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الجمعية السعودية لعلوم الأرض
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Al-Amri's Encyclopedia of Earth Sciences

موسوعة العمري في علوم الأرض

321 Q & A سؤال جواب

In

Origin and Evolution of the Earth

أصل وتطور الأرض

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بِسْمِ اللَّهِ الرَّحْمَٰنِ الرَّحِيمِ

﴿ وَفِي ٱلْأَرْضِ ءَايَٰتٌ لِّلْمُوقِنِينَ ﴾

[سورة الذاريات : آية 20]

﴿And on the Earth are Signs for Those Whose Faith is Certain﴾

موسوعة العمري في علوم الأرض

Preface

Praise and thanks to Allah who helped me accomplish this modest effort associated with writing the Scientific Encyclopedia. The comprehensive scientific encyclopedia in earth, environment and energy sciences aims to provide and serve researchers, school and university students and groups of society, due to the suffering of those interested in the problems of the scarcity of Arab references in this field. The encyclopedia is one of the largest in the world includes 30 scientific and cultural books documented and supported by pictures and simplified illustrations in approximately 6000 pages, covering five main parts:

The First Part consists of six books that discuss the age of the Earth, its shape, movements, internal structure, minerals and mining ores, gravity and its relationship to tides:

- Estimating Age of the Earth
- Earth's Shape & Movements
- Earth's Gravity & its Applications
- The Internal Structure of the Earth
- Minerals & Mining
- Tides

As for the Second Part of the encyclopedia, it included six books that link the Earth's relationship with the solar system, especially the moon, and the atmosphere, water, and vitality surrounding the Earth. As well as the role of earthquakes, explosions, volcanoes and tsunamis in affecting the structure of the earth and how to reduce its risks:

- Tsunami Waves
- Earthquakes & Explosions
- Seismic Hazard Assessment
- Volcanoes & Ways to Confront Them
- Geology of the Moon
- Spheres Surrounding the Earth

The Third Part consists of six books related to everything related to environmental problems and disasters and their solutions, climatic changes, the importance of afforestation and the treatment of global warming:

- Environmental Problems & Their Solutions
- Afforestation: Challenges & Solutions
- Climate Change & Global Warming
- Slips, Landslides & Floods
- Desertification & Drought
- Torrents & Water Dams

The Fourth Part of the encyclopedia consists of six books that discuss the relationship of Earth sciences with other sciences nuclear, and medically, as well as the role of clean, sustainable energy, economically and environmentally:

- Geothermal Energy
- Is the Age of Oil Over?
- Nuclear Geophysics
- Medical Geology
- The Future of Energy in our World
- Guide to Writing Theses & Scientific Publication

As for the Fifth Part, it consists of six books that contain 2020 Questions and Answers (Q & A) to help university students and researchers and prepare them for comprehensive and qualifying exams for postgraduate studies and practice the profession.

- 321 Questions & Answers in the Evolution of the Earth
- 358 Questions & Answers in Petrology, Geochemistry, Remote Sensing and GIS
- 358 Questions & Answers on Natural Resources
- 380 Questions & Answers in Geological Hazards
- 303 Questions & Answers in Seismology and Engineering Seismology
- 300 Questions & Answers in Applied Geophysics

Introduction

Fossils are one of the most immediately recognizable aspects of geology. The occurrence and distribution of fossils provides fundamental information about the age of sedimentary rocks and clues to the environment in which they were formed. Fossil data can show how different sedimentary rock successions in different regions are related, and can be used to identify particular geological units. Applied paleontology denotes the geological applications of paleontology, which biostratigraphy as well as other applications such as paleoenvironmental interpretation. Economic micropaleontology refers specifically to the industrial application of microfossils. Biostratigraphy is often used in a broader sense to encompass all applications of paleontology to solve geological problems.

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Questions & Answers in Paleontology & Biostratigraphy

1 What is Paleontology?

Paleontology is the study of fossils. A fossil is defined as any trace of a past life form. Thus, although bones and shells are the most common fossils, under certain conditions, soft tissues, tracks and trails, and even coprolites (fossil feces) may be preserved as fossils. Although most of the fossils that paleontologists study are several thousands to several billions of years old, there is no absolute minimum age for a biological structure to be a fossil. Paleontologists study these fossils and attempt to use them to reconstruct the history of the Earth and the life on it. Some study the ecology of the past; others work on the evolution of fossil taxa.

2 What is Biostratigraphy?

The element of stratigraphy that deals with the distribution of fossils in the stratigraphic record and the organization of strata into units on the basis of their contained fossils. **Biostratigraphic units (biozones)** are bodies of strata that are defined or characterized on the basis of their contained fossils exist only where the particular diagnostic feature or attribute on which they are based has been identified.

3 What is meant by Palynology?

Palynology deals with plant spores and pollen that are both ancient and modern. It plays an important role in the investigation of ancient climates, particularly through studies of deposits formed during glacial and interglacial stages. Study of a sequence of spore- or pollen-bearing beds may reveal successive climatic changes, as indicated by changes in types of spores and pollen derived from different vegetative complexes. Spores and pollen are borne by the wind and spread over large areas.

4 How does paleontology differ from archaeology and anthropology?

Archaeologists primarily work with human artifacts -- objects that have been made by humans -- and with human remains. **Anthropologists** work with humans -- their cultures, societies, languages, and ways of life, in addition to their bones and artifacts. Some paleontologists do study the fossil record of humans and their relatives. However, paleontology as a whole encompasses all life, from bacteria to whales. Paleontology does not usually deal with artifacts made by humans.

5 What are the practical uses of paleontology?

A number of natural resources are in fact fossils, or derived from fossils. Coal, oil, and peat are derived from fossil plant material; marble is metamorphosed limestone, which is often biogenically deposited; diatomaceous earth is made up of fossil microscopic siliceous skeletons of certain algae. Some paleontologists work for the petroleum industry, and use fossils to interpret sequences of sedimentary rocks and to reconstruct past climates and environments. Paleontologists can provide historical data on past climates and apply it towards understanding future trends and their likely effects. Paleontology can potentially provide much data on the evolutionary relationships of organisms, which in turn gives a deeper understanding of biodiversity.

6 How do paleontologists know how old their fossils are?

Paleontologists deal with two types of dating, absolute and relative. Absolute dating, which estimates the age of a rock or fossil in years, is most usually done by measuring the amounts of a radioactive isotope and its decay product; since isotope decay rates are known to be constant, the age can be calculated from the relative amounts of parent isotope to daughter product.

7 How to estimate age of rocks from Absolute dating?

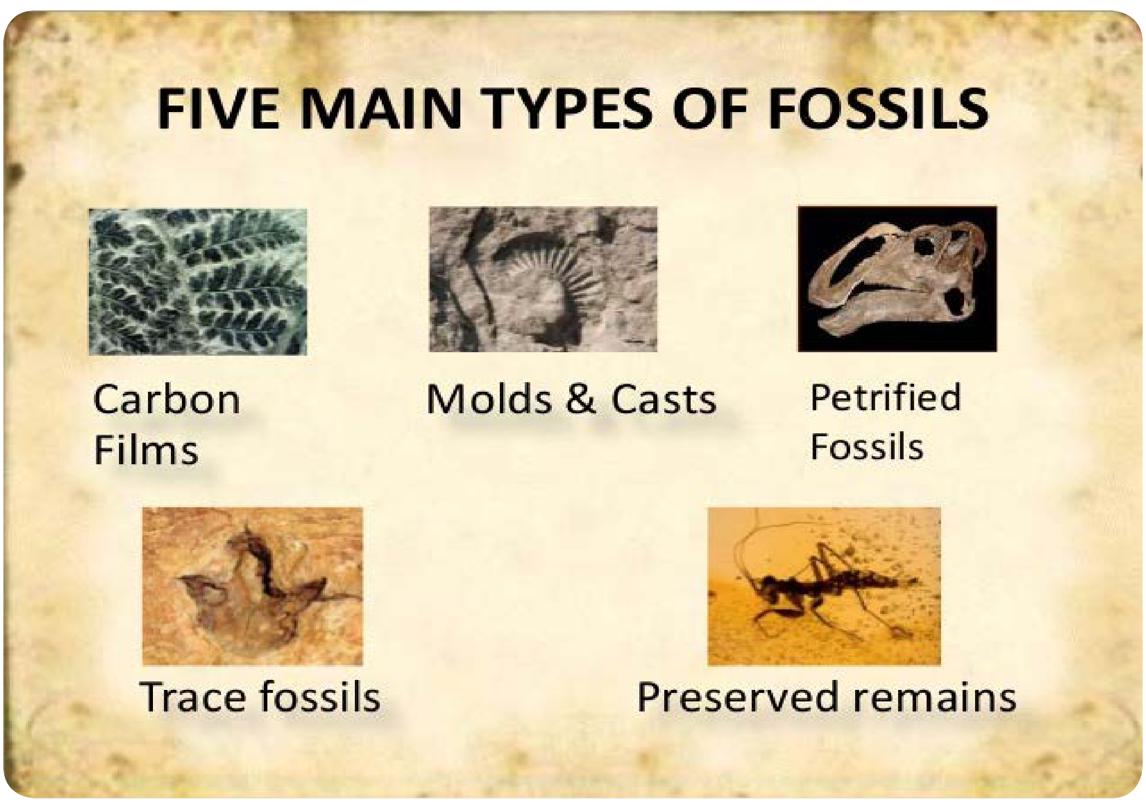
Fossils up to about 40,000 years old can be dated using carbon-14 if there is enough organic matter present. Older rocks can be dated using potassium-40, which decays to argon-40, or uranium-235, which decays to lead-207. However, many sedimentary rocks cannot be dated directly by these methods; dates usually are obtained from igneous rocks within a sedimentary sequence, such as lava flows or ash beds.

8 How to estimate age of rocks from Relative dating?

Relative dating has been practiced for nearly 200 years, arising from the observation that different layers of a sedimentary rock section contain different fossils, and that this sequence can be recognized in other sections, even those far away from the initial section. This allows fossil-bearing rocks to be dated relatively; on the basis of its fossils a rock might be placed in. Not all fossils are equally useful for relative dating, or correlation; some are rare, restricted to small geographic areas or to particular environments, difficult to recognize, or have such long ranges as to make precise correlation impossible.

9 What is a fossil?

Fossil, remnant, impression, or trace of an animal or plant of a past geologic age that has been preserved in Earth's crust. The complex of data recorded in fossils worldwide—known as the fossil record—is the primary source of information about the history of life on Earth. The critical factor is age. Fossils have to be older than 10,000 years, the generally accepted temporal boundary marking the end of the last Pleistocene glacial event. Fossil remains include bones, teeth, shells, and wood. Fossil traces include footprints, burrows, impressions, molds, casts, and coprolites.



10 What is the Period?

A period is known to be a long time wherein the characteristics are very obvious. The **era** is a long time that may become more evident because it is marked by an event. The period also comes from the Greek word "periodos." This means "cycle of time." Era does not come from a Greek word. Rather, this comes from the Latin word "aera," which means "counters used for calculation." There are a lot of people who use these two terms interchangeably, but most people would use era for longer time frames while period can sometimes be used for shorter time frames. For example, people use the term "period of time," which means a short time.

11 How long has the earth been here?

Based on **relative and absolute age dating** techniques, geologists now think that the earth was formed about 4.6 BY. The oldest rocks found on earth are 4.0 BY from NW Canada. 4.3 BY zircons have been found in younger sandstones in Australia. Meteorites and moon rocks are 4.6 BY. Rocks older than 4.0 BY on earth have apparently been destroyed by weathering and plate tectonics.

12 How has life shaped Earth – and how has Earth shaped life?

The interactions between geology and biology are key to understanding life's role in injecting oxygen into the atmosphere, **mass extinctions** and the course of evolution.

13 What is the Principle of Superposition?

The principle states that any undeformed sequence of sedimentary rocks, each bed is younger than the one below it and older than the one above it. This is the basis of relative ages of all strata and their contained fossils.

14 What are Unconformities and Nonconformity?

Unconformities represent major gaps of time. They are the result of periods of erosion or non-deposition. They help us to understand the great age of the earth. **Nonconformity** recognized by sedimentary rocks resting on an eroded surface of igneous or metamorphic rocks.

15 What is Angular Unconformity?

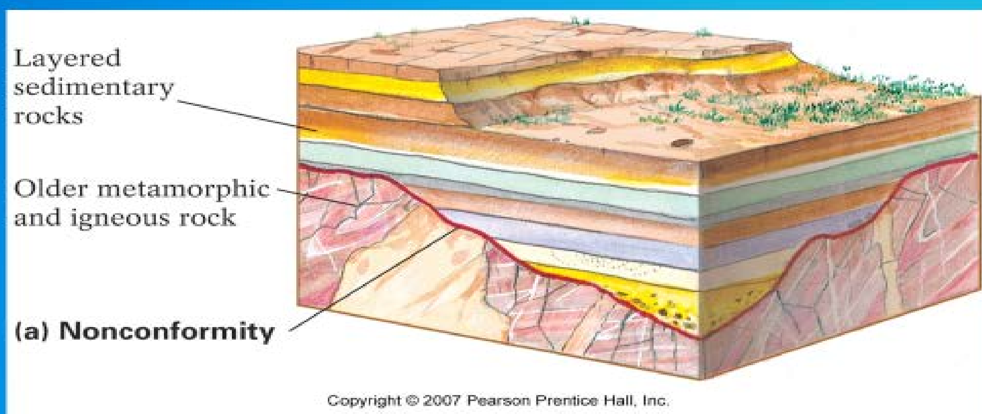
When a horizontal layer of sedimentary rock is later laid down on top of the tilted, eroded layers–Usually occurs during mountain building.

16 What are Disconformity and Para conformity?

The **unconformity** is an erosion surface within a sequence of flat-lying sedimentary rocks. If there is no erosion, the presence of the disconformity is difficult or impossible to detect. The break or gap in time represented by a disconformity is called a **hiatus or a diastem**. **Paraconformity.** Para means "near", as in nearly conformable. An unconformity with no obvious erosion surface. There is a distinct gap in the fossil record

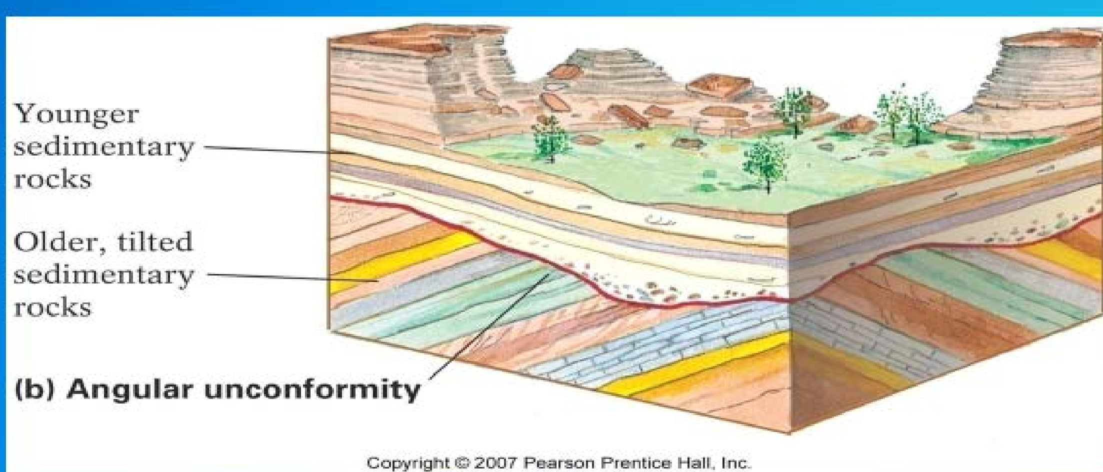
Unconformities

Gaps in the geologic record separating rocks of different ages.



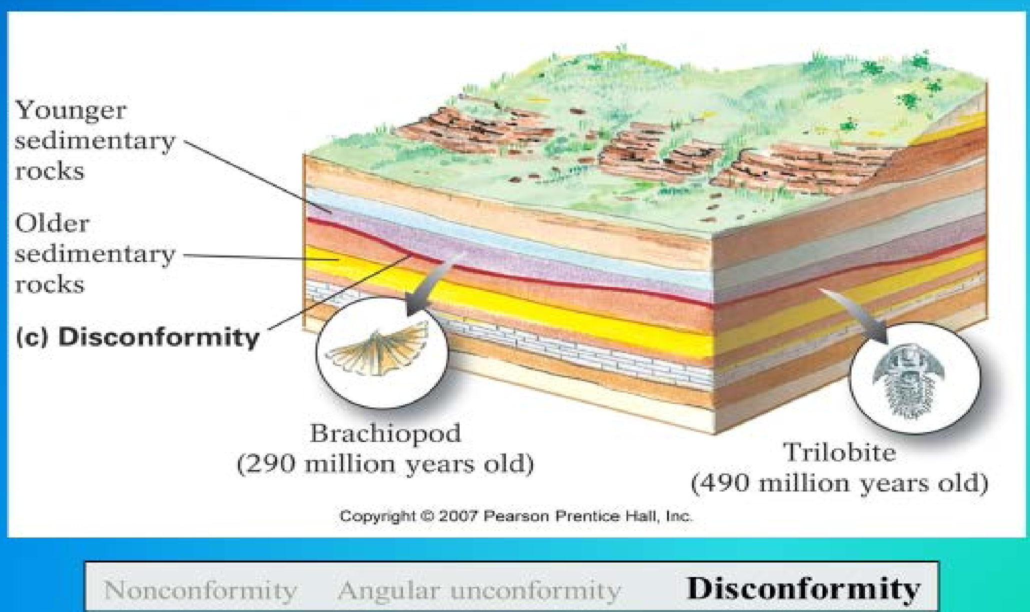
Nonconformity | Angular unconformity | Disconformity

Unconformities



Nonconformity | **Angular unconformity** | Disconformity

Unconformities



17	**What is meant by Radiometric Dating?**

Actually a simple technique. Only two measurements are needed:
1. The parent : daughter ratio measured with a mass spectrometer.
2. The decay constant measured by a scintillometer (detects gamma rays). Radiometric Dating.

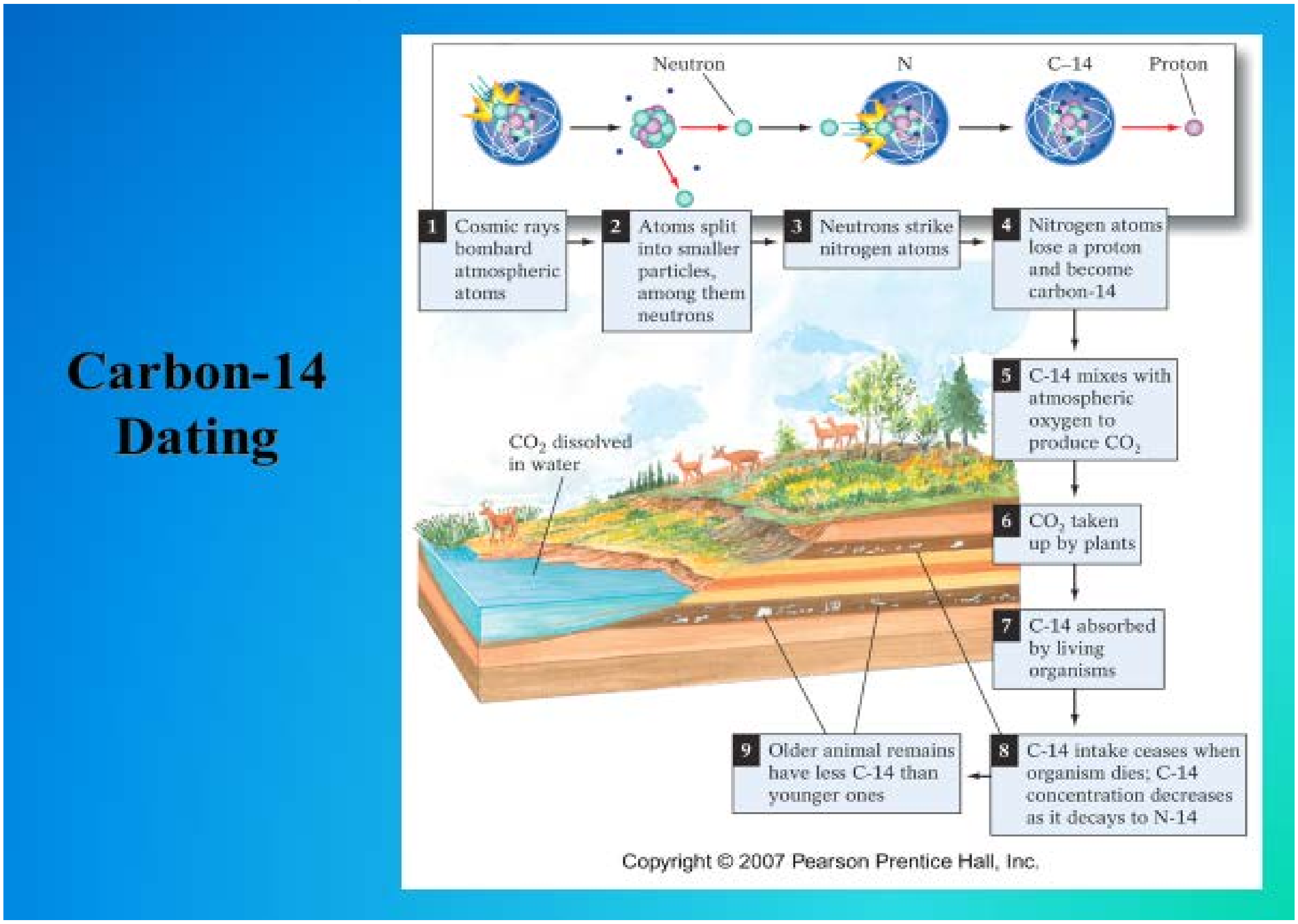
• Scientists look at how much of the parent and daughter are remaining to determine the age. This works because as the amount of the parent decreases the amount of daughter increases. Basis of the Technique. Radioactive elements "decay." Decay occurs as an element changes to another element, e.g. uranium to lead. The parent element is radioactive, the daughter element is stable. The decay rate is constant

18 What is Radioactivity?

Radioactivity occurs when certain elements literally fall apart. Usually protons and neutrons are emitted by the nucleus. Sometimes an electron is emitted by the nucleus, which changes a neutron to a proton. Sometimes an electron is captured, which changes a proton to a neutron.

19 What causes radioactivity?

Carbon-14 is produced by cosmic ray bombardment of Nitrogen-14 in the atmosphere. All other radioactive elements were produced by supernova explosions before our solar system formed. This is called explosive nucleosynthesis. Common Radioactive Elements, Parents and Daughters• Carbon-14, C14 , Nitrogen-14, N^{14}• Uranium-235, U^{235} Lead-207, Pb^{207}• Potassium-40, K^{40} , Argon-40, Ar^{40}• Uranium-238, U^{238} Lead-206, Pb^{206}• Rubidium-87, Rb^{87} Strontium-87, Sr^{87}.



20 What is Half-Life?

The amount of time for half the atoms of a radioactive element to decay. Doesn't matter how many atoms started, half will decay. After one half-life –1:1 ratio of parent to daughter (50% / 50%)–After two half-lives –1:3 ratio of parent to daughter (25% / 75%)–After three half-lives –(12.5 % / 87.5 %)–After four?

21 How to identify Dating of Rocks?

Can be used to date igneous and metamorphic rocks (not sedimentary). Examine ratio of parent : daughter in rock. Isotope used depends on approximate age of the rock–Uranium-235 would be best for a rock that is a few tens of millions years old (half-life = 700 million years)–Urianium-238 would be best for a rock that older (half-life = 4.5 billion years). Carbon-14 has relatively short half-life (5730 years); it is used to date organic materials. This works because all living things contain C-14 that is replenished throughout life but begins to decay into nitrogen at death.

Absolute Dating Using Radioactivity

Isotopes Frequently Used in Radiometric Dating

Radioactive Parent	Stable Daughter Product	Currently Accepted Half-life Values
Uranium-238	Lead-206	4.5 billion years
Uranium-235	Lead-207	713 million years
Thorium-232	Lead-208	14.1 billion years
Rubidium-87	Strontium-87	47.0 billion years
Potassium-40	Argon-40	1.3 billion years

These systems are useful for dating very old rocks. For some systems, the half-life exceeds even the age of the Universe.

22 **Why is the potassium-argon method more generally useful than the other radiometric methods?**

The half-life of rubidium 87 is 47 billion years, so the rubidium-strontium method can only be used to date extremely old rocks. Potassium 40 has the more suitable half-life of 1.3 billion years and is a much more widespread constituent of minerals than uranium. Such common minerals as the micas, the feldspars, and hornblende all contain sufficient potassium to permit their dating by the potassium-argon method.

23 **Why is it difficult to date clastic sedimentary rocks by radiometric methods?**

A clastic sedimentary rock consists of fragments of other rocks that have become cemented together. The parent rocks may have been of very different ages since erosional debris is commonly transported for some distance from its origin to the place of deposition. Since the age of a sedimentary rock refers to the time it become lithified, the only relationship between the age of the rock and the ages of the fragments of which it is composed is that the rock is younger than the fragments; but it is seldom possible to say how much younger. Only in a few cases does the cementing material contain sufficient potassium to permit its dating by the potassium-argon method.

24 **What is Ice Cores?**

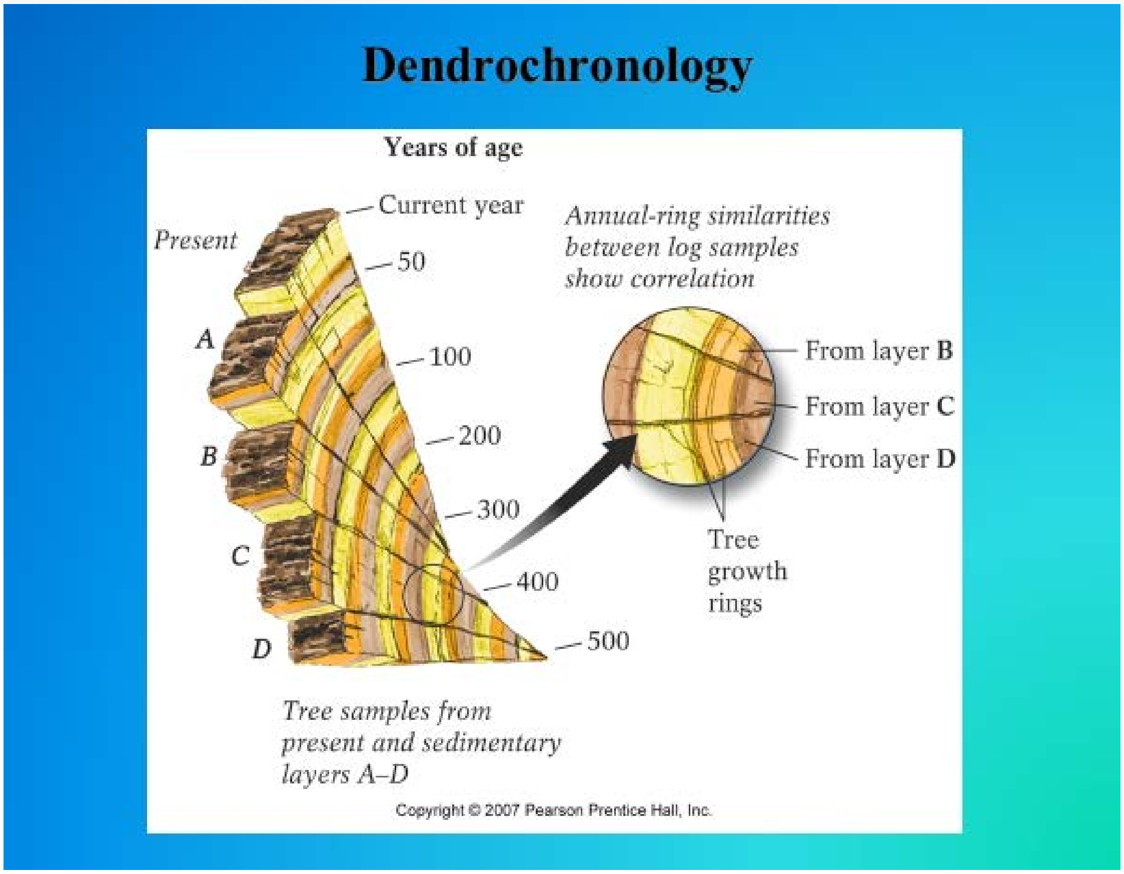
Ice cores contain a record of past environmental conditions in annual layers of snow deposition. Geologists use ice-core chronologies to study glacial cycles through geologic history. Also used to study climate change

25 What is Varves?

Bands of alternating light and dark sediments. Usually in lakes. Sand-sized particles usually represent summer and traces of living things. Thinner, fine-grained sediments can represent winter.

26 What is meant by Dendochronology?

Dendrochronology, also called **tree-ring dating**, the scientific discipline concerned with dating and interpreting past events, particularly paleoclimates and climatic trends, based on the analysis of tree rings. Samples are obtained by means of an increment borer, a simple metal tube of small diameter that can be driven into a tree to get a core extending from bark to center. This core is split in the laboratory, the rings are counted and measured, and the sequence of rings is correlated with sequences from other cores. Dendrochronology is based on the fact that many species of trees produce growth rings during annual growing seasons.



27 What are limitations of Dendrochronology?

There are limitations on dendrochronology. Some of those limitations include:

- In some areas of the world, particularly in the tropics, the species available do not have sufficiently distinct seasonal patterns that they can be used.
- Where the right species are available, the wood must be well enough preserved that the rings are readable. In addition, there must be at least 30 intact rings on any one sample.
- There also must be an existing master strip for that area and species. There is an absolute limit on how far back in the past we can date things with tree rings.
- The prehistoric people being studied had to have built fairly substantial structures using wood timbers. In most of the world that did not begin to happen until about 4,000 to 5,000 years ago!

28 **What procedure would you follow to find the age of an ancient piece of wood by radiocarbon dating?**

The procedure is to determine the radioactivity of a known mass of carbon from the ancient wood and to compare it with the radioactivity of the same mass of carbon from a piece of wood of recent origin. The difference between the two activities can be converted into an age figure for the ancient wood by taking into account the 5600-year half-life of radiocarbon.

29 **Why does the radiometric age of a metamorphic rock often refer to the time of the metamorphism rather than to the time the original rock was formed?**

In both uranium-lead decay series, one of the intermediate products is an isotope of the gas radon, and the stable daughter product of the decay of potassium 40 is an isotope of the gas argon.. During the metamorphism of a rock some of the original minerals recrystallize into other minerals, and the gas atoms present may not be incorporated in the new mineral grains. The loss of the decay products from the mineral grains means in effect that the radioactive clock starts again from zero in such rocks at the time of metamorphism.

30 **What is the age of the oldest rocks known? How was this age determined?**

Rocks 4 billion years old have been found in Greenland; their ages were established by radioactive dating.

31 **The half-life of a radioactive isotope of hydrogen called tritium is 12.5 years. If we start out with 1 g of tritium, how much will be left undecayed after 25 years?**

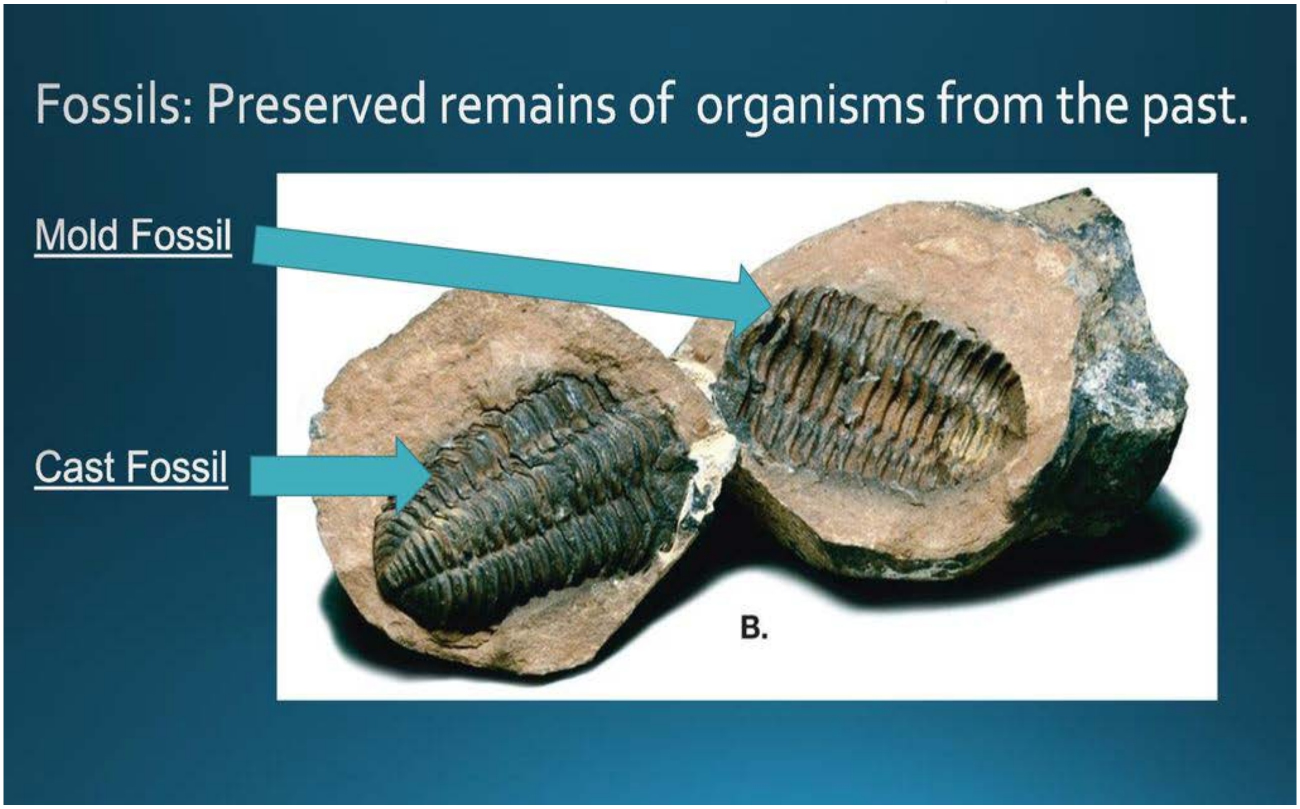
Since 25 years is two half-lives here, 0.5 x 0.5 = 0.25 of the original amount of tritium will be left, which is 0.25 g.

32 **What are Molds and Casts?**

Body fossils include molds and casts.

A mold is the imprint left by the shell on the rock that surrounded it. An external mold is a mold of the outside of the shell. Each time we break a shell or bone out of the rock, an external mold is left behind. Molds of the underside of shell may be left on the surface of rock that formed when sand or mud filled the inside of the shell. These are called internal molds.

Casts are replicas of the shell or bone that are formed from external or internal molds. Casts can be produced naturally, but paleontologists can also produce casts from molds with latex rubber or even modeling clay. These artificial casts can provide extra information about the fossils under study.



33 How Geologic Time is Organized?

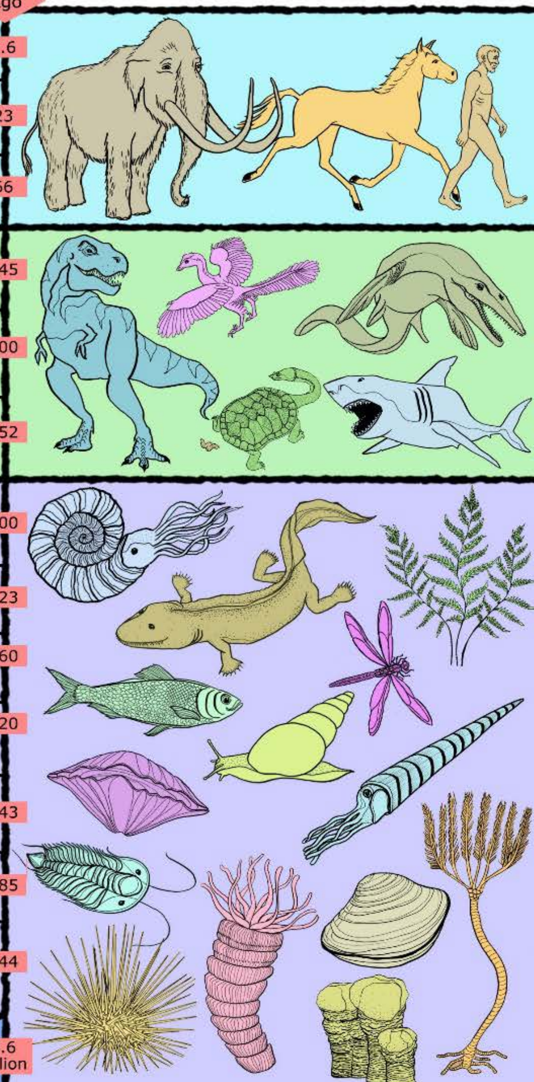
Started in 1795 but constantly revised with new data. The Geologic Time Scale (GTS) is an arbitrary chronological arrangement or sequence of geologic events, used as a measure of the relative or absolute duration or age of any part of geologic time, and usually presented in the form of a chart showing the names of the various rock-stratigraphic, time-stratigraphic, or geologic-time units.

GEOLOGICAL TIME SCALE

This time scale has been created by scientists. They have divided time into Eras and Periods, in order to classify things. As new fossils are discovered, and as scientific methods change, the years of these Eras and Periods continue to be readjusted, according to new information. We have listed only a few animals and plants that appeared in each time period. You can find much more information in books or via the internet. These examples are meant simply to get you started in the exciting journey of discovery throughout the geological time scale. **Have fun!**

Era	Period	Millions of Years Ago
Cenozoic	**Quaternary** Evolution of humans	2.6
	Neogene Early primates, animals diversify	23
	Paleogene Rise of mammals	66
Mesozoic	**Cretaceous** Extinction of dinosaurs	145
	Jurassic First bird, dinosaurs diversify	200
	Triassic First dinosaurs	252
Paleozoic	**Permian** Major extinctions, mosses, beetles & flies evolve	300
	Pennsylvanian First reptiles	323
	Mississippian First insects	360
	Devonian Ferns, seed-bearing plants	420
	Silurian First jawed fishes	443
	Ordovician Corals	485
	Cambrian Gastropods, clams, sea urchins, brachiopods	544
Precambrian/Earth Forms Algae, stromatolites, multi-celled animals		4.6 Billion

Life Forms

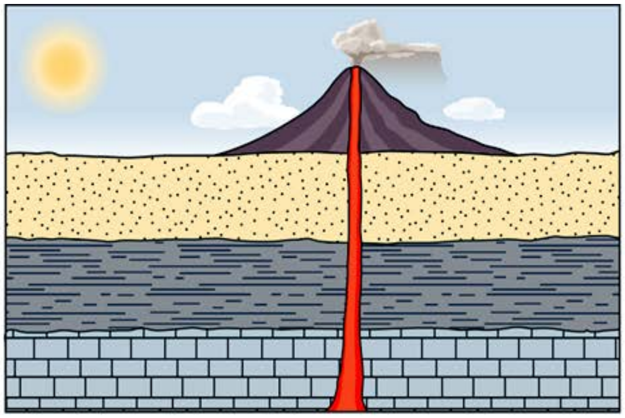


34 Who is James Hutton?

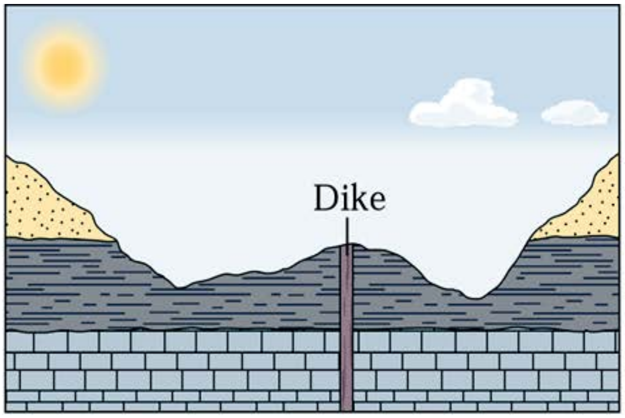
JAMES HUTTON (1726 - 1797) discovered the Principle of Uniformitarianism: "The present is the key to the past" i.e. geologic processes operating today also operated in the past. e.g. river deposits forming today have a similar composition and character as their ancient counterparts; glacial erosional and depositional features are basically the same today as in the past...etc.

35 What is Cross-cutting Relationships?

States that intrusions are younger than the rock it cuts across–This also applies to faults



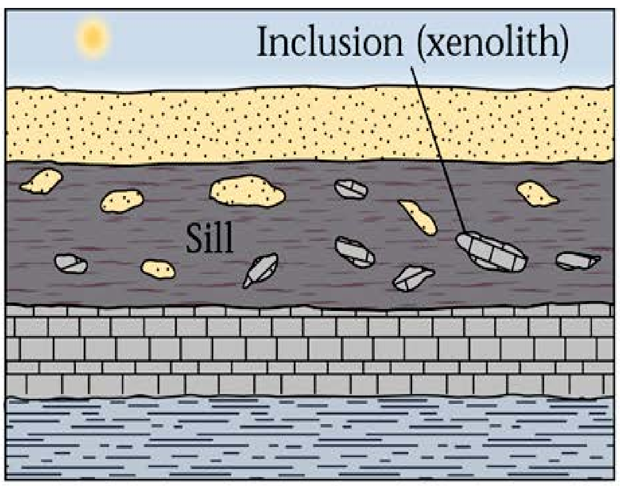
Time 1

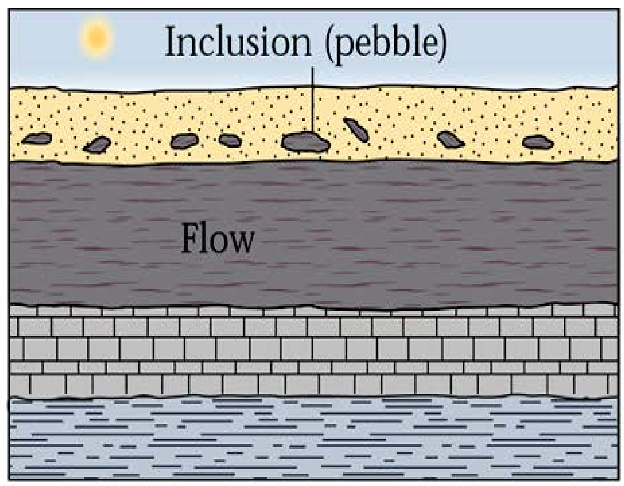


Time 2

36 **What is the Inclusions?**

Inclusion states that fragments (inclusions) in a rock layer must be older than the rock layer that contains them Inclusions.





37 **When the Glaciations occur?**

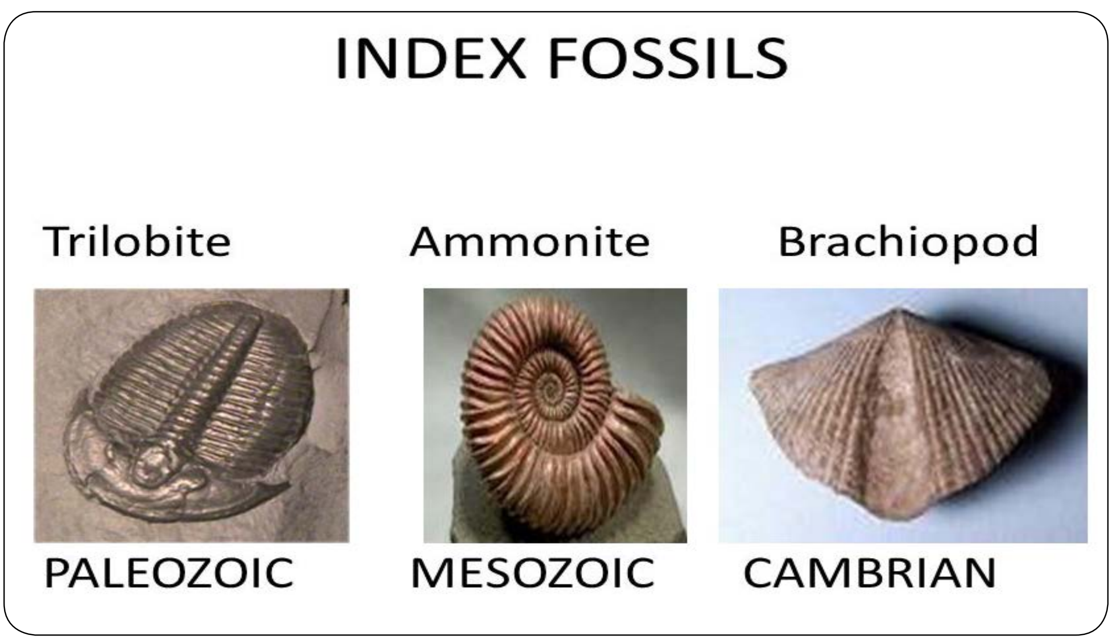
The **glaciations** occur periodically in Earth's history from a series of possible causes like the change of continental positions, the uplift of continental blocks, the reduction of CO_2 in the atmosphere, astronomical variations etc. The major glaciations took place in the Late Proterozoic (800-600 million years ago), in parts of Ordovician and Silurian, in the Carboniferous and Permian and from the Late Neogene (Pliocene) to Quaternary (the last 4 million years). This last Ice Age ended about 10000 years ago, simultaneously with the last mass extinction.

38 What is Key Beds?

A rock or sediment layer that serves as a time marker in the rock record and results from volcanic ash or meteorite-impact debris that spread out and covered large areas of Earth

39 What is Index Fossils?

Fossils that are easily recognized, abundant, widely distributed geographically, and from organisms who lived in a relatively short period of time–Allows scientists to quickly date rock layers.



40 What is meant by Flora and Fauna?

Flora and fauna refer to the plants and animals of an environment. To remember them, **fauna** sounds similar to fawn, indicating it refers to animals, whereas **flora** sounds like flowers, indicating it refers to plants. Flora and fauna refer to plants and animals in the broadest sense of the words, encompassing pretty much all life on Earth. The term **flora refers to the plant life** that exists in a particular place at a particular time. This typically includes all indigenous plant life. Similarly, **fauna refers to animal life** that exists in a particular place at a particular time.

41 What is difference between Stratum and Strata?

A **stratum** (plural: **strata**) is a layer of sedimentary rock or soil, or igneous rock that was formed at the Earth›s surface, with internally consistent characteristics that distinguish it from other layers. The «stratum» is the fundamental unit in a stratigraphic column and forms the basis of the study of stratigraphy.

Strata is the plural of stratum, which in geology means a layer of sedimentary material that has been shaped in a natural or artificial way, and which represents a continuous deposition of the same type of rock.

42 What is a Formation?

A genetic unit of strata deposited under essentially uniform conditions or an alternation of conditions. Boundaries are to be drawn at points in the section where lithologic features change or where there are significant breaks in continuity of sedimentation

43 What is the Principle of Intrusive Relationships?

Invading igneous rock is always younger than the rock it intrudes.• This is an indicator of relative age

44 What is the Principle of Fossil Succession?

Fossils are not randomly distributed in rocks. They occur in a unique vertical order observed from place to place. This allows age correlation of rocks that are widely separated. It allows relative ages of rocks to be determined from one area to another

45 Who is William Smith?

WILLIAM "STRATA" SMITH (1769 - 1839) discovered the Principle of Biological Succession: Different kinds of plants and animals succeed one another in time because life has evolved continuously; therefore only rocks formed during the same age can contain similar assemblages of fossils. Since these fossil assemblages are unique for particular periods of the past, they can be used to : a. correlate rocks from around the world, and to b. order rock layers into a sequence of relative age.

46 **Who is Charles Lyell?**

CHARLES LYELL (1830) discovered the Principle of Cross-Cutting Relationships: Any geologic feature which cuts across or penetrates another body of rock must be younger than the rock mass penetrated. Faults are younger than the rocks they cut through. Older faults are offset by younger faults.

47 **What is the Law of Faunal Succession?**

This law was developed by William "Strata" Smith who recognized that fossil groups were succeeded by other fossil groups through time. This allowed geologists to develop a fossil stratigraphy and provided a means to correlate rocks throughout the world.

48 **Precambrian rocks include sedimentary, igneous, and metamorphic varieties. What does this suggest about geological activity in Precambrian time?**

Precambrian geological activity must have been similar to that of today.

49 **What conspicuous difference is there between Precambrian sedimentary rocks and those of later eras?**

Precambrian sedimentary rocks contain few if any fossils, whereas 1later sedimentary rocks usually contain abundant fossils.

50 What are the chief kinds of organisms that have left traces in Pre-cambrian sedimentary rocks?

Bacteria and algae.

51 Define the meaning of Facies?

Facies is a body of rock characterized by a particular combination of lithology, physical and biological structures that bestow an aspect ("facies") different from the bodies of rock below, above, and laterally adjacent.

52 What is Walther's Law ?

Facies that occur in conformable vertical succession of strata also occur in laterally adjacent sedimentary environments.

53 Discuss the two aspects of Geologic Timescale?

- **Chronostratigraphic**: divisions of rock based on time (upper and lower boundaries are isochronous)
- **Geochronologic**: divisions of time during which each chronostratigraphic unit was formed.

54 What is the basic of Chronostratigraphic unit?

The basic chronostratigraphic unit is the **System**. Each system is comprised of two or three **Series**; each Series is comprised of two or more **Stages**. The boundary between Systems is **instantaneous** (represents · time) and **isochronous** (the same everywhere).

55 What is the basic of Geochronologic unit?

The basic geochronologic unit is the **Period**: that chunk of time between the first deposition of a particular System and the start of deposition of the next system. The geochronologic equivalent to the Series is the **Epoch**, and to the Stage is the **Age**.

Chronostratigraphic Units	Geochronologic Units
(Divisions of Rock)	(Divisions of Time)
Eonthem	Eon
Erathem	Era
System	Period
Series	Epoch
Stage	Age (although the International Commission on ("Stratigraphy proposes to replace this with "Stage

56 **Why are fossils never found in igneous rocks and only seldom in metamorphic rocks?**

Igneous rocks have hardened from a molten state, and no fossil could survive such temperatures. Metamorphic rocks have been altered under conditions of heat and pressure severe enough to distort or destroy most fossils.

57 **Why is it believed that large parts of the United States were once covered by shallow seas?**

Sedimentary rocks that contain the fossil shells of marine organisms are found in many parts of the United States.

58 **About 200 million years ago today's continents were all part of the supercontinent Pangaea. During what geological era did Pangaea break apart into Laurasia and Gondwanaland?**

During what era did Laurasia break up into North America, Greenland, and Eurasia? Mesozoic era; Cenozoic era.

59 **What major change in land animal life occurred between the late Mesozoic and early Cenozoic era?**

Reptiles, the dominant form of land animals during the Mesozoic, declined and were superseded by mammals, which are dominant in the Cenozoic.

60 **During what geological era did birds develop? From what type of animal did they evolve?**

Mesozoic era; reptiles.

61 **Minnesota has a great many shallow lakes. How did they originate?**

The Pleistocene glaciation in that region left many depressions which subsequently filled with water to form lakes.

62 **What is the difference between Plankton and Nekton?**

Plankton and nekton are two types of marine aquatic organisms. The main difference between plankton and nekton is that plankton are passive swimmers that are carried by the water currents whereas nekton are actively-swimming organisms that swim against the water currents. Plankton possess a Reynolds number less than 10 while nekton possess a Reynolds number greater than 1000. Reynolds number predicts the transition of the flow from laminar to turbulent. Some organisms begin their life as plankton and then transit to nekton later. Plankton can be microscopic animals such as diatoms, dinoflagellates, coccolithophores, foraminifera, and radiolarian and larvae of marine animals such as crabs and sea stars as well as larger organisms like jellyfish and floating sargassum weed. Nekton include fish, whales, and squids.

63 What is Benthic?

The term benthic refers to anything associated with or occurring on the bottom of a body of water. The animals and plants that live on or in the bottom are known as the benthos.

64 What is Taphonomy?

The study of the preservation of fossils is called **taphonomy**. Two major types of fossils:

- **Trace fossils**: the record of organisms' behavior preserved in rock.
- **Body fossils**: the physical remains of an organism preserved in rock.

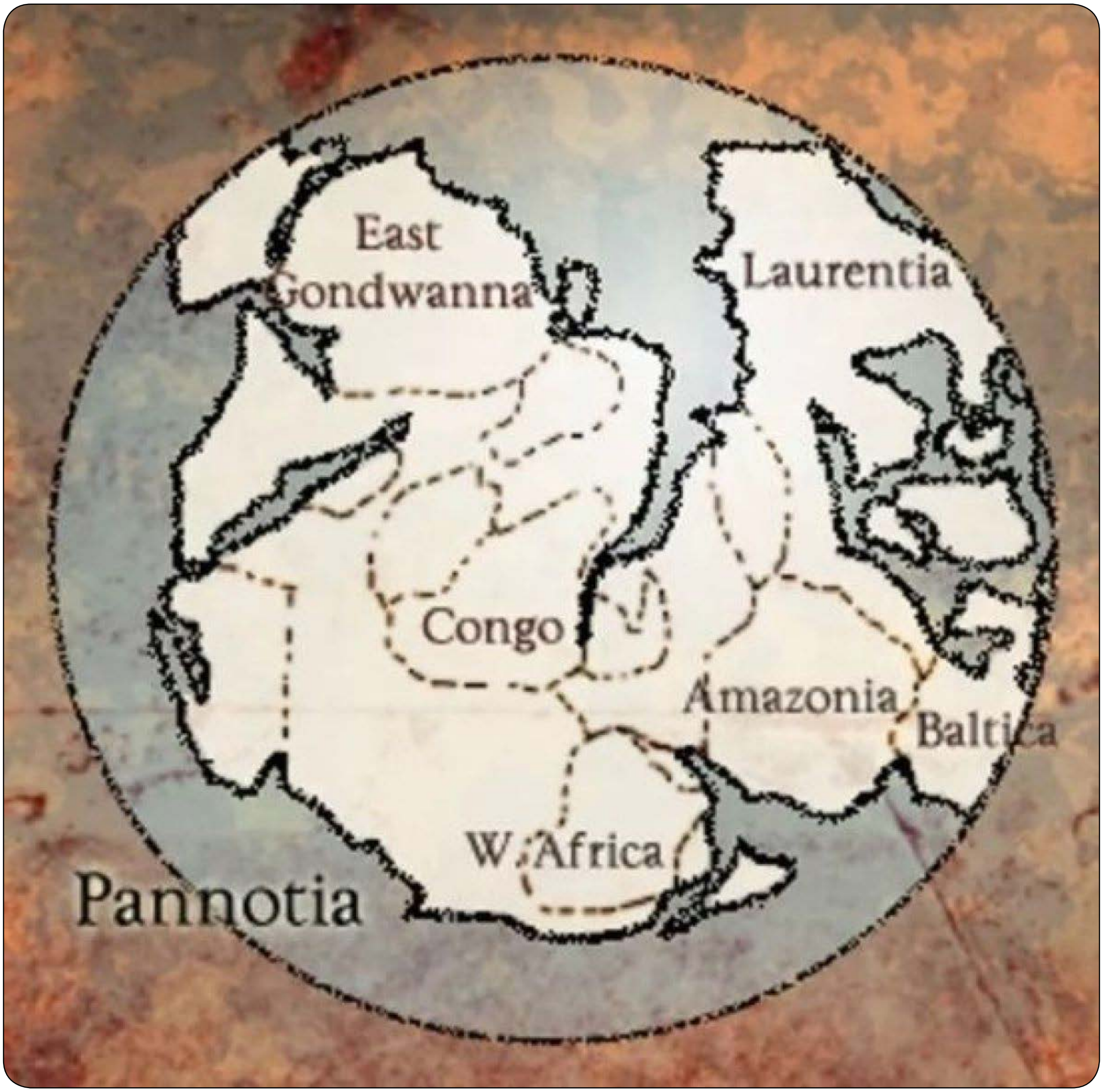
65 Show how Proterozoic distinct from Archean?

- Clear evidence of "modern-style" (continent-scale) plate tectonics
- Decrease in abundance of komatiites & greenstone belts
- **HUGE** deposits of Banded Iron Formations during \rst half of Paleoproterozoic
- Complex unicellular, and first multicellular life
- Indications of higher levels of oxygen

66 What is Pannotia?

Pannotia (supercontinent) breaks apart at or near the base of the Cambrian. Breaks up into:

- **Gondwana** (modern South America, Africa, Madagascar, India, Antarctica, Australia,and assorted fragments): mostly emergent in Cambrian
- **Laurentia** (modern North America (except for far west) and Greenland); mostly submerged by end of Cambrian
  - Separated from Baltica and Gondwana by **Iapetus Ocean**
- **Baltica** (much of modern western and northern Europe): mostly submerged
  - Separated from Gondwana by **Tornquist Sea**, from Siberia by **Paleo-Asian Ocean**
- **Siberia** (much of northwestern Asia)
- various Asian blocks: all mostly submerged


East
Gondwanna
Laurentia
Congo
Amazonia
Baltica
W. Africa
Pannotia

67 What is the Evolution of Life in the Cambrian and Ordovician?

Marine invertebrate communities are often broken down into three **separate "evolutionary faunas"**:

- The **Cambrian fauna** (or **Trilobite fauna**): trilobites, archaeocyathids, hyoliths, monoplacophorans, inarticulate brachiopods, primitive echinoderms
- The **Paleozoic fauna** (or **Brachiopod fauna**): rhynchonelliform brachiopods, stony and lacy bryozoans, stromatoporoids, cephalopods, crinoids and blastoids, starfish, graptolites
- The **Modern fauna** (or **Bivalve-Gastropod fauna**): bivalves, gastropods, vertebrates, echinoids, crustaceans, gymnolaemate bryozoans.

68 Give some important groups in Cambrian and Ordovisian?

Trilobites is the main index fossils of the Cambrian, first appearance of Brachiopods, Echinoderms, Conodonts.

69 When was "Romer's Gap"?

Few terrestrial stegocephalians between Late Devonian and Late Mississippian, as well as little diversity increase in arthropods at this time. Why the delay? Possibly a sampling issue, but it has been suggested that lower oxygen level may have held back terrestrial radiations.

70 **Determine the general Categories of Fossils?**

- Body Fossils – Most common kind; have a remnant animal body or plant Frozen mammoth, bone, clam, shell, carbonized leaf
- Trace Fossils/ ichono fossils – Things that show where the animal was Burrows, borings, footprints, nests, dungs
- Organo sedimentary structures – Not quite body or trace fossils Stromatolites and reefs
- Biomarkers— Groups of organisms that create a chemical no other plant / animal creates Geologically stable molecules, mostly lipids, of known biosynthetic origin; also a distinctive isotopic ratio (usually involving carbon or sulfur isotopes) Sponges

71 **Who discovered the Burgess Shale, when was it discovered (approximately), and where is it located geographically?**

The Burgess Shale was discovered by Charles Walcott in 1909. It was discovered in Western Canada in British Columbia

72 **What is the age of the Burgess Shale (not the age in millions of years, but the age in terms of the geologic time scale)?**

The Burgess Shale comes in at the middle of the Cambrian

73 **What are trace fossils? How does the naming of trace fossils compare to the naming of body fossils?**

A trace fossil is a fossil of a footprint, trail, burrow, or other trace of an animal rather than of the animal itself .Trace fossils sometimes record the behavior of an animal, which would NOT be passional with body fossils. Trace fossils have their own ICHNO genus & ICHNO species names independent of the organism that made them

74 **What are four characteristics of a good index fossil?**

- Well preserved fossil (easy to find)
- Widely distributed (in a variety of environments)
- Narrow-stratigraphic rang (changes quickly with time)
- Abundant

75 **What kinds of fossils are typically used as index fossils in each of the following time intervals:**

a. Lower Paleozoic shale: **Trilobites**
b. Paleozoic limestones: **Conodonts**
c. Late Paleozoic limestones: **Fusulinid Forams**
d. Mesozoic: **Ammonites**
e. Cenozoic: **Forarms mammals**

76 **What is Permineralization?**

A process of fossilization by which mineral material (most commonly SiO_2) is deposited in the pore spaces of the original hard parts or woody parts of an organism Petrified wood.

77 **Define Homologous vs. Analogous?**

Homologous Structures: Structures that are related to each other through common descent though now perhaps functioning differently. For example, the forelimbs of fish, amphibians, mammals (including whales), and birds are homologous structures .
Analogous Structures: Structures that perform the same function in different groups, such as the wings of bats and the wings of insets, but do not show a common underlying plan of structure

78 What is the difference between Holotype and Paratype?

The holotype is the single specimen designated as the type specimen of a species or subspecies at the time its original description is published. **Paratype**—A paratype specimen, other than a holotype, upon which the original description of a species or subspecies is based .

79 What are the key differences between eukaryotic and prokaryotic organisms?

Bacteria & Archaea belong in Prokaryotes and Eurkarya belongs in Eukaryotes. Eukaryotes contain at least 1000 times more DNA than Prokaryotes and are generally must larger in size. Sexual reproduction is present in Eukaryotes but not in Prokaryotes
Eukaryotes: Sexual reproduction Built in genetic variability
Diversification of protists (single-celled eukaryotes) at around 1.0 GYA may reflect the evolution of sexual reproduction.
Eukaryotes have about 1000 times more DNA than prokaryotes and are much larger (10-100 microns)
Prokaryotes: Small size (0.2-10 microns), Narrow specialists that cannot adapt quickly but are very good at specific things.

80 Explain how stromatolites form, with special attention to the tiny laminae?

During daylight hours, cyanobacteria removes carbon dioxide from the environment. In water, carbon dioxide forms a carbonic acid, which lowers the pH of water. By this removal in water, the cyanobacteria must raise the pH (the water becomes more basic), which in turn causes the precipitation of Calcium Carbonate in the form of lime mud. The lime mud sticks to the mucus sheaths of the cyanobacteria, forming a thin film of calcium carbonate.

81	**What group of organisms is most important in the formation of stromatolites?**
	Filamentous Cyanobacteria

82 **According to geologic evidence, when did O2 become present in Earth's atmosphere? What are banded iron formations (BIFs), and what do they tell us about the availability, or lack of availability, of oxygen?**

The presence of periodic free oxygen was apparently recorded at about 2.5 GYA.
BIF's are alternating layers of iron-rich and iron-poor sedimentary rock. The iron-rich layers contain oxidized iron which implies the presence of free oxygen in the atmosphere. The iron-poor regions imply the lack of availability of oxygen.

83 **What is the Principle of Fossil Succession?**

In sedimentary sequences, fossil species succeed one another in and orderly, systematic fashion, reflecting cycles of evolution and Extinction. Fossils can be used to assign relative ages to rock units based on the fact that each fossil species lived for a only brief time and then died out.

84 What are major features in Paleozoic Era?

The Cambrian period, at the beginning of the Paleozoic, was the first time that multi-cellular life forms flourished on Earth. By the end of the Paleozoic, and beginning of the Mesozoic, all the continents of the Earth came together to form the giant continent called PANGAEA and dinosaurs began to roam on land.

Cambrian 570 M-500 M. Earliest Record of Marine life- Trilobites are dominant

Ordovician 500M- 435 M. Echinoderms (Starfish, Sand dollar , sea urchin and sea cucumbers). Invertebrates are dominant, mollusks become abundant. Earliest Fish that are Jawless and later, jawed and armored fish.

Silurian 435 M- 395M. Earliest terrestrial plants and animals. Tiktaalik Eurypterids develop

Devonian 395 M- 345M. Armored fish go extinct, but abundance of several species of fish. Earliest amphibians and ammonites.

Carboniferous 345M-280M (Mississippian, Pennsylvanian) Abundant sharks and amphibians. Large swamps and coal forming forests. Earliest reptiles. Scale trees and seed ferns

Permian 280 M-225M. Extinction of many types of marine animals including trilobites.

85 What are major features in Mesozoic Era?

The Mesozoic is the period in which the dinosaurs lived, and its end was marked by the K-T extinction. This extinction event dramatically changed the Earth's flora and fauna, and its causes are still being investigated by scientists around the world. During the Mesozoic, the giant continent Pangaea broke apart into the continents we have today.

Triassic- 225M-195M. Earliest Dinosaurs, abundant cycads and conifers

Jurassic- 195M-136M. Earliest birds and mammals abundant dinosaurs and ammonites

Cretaceous- 136M-65M. Earliest flowering plants, climax of dinosaurs followed by their extinction. Great decline of brachiopods. Abundance of bony fish

86 What are major features in Cenozoic Era?

The beginning of the Eocene was a period when the Earth was very hot, with palm trees and alligators at the north pole. Earth but cooled by the start of the Quaternary. This period relates to today’s concern about global warming. Homo sapiens evolved and Ice Ages occurs towards the end of this time.

Tertiary- 65 M- 1.8M. Earliest Placental Mammals, modern mammals, large running mammals

Quaternary- 1.8 M – Present. Large Carnivores, Neanderthals, Humans, mastodons

87 How to order rock strata into meaningful units?

Three main ways of ordering rock strata into meaningful units :

- Lithostratigraphy: based on characters of sedimentary rocks themselves
- Biostratigraphy: based on fossils in the rocks
- Chronostratigraphy: combination of relative methods of telling time using litho- and biostratigraphy, and absolute methods

88 What are biostratigraphic sampling biases and why are they important?

Biostratigraphic Sampling Biases. Many macroevolutionary hypotheses are based on patterns that emerge from the stratigraphic distribution of groups of named taxa. If these ranges are to be interpreted with respect to evolution, then FADs(first appearance datum) must be assumed to represent the true evolutionary origin of a taxon, and LADs (last appearance datum) must represent the true extinction of a taxon.

89 **What is Phylogeny?**

- The process of evolution itself causes organisms to change over time.
- A lineage can persist even though individual named taxa may originate and become extinct within the lineage.

90 **How Correlation be determined?**

Determination of the equivalence of bodies of rock at different locations. There are two kinds of correlation: Lithostratigraphic- matching up continuous formations. Chronostratigraphic- matching up rocks of the same age. Usually done with fossils using biostratigraphy. Correlation Over short distances litho-stratigraphic correlation is the same as chronostratigraphic correlation. Over medium distances they are not the same. Over long distances only chronos-tratigraphic correlation can be used.

91 **How many types of Types of fossil assemblages?**

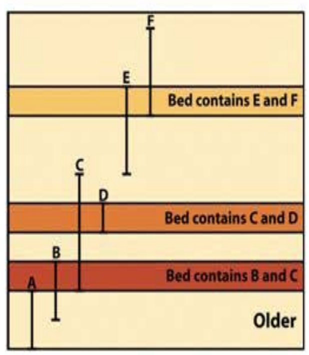
Two types of fossil assemblages :

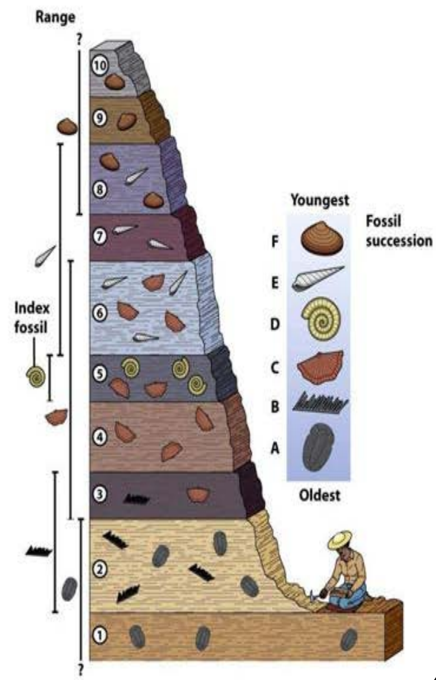
1. Biocoenosis
2. Thanatocoenosis .

Biocoenosis is an assemblage representing the living assemblage of an particular environment. This is a natural assemblage which is reliable for biostratigraphy. **Thanatocoenosis** is an assemblage which undergone transp ortation or reworked. This assemblage cannot be used for age determination.

Fossil Succession

- Fossil range – First and last appearance.
  - Each fossil has a unique range.
  - Overlapping ranges provide distinctive time markers.
- Permit correlation of strata.
  - Locally.
  - Regionally.
  - Globally.





92 **What are Biostratigraphic events?**

Fossil events are the result of the continuing evolutionary trends of life on earth; they differ from physical events in that they are unique, non-recurrent, and that their order is irreversible. Events that usually utilized in biostratigraphy are – First appearance (**FAD**) – Last occurrence (**LAD**) – Rapid increase in population – Rapid decrease in population.

93 What is the Fundamental Unit in Biostratigraphy?

The biozone is the fundamental unit of biostratigraphic classification. Biozone is a condensed expression for ''biostratigraphic zone.''

94 How many Kinds of Biostratigraphic Units?

The biozone is the fundamental biostratigraphic unit. Five specific kinds of biozones are recognized : range biozone, – interval biozone, – lineage biozone, – assemblage biozone, and – abundance biozone

• These five kinds of biozones are not hierarchically interrelated.

95 What is Range biozone?

A range biozone is a body of rock representing the known stratigraphic and geographic range of occurrence of any selected element or elements of the chosen fossil taxon, or taxa, present in the rock record.
• Three types of range biozones – Taxon range biozone – Concurrent range biozone – Partial-range biozone.

96 What is Taxon range biozone?

A taxon range biozone is a body of rock representing the known stratigraphic and geographic range of a chosen taxon

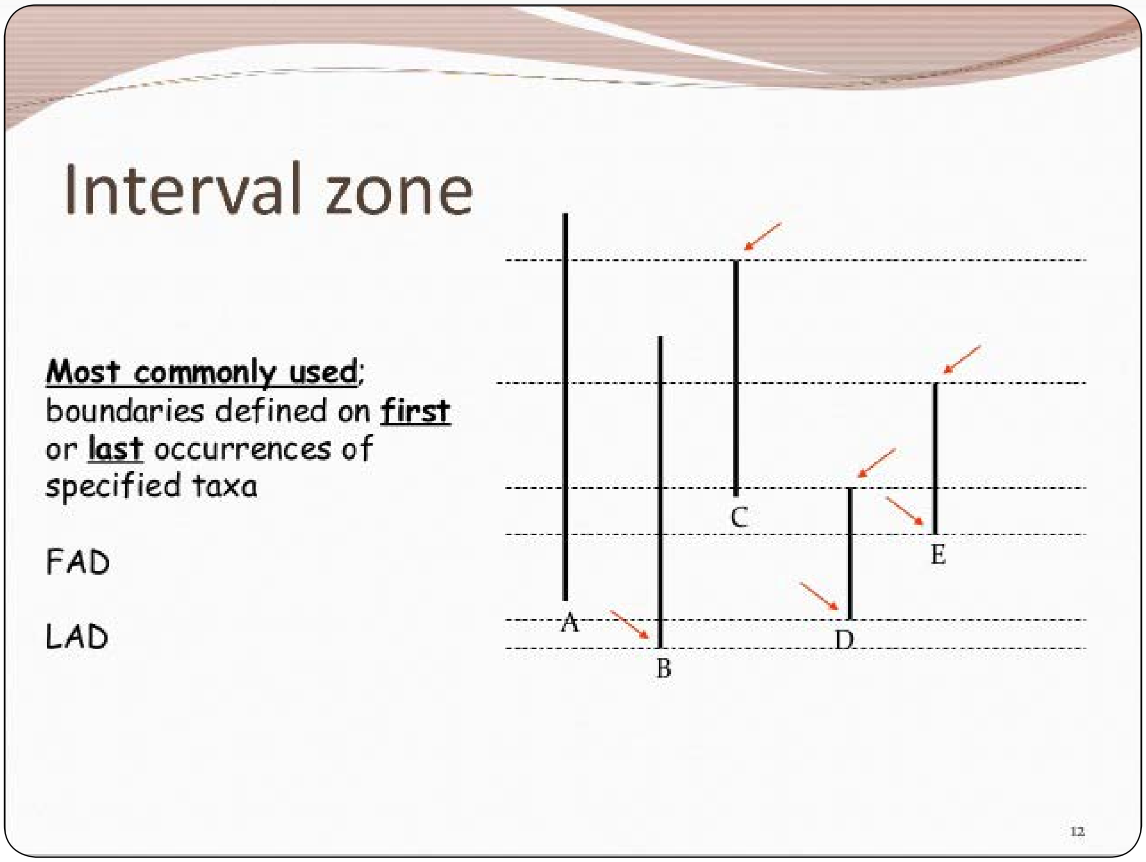
- The lower boundary is marked by first appearance datum (FAD) and the up per boundary is marked by last appearance datum (LAD) of the same spec ies.

97 What is the Principle of faunal succession?

Rocks formed during any particular interval of geologic time can be recognized and distinguished by their fossil content from rocks formed during other time intervals.

98 What is meant by FAD and LAD?

First appearance datum **(FAD)** The earliest (lowest) occurrence in a stratigraphic section for a particular species. First appearance occurs as members of a new species increase in numbers, they may eventually become abundant and widespread enough to show up in the geologic record. Last appearance datum **(LAD)** The latest (highest) occurrence in a section for a particular species. Last appearance occurs when the species is no longer able to adjust to shifting environmental conditions, its members decrease in number and eventually disappear

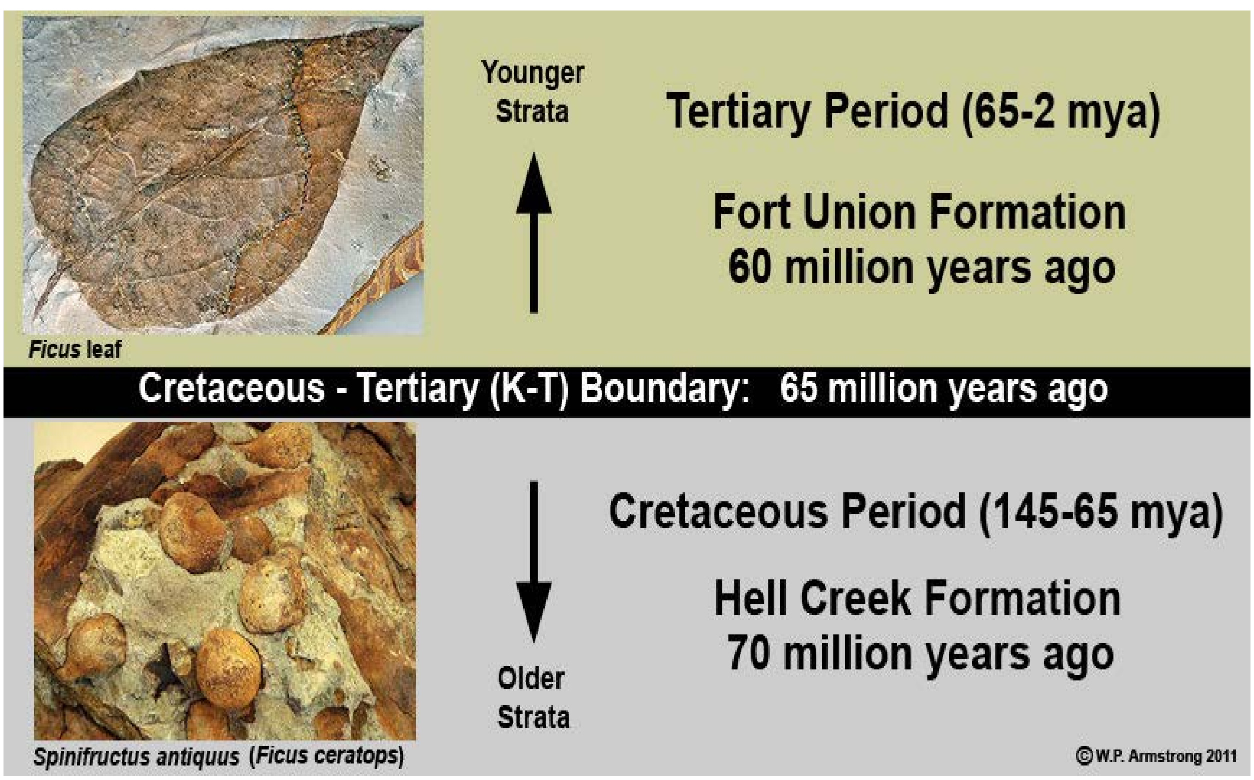


99 **What are the biggest Mass Extinctions?**

Five major extinctions (Big five)
1. End of Ordovician (~435 Ma)
2. End of Devonian (~355 Ma)
3. End of Permian (~250 Ma)
4. End of Triassic (~203 Ma)
5. End of Cretaceous (~65 Ma)

100 **What is K/T boundary?**

The end of Cretaceous mass extinction (The K/T Boundary) Sixty-five million years ago the curtain came down on the Age of Dinosaurs when a cataclysmic event led to mass extinctions of life. This interval of abrupt change in Earth's history, called the K/T Boundary, closed the Cretaceous (K) Period and opened the Tertiary (T) Period. At least 75 % of species on our planet were extinguished forever at this boundary. Rock deposited during the Cretaceous Period and Tertiary Period are separated by a thin clay layer that is visible at several sites around the world.



101 What are Major factors that control the dispersal and distribution of species of marine invertebrate organisms?

1. **Temperature**: Temperature barriers are most important latitutinally. Warm-water taxa vs. cold-water taxa.
2. **Geographic barrier**: Geographic barriers arise out of the distribution pattern of landmasses and oceans and variations in water depths of the oceans
3. **Sea-level changes**: Fluctuations in sea level cause significant interruptions in biogeographic provinces owing to variations in water depths on the continental shelves.
4. **Plate movements**: Major changes in the environmental framework of the marine realm occur as the geographic positions, configurations, and sizes of continents and ocean basins are changed by global plate tectonic processes.
5. **Other barriers**: Salinity difference, for example, constitute and important boundary between freshwater and marine provinces.

102 What Good biostratigraphy requires?

1. Common fossils 2. Good taxonomy 3. Accurate location of these fossils in carefully measured sections. This requires: The vertical changes in fossils can be noted at one place and convenient boundaries chosen. These changes and boundaries must be recognized at other places.

103 What are differences between Facies Fossils Zone Fossils?

Facies Fossils are the fossil space may correspond with the rock space if the organisms were controlled by the same factors controlling the deposition of the sediment. **Zone fossils** are the fossil space may appear completely independent if the rock units; also, different taxa may give different fossil spaces.

104 What is meant by interval biozone?

An interval biozone is a body of rock between two specified biostratigraphic surfaces (biohorizons). The features on which biohorizons are commonly based include lowest occurrences, highest occurrences, distinctive occurrences, or changes in the character of individual taxa (e.g., changes in the direction of coiling in foraminifera or in number of septa in corals).

105 Why do fossils of some dinasour's doesn't decompose?

Generally, when any creature dies, the flesh decomposes leaving behind the bones. The bones, if not eaten by scavengers are often carried off by those scavengers for future gnawing. So, generally the discovery of a whole intact skeleton is unusual. But it does happen. The circumstances are often unusual but it could be a flood, a land slide, an eruption, or any number of other geophysical occurrences that cause the animal's death and entombment. When this occurs, the body decays under the dirt or mud and this occurs slowly because the normal bacterial and insect activities is slowed by the fact that it is buried.

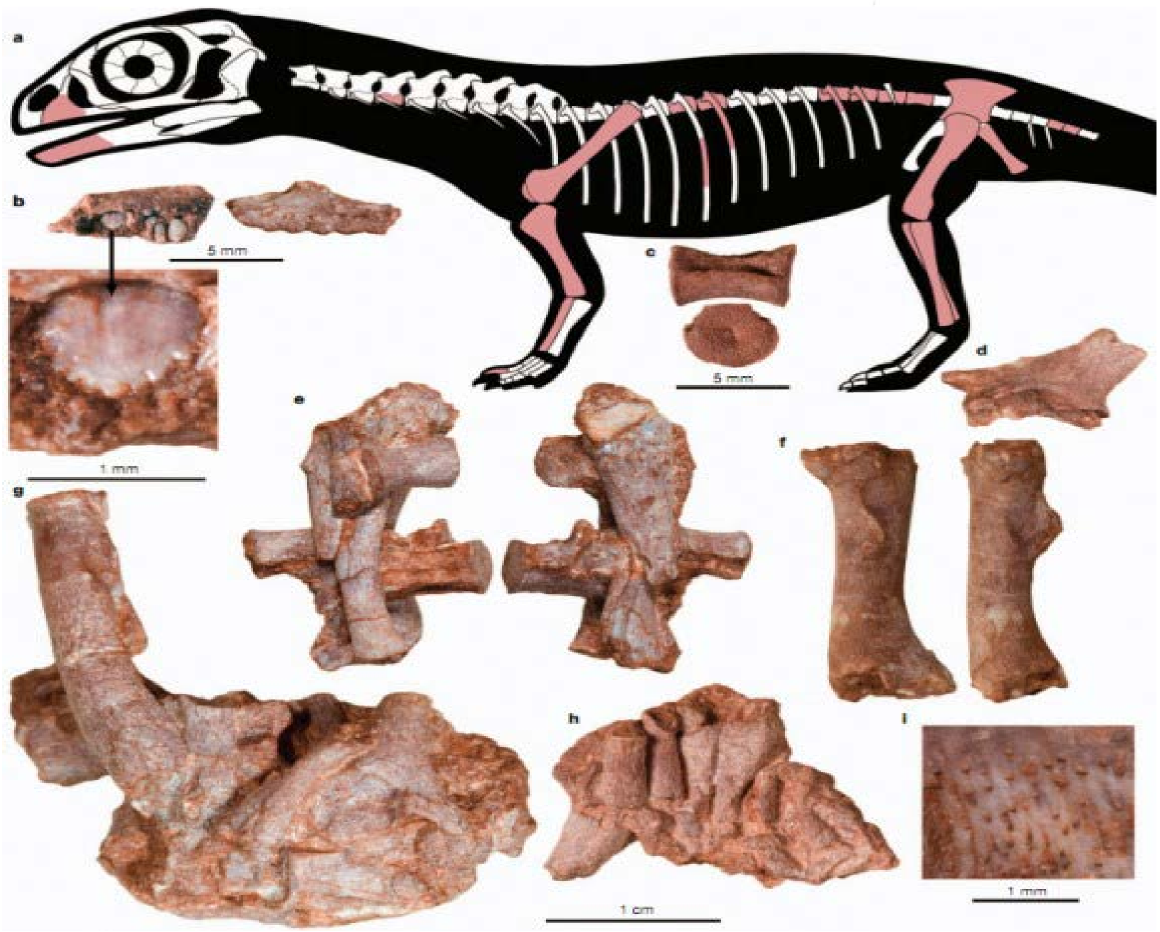
106 When are dinosaurs existed and extinct?

Most people are aware that 66 million years ago, at the end of the Cretaceous Period, the world experienced a **Mass Extinction.** People commonly call it the "Extinction of the Dinosaurs." But this is a misleading name for these reasons:

1. Most dinosaurs weren't even there. Dinosaurs first evolved 230 million years ago, and over time new species arose and old species died out just like any other organisms, for many different reasons. The end-Cretaceous wasn't even the first mass extinction dinosaurs experienced, although...
2. The end-Cretaceous was a BIG event. Somewhere around 80-90% of life on earth died out, including all the pterosaurs, ammonites, mosasaurs, and more, as well as ***almost all*** of the corals, mammals, reptiles, and many more. Every living group suffered in this extinction, including the dinosaurs alive at the time, but...
3. Dinosaurs survived. By the time of the extinction, one group of dinosaurs had already become small, feathered, flying animals we call birds. Nearly all the birds went extinct during the event, but some hung on, ultimately giving rise to the dinosaurs we have flying around us today.

107 Are all fossils dinosaur bones?

No. Fossils are signs or actual remains of living organisms more than 10 000 years ago. Examples of fossils are mummified or dried remains, frozen remains, insects preserved in amber which is tree resin and casts or molds.



108 **A lot of dinosaurs have the suffix 'saurus'. What does this mean?**

A. 'Saurus' means 'thunder lizard' and is meant to describe the sound they probably made when walking or running

109 What does stratigraphy do?

Stratigraphy is the scientific discipline in Geology where the progression of rock layers are studied to shed light on the earth's history. Stratigraphy can tell us the relative age of things, it can help us under stand the progression of events in complex area. Stratigraphy was arguably the first area of geologic study and led to the first geologic maps.

110 What are two of the main principles of Stratigraphy?

The two main principles of stratigraphy are as follows:-

1. Lithological Character
2. Paleontological Characters . But there is also an important principle known as "Principle Of Superposition" which is under Axiom. Generally this principle generates a lot of confusion. That's why it is not regarded as important principle of stratigraphy.

111 Why is sequence stratigraphy important to study?

Sequence stratigraphy is important to study because this approach to stratigraphic correlation helps geologists solve real-world problems in the exploration for and production of resources...whether the resources be water, coal, oil, or natural gas. In essence, sequence stratigraphy is a methodology for packaging genetically-related strata (such as sandstones or limestones and the associated mudstones) for the purpose of better describing and reconstructing geological history in sedimentary basins. In theory, the sequences are bounded by unconformities or their correlative conformities.

112 How does a sedimentary rock become sediment?

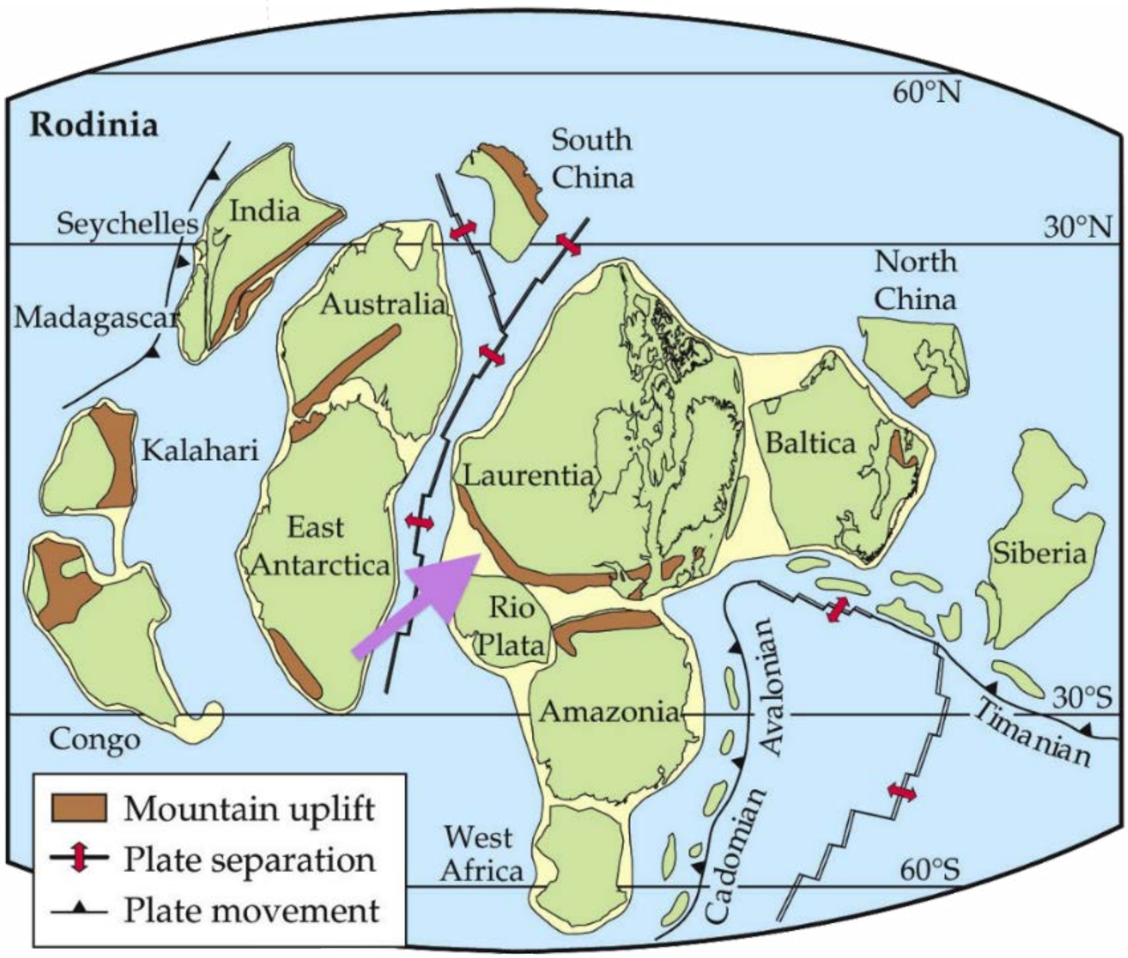
By erosion. Rocks are, over time, broken down by physical or chemical processes, reducing it to movable pieces, allowing for it to be transported away as sediment. Depending on mineralogy and composition of the source rock, different sediments (grain sizes) are produced. Some rocks weathers to shale, others to silt or sand.

113 Why are clay minerals easily erodible?

They are very, very fine and they are hydrophilic for the most part. . Clays have thin plate-shaped particles held together by electrostatic forces, presenting a cohesive plastic mass when wet. Few clay particles are larger than 5 microns. The same chemistry that makes it plastic and slippery when wet makes it easily picked up by flowing water. They can easily form a slurry with water and be washed away. The particles are so little that it takes still water and a long time for them to settle out of a water column. It is not just the size that makes clay but also the surface characteristics and the chemistry.

114 When did Rodinia form?

the break-up of Rodinia occurred diachronously. The first major break-up event occurred along the western margin of Laurentia , possibly as early as 750 Ma. Rifting between the Amazonia craton and the southeastern margin of Laurentia started at approximately the same time, but only led to break-up after ca. 600 Ma. By this time most of the western Gondwanan continents had joined together, although the formation of Gondwanaland was not complete until ca. 530 Ma.



115	What is the difference between weathering and leaching?

Leaching is the loss of water-soluble plant nutrients through water- so rain, irrigation, etc. weathering is the breaking down of soil, rock, etc through the atmospheric biome such as rivers, rain, the atmosphere, etc. The only difference is that in leaching, you aren't breaking down the soil, rather you are just losing water-soluble plant nutrients.

116 What is the Gondwana succession?

Gondwana is a district of India in which occurs a distinctive sequence of beds, including tillite (consolidated glacial debris) and coal deposits, laid down from about 400 million to 200 million years age. The same "Gondwana succession " of beds is found in South America, Australia, and Antarctica. An important feature of the Gondwana succession is the presence of certain plant fossils which are the same in beds of the same age throughout the southern hemisphere. Thus the geological and biological records point strongly to the existence of a single land mass, Gondwanaland, in the southern hemisphere in the distant past .

117 Ordovician (500-440 million years ago): Which well known group of animals thrived during this period?

Trilobites were a successful group of arthropods, counting over 15000 species, which populated the Paleozoic oceans for almost 300 million years. They are well known to paleontology because their hard shells were excellently preserved. Their name comes from the three lobes that make up their body: the axial lobe and the right and left pleural lobes.

118 How does the origin of the Himalayas differ from that of the oceanic mountains that constitute the Mid-Atlantic Ridge?

The Himalayas were thrust upward by the collision of the Indian plate and the Eurasian plate. The Mid-Atlantic Ridge was formed by the upwelling of molten rock.

119 **Why are fossils still useful in dating rock formations despite the development of radioactive methods?**

Fossils are found in sedimentary rocks, and radioactive dating is not generally useful in such rocks. Dating by means of fossils is usually much easier than radioactive dating, which requires elaborate apparatus. Since the geological periods that correspond to specific fossil types are well established, fossil dating is reasonably accurate.

120 **How can index fossils accurately indicate the age of sedimentary rocks?**

Actually index fossils can not accurately indicate the age of sedimentary rocks. Index fossils are assumed to have only lived during a narrow specific period of geological time. If an index fossils is found it then the fossil is used to establish the age of the sedimentary strata. One index fossil was the coelacanth or Latimeria. This fossil was thought to be an intermediate between fish and amphibians. The coelacanth was believed to have become extinct 80 million years ago. So if this index fossil was found the age of the strata could be established. However a living coelacanth was found in East Africa in 1938. Hundreds specimens of this species have since been found alive. The assumption that this index fossil only lived in a narrow time period has been proven false. Index fossils can be used to date geological data, but the accuracy of the dating is based on assumptions that may or may not be true.

121 **What is the difference between a sill and a dike, and how do both differ from a pluton or batholith? Identify the intrusions shown.**

A sill is a tabular, horizontally oriented igneous intrusion, while a **dike** is a tabular, vertically oriented intrusion . A sill intrudes parallel to pre-existing layering while a dike cuts across pre-existing layering (bedding or foliation) of wall rock. Plutons and batholiths are larger igneous intrusions that are irregular or blob-shaped and may be hundreds of kilometers wide (in the case of a batholith).

122 **How are coral reefs formed ?**

Coral reefs are formed from what are the hard, limestone "skeletons" of coral. A brown algae living symbiotically with the coral help the coral to produce limestone.

123 **Why is the evolution of the cyanobacteria important to the evolution of an oxygen-rich atmosphere on planet Earth?**

Cyanobacteria utilized photosynthesis to convert light into chemical energy. The products of this process are glucose and oxygen. Hence, cyanobacteria were essential for the development of an oxygen-rich atmosphere

124 **Are there mountains under the ocean?**

There are mountains as high as Mt Everest under the ocean.

125 A unit that displays a different lithological aspect relative to rocks above and below is called a ____________________________ unit.

Rock-stratigraphic unit

126 The most common rock-stratigraphic unit is the ___________________.

Formation

127 Formations can be subdivided into _____________________.

Members

128 Members can be subdivided into _____________________.

Beds

129 Two or more formations compose a ____________________.

Group

130 All rocks around the globe that formed during the same interval of time form a ____________________ unit.

Time-stratigraphic

131 The primary time-stratigraphic unit is the ____________________.

System

132 A system is subdivided into ____________________.

Series

133 **The stage is the ________________ subdivision of time-stratigraphic units.**

Smallest

134 **The eonothem is the ________________ subdivision of time-stratigraphic units is the.**

Largest

135 **Paleontologists have traced the lineage of Homo back to Australopithecus afferences. This now extinct ancestor of Homo lived in the Paleocene between about _______ and _______ million years ago**

4 , 2.7

136 **Geological time units correspond to the time that a specified __________ was deposited.**

Time-stratigraphic unit

137	**The geologic-time unit representing the longest interval of time is the ___________.**
	Eon

138	**The geologic-time unit representing the smallest interval of time is the _____________.**
	Age

139	**The geologic-time unit corresponding to the time that a system was deposited is the ____________.**
	Period

140	**The geologic-time unit corresponding to the time that a series was deposited is the ___________.**
	Epoch

141 **The geologic-time unit corresponding to the time that an earthem was deposited is the _________.**

Era

142 **The geologic-time unit corresponding to the time that an eonothem was deposited is the ____________.**

Eon

143 **Geologists use both _____________ and _____________ criteria to correlate strata.**

Physical, Biological

144 **What is the oldest age obtained from a mineral or rock on our planet?**

4.4 billion years

145 **The first life forms on planet Earth occur during the Archean between about _______ and _______ billion years ago.**

4.0 , 2.5

146 **What is the age of the Earth?**

4.6 billion years

147 **The first animals with preservable hard parts first appear in the _______________?**

Cambrian

148 **Why is Cooksonia significant, and in what approximate time range did it evolve?**

First vascular land plant – evolved approximately 443 – 417 million years ago

149 **In what system is Cooksonia first found?**

Silurian

150 **What is Rodinia?**

First supercontinent to form on planet Earth

151 **The dinosaurs evolved and become dominant during the _______________, between about _________ and ___________ million years ago? .**

Mesozoic, 248, 65

152 **What is the age of the meteorite impact at the Cretaceous/Tertiary boundary?**

49. 65 million years

153 153. during the Pleistocene about _______ million years to _____________ years ago?.

1.8, 10,000

154 A world-wide drop in _______ may have contributed to the extinction of the dinosaurs by destroying their _____________ habitats.

Sea level, coastal

155 When did the Earth first develop an atmosphere and oceans?

Archean- ~4.0-2.5 b.y. ago

156 What epoch do we live in?

Holocene

157 **In what period do primates first appear?**

Early Tertiary

158 **What is Pangaea and when did it form?**

Second supercontinent to form on planet Earth- ~248 m.y. ago

159 **How do geologists determine the absolute ages of rocks with radio-active decay?**

Megan

160 **The ratio of the number of daughter nuclides to the number of parent nuclides after a decay**

Period of 3 half-lives is

161 **What was the name of the large southern continent created by the breakup of supercontinent Pangea?**

Gondwana. Gondwana was made up of today's locations: Antarctica, Madagascar, India, Australia, Africa, South America, Arabia, and New Guinea

162 **What was the "Panthalassa"?**

The giant global ocean surrounding the supercontinent Pangea. The Panthalassic Ocean eventually became the Pacific Ocean.

163 **The name of Earth is derived from words meaning what in English and German?**

Ground, The name came from the Old English ertha or eorthe, or the German version which is erde. Either way, it just means ground or soil.

164 **Stratosphere: Which type of radiation is least likely to be filtered by the ozone layer situated within this atmospheric region?**

Infrared radiations. The stratosphere is situated above the troposphere and extends up to 50 km- marked by the stratopause. The temperature rises from -60 to-4 degrees Celsius because of the ozone layer (between 20-40 km) which absorbs the solar ultraviolet radiation and reflects the cosmic radiation.

165 **Earth's atmosphere consists mostly of?**

Oxygen and nitrogen. While oxygen and hydrogen (H_2O) do form water, they make up the oceans and rivers, not the atmosphere. There are other trace elements in Earth's atmosphere

166 **Does any rock besides kimberlite decay into blue clay and then into yellow dirt/clay?**

Many minerals can decay into "blue" and/or "yellow" clay. Clay is just the state of minerals when they have been sufficiently decayed into small enough...

167 **The study of the spatial and temporal relationships between bodies of rock is called**

Stratigraphy

168 **The geological time scale is the ____________ framework in which geologists view Earth history.**

Temporal

169	**Both ________________ and absolute scales are included in the geological time scale. .**
	Relative

170	**Beds represent a depositional event. They are _________ 1 cm in thickness.**
	Greater than

171	**Laminations are similar to beds but are ___________ 1 cm in thick-ness.**
	less than

172	**An unconformity represents an absence of ________________ due to erosion or non-deposition.**
	Sedimentation

173 **The idea that most beds are laid down horizontally or nearly so is called the**

A.	Principle of Original Continuity	C.	Principle of Cross-Cutting Relationships
B.	Principle of Fossil Succession	D.	Principle of Original Horizontality

174 **The idea that beds extend laterally in three dimensions until they thin to zero thickness is called the**

A.	Principle of Cross-Cutting Relationships	C.	Principle of Original Continuity
B.	Principle of Original Horizontality	D.	Principle of Fossil Succession

175 **Which of the following is not a time-stratigraphic unit?**

A.	eonothem	C.	system
B.	erathem	D.	none of the above

176 **The Great Dying occurred in __________**

A.	Cambrian	C.	Triassic
B.	Cretaceous	D.	Permian

177 **The idea that younger beds are deposited on top of older beds is called the**

A.	Principle of Original Horizontality	C.	Principle of Cross-Cutting Relationships
B.	Principle of Fossil Succession	D.	<u>Principle of Superposition</u>

178 **The idea that a dike transecting bedding must be younger than the bedding it crosses is called the**

A.	Principle of Original Horizontality	C.	Principle of Fossil Succession
B.	Principle of Original Continuity	D.	<u>Principle of Cross-Cutting Relationships</u>

179 **The idea that fossil content will change upward within a formation is called the**

A.	Principle of Cross-Cutting Relationships	C.	<u>Principle of Fossil Succession</u>
B.	Principle of Original Horizontality	D.	Principle of Original Continuity

180 **The Earth formed from a cloud of gas and dust orbiting the Sun. During its formation and early history it was bombarded by comets and asteroids, and its surface was probably**

A.	Green and lush	C.	Rocky and solid
B.	Covered with an ocean	D.	<u>Molten</u>

181 **The Tethys was located between**

A.	North America and South America	C.	Eurasia and Africa
B.	North America and Eurasia	D.	Antarctica and Australia

182 **Which of these statements isn't evidence for the theory of continental drift?**

A The bulge of South America fitting into the indent in Africa
B Rock sequences in Scotland matching sequences in Canada
C Similar fossil remains being found in South America and Southern Africa
D Volcanoes on the edges of existing plate boundaries

183 **Troposphere: Which of the following is not true about this layer?**

A It concentrates about 75% of the atmospheric mass
B It contains 99% of the water vapors in the atmosphere
C. It is the layer within which all weather phenomena occur
D It is located about 50 to 85 km above the Earth's surface

184 **Fossil evidence has indisputably shown that the origin of the camel was in which one of the following regions?**

A.	Indo-China	C.	Australia
B.	Egypt	D.	North America

185 **The zone of the atmosphere that is closest to the earth's surface is called the :**

A.	exosphere	C.	stratosphere
B.	ionosphere	D.	<u>troposphere</u>

186 **Which one of the following types of fossil organisms has a short life span and worldwide distribution?**

A.	Fossil assemblages	C.	<u>Index fossils</u>
B.	Fossil species	D.	Historical fossils

187 **In which one of the following are fossils LEAST likely to be found?**

A.	Aeolian sediments	C.	Marine sediments
B.	Continental sediments	D.	<u>Intrusive igneous rocks</u>

188 **50-Which one of the following is especially important in identifying oil horizons?**

A.	<u>Foraminifera</u>	C.	Radiolaria
B.	Diatoms	D.	Graptolites

189 **Which one of the following groups BEST describes ostracoderms ?**

A.	Primitive, bony, possessing lungs	C.	Ray-finned, fan-tailed
B.	<u>Primitive, jawless, armored</u>	D.	Lobe-finned with only a fringe of true fin

190 **Of the following, which one left the POOREST fossil record?**

A.	Echinodermata	C.	Mollusca
B.	<u>Annelida</u>	D.	Brachiopoda

191 **Trilobites were most abundant in the**

A.	Cenozoic era	C.	<u>Paleozoic era</u>
B.	Mesozoic era	D.	Proterozoic era

192 **Of the following , the example of an epoch in the geologic time scale is**

A.	Mesozoic	C.	Mississippian
B.	Permian	D.	<u>Pliocene</u>

193 **Which of the following events marks the beginning of geologic time?**

A.	Formation of the first igneous rock	C.	Preservation of the first sedimentary rock
B.	<u>Formation of the first sedimentary rock</u>	D.	First appearance of man on earth

194 **The approximate percentage of geologic time represented by the pre-Cambrian Era is**

A.	20%	C.	60%
B.	40%	D.	<u>80%</u>

195 **Foraminifera are primitive**

A.	single-celled plants	C.	<u>single-celled invertebrates</u>
B.	multi-celled invertebrates	D.	vertebrates

196 **Development of cross-bedding is LEAST likely to occur in sedimentary deposits laid down by**

A.	Wind	C.	ocean currents
B.	<u>ice</u>	D.	streams

197 **An interpretation based upon an observation is called a (n)**

A.	fact	C.	classification
B.	inference	D.	measurement

198 **The most favorable environment for the preservation of fossils is**

A.	Terrestrial	C.	Fluvial
B.	Lacustrine	D.	Marine

199 **The kind of coal Most likely to be found in strata that were deeply buried, but not folded is :**

A.	Ignite	C.	anthracite
B.	bituminous	D.	peat

200 **The type of coal Most likely to be found in strata that were deeply buried and strongly folded is :**

A.	bituminous coal	C.	anthracite
B.	lignite	D.	peat

201 **Dikes are distinguished from sills by the fact that they:**

A.	<u>cut across the structure of the country rocks</u>	C.	fill fractures in the country rocks
B.	are vertical or near-vertical in attitude	D.	are intrusive in origin

202 **The latest of the geological Eras is called the :**

A.	<u>Cenozoic</u>	C.	Proterozoic
B.	Paleozoic	D.	Mesozoic

203 **Which one of the following units represents the longest period of geologic time?**

A.	Epoch	C.	Age
B.	period	D.	<u>Era</u>

204 **Amphibians arose during which one of the following times?**

A.	Mississippian	C.	<u>Ordovician</u>
B.	Cretaceous	D.	Silurian

205 **The theory of earth movements advanced by Wegener is known as the :**

A.	Contraction Theory	C.	Convection Hypothesis
B.	Continental drift Theory	D.	Theory of Gravitational sliding

206 **An unconformity is the line of contact between :**

A.	displaced horizontal layers	C.	rocks of different ages of the earth's history
B.	rocks on both sides of a thrust fault	D.	unconsolidated material and sedimentary rock

207 **The cause of the most recent glacial period in the earth's history is :**

A.	not yet established	C.	variation in inclination of the earth's axis
B.	fluctuation in sunspot activity	D.	change in elevation of large surface areas

208 **Of the following , carbon 14 dating may be used MOST success-fully to determine the age of objects**

1	100 years old	3	500,000 years old
2	5,000 years old	4	5,000,000 years old

209 **The process responsible for the formation of coal is**

A.	Decomposition	C.	Petrification
B.	Distillation	D.	Replacement

210 **The one of the following which is the basis for the MOST accurate method of determining the age of rocks is**

1	Index fossils	3	Radioactivity
2	Rate of decomposition	4	None of these

211 **The earth is classified as a**

1	Star	3	Satellite
2	Comet	4	Planet

212 **Of the following , the region that is CLOSET to the earth is the**

1	Troposphere	3	Mesosphere
2	Stratosphere	4	Ionosphere

213 **Fossils are least likely to be found in :**

A.	sandstone	C.	limestone
B.	coquina	D.	Gneiss

214 **The geologic period for which the trilobite is an index fossil is the :**

A.	Cambrian	C.	Cretaceous
B.	Jurassic	D.	Triassic

215 **The most definite evidence of a continental (subaerial)**

A.	torrential cross-bedding	C.	arkose sandstone
B.	ripple marks	D.	graded bedding

216 **Stromatolites are**

A.	Green algae	C.	Blue algae
B.	Organo-sedimentary structures	D.	Sedimentary structure

217 **The time taken for light from the sun to reach the earth**

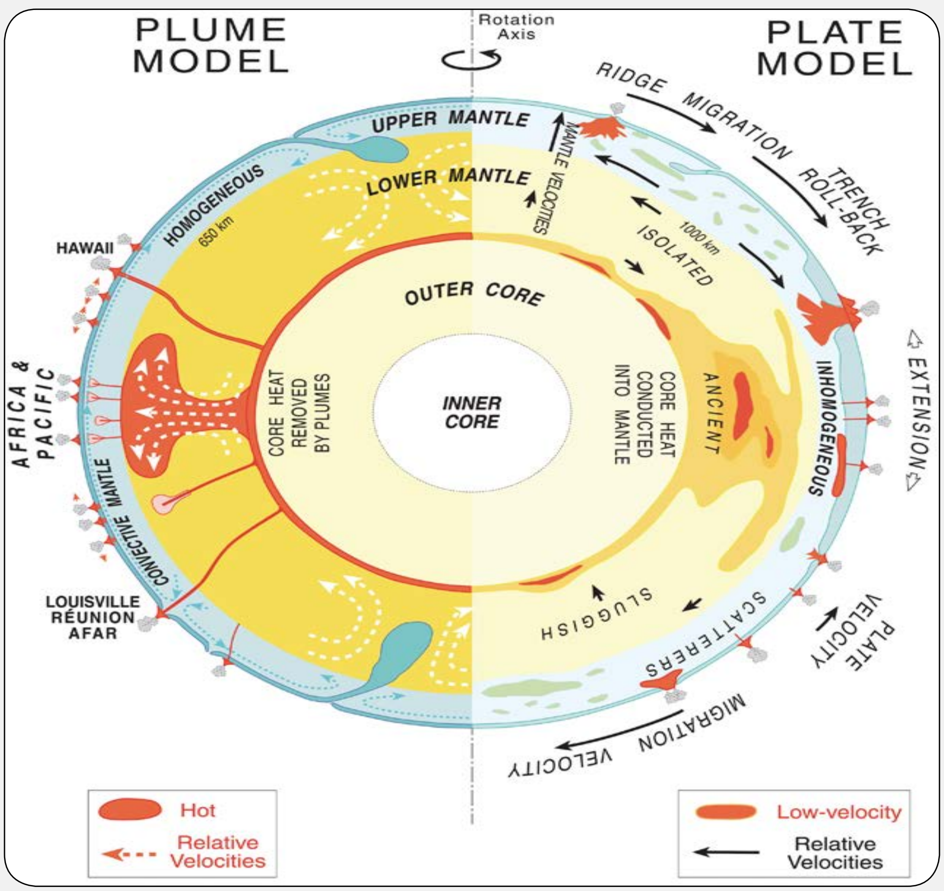
A.	499.720 secs	C.	489.720 secs
B.	499.012 secs	D.	489.012 secs

218 **Primates first appear In**

A.	Permian	C.	Jurassic
B.	Triassic	D.	Early Tertiary

103

Questions & Answers in Earth's Interior & Geodynamics



Introduction

As planets age and cool off, their internal and surface processes gradually change. Manifestations of changes within Earth's interior such as the development of mountains and volcanoes have a huge influence on the nature of Earth's surface and atmosphere. Scientists know that much of the rock in the Earth's mantle which is under extreme pressure and very high temperature, behaves like a viscous liquid. Despite continuing advances, however, scientists are only beginning to explore the connections between Earth's core, magnetic field, mantle, and surface and to investigate why Earth differs from other planets, or how it may change in the future. Although plate tectonic theory explains many of Earth's surface features, it is not known why Earth has plates or what the relationships are between plate tectonics and Earth's abundant water, continents, and the existence of life.

1 **What is Geodynamics refers to?**

Geodynamics refers to the processes by which mantle convection shapes and reshapes the Earth. It applies physics, chemistry and mathematics to the understanding of the theory of Plate Tectonics. The goal is to give you the tools you need to understand the conceptual underpinnings of plate tectonics, including the kinematics and dynamics of plate motions.

2 **What is meant by Dynamic earth?**

The **Earth** is a dynamic, actively evolving planet. The surface of the Earth has been shaped and reshaped over billions of years by the forces of plate tectonics and weathering. Most of the surface is relatively young, a few 10s to 100s of Millions of years old for the most part.

It is active today because the Earth's interior is still hot and molten. Started out in a hot, molten state of formation. About 80% of crustal heat comes from radioactive decay.

3 **What are major layers of earth's interior?**

The **earth** is divided into four main layers: the **inner core, outer core, mantle, and crust**. The core is composed mostly of iron (Fe) and is so hot that the outer core is molten, with about 10% sulfur (S). The inner core is under such extreme pressure that it remains solid. Most of the Earth's mass is in the mantle, which is composed of iron (Fe), magnesium (Mg), aluminum (Al), silicon (Si), and oxygen (O) silicate compounds. At over 1000 degrees C, the mantle is solid but can deform slowly in a plastic manner. The crust is much thinner than any of the other layers, and is composed of the least dense calcium (Ca) and sodium (Na) aluminum-silicate minerals. Being relatively cold, the crust is rocky and brittle, so it can fracture in earthquakes.

4 What is the Crust?

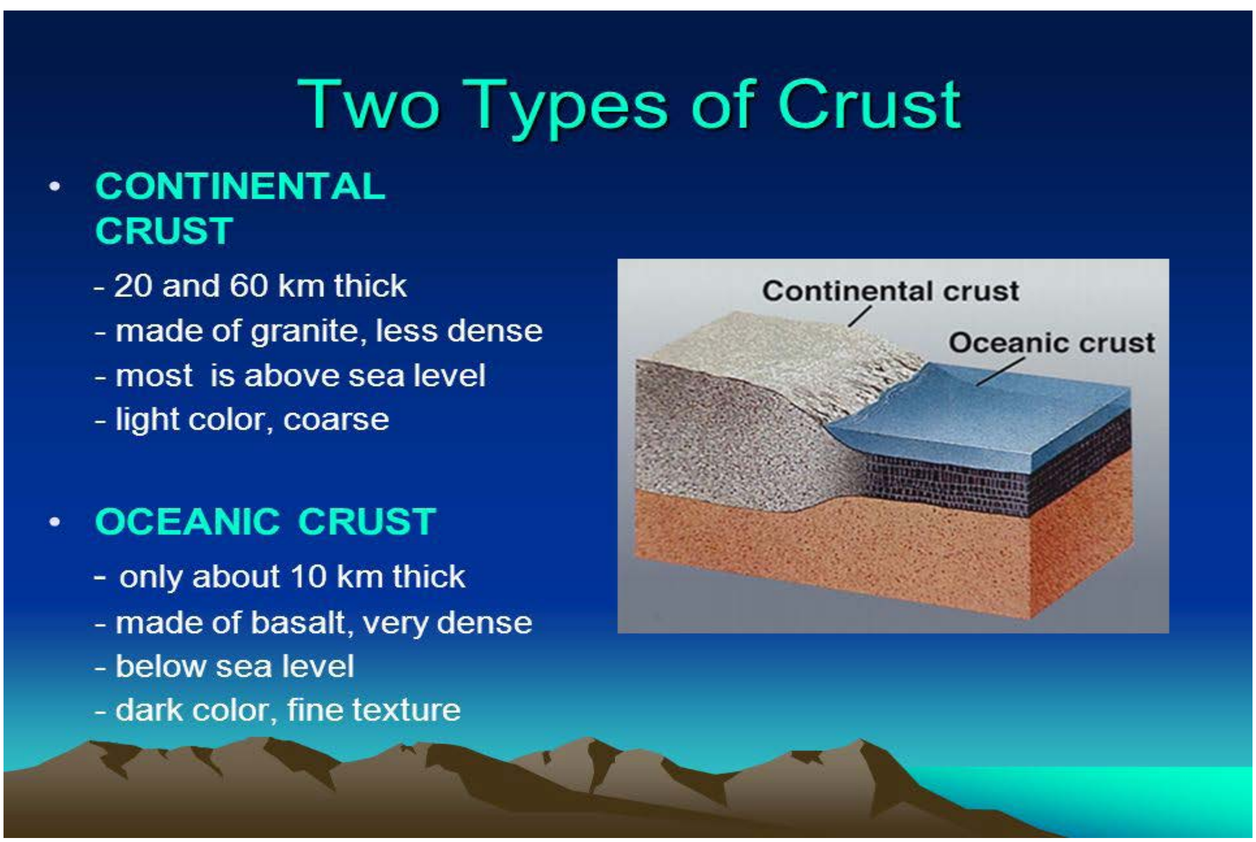
The Earth's Crust is is very thin is only about 6-11 kilometers thick under the oceans (oceanic crust) and about 25-70 kilometers thick under the continents (continental crust). The crust is composed of two rocks. The continental crust is mostly granite. The oceanic crust is basalt. Basalt is much denser than the granite. Because of this the less dense continents ride on the denser oceanic plates. The Basalt is formed when hot material in the upper mantle is decompressed, allowing it to melt and form liquid magma, which cools off quickly.

5 What is the properties of Continental Crust?

The continents include a wide range of rock types, including granitic igneous rocks, sedimentary rocks, and the metamorphic rocks formed by the alterations of both. They contain a lot of quartz, a mineral absent in oceanic crust. This core foundation is often referred to as a shield or basement rock. Rocks found in the shields were formed during the Precambrian and are some of the oldest rocks found on the Earth. The first continental rocks were the result of repeated melting, cooling, and remixing of oceanic crust, driven by volcanic activity above mantle convection cells, which were much more numerous and vigorous than today's. Geologists believe that the major continental cores were formed by the early solidification of the lighter components of magma between 3.9 and 3.8 billion years ago. The continental shields are generally covered by younger sedimentary deposits. These sedimentary rocks constitute the interior platforms of the continents.

6	What is the properties of Oceanic Crust?

The rocks of the oceanic crust are very young, not older than 200 million years, compared with the rocks of the continental crust 3.6 billion years old. The decompression occurs beneath rifts in the crust, such as those found at the mid-ocean ridges, and it is through these rifts that lava is extruded onto the surface to create new ocean crust. Oceanic crust is continuously being created at mid-ocean ridges. At these ridges, magma rises into the upper mantle and crust, as the plates diverge. As it moves away from the ridge, the lithosphere becomes cooler and denser, and sediment gradually builds on top of it. The youngest oceanic lithosphere is at the oceanic ridges, and is progressively older away from the ridges.



7 What is composition of Mantle?

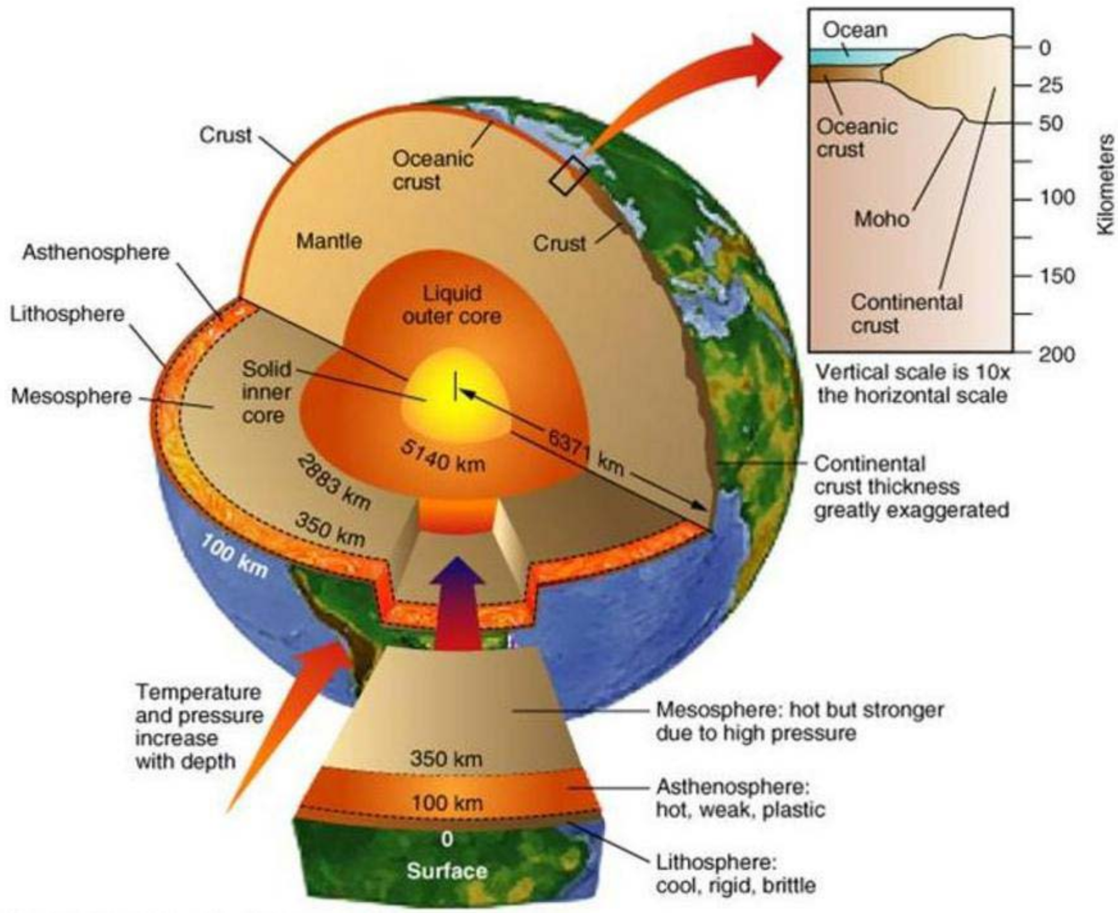
Mantle is 3488 km thick, made up of a rock called peridotite (Olivine + Opx + Cpx). Evidence comes from Seismic wave velocities, experiments, and peridotite ***xenoliths*** (foreign rocks) brought to the surface by magmas. Mineralogy of peridotite changes with depth in the Earth. At low pressure, the mineral assemblage is Olivine + Cpx + Opx + Plagioclase (plagioclase peridotite). At higher pressure the assemblage changes to Olivine + Cpx + Opx + Spinel $[(Mg,Fe^{+2}) (Cr, Al, Fe^{+3})_2O_4]$ (spinel peridotite). At pressures above about 30 kilobars, the assemblage changes to Olivine + Cpx + Opx + garnet (garnet peridotite). This occurs because Al changes its coordination with increasing pressure, and thus new minerals must form to accommodate the Al. At greater depths, such as the **400 km** discontinuity and the **670 km** discontinuity, olivine and pyroxene likely change to high pressure polymorphs.

8 What is the composition of Core?

Since the core makes up about one-third of the Earth's mass it must be a material that is common in the solar system. It must account for the observed seismic velocities. It should also be a material with magnetic properties to account for the Earth's magnetic field. Iron is the obvious candidate. **Core** is 2883 km radius, made up of Iron (Fe) and small amount of Nickel (Ni). Seismic evidences suggest that iron is remnants of other differentiated planets that were broken apart due to collisions.

Outer Core is 2250 km thick and liquid even with all of the pressure and heat on top of it due to the S-wave velocities are zero in the outer core. If $V_s = 0$, this implies $\mu = 0$, and this implies that the material is in a liquid state. The outer core is a layer of molten material that surrounds the inner core. The outer core is about 4,400 Celsius- 6,100 Celsius and is made up of iron and nickel. Scientists think that movements in the outer core create Earth's magnetic field.

Inner Core at 5145-6371 km depth , Vp increases and Vs inferred > 0, -> solid inner core. Even inner core is not homogeneous. Layered and anisotropic. In the inner core, extreme pressure squeezes the atoms of iron and nickel so much that they can't spread to become liquid. The inner core is a solid and is 1,216 km thick so even though it is the deepest it is not the thickest .Its solid because indirect evidence of studying Earth's interior, seismic waves cannot pass through it.

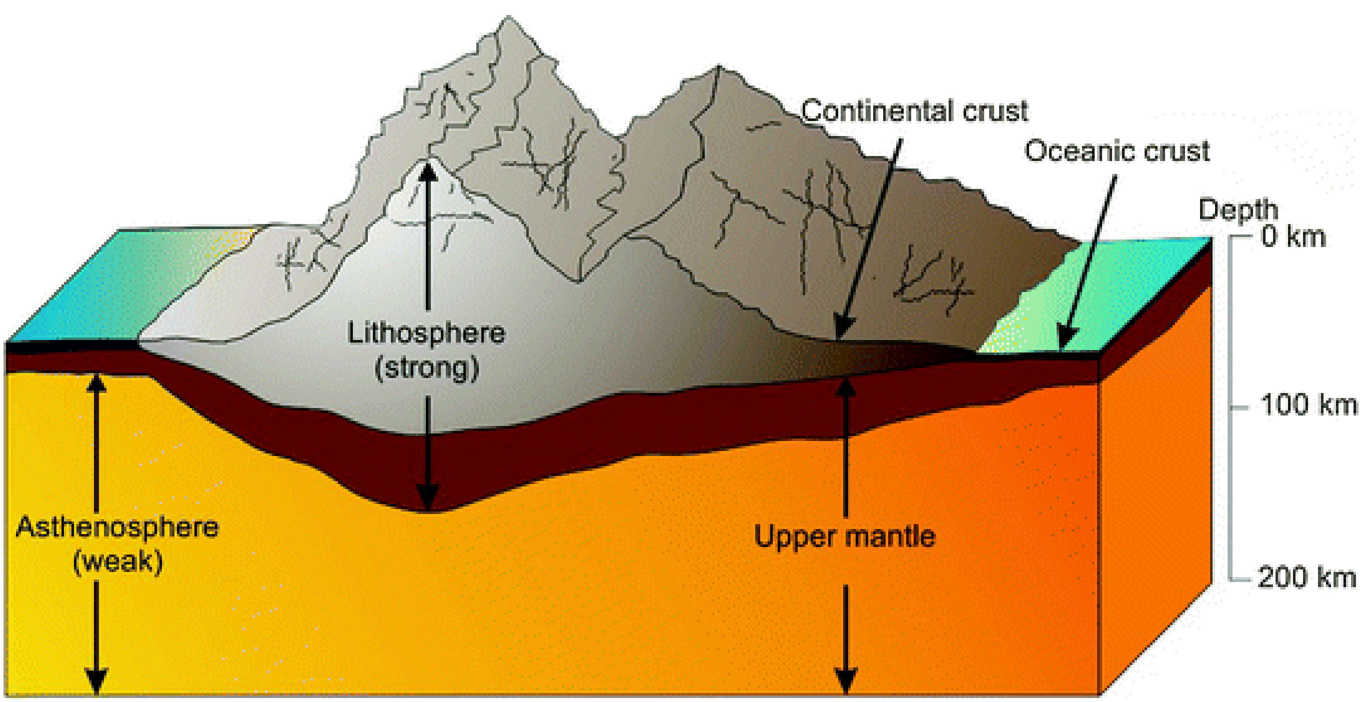


9 What is Lithosphere?

Lithosphere. Litho is a Greek word, which means stone, is about 100 km thick (up to 200 km thick beneath continents, thinner beneath oceanic ridges and rift valleys), very brittle, easily fractures at low temperature. The lithosphere is comprised of both crust and part of the upper mantle. The plates are made up of the lithosphere, and appear to float on the underlying asthenosphere.

10 What is Asthenosphere?

Asthenosphere is about 250 km thick - solid rock, but soft and flows easily (ductile). The top of the asthenosphere is called the Low Velocity Zone (LVZ) because the velocities of both P- and S-waves are lower than the in the lithosphere above. But, not that neither P- nor S-wave velocities go to zero, so the LVZ is not completely liquid.



11 Where is Mohorovicic Seismic Discontinuity?

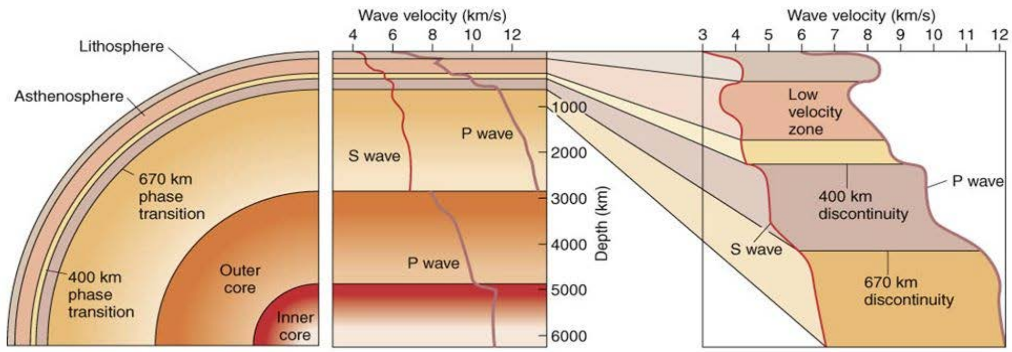
Mohorovicic (1909) discovered that seismic waves recorded beyond 200 km from the earthquake source had passed through a lower layer with significantly higher seismic velocity. This seismic discontinuity is now know as the **Moho.** It is the boundary between the felsic/mafic crust with seismic velocity around 6 km/sec and the denser ultramafic mantle with seismic velocity around 8 km/sec. The depth to the Moho beneath the continents averages around 35 km but ranges from around 20 km to 70 km. The Moho beneath the oceans is usually about 7 km below the seafloor (i.e., ocean crust is about 7 km thick).

12 What is Low Velocity Zone?

Seismic velocities tend to gradually increase with depth in the mantle due to the increasing pressure, and therefore density, with depth. However, seismic waves recorded at distances corresponding to depths of around 100 km to 250 km arrive later than expected indicating a zone of low seismic wave velocity. Furthermore, while both the P and S waves travel more slowly, the S waves are attenuated or weakened. This is interpreted to be a zone that is partially molten. Alternatively, it may simply represent a zone where the mantle is very close to its melting point for that depth and pressure that it is very "soft." Then this represents a zone of weakness in the upper mantle. This zone is called the **asthenosphere** or «weak sphere.»

The asthenosphere separates the strong, solid rock of the uppermost mantle and crust above from the remainder of the strong, solid mantle below.

Earth's Internal Structure
Major Discontinuities



- crust/mantle - the MOHO
- inside mantle (400 km and 670 km)
- mantle/outer core (CMB)
- outer/inner core (ICB)

13 **What is 400 km Seismic Discontinuity?**

410 km: Above this depth the Mg, Fe, Si and O are primarily within olivine and pyroxene. Below this depth the olivine is no longer stable and is replaced by a higher density polymorph- spinel. The material has a similar overall composition but the minerals have a more compact structure. At 400 km have discontinuity in Vp and Vs. Density increases, this could be due to:- (1) same minerals but with higher molecular weight (i.e. more Fe, less Mg). (2) structural phase change to a more densely packed structure. (3) a combination of (1) and (2). At about 120 kb + 1400^{o} C (400 km), Forsterite-> Beta-Mg2SiO4 (wadsleyite).

14 What is 670 km Seismic Discontinuity?

Below the low velocity zone are a couple of seismic discontinuities at which seismic velocities increase. Chemical and seismic evidences show that at these depths (pressures) ultramafic silicates will change phase (atomic packing structure or crystalline structure) from the crystalline structure of olivine to tighter packing structures. The 670 km discontinuity results from the change of spinel structure to the ***perovskite*** crystalline structure which remains stable to the base of the mantle. Perovskite (same chemical formula as olivine) is then the most abundant silicate mineral in the Earth. The 670 km discontinuity is thought to represents a major boundary separating a less dense **upper mantle** from a more dense **lower mantle.**

15 What is Gutenberg Seismic Discontinuity / Core-Mantle Boundary

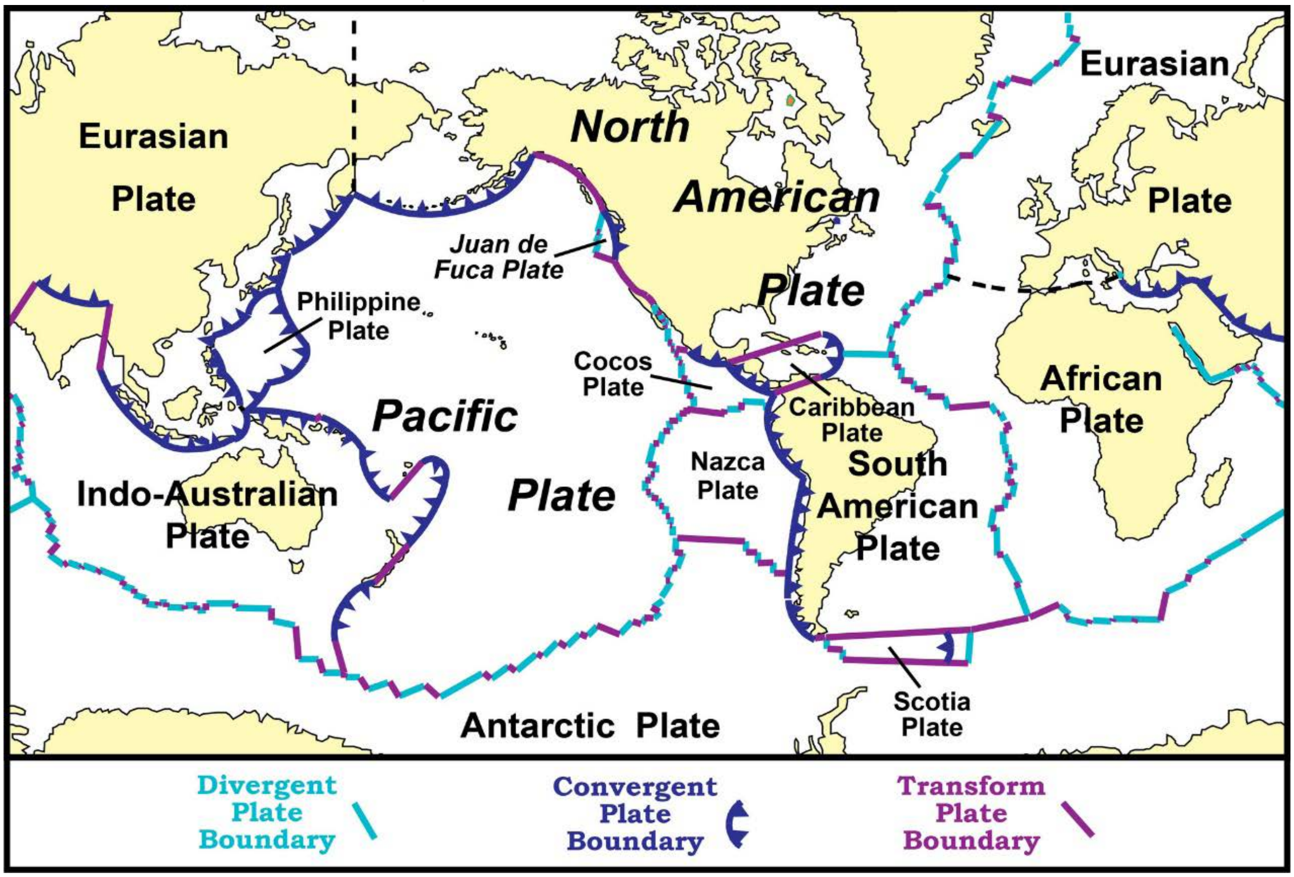
Seismic waves recorded at increasing distances from an earthquake indicate that seismic velocities gradually increase with depth in the mantle except at Low Velocity Zone and 670 km Discontinuity. However, at arc distances of between about 103° and 143° no P waves are recorded. Furthermore, no S waves are record beyond about 103°. Gutenberg (1914) explained this as the result of a molten core beginning at a depth of around 2900 km. Shear waves could not penetrate this molten layer and P waves would be severely slowed and refracted (bent).

16 **What is Lehman Seismic Discontinuity?**

Between 143° and 180° from an earthquake another refraction is recognized **(Lehman, 1936)** resulting from a sudden increase in P wave velocities at a depth of 5150 km. This velocity increase is consistent with a change from a molten outer core to a solid inner core. **Lehmann discontinuity** ~ 220 km depth. Increase in Vp and Vs by 3-4%. It may not be ubiquitous.

17 **What is the theory of Plate Tectonics?**

The **Earth's crust** is divided into six primary and nine secondary plates which are moved in various directions. This plate motion causes them to collide, pull apart, or scrape against each other. Each type of interaction causes a characteristic set of Earth structures or "tectonic" features. The word, tectonic, refers to the deformation of the crust as a consequence of plate interaction. There are 12 major plates on Earth, each of which slide around at a rate of centimeters per year, pulling away from, scraping against or crashing into each other. Each type of interaction produces a characteristic "tectonic feature", like mountain ranges, volcanoes and (or) rift valleys.



18	**How many major tectonic plates exist?**

Primary plates are 6 comprise the bulk of the six continents and the Pacific Ocean. African Plate, Antarctic Plate, Eurasian Plate, Indo-Australian Plate, North American Plate, Pacific Plate, South American Plate.

Secondary plates are 9: Arabian Plate, Caribbean Plate, Cocos Plate, Indian Plate, Juan de Fuca Plate, Nazca Plate, Philippine Sea Plate, Scotia Plate, Tertiary plates

19 What are Tertiary Plates?

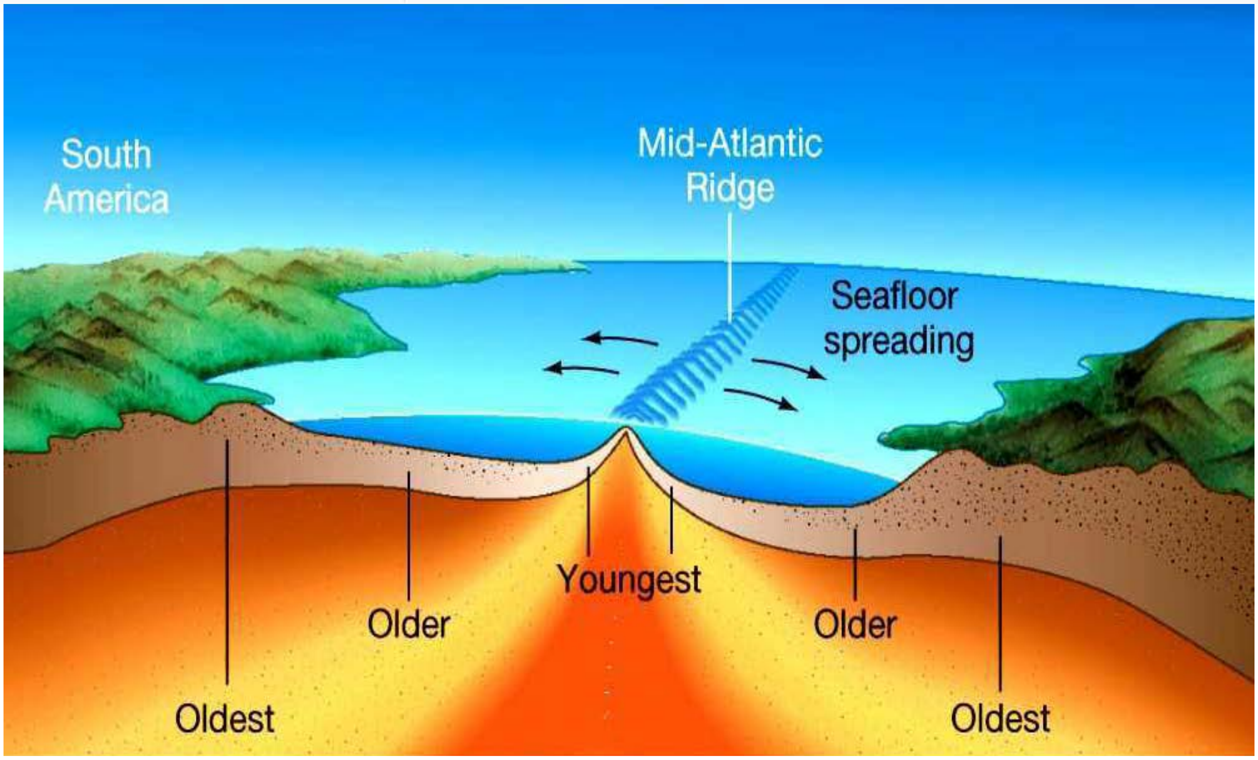
Tertiary plates are grouped with the major plate that they would otherwise be shown as part of on a major plate map. Mostly these are tiny microplates, although in the case of the Nubian-Somalian and Australian-Capricorn-Indian plates these are major plates that are rifting apart. Some models identify more minor plates within current orogens like the Apulian, Explorer, Gorda, and Philippine Mobile Belt plates. The remainder of the tertiary plates are the dwindling remains of much larger ancient plates. There may or may not be scientific consensus as to whether a tertiary plate is a separate plate yet, is still a separate plate, or should be considered a separate plate.

20 What happens at tectonic plate boundaries?

Three types of plate boundaries are recognized. **Divergent, Convergent, Transform**. Divergent boundaries are where plates move away from each other. Convergent boundaries are where the plates move towards each other. Transform boundaries are where the plates slide past each other.

21 What are Divergent Boundaries Spreading ridges?

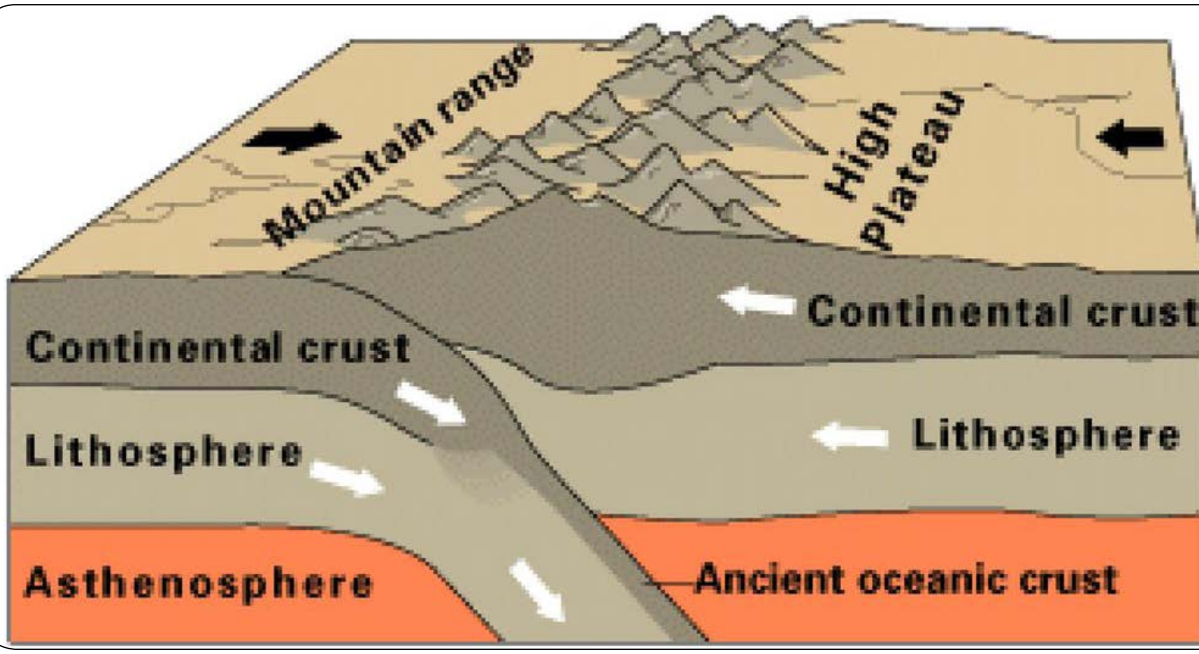
In plate tectonics, a divergent boundary is a linear feature that exists between two tectonic plates that are moving away from each other. These areas can form in the middle of continents or on the ocean floor. As the plates pull apart, hot molten material can rise up this newly formed pathway to the surface - causing volcanic activity. Where a divergent boundary forms on a continent it is called a RIFT or CONTINENTAL RIFT, e.g. African Rift Valley. Where a divergent boundary forms under the ocean it is called an OCEAN RIDGE. Spreading ridges. As plates move apart new material is erupted to fill the gap.



22 **What are types of Convergent Boundaries?**

Convergent boundaries are where the plates move towards each other. There are three styles of convergent plate boundaries. Continent-continent collision. Continent-oceanic crust collision. Ocean-ocean collision.
Continent-Continent Collision. Forms mountains, e.g. European Alps, Himalayas. When continental crust pushes against continental crust both sides of the convergent boundary have the same properties. Neither side of the boundary wants to sink beneath the other side, and as a result the two plates push against each other and the crust buckles and cracks, pushing up (and down into the mantle) high mountain ranges. For example, the European Alps and Himalayas formed this way.

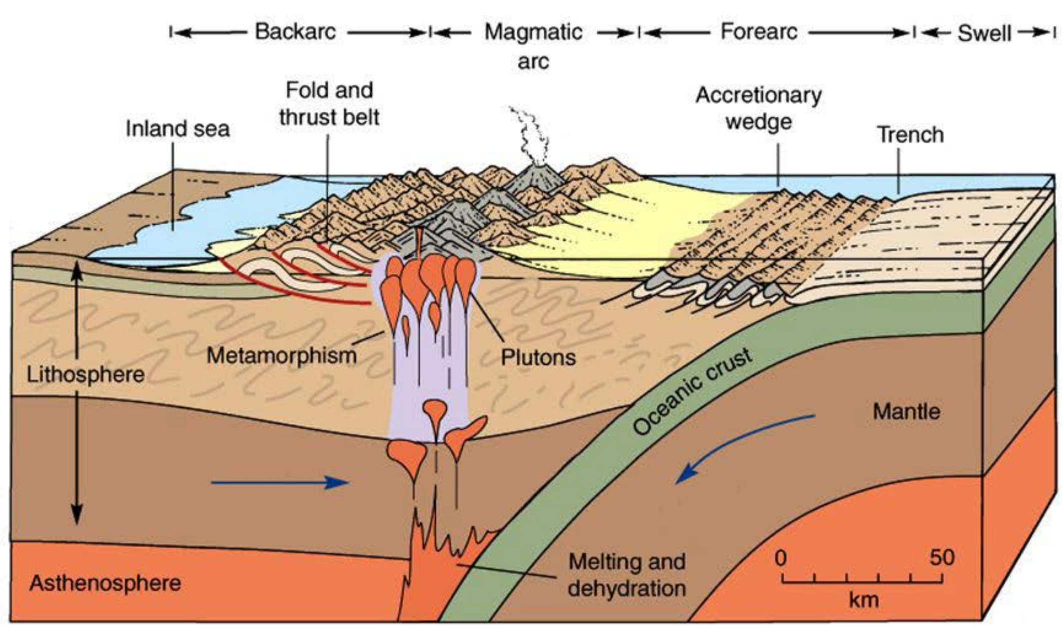
Continental-Continental Convergent Plate Boundary



Continent-Oceanic Crust Collision

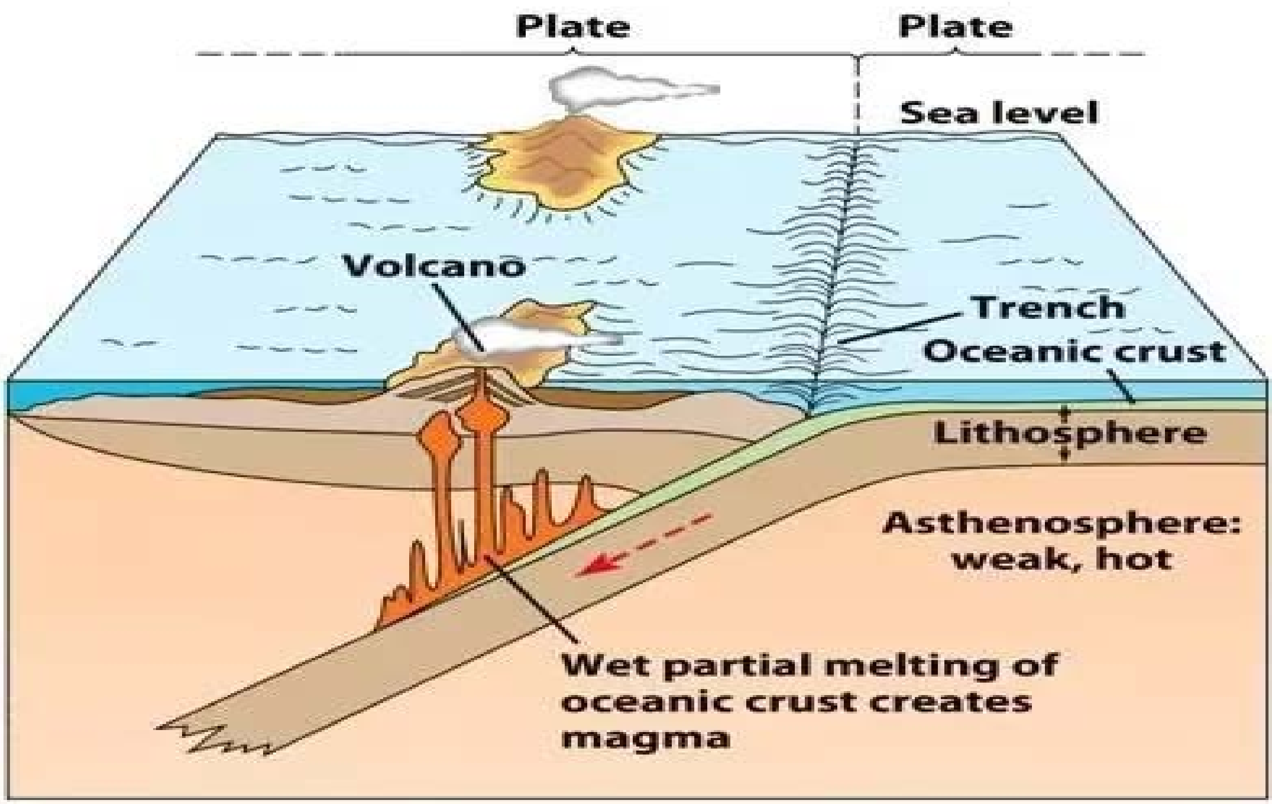
Called SUBDUCTION. At a convergent boundary where continental crust pushes against oceanic crust, the oceanic crust which is thinner and more dense than the continental crust, sinks below the continental crust. This is called a Subduction Zone. The oceanic crust descends into the mantle at a rate of centimeters per year. This oceanic crust is called the "Subducting Slab". When the subducting slab reaches a depth of around 100 kilometers, it dehydrates and releases water into the overlying mantle wedge. Subduction is a way of recycling the oceanic crust. Eventually the subducting slab sinks down into the mantle to be recycled. It is for this reason that the oceanic crust is much younger than the continental crust which is not recycled.

Ocean-Continent Collision



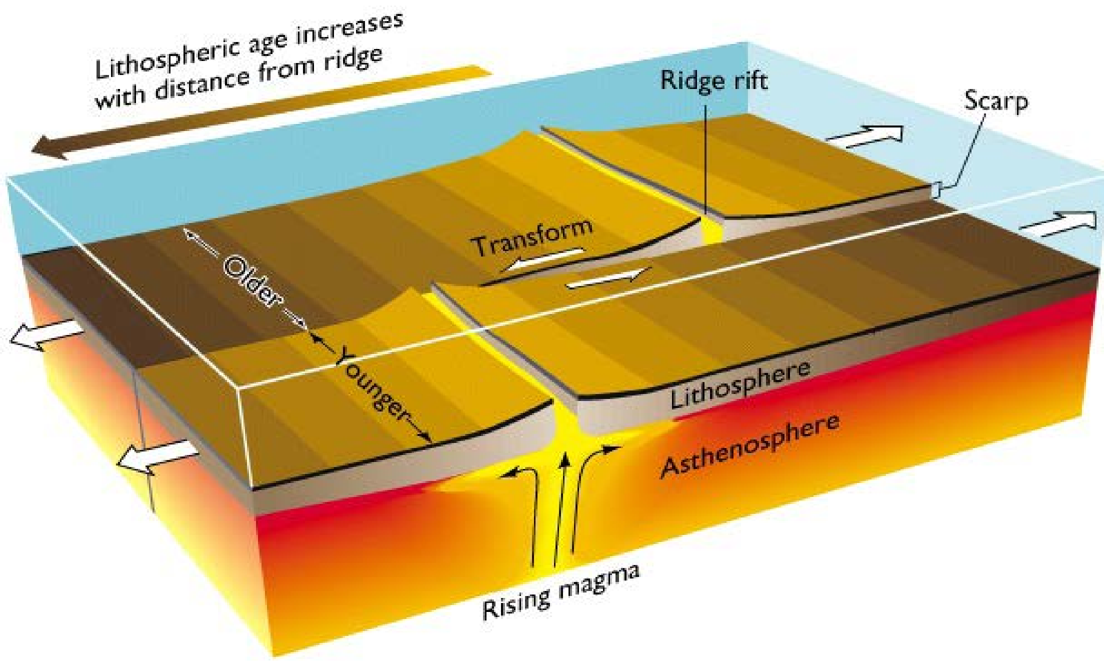
Ocean-Ocean Plate Collision

When two oceanic plates collide, one runs over the other which causes it to sink into the mantle forming a subduction zone. The subducting plate is bent downward to form a very deep depression in the ocean floor called a trench. The worlds deepest parts of the ocean are found along trenches. E.g. The Mariana Trench is 11 km deep.



23	**What are Transform Boundaries?**

The third type of boundary are transform boundaries, along which plates slide past each other. The San Andreas fault (Right lateral), between the Pacific plate and the North American plate. Gulf of Aqabah (Left lateral) is also another transform boundary between Arabian pate and Sinai plate.



24 **How do people have knowledge about tectonic plates if they are deep beneath the surface?**

Tectonic plates are the surface of earth. We live on them! We farm, ranch, mine, excavate, drill and populated them. So, we know a lot about the plates—from the surface, in particular. For looking far below, we have the advantage that in many places, plates are grinding together, or pushing up mountains, or pulling apart, giving far more views to their mechanics. We use a lot of remote sensing now: using quakes as a sort of tomography, or sonar scan of earth's interior. Gravitic and magnetic, and even electrical sensing tell us a lot more. The earth rings like a bell from big quakes, and we can gather data from the waves then traveling across and even through the planet. The Himalayas, and the Ural mountains were formed by different plates colliding and fusing together. The San Andreas fault is where two plates grind past each other; the East Africa Rift is where a continent is ripping apart. We have lots of places to look deep into plates!

25 **Explain the mechanism of movement of Plate boundaries?**

Each plate is part of a shell on a sphere, so different parts of the plate move at different velocities. The direction of plate motion can be determined from (a) trends of spreading centers and fracture zones, (b) seismic data, (c) ages of the sea floor on either side of the ridge, and (d) ages of island chains. Rates of plate motion can be measured by dating patterns of magnetic reversals on the sea floor. Plates move at significantly different rates, ranging from less than 2 cm per year to more than 10 cm per year.

The major structural features of the Earth are formed along plate boundaries. There are three types of Plate boundaries**. At divergent plate boundaries**, the lithosphere is under tension, and the major geologic processes are (a) rifting and block faulting, (b) the generation of basaltic magma and the formation of new oceanic lithosphere, and (c) rifting of continents.

At convergent plate boundaries, the important geologic processes include (a) subduction, (b) generation of andesitic to granitic magma, as well as (c) metamorphism and mountain building.

Transform fault boundaries are zones where plates slide passively past each other. A number of forces act upon the plates and influence their motion. The most important of these are (a) gravitational pulls in subduction zones, (b) gravitational sliding of elevated ridges, (c) frictional drag on the bottom and sides of plates, and (d) collisional resistant forces between covering plates.

26 What are the benefits of plate tectonics?

Mineral resources are located at the plate margins and boundaries. These are exploited for human consumption. Almost all minerals that we mine today have a direct or indirect relation to plate tectonics. Volcanic eruptions due to plate movements have given rise to fertile soil favoring agricultural activities. Also some active plate margins and volcanic regions provide geothermal energy. Plate tectonics trapped atmospheric carbon dioxide into rocks and thereby stabilizing our climate, making Earth habitable.

27 How plate tectonics affect climate?

vulcanism or volcanic activity is due to tectonic plates sliding under each other, with some material melting and returning to the surface in the form of volcanoes and flood basalts. Volcanic ash in the atmosphere, in sufficient quantities, can block sunlight and affect the weather and, in extreme cases, even the climate. Studies of the onset of ice ages attributes vulcanism as a possible source for ash in the atmosphere cooling the planet. Also, in the debate about mass extinctions, volcanic ash cooling the atmosphere is often cited as a cause. Vulcanism was considered the leading cause for the extinction of dinosaurs before evidence indicated an asteroidal impact as a more likely source for the atmospheric ash that cooled the Earth's atmosphere and cut off sunlight beyond their viable range of comfort.

28 How does the moon affect plate tectonics?

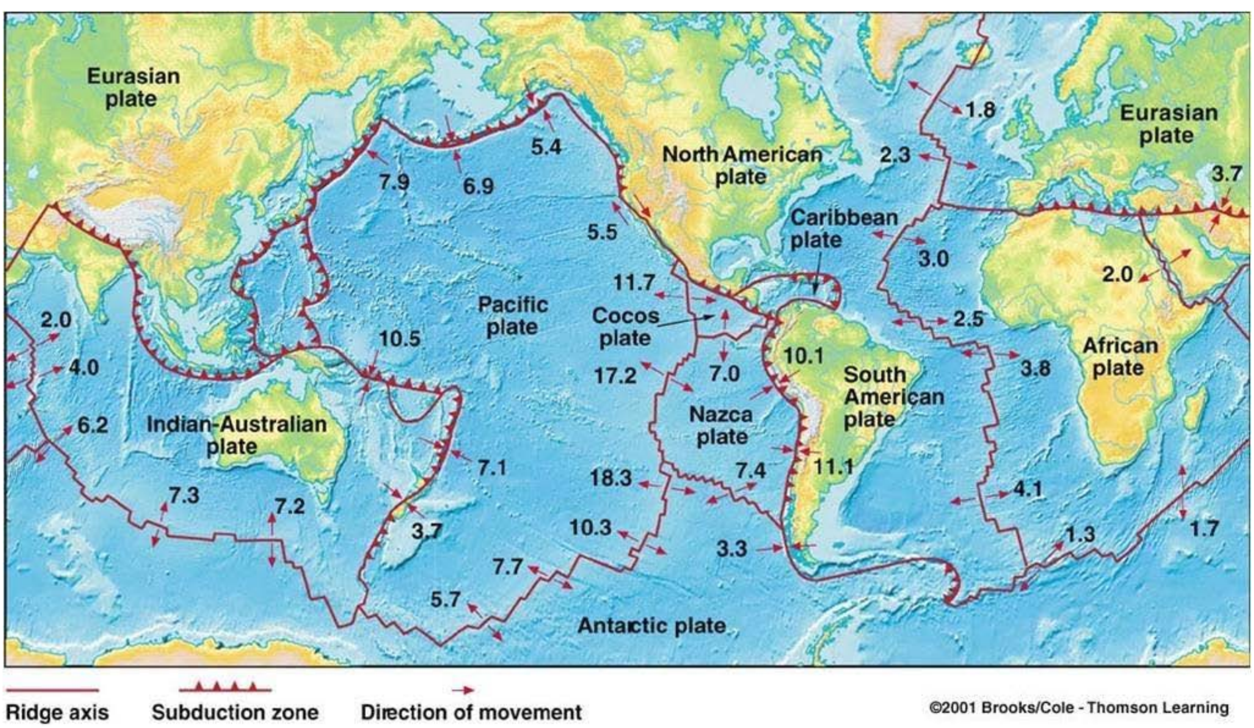
Tide´s effect is not just moving the sea water, it also deformates the lithosphere hold by plates (monitoring fluid pressure in closed reservoirs few tenths of PSI can be detected in coincidence with tides). Crust deformation plays a role changing friction from static to dynamic allowing faster displacements as the interplates tension required are lower.

29 How do tectonic plates affect the sea?

Tectonic plate affect the sea in two main ways. Tectonic plate are constantly moving. Over time this can increase or decrease the shape and volume of the ocean basins. In subduction zones, oceanic crust gets carried down into the mantle, including a great deal of ocean water. This is from serpentinized mantle rock (which forms near spreading centers) and from hydrated silicates, which make up much of the sedimentary rock on top of the oceanic plate. (The other half of the cycle is water coming back up from the mantle through volcanic eruptions, especially mantle-plume eruptions.)

30 **Which continental plate is moving the fastest and why?**

There is a big difference in the movement rates, with the highest creation rate along the East Pacific Rise (between the Pacific plate, the Cocos plate, the Nazca plate, and the Antarctic plate), and the highest subduction rate along the intersection of the Pacific plate with the Eurasian plate and the now-split Indian and Australian plates. Generally, the Cocos and Nazca plates (in the pacific ocean) are right now the quickest, moving at over 10 cm/yr. However typical plate movements are less quick, at rates about 2-3 cm/yr. Oceanic plates move faster than continental plates. o Oceanic plates tend to have ridges (pushing) and attached subducting slabs (pulling). At the base of oceanic plates in the LVZ (low velocity zone), a region of partial melting that provides 'lubrication" at the base of the plates.



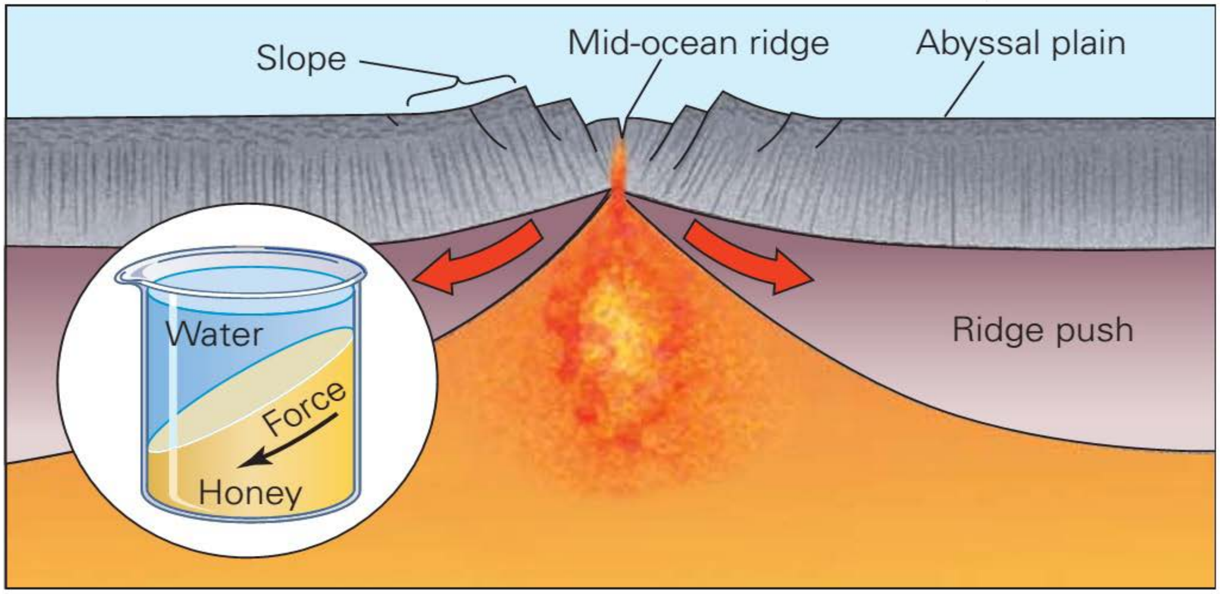
31 Why do tectonic plates move slowly?

Alfred Wegener first proposed the theory of Continental Drift; that the continents were one huge land mass called **Pangaea**, but slowly drifted apart over time. His theory was never accepted because he had no evident of how this occurred; no driving mechanism for how they drifted apart. At the end of WWII HARRY HESS, US Navy, was using sonar to locate mines on the ocean floor when to his surprise discovered a mountain range from his sonar mapping of the ocean floor. This range was created by sea floor spreading caused by convection currents in the asthenosphete which moved the plates apart at divergent boundaries, allowing magma to rise, thus creating new oceanic crust to form; a creative zone. This would be Wegener's mechanism for how Pangaea broke apart and drifted. This movement happens very slowly, and luckily so, due to the melting of lithospheric subduction at convergent boundary destructive zones (causing volcanoes and earthquakes). The crust melts, becomes less dense and rises. It then cools and drags the lithospheric plates either colliding or away from other plates, cooling magma becomes more dense.

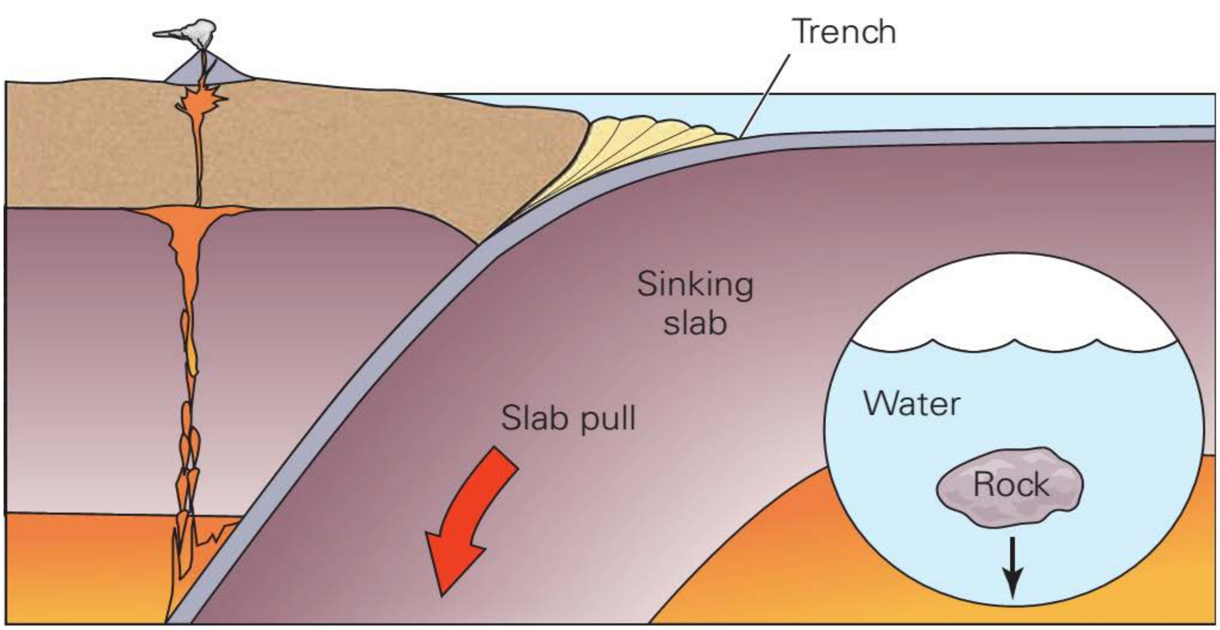
32 Why do tectonic plates move?

Tectonic plates move because they are floating on top of the mantle. The mantle itself moves due to convection currents: hot rock rises, gives off some heat, then falls. This creates vast swirls of moving rock under the crust of the earth, which jostles the plates of crust on top.

There are mainly three causes for the movement of mechanically stronger tectonic plates (lithosphere) over the mechanically weaker asthenosphere. These are **Mantle convection, ridge push and the slab pull.** Mantle convection occurs because of the density difference and the heat release in the mantle. The density difference leads to the **convection** as the more denser materials tend to go down with gravity in comparison to less denser materials. The other more important reason is the **heat release** from the much hotter earth's core and other radioactive reaction heat release in the lower mantle. Because of the heating from downside the warm materials becomes buoyant and rises to towards the surface and after loosing heat it becomes cooler and moves down due to increase in density. This leads to the convection of the material in the mantle. It is analogous to the boiling of water. **The ridge push** is the push of the tectonic plates as the buoyant materials from inside earth comes out at the spreading ridges. This push also drives the movement of the plate. **The slab push** is considered the most important cause of the movement of tectonic plates. At the subduction zone, when the density of the plate increases, the plate tends to subduct more, and with its subduction it pulls the tectonic plates and hence drives its movement. The increase in density is because of the phase change of many minerals in the subducting tectonic plate.



(a) Ridge push develops because the region of a rift is elevated. Like a wedge of honey with a sloping surface, the mass of the ridge pushes sideways.



(b) Slab pull develops because lithosphere is denser than the underlying asthenosphere, and sinks like a stone in water (though much more slowly).

33 What lies beneath the tectonic plates?

Below the lithosphere (which makes up the tectonic plates) is the asthenosphere. The asthenosphere, beneath the lithosphere, is part of the upper mantle and is so hot that it is 1 – 5% liquid (I.e. 95 – 99% solid). This liquid, usually at the junctions of the crystals, allow it to flow – which is why 'astheno' means weak.' Beneath the asthenosphere is the rest of the mantle, which is completely solid – but can also flow because of the intense temperatures and pressures involved. The base of the lithosphere-asthenosphere boundary **(LAB)** corresponds approximately to the depth of the melting temperature in the mantle.

34 What is meant by LAB and CMB?

The lithosphere–asthenosphere boundary **(LAB)** is a first-order structural discontinuity that accommodates differential motion between tectonic plates and the underlying mantle. Although it is the most extensive type of plate boundary on the planet, its definitive detection, especially beneath cratons, is proving elusive.

The largest compositional discontinuity within the Earth is the core-mantle boundary **(CMB),** at a depth of 2889 km. This boundary and the adjacent transition zones in the lowermost mantle and outermost core play a critical role in the Earth's thermal and chemical evolution. Estimates of the heat flux out of the core indicate that the 200-km-thick D" region at the base of the mantle is a major thermal boundary layer.

35 What is D'' region?

At **CMB**, have D'' an anomalous region just above the **CMB** (Core-Mantle Boundary) with seismically fast and slow regions, Ultra Low Velocity zones (**ULVZ**) possibly due to partial melt; this region also possible slab graveyard, possible perovskite to post-perovskite transition, possible repository of primordial material. This is known as the D" discontinuity, and while we don't know much about it, it appears to be ubiquitous, although its position varies from less than 100 km to over 300 km above the **CMB.**

36 What is Rheology?

Rheology is the science of the deformation and flow of solids. Or how a material reacts to stress (what kind of strain and what are the rules governing stress-strain relations?)

37 What is Viscosity of the earth's Interior?

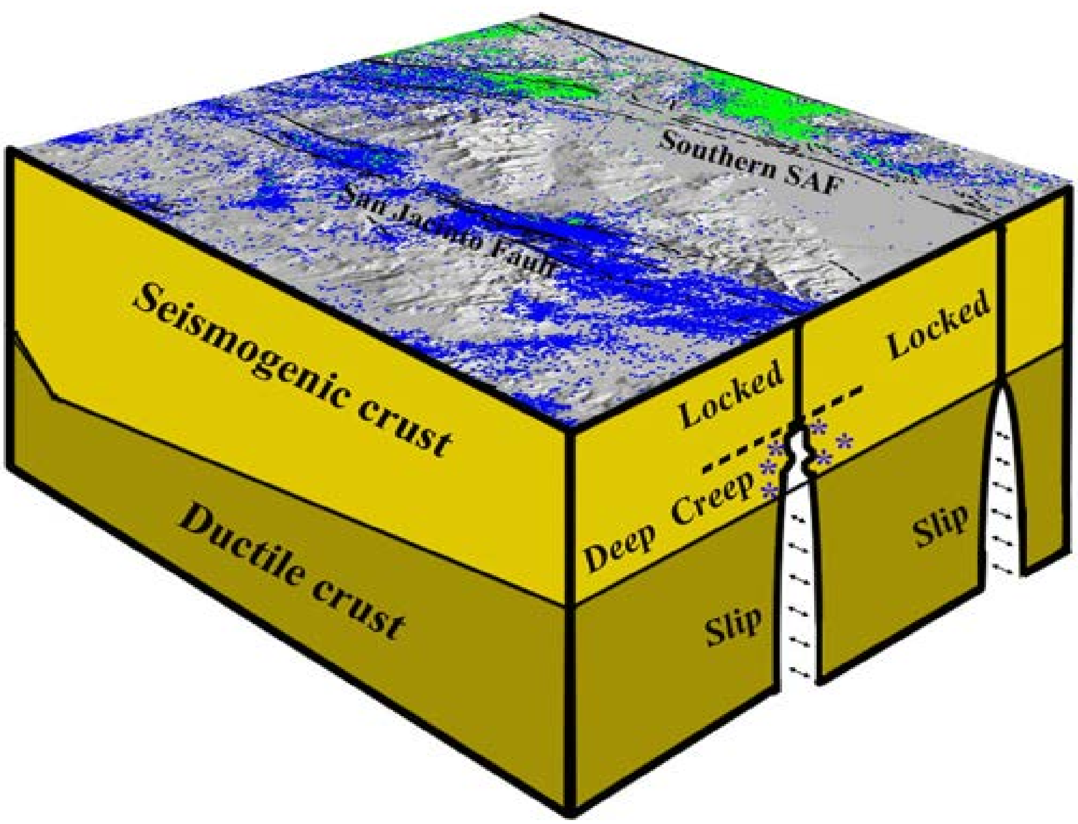
Viscosity characterizes the internal friction of the flow and is one of the key quantities determining the mechanical behavior of the mantle. Plate velocities, deep-earthquake source mechanisms, the stress distribution in subduction zones, and estimates of geochemical mixing time scales are all strongly affected by the pattern of convective flow which. in turn, is strongly influenced by the viscosity structure of the mantle. If the lower mantle has more than 10^4 times the viscosity of the upper mantle, convection would be confined to the upper mantle. If the viscosity contrast is not so sharp, whole mantle convection would occur instead.

38 What is meant by Creep?

Creep. Most solids will deform even at low stresses due to some fraction of atoms in a lattice having enough energy to jump into vacancies. (Maxwell – Bolzman law).
The distribution function f(E) is the probability that a particle is in energy state E. Note that M is the molar mass and that the gas constant R is used in the expression. If the mass m of an individual molecule were used instead, the expression would be the same except that Boltzmann's constant k would be used instead of the molar gas constant R.

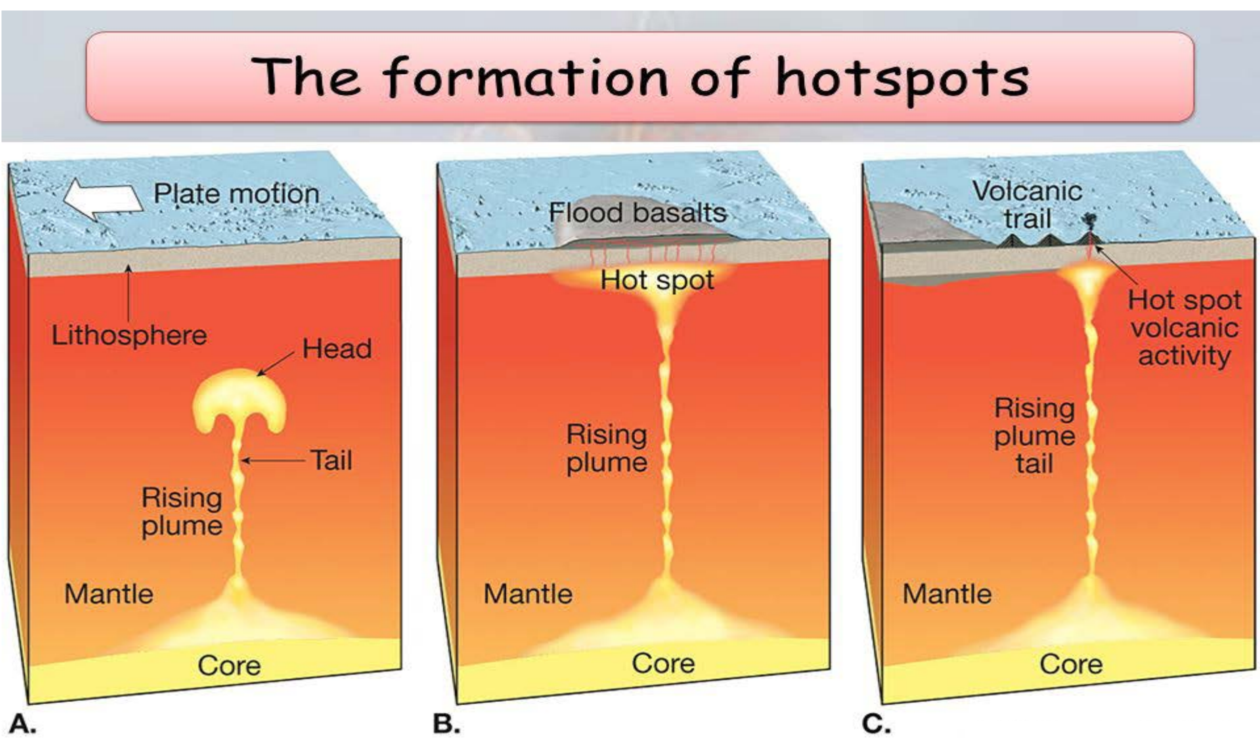
39 What are Types of Creep?

The most important types of creep are Plastic Flow, Dislocation or Power Law Creep and Diffusion creep. The regimes depend mostly on temperature, and in particular the fraction of the melting temperature (the homologous temperature).Plastic Flow takes place at low temperatures and is most important in the lower crust. Large strains possible, but large differential stresses are required as well.



40 What are Hot Spots?

A **hot spot** occurs because of the intense heat of the outer core. This heat radiates through the mantle bringing hot solid rock upward to the hot spot. These areas of rising solid rock are called mantle plumes. Because of lower pressure in the upper region of the mantle the rock begins to melt. Hot spots are located in the middle of plates : Plume of magma from the crust/mantle transition region wells up towards the surface. Builds up Shield Volcanos in the middles of the plates. As the plate slides over the fixed hot-spot, get long chains of shield volcanoes. Example: Hawaiian Island Chain, Big Island is the youngest & most active island, The further along the chain you go, the older the island.



41 Where do Magmas Come From?

Magmas are not likely to come from the only part of the Earth that is in a liquid state, the outer core, because it does not have the right chemical composition. The outer core is made mostly of Fe with some Ni, magmas are silicate liquids. In the ocean basins, magmas are not likely to come from melting of the oceanic crust, since most magmas erupted in the ocean basins are basaltic. To produce basaltic magmas by melting of the basaltic oceanic crust would require nearly 100% melting, which is not likely. In the continents, both basaltic and rhyolitic magmas are erupted and intruded. Basaltic magmas are not likely to have come from the continental crust, since the average composition is more siliceous, but more siliceous magmas (andesitic- rhyolitic) could come from melting of the continental crust. Basaltic magmas must come from the underlying mantle. Thus, with the exception of the continents, magmas are most likely to originate in the mantle from melting of mantle peridotite.

42 How many kinds of Meteorites found on the earth?

There are several kinds of meteorites that are found on Earth. One class are called **differentiated meteorites**. They are thought to represent a planetesimal(s) that was forming with Earth and the other planets. The planetesimal attained a large enough size to become partly/largely molten and segregate into silicate mantle and metallic core which then slowly cooled and crystallized. But the growing planet broke up because of the conflicting gravitational tugs of the Sun and Jupiter. The remains lie in orbit between Mars and Jupiter. Some of the pieces that fall to Earth are stony (mafic and ultramafic silicates) and some are iron. Iron meteorites are presumably the remains of the planetesimal's core.

43 Where is Shadow zone?

The region that extends from 103° to 143° from the ***epicenter*** of an ***earthquake*** and is marked by the absence of ***P wave***s. The P-wave shadow zone is due to the refraction of ***seismic waves*** in the liquid outer ***cor***e. The region within an arc of 154° directly opposite an earthquake's epicenter that is marked by the absence of ***S wave***s. The S-wave shadow zone is due to the fact that S waves cannot penetrate the liquid outer core.

44 What Causes the Earth's Magnetic Field?

There are two major problems.
First, it became apparent that the magnetic field drifts over time; the magnetic poles move.
Second, magnetic minerals only retain a permanent magnetism below their Curie temperature (e.g., 580°C for magnetite).
Most of the Earth's interior is hotter than all known Curie temperatures and cooler crustal rocks just don't contain enough magnetic content to account for the magnetic field and crustal magnetization is very heterogeneous in any case. The discovery of the liquid outer core allowed another hypothesis: the geodynamo. Iron, whether liquid or solid, is a conductor of electricity. Electric currents would therefore flow in molten iron. Moving a flowing electric current generates a magnetic field at a right angle to the electric current direction (basic physics of electromagnetism). The molten outer core convects as a means of releasing heat. This convective motion would displace the flowing electric currents thereby generating magnetic fields. The magnetic field is oriented around the axis of rotation of the Earth because the effects of the Earth's rotation on the moving fluid (coriolis force).

45 What does it mean by Cooling Earth theory?

We already know that over time, the Earth's crust cooled. The crust is thin, relatively, varying from a few tens of kilometers thick beneath the continents to less than 10 km thick beneath the oceans. The crust and upper mantle together constitute the lithosphere, which is typically km thick and is broken into large plates. These plates sit on the asthenosphere. The asthenosphere is kept plastic largely through heat generated by radioactive decay. This heat source is relatively small, but nevertheless, because of the insulating properties of the Earth's rocks at the surface, this is sufficient to keep the asthenosphere plastic in consistency.

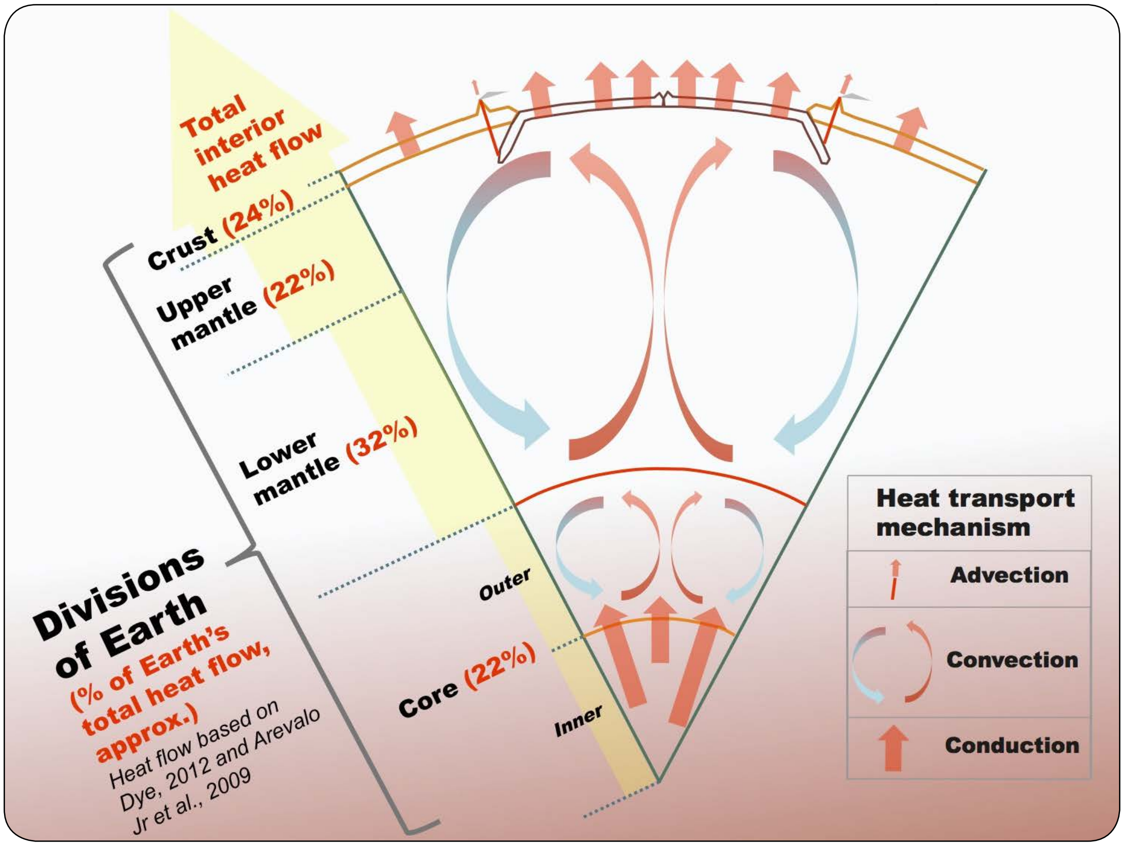
46 Where the Heat Sources in the Earth came from?

1. Heat from the early accretion and differentiation of the Earth still slowly reaching surface 2. Heat released by the radioactive breakdown of unstable nuclides.

47 What are types of Heat Transfer?

1. Radiation 2. Conduction 3. Convection

1. **Radiation** Requires transparent medium Rocks aren't (except perhaps at great depth)
2. **Conduction** Rocks are poor conductors Very slow
3. **Convection** Material movement (requires ductility) . Heat-induced expansion and buoyancy. Much more efficient than conduction



48 Is Heavy iron isotopes leaking from Earth's core?

Earth's molten core may be leaking iron. The new study suggests heavier iron isotopes migrate toward lower temperatures -- and into the mantle -- while lighter iron isotopes circulate back down into the core. This effect could cause core material infiltrating the lowermost mantle to be enriched in heavy iron isotopes. The boundary between the liquid iron core and the rocky mantle is located some 2,900 km below Earth›s surface. At this transition, the temperature drops by more than a thousand degrees from the hotter core to the cooler mantle. The new study suggests heavier iron isotopes migrate toward lower temperatures—and into the mantle—while lighter iron isotopes circulate back down into the core.

49 Show the temperature gradients in the Earth's outermost core?

Evidence that the outermost portion of the Earth's core is stratified is provided by earthquake data. The Earth's core is composed mainly of iron, but it is also known to contain a small amount of lighter elements, such as oxygen and sulphur. As the Earth's inner core solidified, it is thought to have expelled most of these light elements, which then migrated up through the liquid outer core, perhaps becoming concentrated in the outermost portion of the core, near the core/mantle boundary. The speeds at which seismic waves travelled through the outer core at different depths suggest that it is not a homogenous liquid, but that the uppermost 300 kilometers or so of the core is stratified, with the portion nearest the core/mantle boundary containing up to five per cent by weight light elements. This stratification would affect temperature gradients in the outermost core.

50 What heats the earth's core?

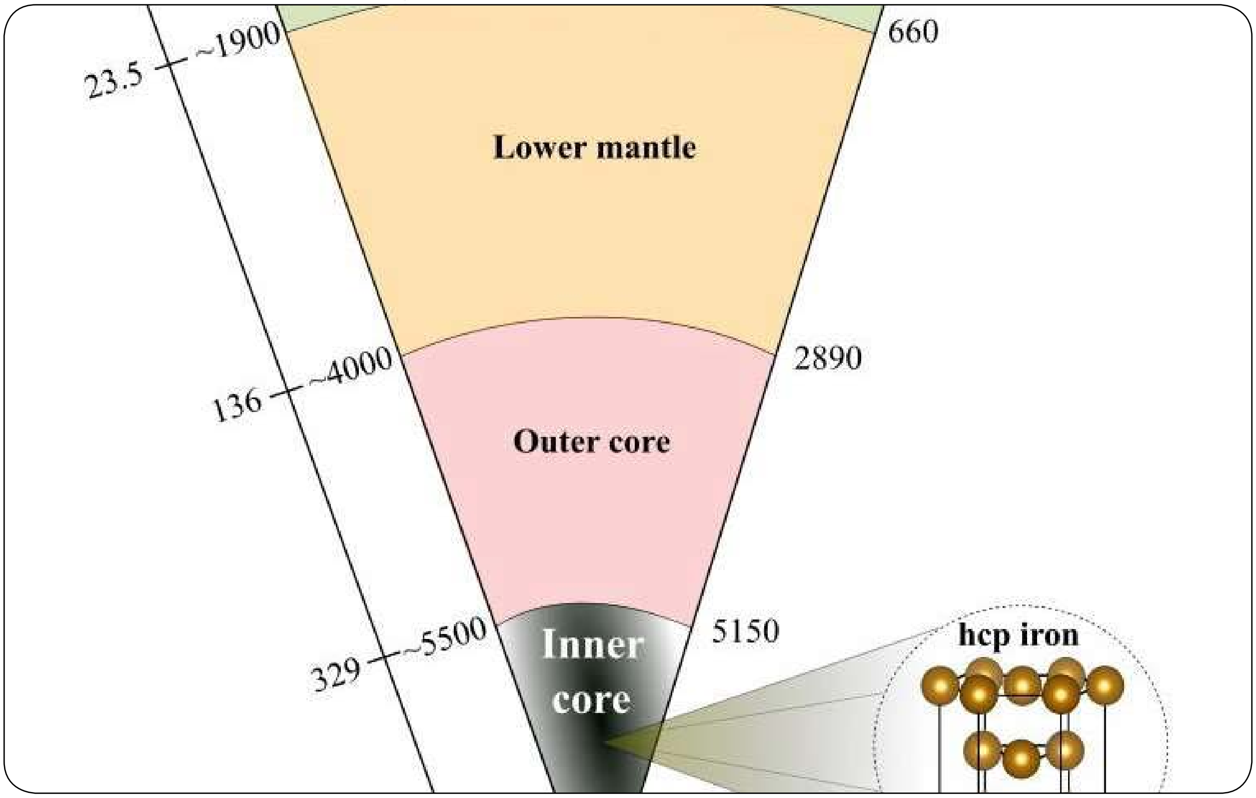
Most of Earth's heat is stored in the mantle, and there are four sources that keep it hot. First, there's the heat left over from when **gravity first** condensed a planet from the cloud of hot gases and particles in pre-Earth space. As the molten ball cooled, some 4 billion years ago, the outside hardened and formed a crust. The mantle is still cooling down. In a gravitational sorting process called **differentiation**, the denser, heavier parts were drawn to the center, and the less dense areas were displaced outwards. The friction created by this process generated considerable heat, which, like the original heat, still has not fully dissipated. Then **there's latent heat,** . This type arises from the core's expanding as the Earth cools from the inside out. Just as freezing water turns to ice, that liquid metal is turning solid—and adding volume in the process. "The inner core is becoming larger by about a centimeter every thousand years. The heat released by this expansion is seeping into the mantle. The vast majority of the heat in Earth's interior—up to 90 percent—is fueled by the **decaying of radioactive isotopes** like Potassium 40, Uranium 238, 235, and Thorium 232 contained within the mantle. These isotopes radiate heat as they shed excess energy and move toward stability. "The amount of heat caused by this radiation is almost the same as the total heat measured emanating from the Earth."

51 Does Earth's inner core is melting and freezing?

1. The **inner core** of the Earth is simultaneously melting and freezing due to circulation of heat in the overlying rocky mantle. The Earth's inner core is a ball of solid iron about the size of our moon. This ball is surrounded by a highly dynamic outer core of a liquid iron-nickel alloy, a highly viscous mantle and a solid crust that forms the surface where we live. Over billions of years, the Earth has cooled from the inside out causing the molten iron core to partly freeze and solidify. The inner core has subsequently been growing at the rate of around 1mm a year as iron crystals freeze and form a solid mass. The heat given off as the core cools flows from the core to the mantle to the Earth's crust through a process known as **convection.** Convection currents move warm mantle to the surface and send cool mantle back to the core. This escaping heat powers the geodynamo and coupled with the spinning of the Earth generates the magnetic field.

52 Is the Earth's inner core oscillating and translating anomalously?

The **inner core** is likely composed of the hexagonal close packed phase of iron and located at the center of the Earth at pressures between 329 and 364 GPa and temperatures of ~5000 to ~6000 K. A theoretical mineral physics approach based on the ab initio methods was adopted to determine the viscosity of hexagonal, close-packed iron at the extreme pressures and temperatures corresponding to the Earth's inner core. The results are found to deny geophysical observations of large fluctuations in the inner core rotation rate. The obtained viscosity also rules out inner core translation and provides support that the dynamics of the inner core may be governed by solid-state convection.



53 What is Seismic Anisotropy?

Seismological observations previously revealed that the velocity of seismic waves produced by earthquakes depend strongly on their direction when traveling through the inner core, a phenomenon known as **"seismic anisotropy**." This is due to the alignment of the iron crystals, something that may be caused by deformation inside the inner core. Although previous geodynamic modelings predict that the hemispherical asymmetry of the seismic anisotropy structure can be explained by "a translational motion of the inner core" and that variations in the length of a day can be explained by the gravitational coupling between the mantle and a weak inner core.

54 What controls viscosity of volcanic eruptions ?

The nature of volcanic eruptions and type of volcano produced is highly dependent on magma viscosity which is controlled by magma composition, temperature, volatiles and amount of crystallization.

55 What is the composition of Magma?

Magma Composition: Magmas rich in silica (SiO2) are typically formed at destructive plate boundaries, by partial melting of crustal rocks which are richer in silica than mantle rocks. Such magmas erupt as andesite and rhyolite lavas. The higher silica content makes these magmas highly viscous, so when eruption occurs it is usually explosive (e.g. Mt St Helens).Low-silica magmas are typically formed by partial melting of mantle rocks beneath mid-ocean ridges or above mantle plumes like in Hawaii. These magmas erupt as basalts and the lower silica content makes them far less viscous. Eruptions are generally effusive.

56 What is the Temperature of Magma?

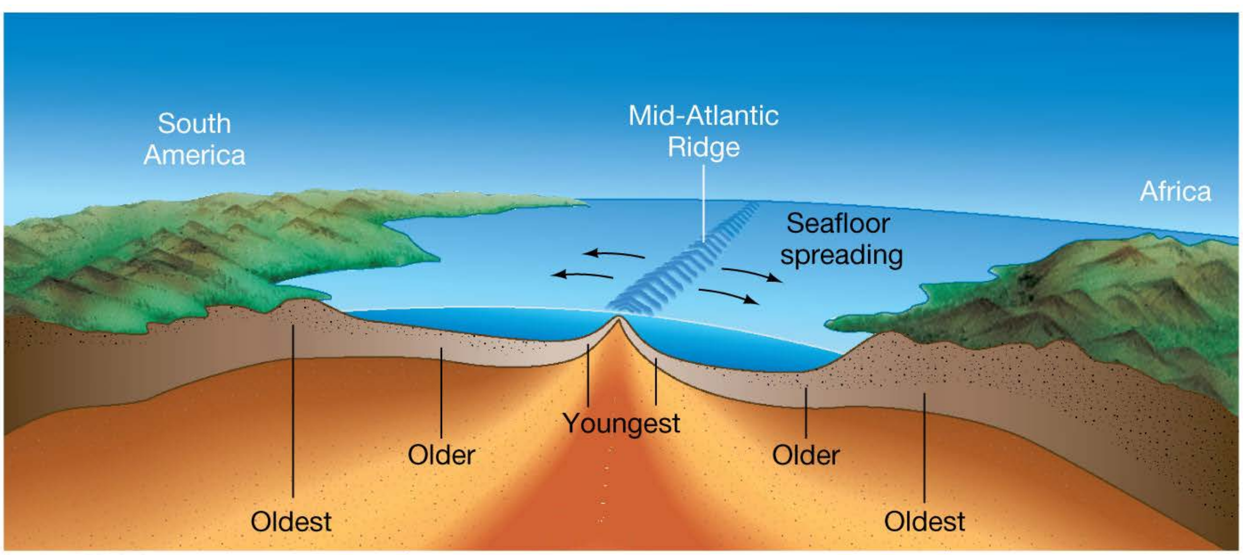
Magma temperatures reflect the melting points of their mineral components. Not surprisingly, magmas formed by partial melting of mantle rocks are much hotter – over 1200°C for some Hawaiian basalts. Rhyolites may reach the surface at temperatures of less than 800°C, and so have much higher viscosity.

57 **What is meant by NIFE?**

The central part of the earth is called Core. It has thickness of 2900 km. This layer is made of very hard mineral like Nickel (Ni) and iron (Fe) and so it is called **NIFE** (Ni + Fe). Here there is intense heat and pressure and this region is elastic and viscous in nature.

58 **What is the difference between SIAL and SIMA?**

The upper most layers is called the crust of the earth. It has a thickness of 50 km and thus the crust is made of two layers. Silica (**Si**) and Aluminium (**Al**) are the elements found in the first layer. Therefore this layer is called SIAL (**Si + Al**). This layer is also called 'Granitic layer.' Below the SIAL ties a layer called SIMA which composes of silica (**Si**) and Magnesium (**Mg**). This layer is also called Basaltic layer.

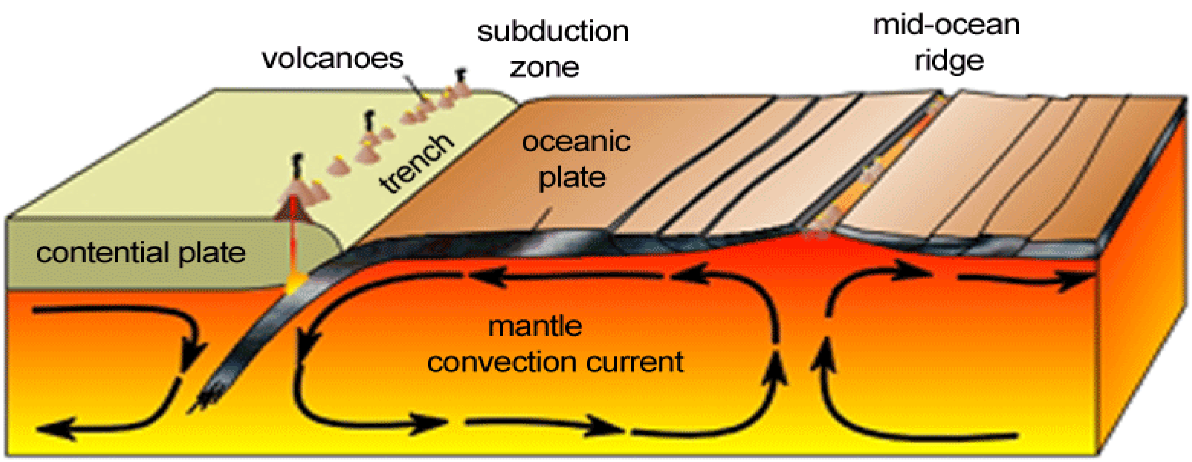


59 **What is the concept of Sea floor spreading?.**

Seafloor spreading is a geologic process in which tectonic plates—large slabs of Earth's lithosphere—split apart from each other. Seafloor spreading and other tectonic activity processes are the result of mantle convection. Seafloor spreading occurs at divergent plate boundaries. As tectonic plates slowly move away from each other, heat from the mantle's convection currents makes the crust more plastic and less dense. The less-dense material rises, often forming a mountain or elevated area of the seafloor. Eventually, the crust cracks. Hot magma fueled by mantle convection bubbles up to fill these fractures and spills onto the crust. This bubbled-up magma is cooled by frigid seawater to form igneous rock. This rock (basalt) becomes a new part of Earth's crust.

60 **What is convection in the Mantle?**

Convection currents transfer heat from one place to another by mass motion of a fluid such as water, air or molten rock. The Mantle is the largest layer of the Earth. The middle mantle is composed of very hot dense rock that flows like asphalt under a heavy weight. The movement of the middle mantle (asthenosphere) is the reason that the crustal plates of the Earth move. The middle mantle "flows" because of convection currents. Convection currents are caused by the very hot material at the deepest part of the mantle rising, then cooling and sinking again--repeating this cycle over and over. When the convection currents flow in the asthenosphere they also move the crust. Convection currents do not cause the movement of the earth as a whole, but only of the tectonic plates that make up the earth's crust.



61 **What evidence is there in favor of the idea that the earth's interior is very hot ? What temperatures are believed to occur there?**

Three observations that support the notion of high interior temperatures are :

- Measurements made in mines and wells indicate that temperature increases with depth.
- Molten rock from the interior emerges from volcanoes.
- The outer core is liquid, which means it must be at a high temperature.
- The present temperature distribution within the earth is believed to increase fairly rapidly in the mantle from less than 100 C at its top to perhaps 3000 C at the core boundary. The rise is slower in the core, and the temperature at the center of the earth is estimated to be in the neighborhood of 4200C , though this figure is far from being certain.

62 **What are Earth's radioactive isotopes?**

Four **radioactive isotopes inside Earth** account for about 50% of Earth's internal heat.These four isotopes generate 50% of Earth's radiogenic heat:

- Uranium-238 (^{238}U)
- Uranium-235 (^{235}U)
- Thorium-232 (^{232}Th)
- Potassium-40 (^{40}K)

The majority of internal heat transfer occur at mid-oceanic ridges. Whereas, the least amount of heat transfer is from the continental interiors.

63 **What is the source of energy of the dynamo mechanism responsible for the earth's magnetic field?**

The geomagnetic field arises from coupled fluid motions and electric currents in the outer core. The energy source is heat from the inner core that causes convection in the outer core which is influenced by the earth's rotation to give the flow patterns involved in the production of the magnetic field. The heat of the inner core is thought to be heat of fusion which is released by the continuing crystallization of the molten nickel-iron of the outer core as the inner core grows in size. Radioactivity in the inner core is another source of heat, but it is probably too small to account for the required energy.

64 **Why are the ocean floors so much younger than the continents?**

Owing to their low density and consequent buoyancy , the continental blocks are not forced down into the mantle in subduction zones but remain as permanent features of the lithospheric plates they are part of . The ocean floors, on the other hand, are continually being destroyed in such zones, as new ocean floors are deposited at midocean ridges.

65 **What is the chief factor that determines the viscosity of a magma, that is, how readily it flows? What kinds of landscapes are produced by volcanoes whose lavas have relatively high and relatively low viscosities?**

The greater the silicon content of a magma, the higher its viscosity and the less readily it flows. Highly viscous lavas usually produce steep conical mountains and, in general, a rugged landscape; less viscous lavas spread out to produce more even landscapes.

66 **What are the tree types of magma?**

Basaltic magma, Andesitic magma and Rhyolitic magma

67 **What forces drive plate tectonics?**

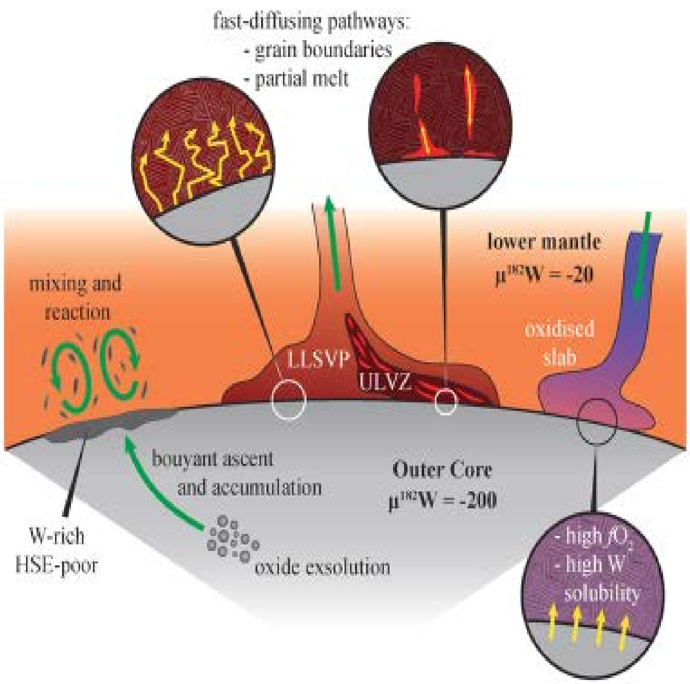
The theory is the heat of nuclear decay in the mantle and core. The heat produced in the interior of the earth is thought to be the driving force behind plate tectonics. That heat creates convections currents that can be observed in volumes of air and liquid is a known fact. There is substantial evidence that heat is produced in the core and mantle of the earth. The theory is that the heat from the interior of the earth creates convection currents in the semi liquid mantle. These convection currents push new crust up from the mantle at the divergent boundaries. The new crust creates pressure pushing the plates at the divergent boundary apart. At other places called convergent boundaries the crust that is being pushed by the emergence of new crust is pushed together. The idea that convection currents created by the heat in the interior of the earth drives plate tectonics is well established.

68 What are density differences in the asthenosphere caused by?

Temperature and pressure. As you go down under the earth's surface the temperature increase mainly because of the increasing pressure caused by overlaying mass of rocks. As you know temp is inversely proportional to density (which means when temp increase the density decrease) while pressure is directly proportional to density (when pressure increase density increase).

69 How are hot spots related to plate tectonics?

A moving tectonic plate over a hot spot will lead to over time a long chain of volcanoes. The best example for a hot spot is the hot spot in the pacific ocean, that hot spot that produces the long chain of volcanoes known as the Hawaiin islands. A hot spot as you may or may not already know is an area where lava rises from the earth to the surface. The lava cools down and forms a volcano. The hot spot itself never changes position, but the tectonic plates are constantly moving, so the volcano formed will "move" along with the tectonic plate to the direction where ever the tectonic plate is heading, but at the same time the hot spot doesn't stop producing lava. When the tectonic plate moves, another volcano is formed, and over time as the tectonic plate moves, that volcano moves towards the direction that tectonic plate is moving, and the process repeats. That's exactly what has been happening to the Hawaiin islands, and over time those formed volcanoes might descend deeper into the ocean until they are no longer islands.



Schematic cartoon showing possible processes for core-mantle chemical interaction.

70 **How do we measure seafloor spreading today?**

By satellite triangulation. The procedure does not differ much from your **GPS**. That is satellite triangulation. Commercial **GPS** can be precise to the nearest few meters.

Military systems, that are also used for scientific research, can be exact to a few centimeters.

71 **Describe the three processes that are responsible for the formation of magma.**

Magmas form from melting within the Earth. There are three types of melting: decompression melting, where magmas form when hot rock from deep in the mantle rises to shallower depths without undergoing cooling (the decrease in pressure facilitates the melting process); flux melting, where melting occurs due to the addition of volatiles such as CO_2 and H_2O;and heat transfer melting, where melting results from the transfer of heat from a hotter material to a cooler one.

72 **Why are there so many different compositions of magma? Does partial melting produce magma with the same composition as the magma source from which it was derived?**

Magmas are formed from many different chemical constituents. Partial melting of rock yields magma that is more felsic (silicic) than the magma source because a higher proportion of chemicals needed to form felsic minerals diffuse into the melt at lower temperatures. Magma may incorporate chemicals dissolved from the solid rock through which it rises or from blocks of rock that fall into the magma. This process is called assimilation. Finally, fractional crystallization can modify magma composition as minerals crystallize out of a melt during the cooling process, causing the residual liquid to become progressively more felsic.

73 **Why does magma rise from depth to the surface of the Earth?**

Magma rises toward the surface of the Earth because it is less dense than solid rock and buoyant relative to its surroundings. Buoyancy lifts magma upward through denser rock just as buoyancy lifts less dense Styrofoam upward through denser water. Magma also rises because the weight of the overlying rock produces pressure at depth that literally squeezes the magma upward.

74 **What factors control the viscosity of a melt, and how does viscosity affect the behavior of magma or lava?**

Viscosity in a melt is controlled by its composition (specifically, silica content) and temperature. Temperature affects viscosity because heat causes chemical bonds to break more easily. Therefore, a hotter lava of a given composition is less viscous than a cooler lava of the same composition. Magmas and lavas with higher viscosity are stickier and flow less smoothly.

75 **What factors control the cooling rate of a magma?**

The main factor that affects the cooling time of a magma is how fast heat transfers from the melt into its surroundings. The rate of heat transfer depends on the temperature of the environment in which cooling takes place, the shape and size of the molten mass, and the ability of the surroundings to extract heat.

76 **Why is the interior of the earth very hot?**

The temperature of the earth's core is so high mainly because "it contains radioactive materials which release heat as they break down into more stable substances."

77 How to delineate the boundary between Crust and Mantle?

The **crust** is distinguished from the mantle beneath it by a sharp difference in seismic wave velocity, which suggests a difference in the composition of the minerals involved, or in their crystal structure, or in both. The lithosphere is distinguished from the asthenosphere beneath it by a difference in their behaviors under stress: the lithosphere is rigid whereas the asthenosphere is capable of plastic flow.

78 What evidence is available from seismic wave studies that supports the existence of the asthenosphere?

The velocity of seismic waves lower in the asthenosphere than above or below it in the mantle, which suggests that its physical properties are different. The difference is consistent with a plastic rather than a rigid character for the asthenosphere material .

79 How is a plastic asthenosphere possible with a rigid lithosphere above it and a rigid mantle below it ?

The **asthenosphere** is plastic because it material is close to its melting point under the conditions of temperature and pressure found in that region of th mantle. Above the asthenosphere the temperature is too low, and below it the pressure is too high, for the material of the mantle to be plastic.

80 **Which person was the first to publish and publicize his view that a single continent existed about 300 million years ago?**

Alfred Wegener, a German, first published his theory back in 1912, and Du Toit and Holmes were two people who supported it. However, most people thought that his theory was ridiculous, and it met with skepticism. It was only until 20 or 30 years after his death (1930) that Wegener's theory was taken seriously. Francis Bacon was an English scientist, who was the first person to notice this, but he and others at the time (early 17th century) didn't take much notice of this, as the idea was absurd

81 **Asthenosphere: What is its major function?**

It enables plate tectonic movements. The asthenosphere is the upper part of the mantle. This viscous and soft layer supports the earth's crust, which consists of plates with different weights. These dip into the asthenosphere more or less until they find a relatively static poise (isostatic equilibrium). Because of the fluidity and the varied temperatures, convection currents form in the asthenosphere. These currents transfer magma between the upper and lower asthenosphere. Some of the hot magma elevated form the interior can penetrate the cracks of the crust, thus giving birth to volcanic lava. The name of this region comes from the Greek "asthenia" meaning weakness.

82 **Soon after the original theory, evidence of sea floor spreading was found. In which ocean was the evidence for sea floor spreading FIRST found?**

Atlantic. Although evidence was later found in the Pacific Ocean for sea floor spreading, the first evidence was found along the Mid-Atlantic ridge. Sea floor spreading involves molten magma rising to the surface and solidifying. This in itself wouldn't be enough to support the theory, but because the earth's magnetic field changes every 400,000 years or so, magnetic 'stripes' form, which are mirrored accurately on the opposite sides of the ridge. The rocks are aligned alternately towards the north and south poles.

83 **Hot spots can also cause volcanic activity. These develop because of a concentration of radioactive elements inside the mantle. Where do hotspots occur in a tectonic plate?**

Anywhere. Hot spots are unique in that they form volcanoes that aren't necessarily related to subduction or any other form of tectonic activity. A good example of hot spots is Hawaii. The Hawaiian islands were formed by hotspots in a process that is still ongoing. Kauai, the most northwesterly Hawaiian island, is the oldest island and was formed first, which is evidence that the Pacific plate is moving northwest. Loihi is the name of an underwater volcano in Hawaii, which is believed to be the next island that will be formed.

84 **What are the gases that are dissolved in magma?**

A whole range of different gases can be found dissolved in magma at depth, but the most common are water vapor (> 60% total gases), carbon dioxide (10–40% total gases) and sulphur as sulphur dioxide or hydrogen sulphide. Whether or not a gas stays dissolved in the magma or comes out of solution, depends on what the gas is, as well as the pressure, temperature and composition of the magma itself. Generally as magma rises to the surface, surrounding pressure on it decreases, and gas is able to come out of solution, or exsolve from the magma. Initially, exsolved gas bubbles are very small, and find it difficult to rise up through the magma, even though they are less dense, because the buoyancy force of the bubble is outweighed by the viscous forces of the magma holding it back. But as magma moves upwards gas bubbles expand as the pressure is further reduced, and many bubbles start to coalesce together forming larger collections of gas, making a foam with the magma. Eventually the amount of gas in the foam is much greater than the amount of magma, causing it to fragment into tiny pieces which are brought up with the rising gases.

85 What makes magma runny or viscous?

The viscosity (thickness) of magma is a major factor in controlling whether an eruption will be explosive or not. This is because viscous magma can trap exsolving gases causing a build up of pressure, whereas fluid magma allows gases to escape easily. The magma composition is a controlling factor which determines magma viscosity, in particular its silica content. Magma with a high silica content will be very viscous whereas magma with a low silica content will be very fluid. Silica-oxygen molecular bonds are very strong and can form long chains, which give the fluid viscous strength. If you melt the Earth's solid mantle at depth, you form a basic low silica content magma.

86 What are main processes which increase the silica content of a magma?

- Crustal Assimilation. The continental parts of the Earth's crust are predominantly made up of high silica content rocks. As magma moves up through the crust it can melt bits of the surrounding rock and assimilate them, becoming more silica rich.
- Magma ponding and evolution. If the magma stalls at depth and doesn't reach the surface it starts to cool very slowly within the crust. Certain iron rich (mafic) minerals within the magma can crystallize at high temperatures, so these minerals crystallize out first and then sink to the bottom. Over long periods of time, by slowly crystallizing the iron rich minerals out, the remaining fluid magma becomes relatively enriched in silica. This is known as magma evolution.

87 **What is difference of magma types In divergent and convergent plate boundaries?**

In **divergent plate boundaries** where two tectonic plates are moving apart, magma doesn’t have thick crust to travel through to get to the surface, and the path upwards is very easy so it doesn’t tend to pond and evolve. So at divergent plate boundaries magma tends to be very basic, with a low silica content and thus effusive splattery eruptions.

On the other hand, at **convergent plate boundaries** where two tectonic plates are moving together and one is forced under the other, magma which is formed has to move through a thick layer of continental crust, where it can assimilate crustal rocks and is likely to pond and evolve. Thus convergent plate margins tend to have higher silica content magma and more explosive eruptions.

88 **What types of igneous intrusions are?**

If magma does not reach the surface it can cool inside the Earth’s crust creating an igneous intrusion. There are several types of igneous intrusion. Sometimes magma moves upwards as a vertical sheet, cooling to form a vertical intrusion known as a dyke. Sometimes magma moves as a horizontal sheet, cooling to form a horizontal igneous sill. In some cases a horizontal sill can become inflated forming a blister like intrusion with a convex upper surface known as a laccolith. Sometimes whole large magma chambers just sit in the crust and cool down with no magma reaching the surface. These large deep intrusions are known as batholiths (or sometimes plutons).

89 Discuss the origin of Dynamo theory

Geophysical theory that explains the origin of Earth's main magnetic field in terms of a self-exciting (or self-sustaining) dynamo. In this dynamo mechanism, fluid motion in Earth's outer core moves conducting material (liquid iron) across an already existing weak magnetic field and generates an electric current. (Heat from radioactive decay in the core is thought to induce the convective motion.) The electric current, in turn, produces a magnetic field that also interacts with the fluid motion to create a secondary magnetic field. Together, the two fields are stronger than the original and lie essentially along the axis of Earth's rotation.

90 What is Adiabatic Compression of the Earth?

Adiabatic compression: the Adams Williamson equation. **Density** changes with depth in the earth because of the effects of changes in (1) pressure, (2) temperature, (3) composition, and (4) crystalline structure. In much of the earth, the last two factors do not change with depth, as appears to be the case within the lower mantle, or the outer core, or the inner core. Within these regions the density changes with depth mainly because the increase in pressure compresses the material. Temperature plays a secondary role within these regions, because the temperature does not change very much within those compositionally more homogeneous parts of the earth. Within those regions the temperature change as a function of depth may be close to **adiabatic**. The biggest discontinuity in the Earth's interior is the core/mantle boundary, because there we have a strong density contrast between the iron core (density between 10-11 g/cm^3) and the silicate mantle (density from 3.3-5.5 g/cm^3, increases with depth).

91 How Temperatures causes Rocks to Melt?

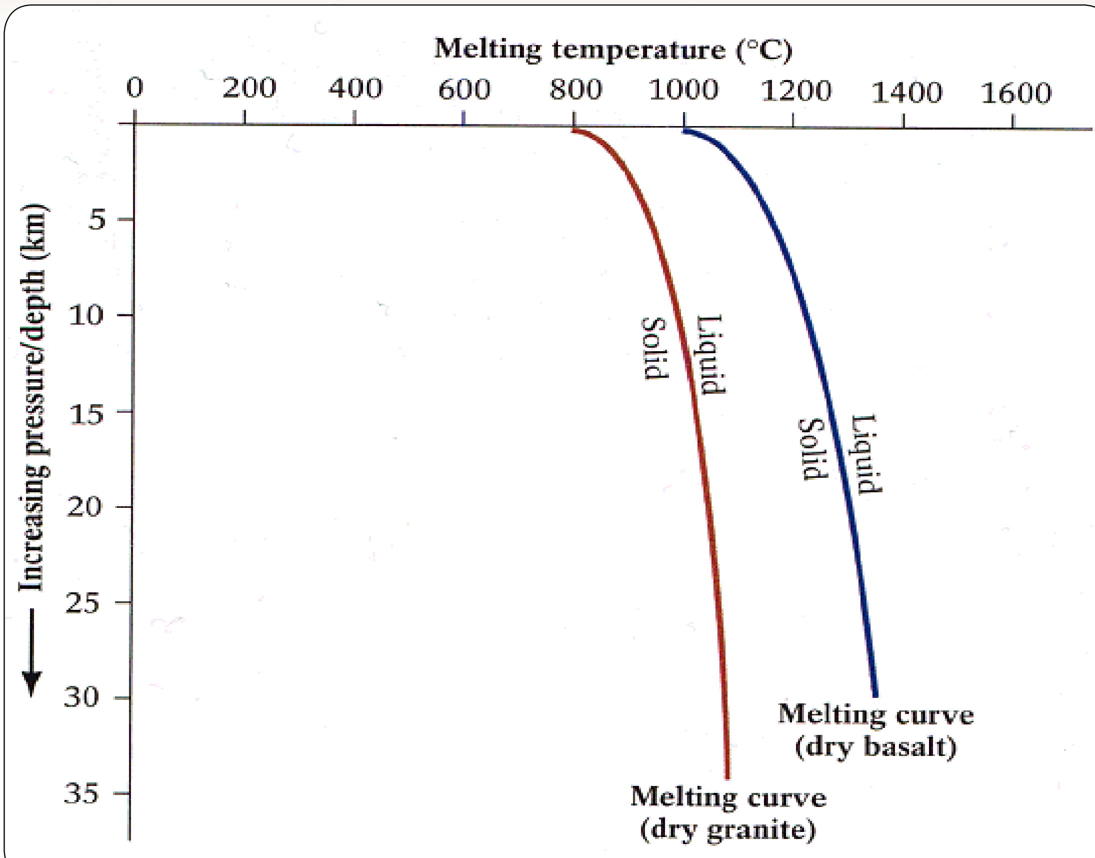
Heat (temperature) , pressure and water content. Temperatures in the Earth increase with depth, at a rate called the geothermal gradient. Temperatures rise rapidly from the surface (at about 30°C/km) and reach around 1000°C at a depth of just over 100 km. The geothermal gradient is lower, about 1.5-2°C/km, beyond 100 km and temperatures don't reach 1500 until around 500 km depth. The important sources of heat are:

- heat left over from the accretion of the planet more than 4.5 billion years ago and still emanating from the Earth's core
- heat released by the continuous decay of radioactive minerals
- frictional heat generated by fault planes and the movement of plates over the asthenosphere.

Magmas rising from greater depths are a form of extra heat and can produce melting in the rocks that they intrude. Such a situation may occur at subduction zones, where magma generated in the mantle rises to the base of the crust and penetrates into the crust.

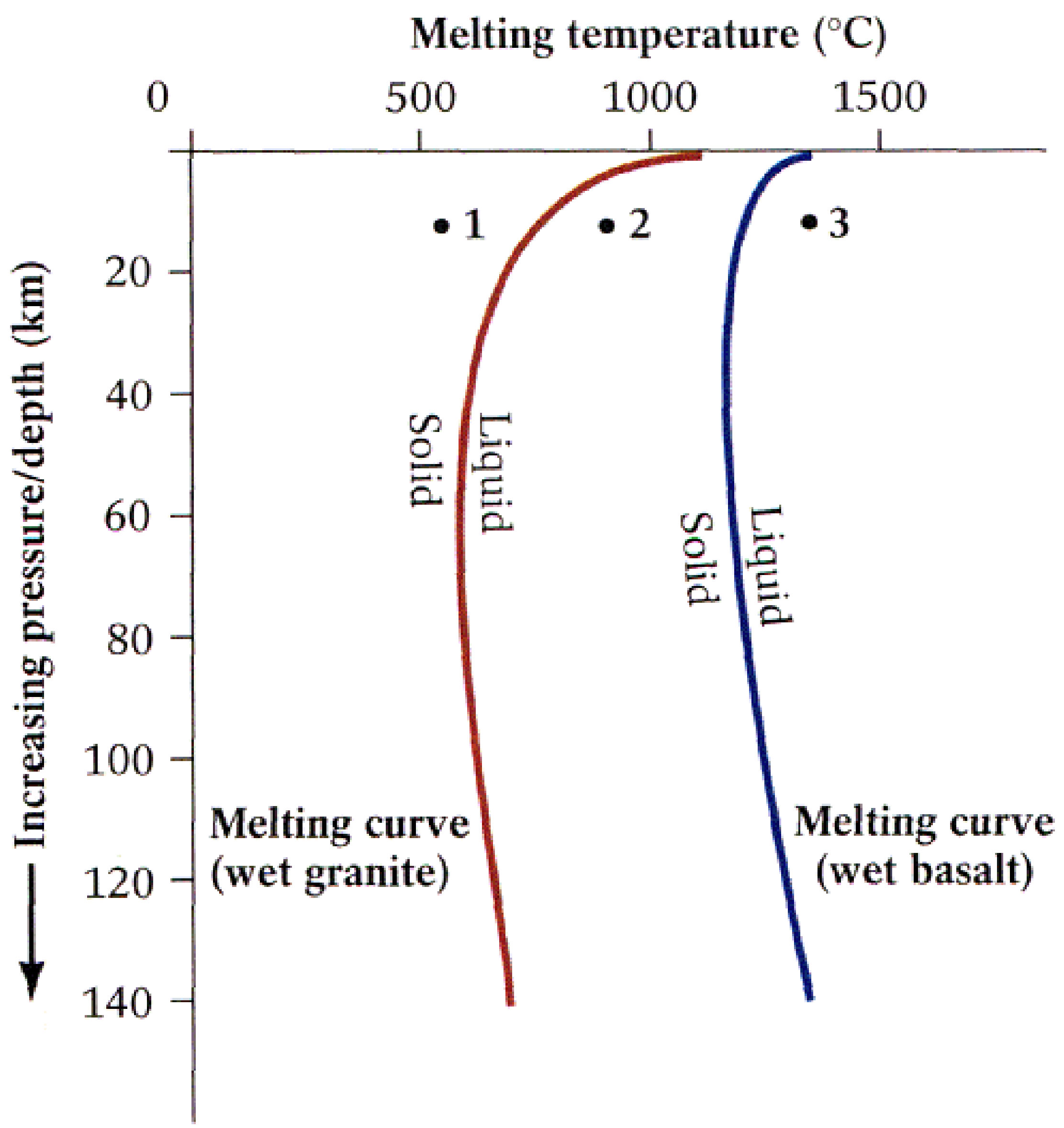
92 How Pressure causes Rocks to Melt?

Pressure increases with depth in a fairly predictable way (lithostatic) due to the rocks piled on top. The rate depends on the density profile of the Earth; near the surface it is about 30 kbars/100 km. For dry melts, the temperature required to commence melting becomes higher as pressure increases. High pressure holds the atoms closer together and it takes greater heat energy in order to vibrate, weaken and break their bonds. It is for this reason that the mantle is still solid, rather than liquid. The region where mantle temperatures and pressures get closest to the melting point of mantle rocks is **the asthenosphere**. If the pressure is reduced, therefore, a rock may start to melt even if its temperature remains the same. Such a situation occurs at divergent margins, where pressure is reduced as the overlying crust is stretched and thinned. Mantle plumes may also undergo melting as they rise towards the surface. This is known as **decompressional melting**.



93 How Water causes Rocks to Melt?

If water is present, even in small amounts, the temperature at which a rock will melt will be considerably lowered. The dipole nature of the water molecule weakens the minerals bonds, allowing lower temperatures to vibrate and break the bonds. Consequently, hydrous minerals, that is, those that contain (OH) in their structure, melt at lower temperatures. Furthermore, whereas dry rocks require greater temperatures to melt with an increase in pressure, wet rocks initially become less resistant to melting at higher pressures. This is because high pressure increases the bond-breaking ability of water. An increase in pressure will also allow a greater amount of water to be dissolved in the melt, decreasing the temperature at which the onset of melting occurs. At subduction zones, the dehydration of the subducting plate allows water to ascend into the overlying mantle and producing melting.



Melting temperature (°C)
0
500
1000
1500
Increasing pressure/depth (km)
20
40
60
80
100
120
140
1
2
3
Solid
Liquid
Solid
Liquid
Melting curve (wet granite)
Melting curve (wet basalt)

94 What are factors controlling viscosity of the Magma?

The **Viscosity** of the magma (that is, how easily it flows) is governed by the silica content, the presence of cations, temperature, and the amount of volitiles present. The higher the silica content, the larger the polymerised groups and the more viscous the magma. Acidic lavas can be tens of thousands of times more viscous than basic lavas. Viscosity increases as magma cools, therefore lavas tend to slow their advance further from the volcano. The ability to flow also affects the ability of the magma to release gasses. The greater the viscosity, the harder it is for gas to escape. Thus, violent eruptions generally are more likely with high silica magmas.

95 What are evidences which support the liquidity of the outer core?

The **outer core**, which has been confirmed to be liquid (based on seismic investigations), is 2300 km thick, extending to a radius of ~3,400 km. In this region, **the density** is estimated to be much higher than the mantle or crust, ranging between 9,900 and 12,200 kg/m^3. The outer core is believed to be composed of 80% iron, along with nickel and some other lighter elements. Denser elements, like lead and uranium, are either too rare to be significant or tend to bind to lighter elements and thus remain in the crust. **The outer core is not under enough pressure** to be solid, so it is liquid even though it has a composition similar to that of the inner core. The temperature of the outer core ranges from 4,030 °C in the outer regions to 5,730 °C closest to the inner core. Because of its high temperature, the outer core exists in a low viscosity fluid-state that undergoes turbulent convection and rotates faster than the rest of the planet. This causes eddy currents to form in the fluid core, which in turn creates a dynamo effect that is believed to influence Earth's magnetic field. The average magnetic field strength in Earth's outer core is estimated to be 25 Gauss , which is 50 times the strength of the magnetic field measured on Earth's surface. The freezing of liquid iron into crystalline form at the inner core boundary produces residual liquid that contains more light elements than the overlying liquid. This in turn is believed to cause the liquid elements to become buoyant, helping to drive convection in the outer core.

96 What are evidences which support the solidity of the inner core?

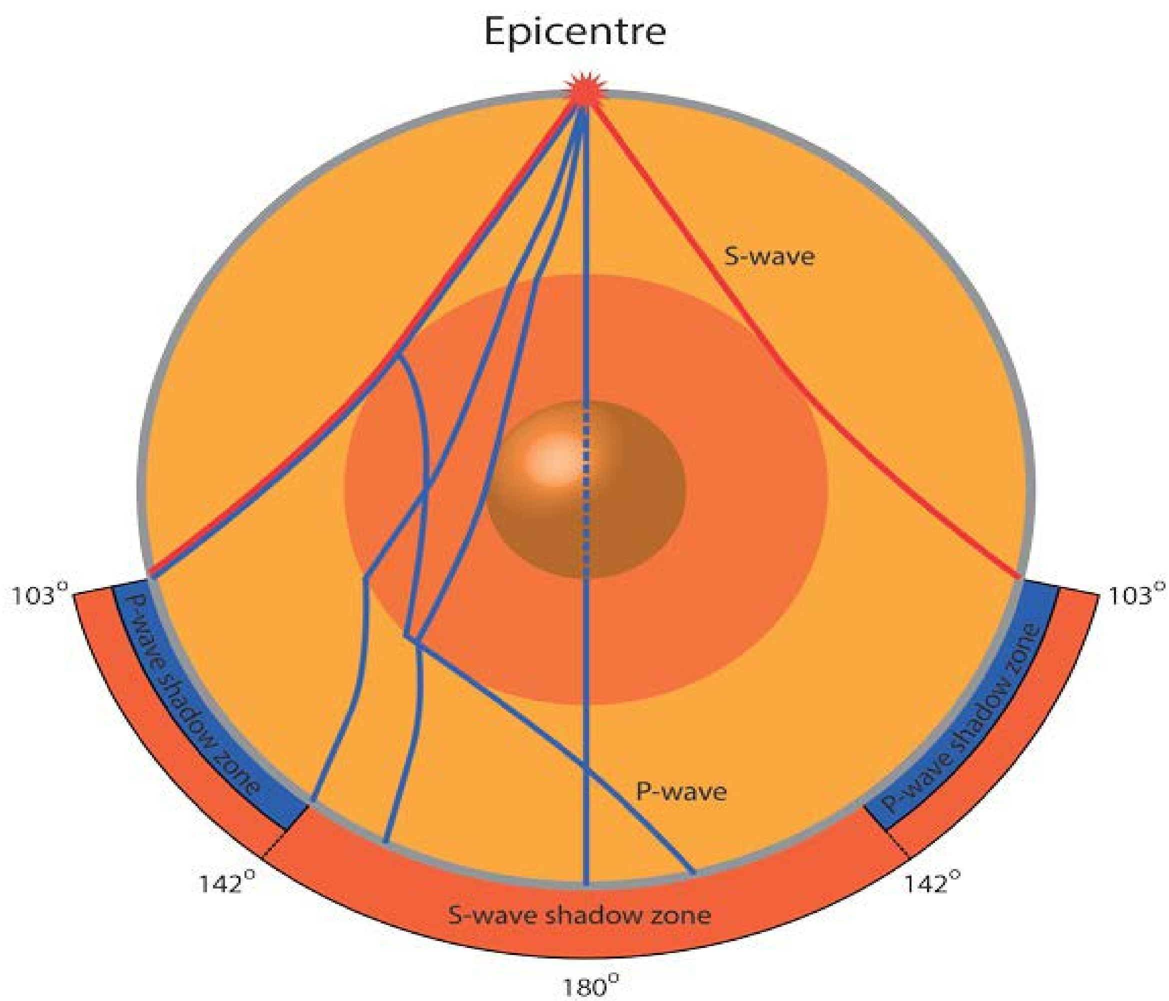
Like the outer core, the inner core is composed primarily of iron and nickel and has a radius of ~1,220 km. **Density** in the core ranges between 12,600-13,000 kg/m^3, which suggests that there must also be a great deal of heavy elements there as well – such as gold, platinum, palladium, silver and tungsten. The temperature of the inner core is estimated to be about ~5,400 °C. The only reason why iron and other heavy metals can be solid at such high temperatures is because their **melting temperatures dramatically increase at the pressures** present there, which ranges from about 330 to 360 gigapascals. Because the inner core is not rigidly connected to the Earth's solid mantle, the possibility that it rotates slightly faster or slower than the rest of Earth has long been considered. By observing changes in seismic waves as they passed through the core over the course of many decades, scientists estimate that the inner core rotates at a rate of one degree faster than the surface. Recent discoveries also suggest that the solid inner core itself is composed of layers, separated by a transition zone about 250 to 400 km thick. This new view of the inner core, which contains an inner-inner core, posits that the innermost layer of the core measures 1,180 km in diameter, making it less than half the size of the inner core. It has been further speculated that while the core is composed of iron, it may be in a different crystalline structure that the rest of the inner core. What›s more, recent studies have led geologists to conjecture that the dynamics of deep interior is driving the Earth›s inner core to expand at the rate of about 1 millimeter a year. This occurs mostly because the inner core cannot dissolve the same amount of light elements as the outer core.

97 How does physics change inside the Earth?

One notable difference happens at the core. Specifically, the core rotates faster than the Earth. It is 1500 miles wide and has a layer of liquid metal that surrounds it, a buffer that enables the core to move and shift. There was a lot of argument in the science community as to how much faster this rotation was than the Earth's, but they were able to pin it down to the core rotating an extra .3–5 degrees faster each year.

98 **How are we certain the Earth has an iron core if the deepest hole drilled is only 40,000+ feet deep?**

First, we know Earth's overall density, and we know the density of the crust and mantle from rock samples. Something pretty dense is in the core. Second, we know there's a planetary magnetic field. Third, we have a good sampling of the composition of other objects in the solar system. Iron is common in rocky asteroids and other terrestrial planets. Fourth, rather importantly, we've mapped the crust, mantle, and core with earthquakes standing in for ultrasound.



99 Will Earth run out of heat?

The percentage of heat from the **sun** to the earth is **one one-billionth** of the Sun's total energy output actually reaches the Earth. Of all the energy that does reach Earth, slightly less than **34 percent** is reflected back to space by clouds. The Earth itself reflects another **66 percent** back to space.
By the way, while the heat energy produced inside Earth is enormous, it's some 5,000 times **less** powerful than what Earth receives from the sun. The sun's heat drives the weather and ultimately causes erosion.

100 Why is Earth's internal heat so important?

The Earth's internal heating causes plate tectonics and the planetary magnetic field. The former gives us volcanoes and new mountain ranges which brings to the surface many chemical elements necessary for life to continue on land- where otherwise rainfall over millions of years would leach them out of he soils and into the sea. The latter protects us from cosmic rays- random atomic nuclei coming from deep space at almost the speed of light- and also from the solar wind which otherwise would have stripped Earth of most of its atmosphere. As well as radio activity producing this heat there is also friction from the tidal deformation due to the Moon's gravity and the latent heat released at the bottom of the liquid core as iron, etc, freezes onto the solid inner core. I believe this latter process keeps the core at a particular temperature and will continue to do so until the freezing is complete.

101 **Why do the pressure and temperature keep on increasing with depth inside Earth?**

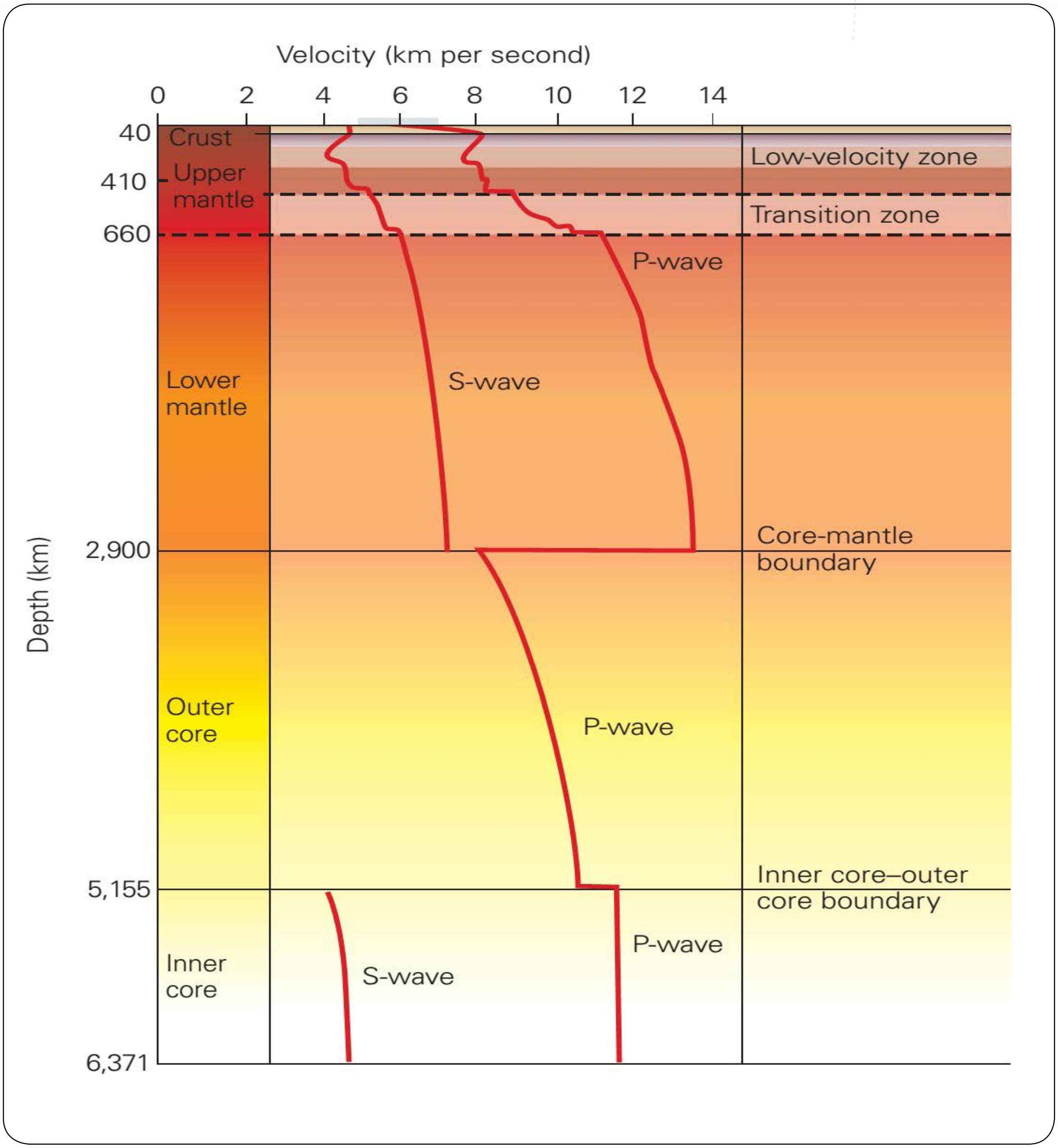
The pressure is due to the aggregate weight of the overlying material. Simple to understand in the ocean, where the density of the water is fairly uniform. Not quite so simple in the solid earth, whose density is more variable. But still: you go deeper, there is more stuff weighing down on you, so the pressure is higher. The gravitational compression alone would account for temperatures being higher deep with the planet than at the surface, but in addition, there is still some amount of internal heating that results from radioactive decay within the earth. It is also possible that the heat generated by the collisions that formed the planet has not fully dissipated.

102 **Why is gravity zero at the center of earth?**

Yes, the gravitational force at the earth's center is zero. The further you go away from earth, lesser the gravitational force you experience. And closer you come to the surface of earth, more gravitational force acts on you. This is because of the inverse square law. But as you keep on moving towards the center of the earth, the gravitational force acting, by the virtue of earth's mass, on you will gradually abate and ultimately go zero once you reach the earth's center. Not because there is no gravitational force down there but because at the center you will be completely surrounded or enveloped by earth, as a result you will be pulled by equal forces in all directions. Hence all the gravitational force lines will cancel out each other leaving you with zero net force.

103 **Draw across section from the surface to the core showing variations of seismic velocities with depth?**

- **Upper mantle :** P waves 8-10 km/s; S-waves 4-6 km/s
- **Lower mantle :** P-waves 12-14 km/s S-waves 6-7 km/s
- **Outer Core :** P-waves 8-10 km/s, S-waves- Do not propagate
- **Inner Core :** P-waves 11 km/s, S-waves 5 km/s


Velocity (km per second)
0
2
4
6
8
10
12
14
Depth (km)
40
410
660
2,900
5,155
6,371
Crust
Upper mantle
Lower mantle
Outer core
Inner core
Low-velocity zone
Transition zone
Core-mantle boundary
Inner core–outer core boundary
P-wave
S-wave
P-wave
P-wave
S-wave

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Al-Amri's Encyclopedia
of Earth Sciences

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Qualifications & Experiences

- Professor of Geophysics at King Saud Univ. My research interests are in the area of crustal structures and seismic micro zoning of the Arabian Peninsula. My recent projects involve also applications of EM and MT in deep groundwater exploration and geothermal prospecting.
- PhD in Geophysics (1990) from the University of Minnesota, USA
- Supervisor of the Seismic Studies Center, KSU.
- Supervisor of the Groundwater Exploration Chair at KSU.
- Supervisor of the Geothermal Energy Center at KSU.
- President of the Saudi Society for Geosciences.
- Head of the Department of Geology & Geophysics, KSU.
- Founder & Editor-in-Chief of the Arabian Journal of Geosciences (AJGS).
- Team Leader of the Scientist Fellowship Program with Oregon State University, USA.
- Team Leader of the Scientist Fellowship Program with Max Planck Institute, Germany.

Consultancies & Memberships

- Consultant of King Abdulaziz City for Science and Technology.
- Consultant of the Saudi Geological Survey
- Consultant of Military Survey & Civil Defense
- Advisor to King Abdullah City for Atomic and Renewable Energy.
- Advisor to the Nuclear and Radiological Resources Authority.
- Principal researcher in several research projects supported by King KACST & Aramco.
- Principal researcher in projects supported by the US Department of Energy, the University of California, Lawrence Livermore National Lab., Universities of Alabama, PSU, OSU, USA
- Member of the American Seismological Society.
- Member of the American Geophysical Union.
- Member of the European Union of Geologists and Engineers.
- Member of the Saudi Building Code Committee.
- Member of the Gulf Seismic Forum (GSF).
- Member of the Earthquake Risk Mitigation Committee of the Eastern Mediterranean Countries (RELEMR)
- Among the list of outstanding Arab achievers by Rivacimento International.
- Among the Who's Who in Asia for Scientific Excellence.
- On the Who's Who in the World List of Scientific Contributions.

Scientific Publication

- Published more than **200** scientific papers in peer-reviewed journals
- Authored **35** scientific books
- issued a digital encyclopedia of earth sciences of **14** volumes and **107** scientific files.

Projects

- Completed **40** local projects, **16** international projects and **74** technical reports.

Conferences

- Participated in more than **125** local and international conferences & **75** specialized seminars and workshops

International Cooperation

- Principal researcher in **13** American and German working groups.

Prizes

- Received Almarai Prize for Scientific Creativity in 2005.
- Received the Golden Excellence Award from KACST in 2006.
- Received Abha Appreciation Award for Scientific Contributions in 2007.
- Received King Saud University Award for Scientific Excellence in 2013.
- Received the American Geophysical Union Award for International Cooperation and Research Activities in 2013.
- Received the Sultan Qaboos University Award for Scientific Contributions in 2013.
- Received the King Saud Prize for inclusion of the Arab Journal of Geological Sciences in the ISI list.
- Received the award for the best editor-in-chief of the scientific journal of the year 2017 & 2018 from the German publisher Springer.
- Recipient of the 2018 Albert Nelson Marquis Lifetime Achievement Award from Who's Who
- Received **85** honorary shields and certificates of appreciation from Saudi Arabia, Oman, Kuwait, UAE, Jordan, Egypt, Tunisia Algeria, Germany and America

موسوعة العمري في علوم الأرض

Al-Amri's Encyclopedia of Earth Sciences

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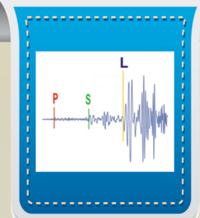
4. التركيب الداخلي للأرض
5. المعادن والتعدين
6. المد والجزر



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14. التغيرات المناخية والاحتباس الحراري
15. التشجير التحديات والحلول
16. الانزلاقات والانهيارات والفيضانات
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