survey has estimated that only about 2 percent of the world's minable coal has so far been exploited; known reserves should last for at least 300 to 400 years. Moreover, new coal basins continue to be found, as, for example, the lignite basin discovered in the mid-1980s in Rājasthān in northwestern India.

Oil and natural gas: During the last half of the 20th century, the consumption of petroleum products increased sharply. This led to a depletion of many existing oil fields, notably in the United States, and intensive efforts to find new deposits.

Geothermal energy: Another alternate energy resource is the heat from the Earth's interior. The surface expression of this energy is manifested in volcanoes, fumaroles, steam geysers, hot springs, and boiling mud pools. Global heat-flow maps constructed from geophysical data show that the zones of highest heat flow occur along the active plate boundaries. There is, in effect, a close association between geothermal energy sources and volcanically active regions.

A variety of applications have been developed for geothermal energy. For example, public buildings, residential dwellings, and greenhouses in such areas as Reykjavík, Iceland, are heated with water pumped from hot springs and geothermal wells. Hot water from such sources also is used for heating soil to increase crop production (e.g., in Oregon) and for seasoning lumber (e.g., in parts of New Zealand). The most significant application of geothermal energy, however, is the generation of electricity. The first geothermal power station began operation in Larderello, Italy, in the early 1900s. Since then similar facilities have been built in various countries, including Iceland, Japan, Mexico, New Zealand, Turkey, the Tibet Autonomous Region of China, and the United States. In most cases turbines are driven with steam separated from superheated water tapped from underground geothermal reservoirs and geysers.

Mineral deposites: Mineral**,** naturally occurring homogeneous solid with a definite chemical composition and a highly ordered atomic arrangement; it is usually formed by inorganic processes. There are several thousand known mineral species, about 100 of which constitute the major mineral components of rocks; these are the so-called rock-forming minerals.

A brief outline of planets

There are 8 planets in our solar system, they are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune.

Planets in our solar system can be divided into two main groups, Terrestrial Planets and Gas Giants. Planets that orbit other stars are referred to as Exoplanets.

- **Mercury's** craters are named after famous artists, musicians and authors.
- **Venus** is the hottest planet in the solar system.
- **Earth's** atmosphere protects us from meteoroids and radiation from the Sun.
- There have been more missions to **Mars** than any other planet.
- **Jupiter** has more than double the mass of all the other planets combined.
- **Saturn** has more moons than any other planet in the Solar System.
- **Uranus** has only been visited by a single spacecraft, Voyager 2.
- It takes like more than 4 hours for light to reach **Neptune** from the Sun.
- Only 8 planets have been discovered in our solar system but there is compelling evidence for a **9th planet**.
- With the exception of Neptune and Uranus the other 6 planets can be seen unaided and all 8 are visible with a small telescope or binoculars.
- Together the planets make up 0.14% of the solar systems mass, 99% of which is the gas giants (Jupiter, Saturn, Uranus and Neptune).

A planet is any of the large bodies that orbit the Sun, including Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune, in order of closeness to the Sun.

Mercury

Mercury is the first of the four **terrestrial planets**. This means it is a planet made mostly of rock. The planets closest to the Sun—Venus, Earth, and Mars—are the other three.Mercury is the smallest of the terrestrial planets. It has an iron core that accounts for about 3/4 of its diameter. Most of the rest of the planet is made up of a rocky crust.Because it is so close to the Sun, it is very difficult to see Mercury. A NASA mission called Messenger is expected to begin orbiting the planet in 2011. It is expected that this will help us learn a great deal more about this rarely seen planet.

Diameter:3,032 miles (4,879 km).

Distance from Sun:28.5 to 43 million miles (45.9 to 69 million km).

Length of year:88 days.

Number of Moons: None.

Venus

Of all the planets, Venus is the one most similar to Earth. In fact, Venus is often called Earth's "sister" planet. As similar as it is in some ways, however, it is also very different in others.Earth and Venus are similar in size. The two planets are very close to each other as they orbit the Sun; because of this, Venus is the most visible planet in the night sky. Both planets are relatively young, judging from the lack of craters on their surfaces.We now know that the environment on Venus couldn't support life as Earth does. Our atmosphere is a breathable mix of oxygen and other gases, but the atmosphere on Venus is mostly carbon dioxide, which is a poisonous gas. The temperature on Earth rarely goes much higher than 100° F (37.8° C), even at the equator, but the temperature on the surface of Venus can exceed 850° F (454° C)!. The atmosphere of Venus would be compared to the exhaust from a car.The Earth is mostly water, but whatever water that may have existed once on Venus has boiled away due to the intense heat.

Diameter:7,520 miles (12,100 km).

Distance from Sun: About 67 million miles (108 million km).

Length of year:225 days.

Number of Moons: None.

Earth

The Earth is the only planet known where life exists. Almost 1.5 million species of animals and plants have been discovered so far, and many more have yet to be found. While other planets may have small amounts of ice or steam, the Earth is 2/3 water. Earth has perfect conditions for a breathable atmosphere. Earth is the largest of the terrestrial planets and the fifth largest in the solar system. It is believed to be about 4.5 billion years old, which makes it very young compared to other celestial bodies!

Diameter:7,926 miles (12,755 km).

Distance from Sun:93 million miles (150 million km).

Length of year:365 days.

Number of Moons: One.

Mars

No planet has sparked the imaginations of humans as much as Mars. It may be the reddish color of Mars, or the fact that it can often be easily seen in the night sky, that has caused people to wonder about this close neighbor of ours. Tales of "Martians" invading Earth have been around for well over fifty years. But is it likely that any kind of life really does exist on Mars?Scientists aren't sure. Life as we know it couldn't survive there. Even so, there is evidence that there may be water on Mars. The presence of methane, which may be given off by organisms, provides another clue.

Does this all mean you need to be concerned about an alien attack from Mars? Hardly. Still, as we learn more and more about the final terrestrial planet, the more mysterious and wonderful Mars becomes.

Diameter:4,217 miles (6,786 km).

Distance from the Sun:142 million miles (229 million km).

Length of year:687 days.

Number of Moons: Two, called Deimos and Phobos.

Jupiter

The planet Jupiter is the first of the **gas giant** planets. Made mostly of gas, they include Jupiter, Saturn, Uranus, and Neptune.Jupiter is first among the planets in terms of size and mass. Its diameter is 11 times bigger than Earth, and its mass is 2.5 times greater than all the other planets combined. The “Great Red Spot” on Jupiter is actually a raging storm.This giant planet comes in first again when it comes to giving off heat. The core of Jupiter may be made of liquid rock that reaches temperatures of 43,000° F (23,870° C).There are at least 63 moons of different sizes orbiting Jupiter. That's the most of any planet. Its largest moon is called Ganymede. It has a diameter of 3,400 miles (5,472 km)—larger than Mercury!

Diameter:88,732 miles (142,800 km).

Distance from Sun:484 million miles (779 million km).

Length of year: Almost 12 Earth years.

Number of Moons:63.

Saturn

Most people know about the rings around Saturn, because they are the brightest and most colorful. These rings are made mainly out of ice particles orbiting the planet. While the rings themselves seem big, the particles are very small, usually no more than 10 feet (3 meters) wide.

Saturn is the second largest planet. It is the farthest planet from the Earth that can be seen without a telescope. It appears flat at the poles because its great rotational speed makes the middle of the planet bulge.

Diameter:74,900 miles (120,537 km).

Distance from Sun:888 million miles (14,290 million km).

Length of year:29.5 Earth years.

Number of Moons: At least 56.

Uranus

Uranus is the first planet so far away from the Earth that it can only be seen with the use of a telescope. When it was first discovered in 1781, scientists didn't know what they had found. As astronomers studied the object more closely, they discovered that it had a circular orbit around the Sun. They had found the seventh planet.

Uranus is so far from the Sun that it takes 84 years to complete an orbit of the Sun. It is the only planet that spins on its side, so each pole is tilted away from the Sun for half its orbit. That means each night and day lasts an amazing 42 years. Imagine staying awake that long! Of course, you'd also get a lot of time to catch up on your sleep!

Diameter: About 32,200 miles (51,819 km).

Distance from Sun:1,783,940,000 miles (2,870,894,600 km).

Length of year:84 Earth years.

Number of Moons:21.

Neptune

Imagine being so good at math that you could figure out the location of a planet you had never even seen! That is what John C. Adams did in 1843 when he discovered Neptune.

Neptune was named after the Roman god of the sea because it is so far out in the deep “sea” of space. The name also fits because Neptune appears to be a beautiful bright blue because of the methane clouds that surround it.

It is the most distant planet from the Sun. It takes a very long time—165 years—to orbit the Sun. Neptune has made only one trip around the Sun since it was discovered.

Diameter:30,777 miles (49,529 km).

Distance from Sun:2,795,084,800 miles (4,498,033,400 km).

Length of year: About 165 Earth years.

Number of Moons:13.

Satellite.

A **satellite** is an object that has been intentionally placed into orbit. These objects are called **artificial satellites** to distinguish them from natural satellites such as Earth's Moon.

A satellite is a moon, planet or machine that orbits a planet or star. For example, Earth is a satellite because it orbits the sun. Likewise, the moon is a satellite because it orbits Earth. Usually, the word "satellite" refers to a machine that is launched into space and moves around Earth or another body in space.

Earth and the moon are examples of natural satellites. Thousands of artificial, or man-made, satellites orbit Earth. Some take pictures of the planet that help meteorologists predict weather and track hurricanes. Some take pictures of other planets, the sun, black holes, dark matter or faraway galaxies. These pictures help scientists better understand the solar system and universe.

Still other satellites are used mainly for communications, such as beaming TV signals and phone calls around the world. A group of more than 20 satellites make up the Global Positioning System, or GPS. If you have a GPS receiver, these satellites can help figure out your exact location.

Comets.

Comets are frozen leftovers from the formation of the solar system composed of dust, rock and ices. They range from a few miles to tens of miles wide, but as they orbit closer to the sun, they heat up and spew gases and dust into a glowing head that can be larger than a planet. This material forms a tail that stretches millions of miles.Comets are cosmic snowballs of frozen gases, rock and dust that orbit the Sun. When frozen, they are the size of a small town. When a comet's orbit brings it close to the Sun, it heats up and spews dust and gases into a giant glowing head larger than most planets. The dust and gases form a tail that stretches away from the Sun for millions of miles. There are likely billions of comets orbiting our Sun in the Kuiper Belt and even more distant Oort Cloud.The current number of known comets is: **3,695**

Asteroids belt.

The **asteroid belt** is a torus-shaped region in the Solar System, located roughly between the orbits of the planets Jupiter and Mars, that is occupied by a great many solid, irregularly shaped bodies, of many sizes but much smaller than planets, called asteroids or minor planets. This asteroid belt is also called the **main asteroid belt** or **main belt** to distinguish it from other asteroid populations in the Solar System such as near-Earth asteroids and trojan asteroids.

Asteroids.

Asteroids are small, rocky objects that orbit the Sun. Although asteroids orbit the Sun like planets, they are much smaller than planets. Asteroids are small, rocky objects that orbit the sun. Although asteroids orbit the sun like planets, they are much smaller than planets.

Meteorites.

A **meteorite** is a solid piece of debris from an object, such as a comet, asteroid, or meteoroid, that originates in outer space and survives its passage through the atmosphere to reach the surface of a planet or moon.

Kepler's law of planetary motion.

Kepler's three laws describe how planetary bodies orbit about the Sun. They describe how (1) planets move in elliptical orbits with the Sun as a focus, (2) a planet covers the same area of space in the same amount of time no matter where it is in its orbit, and (3) a planet's orbital period is proportional to the size of The planets orbit the Sun in a counterclockwise direction as viewed from above the Sun's north pole, and the planets' orbits all are aligned to what astronomers call the ecliptic plane.its orbit (its semi-major axis).

Kepler's First Law: each planet's orbit about the Sun is an ellipse. The Sun's center is always located at one focus of the orbital ellipse. The Sun is at one focus. The planet follows the ellipse in its orbit, meaning that the planet to Sun distance is constantly changing as the planet goes around its orbit.

Kepler's Second Law: the imaginary line joining a planet and the sons sweeps equal areas of space during equal time intervals as the planet orbits. Basically, that planets do not move with constant speed along their orbits. Rather, their speed varies so that the line joining the centers of the Sun and the planet sweeps out equal parts of an area in equal times. The point of nearest approach of the planet to the Sun is termed perihelion. The point of greatest separation is aphelion, hence by Kepler's Second Law, a planet is moving fastest when it is at perihelion and slowest at aphelion.

Kepler's Third Law: the squares of the orbital periods of the planets are directly proportional to the cubes of the semi major axes of their orbits. Kepler's Third Law implies that the period for a planet to orbit the Sun increases rapidly with the radius of its orbit. Thus we find that Mercury, the innermost planet, takes only 88 days to orbit the Sun. The earth takes 365 days, while Saturn requires 10,759 days to do the same. Though Kepler hadn't known about gravitation when he came up with his three laws, they were instrumental in Isaac Newton deriving his theory of universal gravitation, which explains the unknown force behind Kepler's Third Law. Kepler and his theories were crucial in the better understanding of our solar system dynamics and as a springboard to newer theories that more accurately approximate our planetary orbits.

Bode's law.

Bode's law, also called **Titius-Bode law**, empirical rule giving the approximate distances of planets from the Sun. It was first announced in 1766 by the German astronomer Johann Daniel Titius but was popularized only from 1772 by his countryman Johann Elert Bode. Once suspected to have some significance regarding the formation of the solar system, Bode's law is now generally regarded as a numerological curiosity with no known justification.

One way to state Bode's law begins with the sequence 0, 3, 6, 12, 24,…, in which each number after 3 is twice the previous one. To each number is added 4, and each result is divided by 10. Of the first seven answers—0.4, 0.7, 1.0, 1.6, 2.8, 5.2, 10.0—six of them (2.8 being the exception) closely approximate the distances from the Sun, expressed in astronomical units (AU; the mean Sun-Earth distance), of the six planets known when Titius devised the rule: Mercury, Venus, Earth, Mars, Jupiter, and Saturn. At about 2.8 AU from the Sun, between Mars and Jupiter, the asteroids were later discovered, beginning with Ceres in 1801. The rule also was found to hold for the seventh planet, Uranus (discovered 1781), which lies at about 19 AU, but it failed to predict accurately the distance of the eighth planet, Neptune (1846), and that of Pluto, which was regarded as the ninth planet when it was discovered (1930). For a discussion of the roles that Bode's law played in early asteroid discoveries and the search for planets in the outer solar system, *see* the articles asteroid and Neptune.

Orgin of Solar system.

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 percent 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.

Planetesimal model.

Planetesimal Hypothesis, a theory of the origin of the solar system. It was proposed by Forrest R. Moulton and Thomas C. Chamberlin about 1900. The theory states that the planets were formed by the accumulation of extremely small bits of matterplanetesimalsthat revolved around the sun. This matter was produced when a passing star almost collided with the sun. During the near-collision, hot gases were pulled out of both stars and the gases then condensed. The planetesimal hypothesis was widely accepted for about 35 years.

The greatest flaw in the theory is the assumption that the material drawn out of the stars would condense. The extremely hot gases that make up a star are held together by the gravitational forces within the star. Once the material was pulled away to where the gravitational forces were weaker, it would expand because of its heat. Before condensation could take place, the gases would have almost entirely dissipated. The planetesimal hypothesis is no longer considered a likely explanation of the origin of the solar system.

Tidal model

The tidal theory, proposed by James Jeans and Harold Jeffreys in 1918, is a variation of the planetesimal concept: it suggests that a huge tidal wave, raised on the sun by a passing star, was drawn into a long filament and became detached from the principal mass. As the stream of gaseous material condensed, it separated into masses of various sizes, which, by further condensation, took the form of the planets. Serious objections against the encounter theories remain; the angular momentum problem is not fully explained.

Nebular and gas cloud model

This states that the solar system developed out of an interstellar cloud of dust and gas, called a **nebula** . This theory best accounts for the objects we currently find in the Solar System and the distribution of these objects.The Nebular Theory would have started with a cloud of gas and dust, most likely left over from a previous supernova. The nebula started to collapse and condense; this collapsing process continued for some time. The Sun-to-be collected most of the mass in the nebula's center, forming a **Protostar** .

A protostar is an object in which no nuclear fusion has occurred, unlike a star that is undergoing nuclear fusion. A protostar becomes a star when nuclear fusion begins. Most likely the next step was that the nebula flattened into a disk called the **Protoplanetary Disk** ; planets eventually formed from and in this disk.

Three processes occurred with the nebular collapse:

1. Temperatures continued to increase
2. The solar nebula spun faster and faster
3. The solar nebula disk flattened

The orderly motions of the solar system today are a direct result of the solar system's beginnings in a spinning, flattened cloud of gas and dust.

Age of the Earth.

Earth is estimated to be 4.54 billion years old, plus or minus about 50 million years. Scientists have scoured the Earth searching for the oldest rocks to radiometrically date. In northwestern Canada, they discovered rocks about 4.03 billion years old. Then, in Australia, they discovered minerals about 4.3 billion years old. Researchers know that rocks are continuously recycling, due to the rock cycle, so they continued to search for data elsewhere. Since it is thought the bodies in the solar system may have formed at similar times, scientists analyzed moon rocks collected during the moon landing and even meteorites that have crash-landed on Earth. Both of these materials dated to between 4.4 and 4.5 billion years.

Direct methods.

Despite seeming like a relatively stable place, the Earth's surface has changed dramatically over the past 4.6 billion years. Mountains have been built and eroded, continents and oceans have moved great distances, and the Earth has fluctuated from being extremely cold and almost completely covered with ice to being very warm and ice-free. These changes typically occur so slowly that they are barely detectable over the span of a human life, yet even at this instant, the Earth's surface is moving and changing. As these changes have occurred, organisms have evolved, and remnants of some have been preserved as fossils.

There are three general approaches that allow scientists to date geological materials and answer the question: "How old is this fossil?" First, the relative age of a fossil can be determined. **Relative dating** puts geologic events in chronological order without requiring that a specific numerical age be assigned to each event. Second, it is possible to determine the numerical age for fossils or earth materials. Numerical ages estimate the date of a geological event and can sometimes reveal quite precisely when a fossil species existed in time. Third, **magnetism** in rocks can be used to estimate the age of a fossil site. This method uses the orientation of the Earth's magnetic field, which has changed through time, to determine ages for fossils and rocks.

Introduction to Radioactivity.

Radioactive decay, also known as nuclear decay or radioactivity, is the process by which the nucleus of an unstable atom loses energy by emitting radiation, including alpha particles, beta particles, gamma rays and conversion electrons. A material that spontaneously emits such radiation is considered radioactive.

Radioactive minerals.

One of six radioactive elements that occur naturally: potassium, rubidium, thorium, uranium, and associated radium, samarium, and lutecium. Thorium commonly occurs in monazite, a sparsely scattered accessory mineral of certain granites, gneisses, and pegmatites. It is concentrated, however, by weathering processes in sands and gravels as commercial placer deposits along rivers and beaches. The most important primary uranium ore minerals are davidite and uraninite, esp. pitchblende, the massive variety. These minerals are of rather underspread occurrence in certain granites and pegmatites and occur as secondary minerals in metallic vein deposits. The secondary uranium minerals, however, are more underspread and more numerous than the primary uranium ore minerals. Secondary uranium minerals are found in weathered and oxidized zones of primary deposits and, also, in irregular flat-lying sandstones, such as those in the Colorado Plateau, where the uranium mineralization was precipitated from solutions. Carnotite, the potassium uranium vanadate of conspicuous yellow color, is perhaps the most important of the secondary uranium ore minerals. Others are tyuyamunite, which is closely related to carnotite, and the torbernites and autunites which are uranium minerals.

Radioactive decay.

Radioactive decay (also known as **nuclear decay**, **radioactivity**, **radioactive disintegration** or **nuclear disintegration**) is the process by which an unstable atomic nucleus loses energy by radiation. A material containing unstable nuclei is considered **radioactive**. Three of the most common types of decay are alpha decay, beta decay, and gamma decay, all of which involve emitting one or more particles or photons. The weak force is the mechanism that is responsible for beta decay.

Isotopes.

Isotopes are variants of a particular chemical element which differ in neutron number, and consequently in nucleon number. All isotopes of a given element have the same number of protons but different numbers of neutrons in each atom.

Concept of half life .

Half-life, in radioactivity, the interval of time required for one-half of the atomic nuclei of a radioactive sample to decay (change spontaneously into other nuclear species by emitting particles and energy), or, equivalently, the time interval required for the number of disintegrations per second of a radioactive material to decrease by one-half.

Parent are daughter element.

In nuclear science, the **decay chain** refers to a series of radioactive decays of different radioactive decay products as a sequential series of transformations. It is also known as a "radioactive cascade". Most radioisotopes do not decay directly to a stable state, but rather undergo a series of decays until eventually a stable isotope is reached.

Decay stages are referred to by their relationship to previous or subsequent stages. A *parent isotope* is one that undergoes decay to form a *daughter isotope*. One example of this is uranium (atomic number 92) decaying into thorium (atomic number 90). The daughter isotope may be stable or it may decay to form a daughter isotope of its own. The daughter of a daughter isotope is sometimes called a *granddaughter isotope*.

The time it takes for a single parent atom to decay to an atom of its daughter isotope can vary widely, not only between different parent-daughter pairs, but also randomly between identical pairings of parent and daughter isotopes. The decay of each single atom occurs spontaneously, and the decay of an initial population of identical atoms over time t, follows a decaying exponential distribution, $e^{-\lambda t}$, where λ is called a decay constant. One of the properties of an isotope is its half-life, the time by which half of an initial number of identical parent radioisotopes have decayed to their daughters, which is inversely related to λ. Half-lives have been determined in laboratories for many radioisotopes (or radionuclides). These can range from nearly instantaneous (less than 10^{-21} seconds) to more than 10^{19} years.

The intermediate stages each emit the same amount of radioactivity as the original radioisotope (i.e. there is a one-to-one relationship between the numbers of decays in successive stages) but each stage releases a different quantity of energy. If and when equilibrium is achieved, each successive daughter isotope is present in direct proportion to its half-life; but since its activity is inversely proportional to its half-life, each nuclide in the decay chain finally contributes as many individual transformations as the head of the chain, though not the same energy.

Application of U-Pb method

Uranium–lead dating, abbreviated **U–Pb dating**, is one of the oldest[1] and most refined of the radiometric dating schemes. It can be used to date rocks that formed and crystallised from about 1 million years to over 4.5 billion years ago with routine precisions in the 0.1–1 percent range.[2][3]

The method is usually applied to zircon. This mineral incorporates uranium and thorium atoms into its crystal structure, but strongly rejects lead when forming. As a result, newly-formed zircon deposits will contain no lead, meaning that any lead found in the mineral is radiogenic. Since the exact rate at which uranium decays into lead is known, the current ratio of lead to uranium in a sample of the mineral can be used to reliably determine its age.

The method relies on two separate decay chains, the uranium series from ^{238}U to ^{206}Pb, with a half-life of 4.47 billion years and the actinium series from ^{235}U to ^{207}Pb, with a half-life of 710 million years.

K-Ar method

potassium-40 to radioactive argon-40 in minerals and rocks; potassium-40 also decays to calcium-40. Thus, the ratio of argon-40 and potassium-40 and radiogenic calcium-40 to potassium-40 in a mineral or rock is a measure of the age of the sample. The calcium-potassium age method is seldom used, however, because of the great abundance of nonradiogenic calcium in minerals or rocks, which masks the presence of radiogenic calcium. On the other hand, the abundance of argon in the Earth is relatively small because of its escape to the atmosphere during processes associated with volcanism.

Rb-Sr method.

The radioactive decay of rubidium-87 (^{87}Rb) to strontium-87 (^{87}Sr) was the first widely used dating system that utilized the isochron method. Rubidium is a relatively abundant trace element in Earth’s crust and can be found in many common rock-forming minerals in which it substitutes for the major element potassium. Because rubidium is concentrated in crustal rocks, the continents have a much higher abundance of the daughter isotope strontium-87 compared with the stable isotopes. This relative abundance is expressed as the $^{87}Sr/^{86}Sr$ ratio, where strontium-86 is chosen to represent the stable isotopes strontium-88, strontium-86, and strontium-84, which occur in constant proportions in natural materials. Thus, a precise measurement of the $^{87}Sr/^{86}Sr$ ratio in a modern volcano can be used to determine age if recycled older crust is present. A ratio for average continental crust of about 0.72 has been determined by measuring strontium from clamshells from the major river systems. In contrast, Earth's most abundant lava rocks, which represent the mantle and make up the major oceanic ridges, have values between 0.703 and 0.705. This difference may appear small, but, considering that modern instruments can make the determination to a few parts in 70,000, it is quite significant. Dissolved strontium in the oceans today has a value of 0.709 that is dependent on the relative input from the continents and the ridges. In the geologic past, changes in the activity of these two sources produced varying $^{87}Sr/^{86}Sr$ ratios over time. Thus, if well-dated, unaltered fossil shells containing strontium from ancient seawater are analyzed, changes in this ratio with time can be observed and applied in reverse to estimate the time when fossils of unknown age were deposited.

C^14 method.

The Carbon 14, or radiocarbon dating method is one of the best-known methods of dating human fossils.

The element carbon occurs in nature in three isotopic forms. Carbon 12 (12-C) is stable and represents 98.9% of the carbon in the atmosphere. The rest (1.1%) is mostly made up of Carbon 13 (13-C), which is also stable, and Carbon 14 (C-14) which is unstable – or radioactive. In our atmosphere, only about one in a trillion carbon atoms is C-14.
Most of the C-14 in our atmosphere is produced in the upper atmosphere by the action of cosmic rays on nitrogen (N-14) to produce C-14. Once C-14 is produced, it starts to decay back to nitrogen. The atmosphere has constant levels of C-14 – the production of new C-14 in the atmosphere and the decay of C-14 balance each other in a steady state equilibrium.

These three different forms of carbon are oxidised and dispersed through our atmosphere. The oxidised carbon is absorbed by plants through photosynthesis. Once it is in the plants, it enters the food chain. When the C-14 enters the plant or animal, it remains in equilibrium with the atmosphere. However – once the tissue dies (i.e. the animal dies or a tree's sapwood converts into hardwood) then the tissue is no longer being replaced and the level of C-14 continuously decreases through radioactive decay. If we know how much C-14 was in the living tissue, we can measure the amount of C-14 in the dead plant or animal and then compare these to assess how long it has been dead. We can do this because we know the decay rate of C-14 (it has a half-life of 5,730 years). The result is the radiocarbon age of the sample.

Relative dating method.

Geologists have established a set of principles that can be applied to sedimentary and volcanic rocks that are exposed at the Earth's surface to determine the relative ages of geological events preserved in the rock record. For example, in the rocks exposed in the walls of the Grand Canyon (Figure 1) there are many horizontal layers, which are called **strata**. The study of strata is called **stratigraphy**, and using a few basic principles, it is possible to work out the relative ages of rocks.

Cross cutting method. Sometimes sedimentary rocks are disturbed by events, such as **fault** movements, that cut across layers after the rocks were deposited. This is **the principle of cross-cutting relationships**. The principle states that any geologic features that cut across strata must have formed after the rocks they cut through.

Unconformable surface.

An **unconformity** is a buried erosional or non-depositional surface separating two rock masses or strata of different ages, indicating that sediment deposition was not continuous. In general, the older layer was exposed to erosion for an interval of time before deposition of the younger layer, but the term is used to describe any break in the sedimentary geologic record. The significance of angular unconformity (see below) was shown by James Hutton, who found examples of Hutton's Unconformity at Jedburgh in 1787 and at Siccar Point in 1788.[1][2]

The rocks above an unconformity are younger than the rocks beneath (unless the sequence has been overturned). An unconformity represents time during which no sediments were preserved in a region. The local record for that time interval is missing and geologists must use other clues to discover that part of the geologic history of that area. The interval of geologic time not represented is called a **hiatus**. It is a kind of relative dating.

Change in lithology.

Lithology is an essential factor in determining river chemistry (Garrels and Mackenzie, 1971; Drever, 1988, 1994), especially at the local scale (Strahler stream orders 1–3) (Miller, 1961; Meybeck, 1986). On more regional scales, there is generally a mixture of rock types, although some large river basins (area>0.1 Mkm^2) may contain one major rock type such as a granitic shield or a sedimentary platform. When selecting nonimpacted monolithologic river basins in a given region such as France , the influence of climate, tectonics, and distance from the ocean can be minimized, revealing the dominant control of lithology, which in turn depends on (i) the relative abundance of specific minerals and (ii) the sensitivity of each mineral to weathering.

Superposition of bed.

The **principle of superposition** builds on the principle of original horizontality. The principle of superposition states that in an undeformed sequence of sedimentary rocks, each layer of rock is older than the one above it and younger than the one below it (Figures 1 and 2). Accordingly, the oldest rocks in a sequence are at the bottom and the youngest rocks are at the top. In short, each layer of sedimentary rock (also called a "bed") is older than the one above it and younger than the one below it. Steno's seemingly simple rule of superposition has come to be the most basic principle of **relative dating**.

Indirect Methods

Glacial and lacustrine varves

As glacial geologists, some of the biggest questions that we'd like to answer are not only how large former ice sheets were, but also how fast did the recede and how quickly did they thin? This information is vital for numerical models, and answers questions about how dynamic ice sheets are, and how responsive they are to changes in atmospheric and oceanic temperatures.

Unfortunately, glacial sediments are typically difficult to date. Most methods rely on indirect methods of dating subglacial tills, such as dating organic remains above and below glacial sediments. Many methods are only useful for a limited period of time (for radiocarbon, for example, 40,000 years is the maximum age possible). Scientists dating Quaternary glacial sediments in Antarctica most commonly use one of the methods outlined below, depending on what kind of material they want to date and how old it is.

Lake sediments probably constitute the best site for amino acid racemization dating: almost all beds contain fossil remains (invertebrates, vertebrates or plants). Because nearly all the sediments are fine grained the potential of fossil preservation is very high. The usual high thickness of sediments and their low permeability protect fossils from contamination or very extreme environmental changes. Because of the typical sedimentary environment stability, there are high possibilities of a reduced but repetitive faunal and botanical .

Tree rings

These rings can tell us how old the tree is, and what the weather was like during each year of the tree's life. The light-colored rings represent wood that grew in the spring and early summer, while the dark rings represent wood that grew in the late summer and fall. One light ring plus one dark ring equals one year of the tree's life.

Because trees are sensitive to local climate conditions, such as rain and temperature, they give scientists some information about that area's local climate in the past. For example, tree rings usually grow wider in warm, wet years and they are thinner in years when it is cold and dry. If the tree has experienced stressful conditions, such as a drought, the tree might hardly grow at all in those years.

Scientists can compare modern trees with local measurements of temperature and precipitation from the nearest weather station. The National Weather Service has been keeping weather records in the United States since 1891, but very old trees can offer clues about what the climate was like long before measurements were recorded.

Ocean salinity

Although everyone knows that seawater is salty, few know that even small variations in ocean surface salinity (i.e., concentration of dissolved salts) can have dramatic effects on the water cycle and ocean circulation. Throughout Earth's history, certain processes have served to make the ocean salty. The weathering of rocks delivers minerals, including salt, into the ocean. Evaporation of ocean water and formation of sea ice both increase the salinity of the ocean. However these "salinity raising" factors are continually counterbalanced by processes that decrease salinity such as the continuous input of fresh water from rivers, precipitation of rain and snow, and melting of ice.

Earth parameters

Size

The size of Earth, like the size of all of the celestial bodies, is measured in a number of parameters including mass, volume, density, surface area, and equatorial/polar/mean diameter. While we live on this planet, very few people can quote you the figures for these parameters.

12,742 km
Earth/Diameter

Shaped

The Earth is an **irregularly shaped ellipsoid.**While the Earth appears to be round when viewed from the vantage point of space, it is actually closer to an ellipsoid. However, even an ellipsoid does not adequately describe the Earth's unique and ever-changing shape.

Our planet is pudgier at the equator than at the poles by about 70,000 feet. This is due to the centrifugal force created by the earth's constant rotation. Mountains rising almost 30,000 feet and ocean trenches diving over 36,000 feet (compared to sea level) further distort the shape of the Earth. *Sea level* itself is even irregularly shaped. Slight variations in Earth's gravity field cause permanent hills and valleys in the ocean's surface of over 300 feet relative to an ellipsoid.

Rotation

Earth spins around its axis, just as a top spins around its spindle. This spinning movement is called Earth's **rotation**.

Earth rotates once in about 24 hours with respect to the Sun, but once every 23 hours, 56 minutes, and 4 seconds with respect to other, distant, stars . **Earth's**

rotation is slowing slightly with time; thus, a day was shorter in the past. This is due to the tidal effects the Moon has on **Earth's rotation**.

Revolution

the same time that the Earth spins on its axis, it also orbits, or revolves around the Sun. This movement is called **revolution**.

For Earth to make one complete revolution around the Sun takes 365.24 days. This amount of time is the definition of one year. The gravitational pull of the Sun keeps Earth and the other planets in orbit around the star. Like the other planets, Earth's orbital path is an ellipse so the planet is sometimes farther away from the Sun than at other times. The closest Earth gets to the Sun each year is at perihelion (147 million km) on about January 3rd and the furthest is at aphelion (152 million km) on July 4th. Earth's elliptical orbit has nothing to do with Earth's seasons.During one revolution around the Sun, Earth travels at an average distance of about 150 million km.

Milankovitch cycle

A Milankovitch cycle is a cyclical movement related to the Earth's orbit around the Sun. There are three of them: eccentricity, axial tilt, and precession. According to the Milankovitch Theory, these three cycles combine to affect the amount of solar heat that's incident on the Earth's surface and subsequently influence climatic patterns.

Eccentricity

The path of the Earth's orbit around the sun is not a perfect circle, but an ellipse. This elliptical shape changes from less elliptical (nearly a perfect circle) to more elliptical and back, and is due to the gravitational fields of neighboring planets (particularly the large ones – Jupiter and Saturn). The measure of the shape's deviation from being a circle is called its eccentricity.

That is, the larger the eccentricity, the greater is its deviation from a circle. Thus, in terms of eccentricity, the Earth's orbit undergoes a cyclical change from less eccentric to more eccentric and back. One complete cycle for this kind of variation lasts for about 100,000 years.

Axial Tilt

We know the earth is spinning around its own axis, which is the reason why we have night and day. However, this axis is not upright. Rather, it tilts at angles between 22.1-degrees and 24.5 degrees and back. These angles are measured between the angle of the axis to an imaginary line normal (perpendicular) to the Earth's plane of orbit. A complete cycle for the axial tilt lasts for about 41,000 years.

Greater tilts mean that the hemispheres closer to the Sun, i.e., during summer, will experience a larger amount of heat than when the tilt is less. In other words, regions in the extreme upper and lower hemispheres will experience the hottest summers and the coldest winters during a maximum tilt.

Precession

Aside from the tilt, the axis also wobbles like a top. A complete wobble cycle is more or less 26,000 years. This motion is caused by tidal forces from the Sun and Moon.

Precession as well as tilting are the reasons why regions near and at the poles experience very long nights and very long days at certain times of the year. For example, in Norway, the Sun never completely descends beneath the horizon between late May to late July.

The Milankovitch Cycles are among the arguments fielded by detractors of the Global Warming concept. According to them, the Earth's current warming is just a part of a series of cyclical events that take thousands of years to complete, and hence cannot be prevented.

Perigee and apogee positions.

The Moon moves around an elliptical orbit, with the Earth as one of its foci. This means that the distance between the Earth and Moon is always changing. When the Moon is closest to the Earth, it is at its perigee, and when it is furthest away, it is at its apogee.

The progress of the Moon from one perigee to the next is known as the anomalistic lunar cycle and takes 27 days, 13 hours and 18 minutes.The Moon's orbit around Earth is elliptical, with one side closer to Earth than the other.As a result, the distance between the Moon and Earth varies throughout the month and the year. On average, the distance is about 382,900 kilometers (238,000 miles) from the Moon's center to the center of Earth.The point on the Moon's orbit closest to Earth is called the perigee and the point farthest away is the apogee.

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