

ENVS 1060 Final exam study guide

Unit 1 Notes:

Unit 1: Origin of the Solar System and Universe

Origin of the Universe

- Doppler Effect

-- apparent compression or expansion of energy waves related to relative motion between source and receiver

-- stars: red light wavelength is longer therefore redder stars are farther away (moving faster away than others, supporting spreading of Big Bang)

- black hole – density of matter and gravity so great that light can't exit

- *13.7 Billion Years Ago* – age of the universe/initiation of Big Bang from instability of black hole

- bomb blast behavior (outsides=fast, insides=slow), lost neutral status

-- electrons formed, protons - formed nucleus of *Hydrogen*

The First Stars

- rotating, contracting particle clouds formed heavier elements through fusion, eventually became stars

-- particles collided changing kinetic energy to heat... heat energy grew....

- *Fusion* of protons occurred – two atomic nuclei combining to form heavier atom

-- only occurs naturally in stars, planets are not big/hot enough

-- $H + H = He + \text{gamma ray}$; $2He$ formed Be ; Be/H formed C etc....

Supernovas and the Formation of the Solar System

- Supernovas

-- *11 Billion Years Ago*: original stars became unstable and exploded into supernovas

-- clouds of heavier elements formed by stars were scattered

-- one of the clouds became our solar system

- Sun: central cloud generated enough heat for fusion allowing formation

- Planets: smaller clouds around the central generated enough heat to melt into planets

- Moons/Asteroids: even smaller clouds, insufficient heat to melt entirety, smaller bodies

- the sun is a small star with insufficient matter to increase heat, cannot explode into supernova, will cool

Formation of the Earth

- *4.5 Billion Years Ago*: started as a molten ball on iron, nickel silicon, oxygen etc.

- lighter elements rose to surface (He, Kr, Ne), heavier elements sank under gravity (Ni, Fe, Al, Mg)

- earth's layers formed by element densities

Radiation and Heat

- 3 sources of earth's heat:

-- Primeval left from formation

- Fission reactions – radioactive decay from the splitting of an atomic nucleus into two lighter
- Solar – from the sun’s fusion (drives wind, waves, erosion etc.)
- Natural fission reactions within earth- U-238 releasing alpha and daughter particle
- calorie* – Energy required to raise 1g of water by 1°C (sea level)

Development of Atmosphere and Life

- first NO FREE oxygen, only methane and carbon dioxide
- after 500 Million Years, lost surface heat allowed rocks and minerals to form and create crust
- crystallization from volcanism led to water vapor, methane, sulphur dioxide and ammonia
- cyanobacteria* in Archean rocks dated at 3.5 Billion Years – single celled bacteria
 - photosynthetic- use solar E and CO₂ to produce O₂
 - changed the atmosphere into oxygen-rich
- water vapor from volcanism created oceans (3 Billion Years)

3Unit 2 Notes

Unit 2: Earth Structure

Earth Structure

- spherical layers visible:

ATMOSPHERE (multi-layered) → HYDROSPHERE (water portion of Earth) → LITHOSPHERE (rocky shell)

- Earth’s density estimated to be an average of 5.15 g/cm³ is the highest of all planets, surface rocks are half as dense therefore we know the center is different
- Seismology (study of seismic waves) predicts densities by measuring the velocity of an energy wave. Denser materials transmit energy waves faster. Boundaries between two densities cause refraction and reflection of the energy
- the amount of time it takes for an energy wave to reach a receiver (geophone) leads to predictions of *discontinuity* locations (boundary between two layers of different density)
- base of crust/top of mantle(Mohorovicic) → 17 km down below continents, 5-10 km below ocean floor
- P(primary)-waves- fastest
- vibrate parallel to transmission through both solid and liquid
- “slinky”, energy transmitted through compressions and extensions
 - S(hear)-waves
- vibrates in perpendicular plane to transmission through solid
- “rope”, energy transmitted from one end to another up and down
 - 2900 km down s-waves are lost meaning the material is like a fluid (outer core), p-waves slow down
 - near center p-waves speed up again

THIN CRUST (5-50 km)→ MANTLE (2900 km) → LIQUID OUTER CORE → SOLID INNER CORE

- lithosphere – crust and upper mantle (5-200 km) – solid rock

-asthenosphere – lower mantle - easily deformed

Internal Composition

- meteorites – reflect internal composition of former planets and indicate internal composition of Earth

IRON – metallic iron alloyed with magnesium, similar to Earth's Core

STONE – magnesium and iron silicates, similar to Earth's Mantle

○ CHONDRITES – contain small spherical bodies (chondri), similar to whole Earth

○ ACHONDRI – no chondri and variable composition – similar to Earth's crust

- iron similar to core therefore derived from planet with a similar core to earth

- chondrites similar to whole earth therefore derived from an unsuccessful/undifferentiated planet

- achondrites similar to crust therefore derived from planets similar to earth

- this can be tested by taking similar proportions from earth and making them undergo treatment mimicking Earth's interior and comparing the final product to the meteorites

Internal Heat

- *geothermal gradient* - average increase below surface of 30°C/km

· 192 000°C at center predicted

· every known material would be molten at this T but core is solid so it is wrong

- 4000-5000°C predicted, non linear, never exceeds

- CONDUCTION – through rocks it slows down heat carried to surface

- CONVECTION – much faster, transports heat to surface through hot magma that cools when it gets closer to the surface and heat is lost from EARTH

Unit 3 Notes

Lithosphere

The rigid outer layer of the earth. It consists of the uppermost rocky mantle and overlying crust

The lithosphere is broken into 7 major plates and many smaller ones

Small plates include an entire continents plus a large area of the sea floor (north American plate)

Plates are constantly in motion and continually changing in shape and size

7 major plates on earth

Pacific plate, North American plate, South American plate, African plate, Antarctic plate, Eurasian plate, Indo Australian plate

Continental drift

Alfred Wegener proposed the idea

He said there was a supercontinent called Pangaea which began breaking apart 200 million years ago

he said continents drifted to their current position plowing thru oceanic crust

Support for evidence: fit of continents (breakup of Pangaea)

Most plates include continents as well oceans,

All oceans – Pethalassa

All continents – Pangaea

150 million years ago Pangaea broke into Laurasia(North) and Gondwanaland (south)

Australia broke away from Antarctica, India separated from Africa,

fossil evidence

Fossil of reptile Mesosaurus are found in Africa and South America. If this animal was capable of swimming the Atlantic Ocean then the remains should be everywhere, but they are not. Eg same with other animals.

rock types and structures

mountain ranges with similar rock types structures and age are found on both sides of the Atlantic.

climatic evidence.

Paleoclimatic evidence suggest ancient glaciation which are now tropical. Suggest that continents were once joined. Areas show evidence of ancient ice sheets.

Problem with Continental Drift

- Alfred Wegener's work was received with strong criticism and even ridicule.
- Main objection was the inability of the hypothesis to provide a mechanism capable of moving continents across the globe

Paleomagnetism

- Systematic survey flights over the Atlantic ocean revealed magnetic anomalies on the ocean floor.
- They found these stripes to be symmetrical along a line that ran thru Iceland.
- Iron rich magnetic minerals show us whether they were formed under normal magnetic periods or reverse magnetic periods.

Ocean Floor Exploration

- Scientists were able to sample and date rocks on the bottom of the Atlantic Ocean.
- This lead to new information
- Younger rocks are found to be closer to the middle of the ocean
- Older rocks are further away from the middle
- Continental rocks are much older than oceanic rocks

Ocean Spreading

- Fred vine and DH Mathews
- Magnetic evidence – alternating normal and reverse stripes on the ocean floor

- Age of rocks- oceanic rocks are much younger than continental rocks
- Oceanic rocks increase in age away from the mid ocean ridge
- New material pushes older, recently formed crust away from the ridge. This creates ocean spreading.

Plate Tectonics

The Earth is a closed system and it does not grow any larger – where does the material for the newly forming lithosphere come from and where does the old lithosphere go
The earth recycles the material.

Lithosphere forming

Oceanic lithosphere destroyed (occurs in subduction zones because it's more dense than continental lithosphere)

Entire cycle of the movement, creation and destruction of plates is known as plate tectonics
Geologic events like earthquakes, tsunami and volcanic eruptions are related to plate tectonics. Mountain ranges are formed where plates collide.

Rock Cycle

- Concept used to describe the origins of igneous, metamorphic, and sedimentary rocks, their interrelationships and processes that form them.

Unit 4 Notes

Mineral is natural occurring, inorganic solid with regularly repeating internal structure and a definite chemical composition

Minerals are the building blocks of rocks. (quartz, hornblende, orthoclase feldspar) – these minerals commonly make up a granite rock.

Atoms (elements) are composed of protons, electrons and neutrons.

Minerals are composed of elements

Rocks are an agglomeration of minerals

Earth's crust is composed of rocks.

In order to understand minerals, we need to examine each building block.

Introduction to Minerals-

- All matter is composed of atoms.
- A substance composed of only one type of atoms is called an element
- An element is composed of a single type of atom. This atom cannot be chemically split into anything smaller but radio active fission reaction can split the atom.
- Elements differ from one another in size and weight
- This is because the atom can further be subdivided into subatomic particles – protons, neutrons and electrons.

- The number of protons and neutrons an element has will affect the atomic weight.
- Electrons are too light to have an affect
- The atom is electrically neutral which means the positive charge in the nucleus and the negative charge in the orbitals balance each other out.
- Nucleus- consists of protons (+) and neutrons (no charge)
- Electrons (-) orbit around the nucleus
- There are fixed number of electrons allowed in each orbital
- First orbital (closest to nucleus) – maximum 2 electrons
- Second orbital – max 8 electrons
- Third orbital – max 8 electrons
- Protons and neutrons are trapped within the nucleus. Electrons can move in their orbitals
- Inert gases have the maximum permissible number of electrons in their outer orbital. This makes them stable and non-reactive. For example helium has 2 electrons in its orbital and neon has 8 electrons. Both cases negative = positive which creates perfect balance
- Other elements do not have the right number of electrons to fill their outer orbital. Example Carbon (6 electrons total), it has 2 in first orbit and 4 in second but there is still room for 4
- Elements like to achieve a full outer orbital and they will work to get to that state.

Ionization

- How can elements achieve a full outer orbital? – they try to gain or lose electrons
- Sodium achieves a full orbital by losing one electron
- However the protons in the nucleus remains the same. Therefore, the sodium atom becomes positively ionized.
- It is easier for chlorine to gain one electron instead of trying to lose seven electrons
- Again the number of protons in the nucleus remains the same. Therefore with the added electron, the chlorine atom becomes negatively ionized. (Cl⁻)
- The process by which electrons are lost or gained in the outer electron shell is known as ionization
- Inert gases do not undergo ionization – their outer orbitals are already full
- Ions with opposite charge attract each other
- Ions with similar charge repel each other

Ionic bonding

- The attraction of ions with opposite charges lead to an ionic bond (electrostatic)
- The ionic bonds join Na⁺ and Cl⁻ together to form halite crystals (NaCl – table salt)
- Ionic bonds are relatively weak chemical bonds, soluble and soft eg- halite(table salt), gypsum

Covalent Bonding:

- Elements with 4 or 6 electrons in their outer orbitals do not ionize easily
- But when forced together, they share their electrons to achieve greater stability
- Now both oxygens have a quasi full outer orbitals (8 electron)
- Covalent bonds are non electrostatic, difficult to form and very strong after formation
- Example; diamonds- diamonds are made of carbon atoms and form under very high pressure. This pressure forces the carbon atoms close enough to form covalent bonds. They are the hardest thing on earth

Van der Waals Bonds

- Van der waals bonds are weak
- between two helium atoms, there are more weak attractive forces between neutrons and electrons than repulsive forces.
- Van der waals bonds are weak due to stray unsatisfied charges. Good example would be Graphite, made up of carbon atoms but unlike diamond it is soft
- Graphite has both strong covalent bonds and weak van der waal bonds because it was formed at a lower temperature and pressure than diamonds.

Polymorphs

- Minerals with the same composition but different properties are called polymorphs
- Example – diamond and graphite
- They both contain only carbon atoms but different chemical bonds and structures have given them much different properties.

Metallic Bonding

- Pure metal are very good conductors of electricity because they have metallic bonds
- Metallic bonds form between ions which freely share all their outer electrons.
- If electrons can move freely through a substance, it has high electrical conductivity.

Packing

- A cation (positively charged ion) will try and surround itself with as many anions (negatively charged) as possible. This creates a close packing arrangement.
- The silicon tetrahedron is the basic building block for the silicate minerals. It has a coordination number of 4. This means that 4 anions (-) surround the central Cation (+)

Substitution

- Within the building blocks "ions can be substituted for others with similar size. For instance, aluminium can substitute for silicon in a tetrahedron.
- This can occur when the mineral is being formed.

Bowen's reaction series

- Summarizes the sequence of formation of silicate materials from a cooling magma
- At specific temperatures, minerals will crystalize out of the magma – depending on its formation temperature
- These minerals are created from different arrangement of the silica tetrahedron
- It has continuous and a discontinuous reaction series

Island silicates

- Olivine (island Silicates) forms first and at high temp (>1300 C). the silicon tetrahedral do not join directly
- Instead they join via ionic bonds with intermediate Fe⁺³ (iron) and Mg⁺² (magnesium) ions to form the island silicate structure.
- Olivine is a green mineral and often has a granular and sandy looking texture. Its commonly found in dark coloured igneous rocks

Single chain silicates

- As the magma cools more, silicon tetrahedral share corner oxygens, through covalent bonding forming long single chains. These chains typify the pyroxene family of minerals.
- These single chains of silicon tetrahedral are connected to each other by ionic bonds with Fe²⁺ and Mg²⁺ ions
- This bundle of connected single chains forms the crystalline structure that is typical of pyroxene.
- Pyroxene (single Chain) is usually dark green or black. Its commonly found in dark coloured igneous rocks

Double chain silicates

- Double Chains can join through ionic bonds with intermediate Fe²⁺ and Mg²⁺ ions
- This forms 3D crystalline structure typical of the amphibole family of minerals
- Amphibole is the most common double chain silicate
- They are usually dark and light green and found in medium and light coloured igneous rocks

Sheet silicates

- Biotite is a common example of sheet silicate
- As the magma cools even further, silicon tetrahedral gets close enough to share 3 oxygen along basal planes generating sheet silicates.
- Strong covalent bonds connect the si tetrahedra in sheets.
- However, it is weaker ionic bonds that join together the sheets
- This is why micas split so easily into layers

Framework silicates

- Feldspar and quartz framework. Feldspar is often pink or white. When broken, it breaks like chunks. Quartz is light coloured and breaks like glass. They are both common mineral and light coloured igneous rocks.
- At the bottom of Bowen's reaction series at about 800 C, silicon tetrahedral can finally get close enough to share all their oxygens.
- This forms the strong 3D structures of feldspar and quartz.

Unit 5 Notes
Igneous rocks

Igneous Geology

- Igneous rocks are formed from hot molten magma from within the earth
- Some are plutonic rocks which crystallize deep underground. They cool slowly and relatively large crystals.
- There are also volcanic rocks which cool and crystallize quickly at the earth's surface. They are relatively fine grained.

Igneous rocks

- Magma cools and solidifies to form rock
- It consists of liquid, gases and solid (in the form of mineral grains)
- We call this mixture Magma when it is underground. But when the volcano has erupted we call it lava

Bowen's reaction series

- Igneous rocks are composed of 8 silicate minerals
- Continuous series of crystallization- Calcium Rich and then sodium rich as temperature goes down
- Discontinuous series – Olivine, Pyroxene, Amphibole, Biotite Mica, potassium feldspar, Muscovite mica and Quartz (coolest- still 800 degrees)

Classifications

STEP 1 TEXTURE

Phaneritic	Coarse grained. Crystals are largely visible (eg- granite, syenite, diorite, gabbro)
Aphanitic	Fine grained – not all crystals are visible (rhyolite, trachyte, andesite, basalt)
Vesicular	Rocks with Gas bubbles (pumice, scoria)
Glassy	Rocks with Glassy texture (obsidian)
Fragmental	Fragmental (ash, tuff, volcanic breccia)

STEP 2 COLOUR- Determine whether the rock is light or dark

e.g Aphanite igneous rock (fine grained) – Rhyolite is light coloured and Basalt is dark grey to black

STEP 3- Identify the abundant minerals in the rock

- Lots of quartz, <10% quartz, no olivine, lots of olivine.

STEP4- if the rock is too fine grained or broken up to ID minerals, you may be able to identify it using special textures.

Different types of Magma

- Two types of Magma
 - Basaltic Magma-** Found in areas of oceanic crust. This magma is associated with oceanic crust and makes up the ocean floors. It is found at mid ocean ridges and hot spots. Eg hawaii. Hot spots are stationary mantle plumes. They consist of rising magma. Hot magma rises to the surface, creating hot spot volcanism. However the plate that is situated over the plume will continue to move like a conveyer belt. Therefore, the volcano will become extinct and a new hot spot volcano will be formed. This is how hawaiian islands formed.
 - Andesitic magma –** Found at active convergent plate boundaries. This is found in subduction zones where the denser oceanic lithosphere is driven underneath continental lithosphere.
 - This creates new magma from the partial melting of oceanic and continental rocks.

Crystal Fractionation

- Bowen's reaction series shows different minerals forming at different temperatures.
- Every mineral has a different chemical composition and is made from different elements
- So when crystals form in magma, the remaining liquid will become enriched with the elements that weren't used for those crystals. The composition of the magma will change as temperature changes and different minerals crystallize
- At high temperatures, olivine is the first mineral to crystallize
- After crystallization of olivine- increase in Si and Al and decrease in Fe and Mg
- Olivine is rich in iron and magnesium, therefore, the remaining liquid magma will have considerably less. However, after crystallization of olivine, remaining magma is now enriched in these elements.

Event in Magma Chamber

- Magma is a mixture of solid, liquid and dissolved gases.
- After magma has moved into magma chamber from below. Cooling begins and crystals solid develop
- The first minerals to form a cooling magma are those stable at the highest temperatures
- They are olivine and pyroxene
- As olivine and pyroxene crystallize, the volume of liquid magma is reduced
- The dissolved gases in the magma cannot be stored within the crystal structures of olivine and pyroxene
- There gas is released into magma chamber and pressure begins to build.
- As crystallization continues, gas in the magma chamber escapes from the fluid and needs to expand

- It exerts great pressure against the roof of the magma chamber
- When internal pressure exceeds the resistance of the roof of the magma chamber or the neck plug an eruption occurs.
- When the volcano erupts, gases are released into the atmosphere- allowing the pressure in the magma chamber to go down.
- Also solids liquids and gases erupt. Solids include silicate minerals from Bowen's reaction series, liquid is residual magma, gas include CO₂, sulphur dioxide, water vapour.

After an eruption

- magma that is not expelled will flow back into the volcano
- For basaltic volcano, the lava is very hot and flows easily back into the volcano. Therefore it does not form a solid neck plug.
- Basaltic volcanoes- these oceanic volcanoes are prevalent in Hawaii
- Since it does not have a solid neck plug, little gas pressure is required to re-open the vent. Therefore the volcanic eruptions will be frequent but also relatively quiet.
- In andesitic volcanoes, the magma is very thick and viscous (like honey), it is harder for the fluid to flow back into the magma chamber after an eruption.
- Therefore it forms a very solid neck plug
- Because of the solid plug, it takes a great deal of gas pressure before the volcano will erupt. This means it will also take a long time before there will be enough pressure to break through the plug.
- This causes eruptions to be violent but infrequent. (sometimes 100 yrs)
- The violent release of gas from the volcano will pulverize the plug and these pieces along with the liquid magma will explode out as cinder ash, and volcanic bombs (fragmental texture)
- Once the eruption is finished, the top of the volcano often collapses inward and creates a caldera
- Creates a crater lake (after eruption and caldera)

Features of Volcanic Rocks

- If lava extruded from the volcano has a high volume of gas, the lava rock is called aa (blocky)
- If the lava does not have much gas, it is called pahoehoe lava and has a ropy texture.
- Pyroclastic material- this is a general term to describe all rock fragments that are ejected from an explosive volcano. Fine grained (tuff) and coarser grain(volcanic bomb)
- Course grain or phaneretic plutonic rocks form when magma cools underground. This forms different features. One such feature is called batholith.
- Through erosion and uplift, the batholith will become exposed at the surface.
- There are also smaller features associated with plutonic rocks
- * Laccolith- a smaller version of a batholith
- * Dikes- Bodies of intrusive rock that are almost perpendicular to the surrounding rock
- * Sills- These intrude between layers of the surrounding rocks.

Unit 6 Notes

Unit 6: Weathering and Soils

- deterioration of rocks when exposed to the atmosphere generating soils/sediments

- factors of type/rate = temp, O₂, water availability, plant cover, topographic relief, rock properties

Mechanical Weathering

– physical breakdown without changing chemical composition

- increases surface area to volume ratio so chemical weathering can act more easily

- prevalent over chemical in cold/cool, high altitude, dry regions, rock composed of stable minerals

- *frost action* - freeze-thaw cycles, common in Fall/Winter Southern Ontario

- water freezes in cracks and pores at night, causes pressure shatter

- *thermal expansion* – daily temp extremes but no water for frost shattering, common on the Moon

- expansion from heat, shrink from cooling (RPT) à mineral grains lose contact, rock falls apart

- *abrasion* – beaches, streams, desert, beneath glaciers

- scraping surfaces of particles carried by water, wind, ice

- *exfoliation* – affects plutonic rocks (AKA unloading,

- plutonic rocks exposed through erosion peel off as sheets from pressure release

Chemical Weathering

- chemical alteration of a mineral's internal structure upon reaction with H₂O, O₂, CO₂

- prevalent over mechanical in hot, wet climates

- *dissolution* – best with minerals predominantly bound with ionic bonds (halite)

- polar water molecules disrupt attractive forces in minerals causing them to dissolve

- *hydration/dehydration* – anhydrite à gypsum

- emplacement or dehydration of water within crystalline structure

- *hydrolysis* – olivine à brucite

- reaction of mineral with water causes breakdown of both

- *oxidation* – pyroxene à hematite, rusting of Fe

- loss of electrons

- *reduction* – waterlogged soil where little to no oxygen is present

- gain of electrons

- *carbonation* – increases dissolution of calcite

- CO₂ and water react producing carbonic acid that weathers rocks

- o sedimentary rock (limestone) store x10k more C than organic carbon combined

- o increase CO₂ = increase temp/sea level = increase carbonate deposition and CO₂ removal

Soil

- A horizon – topmost, darkest, most organic matter and activity, 10-20cm

- B horizon – little organic matter, accumulation zone

- C horizon – altered bedrock, clays

- *brunisollic (some Luvisolic)* - deciduous forest
- cold, temperate regions
- clay particles transported down from A by percolating water, surface layer of enriched org mat
 - *chernozemic* – grassland
- dry climate
- thick, black surface layer w/partially decomposed plants that builds up
 - *cryosolic* – arctic
- perma-frozen except for active top layer in summer, no developed horizons
- angular rock from frost action, thick ice lenses
 - *gleysolic* - poorly drained
- thick surface layer of org mat because decomposition inhibited under water
- green/grey colour from reduction of Fe due to wet, anoxic conditions
 - *podzolic* – coniferous
- areas of rich quartz parent material i.e. granite, sandy deposits below coniferous
- thin upper surface layer over a bleached horizon over a dark reddish Fe/Al rich horizon
 - *regosolic to solonetzic* – desert
- areas of strong erosion along slopes/rates of high deposition in river floodplain/salt accumulation
- no horizons, weathered parent material
 - *laterite* - wet tropical
- warm, wet environments – final product of long term weathering
- deep, reddish colour, soft when wet/hard when dry
- leached elements, acidic, low natural fertility
- parent rich in Al = bauxite deposits

Geology and Medicine

- micronutrients facilitate enzyme activities
- can intake through plants/animals that have accumulated elements in aging tissues
- areas of highly concentrated elements can lead to cancer i.e. Zi, Co, Fe, Cd in Wales = stomach cancer

Unit 7 Notes

Unit 7: Glacial Geology

- *Glacier*- mass of ice formed from solid atmospheric precipitation, capable of moving independently
 - typically formed at high altitudes/latitudes
- mountain glaciers move downhill, continental glaciers move toward poles of the equator

Formation

- where snowline (altitudes where snow stays past summer) intersects Earth's surface
- yearly increments of snow form large ice mass
- Pleistocene (2.6 million-10 000 yrs ago) last period of major glaciation, surface 4° colder
- a drop triggered by volcanic eruption could cause glaciation

Movement

1. gravity – pull down a slope (parallel force)
2. friction against incline – prevents movement (perpendicular force)

- change to equilibrium = glacier thickens, slope of incline increases
- slope of valley floor
- firn – compacted, granular, snow from last year (transitional stage btwn snow/ice)
- accumulation zone – area of net gain of snow/ice above firn line
- ablation zone – area of net loss of snow/ice on the surface of glacier below firn line
- internal transfer – ice moving through tubes from accumulation to ablation
- melting = internal transfer à balanced budget
- positive budget – net addition of snow/ice and glacier terminus advances
- causes for changing balance
- atmospheric temperature
- base temperature – pressure melting point (large pressure subjects ice to lower T_m) means water at base reduces friction inducing rapid movement
 - temperate glacier ($T_{ice} > T_{pm}$) – has water throughout/at base making move more actively/efficiently
 - polar glacier ($T_{ice} < T_{pm}$) - frozen throughout thus deform slowly and DO NOT transport sediment
 - crevasse – upper crack from stresses exceeding ice strength (parts pulling away)
 - *bergshroud* – crevasse at head of valley glacier pull away from wall separating stagnant/moving

Glacial Erosion

- *striations* – elongated scratches from pieces of rock and sand at the base of a glacier scrape bedrock
- *roches moutonnees* – ice passes over protruding knob of fractured rock, melt water from pressure allows glacier to move up over rock and smooth it, melt-water freezes to rock on downhill plucking away chunks
- *crag & tails* – glacier passes over resistant volcanic rock, eroded material from surrounding area is deposited on the lee side creating a tails
- U-shaped glacial valleys – transformed v-shaped rivers a
- fjord – U-shaped valleys formed by partially floating glaciers, and flooded upon deglaciation
- cirques – mountain glacier features that mold mountains into pyramidal shapes

Glacial Transport

- lateral moraines – debris deposited from valley walls at the margins of an alpine glacier form ridges
- medial moraine – lateral moraines from two valley glaciers merge in the middle
- transverse moraine – merging of all moraines towards terminus in a valley glacier

Glacial Deposition

- *till* – sediment deposited by melted glacier
 - fluted – till eroded/molded into long parallel flow ridges
 - drumlins – teardrop shaped hill formed under temperate glaciers
 - terminal moraine deposit – equilibrium glaciers continually flow internally accumulating sediment
 - recessional moraines – ridge from fast retreating glacier that built up a lot of winter accumulation

- *esker* - well sorted sediment ridges formed from water running in tunnels under/within glacier
- glacio-lacustrine sediment – varves (coarse summer/fine winter clay layers), pluvial lake (heavy rain)
- glacio-fluvial sediment – outwash plain(run off melt water), braided stream(developed from coarse sed)
- *loess* – blanket deposit of fine, silty material carried by wind; produce silt-rich soil mid-west, China

Cause & Effect

Long-term climate modes:

- greenhouse period – little temp difference between equator and poles
300 millions years between switch to
- *icehouse period* – large temp difference between equator and poles
- permanent ice at poles → small changes cause shrinking or expansion into continental ice sheets
- effects: fertile soils developed, formation of great lakes, river patterns
- *isostatic rebound* – rising of the lithosphere after the weight of a glacier is removed (3m/century)
- permafrost – continuously frozen soil for at least 2 years except active upper layer
 - angular pebbles, ice wedges, polygonal patterned ground, gelifluctuation

After Glaciation

- 13 000 yrs ago to 5000/9000 temperature rise, then fluctuation
- cooling after 5000 yrs ago destroyed good crops in Mediterranean
- cooling climate forced Vikings farther to discover North America
- current retreating glaciers impose threat of flooding coastal metropolis (New Orleans, New York etc)

Unit 8 Notes

Sedimentology - It's a long one

Intro

- the study of sediments and sedimentary rocks
- Sediments are formed in a variety of ways in many different environments like reefs, through travel of particles by water and wind and through the evaporation of water and salts
- these rocks are compressed under tons of new material and are compressed and cemented by minerals from groundwater
- because of all the materials that are compressed together in sedimentary rocks they become very valuable (water, petroleum, gold, uranium and gold to name some)

Introduction to Sedimentology

- Sediments become sedimentary rocks through the process of **lithification**
 - This process begins with loose unconsolidated sediment
 - The next stage is compaction and settling

- The final stage is when mineral cement fills the voids between the grains to create the solid sedimentary rock
- The formation of sediments requires:
 - Weathering
 - Erosion
 - Transport
 - deposition
- There are 3 main types of sediments
 - The first are the **terrigenous clastic sediments**, formed from insoluble particles (**gravel, sand, silt and clay**)
 - Other two types are formed from the dissolved ions and are
 - Carbonates
 - Evaporites
- **Terrigenous clastic sediments** are made up of the particles mentions earlier (from most coarse to most fine they are:)
 - Gravel
 - most coarse
 - >2mm
 - Rock names: Breccia and Conglomerate
 - Sand
 - 2nd most coarse
 - From 0.062 - 2mm
 - Rock names: Sandstone
 - Silt
 - 0.004 - 0.062mm
 - 2nd most fine
 - Rock names: Siltstone
 - Clay
 - Most fine
 - < 0.004mm
 - Can't even be seen under a microscope
 - Rock names: shale or mudstone
 - These particles are all classified by their average size
 - Conglomerate and Breccia are the coarsest grained sedimentary rocks
 - Conglomerates consist of rounded pebbles and cobbles cemented together and widely vary in size
 - Breccias are similar but contain particles that are angular
 - Sandstone consist mainly of sand sized particles that are cemented together and can be seen by the naked eye and is the most easily identified sedimentary rock
 - Siltstone and shale are the finest grained sedimentary rocks
 - When they are lumped together they are called mudstones
 - Siltstone is light colored and does not split into thin sheets

- Shale is like a bunch of thin sheets together that can easily split apart and is usually dark colored
 - There are steps to classifying sedimentary rocks
 - 1. Texture - average particle size
 - 2. Name the sediment (Eg. sand)
 - 3. Name the rock... Sandstone
 - (This process seems kind of stupid imo)
- Biochemical - Carbonates (it's the next type of rock mentioned at the beginning)
 - Most of these are limestones were are composed mainly of the mineral calcite
 - Limestone is created from organisms that extract calcite from water and then die, eventually becoming **lithified** (If ole steve isn't lying in the slides there will be more about this soon)
 - **Dolostone** is formed when calcite is replaced with dolomite, it is much more coarse than calcite and can destroy sediment structures
 -
- Chemical - Evaporites
 - These are the purely chemical sediments and require no organic activity
 - Made up of salt crystals from water that has become supersaturated
 - The 2 most common examples are Gypsum and Halite

Processes of Erosion and Transport

- **Gravity** drives all sediment erosion and transport processes
- To understand how sediment moves and accumulates we need to understand
 - Velocity and flow types
 - Flow types and sediments
 - Fluid velocity and sediment transport

Velocity and Flow Types

- We will be looking at a few examples of water flow examples...
- In a stream the **maximum velocity** is found in the middle directly under the surface because this is where the water experiences the least amount of friction and is slower near the river banks (i know it's amazing that water has to deal with that crap too)
- The type of stream flow is dependent on both velocity and roughness of the channel bed
 - Flow can be turbulent or laminar although laminar is rare in nature
 - The reason **laminar** is rare is because it has a smooth idealized flow in a straight and parallel channel and has a low Reynold number
 - **Reynold number:** is a number given from the formula of the same name which calculates the velocity, density, viscosity and diameter of the fluid
 - Although this rarely occurs in nature there are **quasi-laminar flows** which can occur in slow moving water
- **Turbulent flow** has a high Reynolds number and occurs naturally in all streams, waves, currents and winds
 - Increasing velocity and bed roughness cause turbulent flow
 - This type of flow is effective at eroding and moving sediment
- There are **two types** of turbulent flow:

- **Turbulent subcritical**
 - Froude number < 1
 - Surface waves move faster than the main body of water meaning the waves break down water
 - These streams look calmer with slight disturbances on the surface
 - **Video :**
https://courselink.uoguelph.ca/content/enforced/449316-ENVS_1060_DE_W17/units/Unit%20Slides/Unit%208%20-%20Sedimentology/unit8video1.html
- **Turbulent supercritical** (like a double headshot in a video game)
 - Froude number > 1
 - The main body of water flows faster than the surface waves
 - The surface has fast moving and breaking waves
 - **Video :**
https://courselink.uoguelph.ca/content/enforced/449316-ENVS_1060_DE_W17/units/Unit%20Slides/Unit%208%20-%20Sedimentology/unit8video2.html
- **Froude Number**
 - The ratio of gravitational forces to inertial forces. It is what determines if the flow is subcritical or supercritical
- Flow types and types of sediment determine the sedimentary structure that is formed
 - Quasi-laminar flow is slow moving and only moves fine sand creating **ripples**, you can see this on beaches under the water around the shore
 - Turbulent supercritical flow is very fast and shallow which quickly erodes sediment and can create **plane beds**
 - Turbulent subcritical flow can move coarse sands creating **dunes** underwater, layering of these dunes creates **cross-beds and foresets**

Fluid Velocity and Sediment Transport

- The velocity and type of flow of the water will determine what types of sediment are eroded, transported and deposited
- To figure out how quickly or slowly particles in water will settle we use:
 - **Stoke's Law** for smaller particles like fine sand
 - **Rubey's formula** for larger particles
 - In general big particles settle faster than smaller ones
- Looking at **Hjulstrom's diagram** to show the relationship between particle size, settling rates and the erosion, transportation and deposition
 - Honestly it's too much to explain and too confusing, if you really want to take a look at it here ya go...
 - <https://courselink.uoguelph.ca/d2l/le/content/449316/viewContent/1470845/View>
- Extra obscure notes for this part:
 - There are different ways particles are transported through water
 - Silt and clay are transported in **suspension** (doesn't touch stream bed)
 - Ions from chemical weathering are carried in **solution load**

- Gravel and coarse sand travel along the bed which makes up the **bedload**, this is a process called **traction**
 - **Saltation**: sand grains bounce along the channel bed kicking up and moving along more sand grains
 - Video of all this nonsense:
 - https://courselink.uoguelph.ca/content/enforced/449316-ENVS_1060_DE_W17/units/Unit%20Slides/Unit%208%20-%20Sedimentology/SedTransS_tream_GL.html
- Two terms you should know are:
 - **Competence**
 - This relates to the **largest sized** particle a stream can carry
 - **Capacity**
 - This relates to the **total amount** of sediment the stream can carry

Continental Environments

- Now onto looking at a few of the most common sedimentary environments in continental areas
- **Talus Fans:**
 - Are formed by the tumbling of stones caused by weathering, driven by the force of gravity
 - The larger boulders tend to tumble to the bottom of the slope
 - http://www.ngdc.noaa.gov/hazard/icons/med_res/6/6_126.jpg
- **Alluvial Fans:**
 - Forms where a stream exits a narrow valley and splits into several smaller and narrower channels
 - https://www.google.ca/url?sa=i&rct=j&q=&esrc=s&source=images&cd=&cad=rja&uact=8&ved=0ahUKEwiFt_7EuZXTAhUi74MKHbe5AilQjRwIBw&url=http%3A%2F%2Fpages.uoregon.edu%2Fmillerm%2Ffan.html&psig=AFQjCNGGI9a_9AD_AqN9Prt5PFYF5L4gg&ust=1491761153695544
- **Braided streams**
 - They develop because because of strong changes in discharge and abundant coarse sediment
 - They often occur in areas of variable conditions like in front of a melting glacier
 - http://www.geologyclass.org/Stream%20Concepts_files/image002.jpg
- **Meandering Streams**
 - Form where flow conditions are uniform throughout the year
 - River banks do not erode because they are stabilized by vegetation
 - Occurs in alluvial valleys
 - Looks like a winding snake
 - https://www.google.ca/url?sa=i&rct=j&q=&esrc=s&source=images&cd=&cad=rja&uact=8&ved=0ahUKEwi1zZGjwZXTAhUn64MKHVpHAWeQjRwIBw&url=https%3A%2F%2Fwww.geol.umd.edu%2F~jmerck%2Fgeol342%2Flectures%2F10.html&psig=AFQjCNE5pZ_ywav2lrGPacMCYd21Im4Vog&ust=1491763240681265

- The major difference between braided streams and meandering streams is the vegetation
 - Braided streams have high sediment and erosion rates which makes it hard for vegetation to grow
 - Meandering streams have a slow flow allows the establishment of vegetation which stabilizes the sediment
- **Deltas:**
 - A sedimentary body formed at the mouth of a stream or river
 - When a river or stream opens up into a big body of water the sediment it was carrying loses velocity rapidly and settles to the bottom creating an almost underwater beach
 - https://www.google.ca/url?sa=i&rct=j&q=&esrc=s&source=images&cd=&cad=rja&uact=8&ved=0ahUKEwiyoMLmy5XTAhWJ6YMKHR1PBY8QjRwlBw&url=http%3A%2F%2Fwww.dailymail.co.uk%2Fsciencetech%2Farticle-2141291%2FThe-stunning-blood-vessels-planet-How-river-deltas-change-world--lives-500million-people-reside-shores.html&psig=AFQjCNGFVdTp8Je_FiKBkNPX57IPkXAjPA&ust=1491766051850146
- There are three main types of Deltas that depend on factors like size of river, amount of sediment and conditions of the attached body of water
 - **Wave dominated deltas** are caused by waves moving the settled sediment along the coast creating beaches in an arc shape
 - **Tide dominated Deltas** form when tides can erode the sediment that has been deposited creating a wide v shape coming from the river mouth
 - **River dominated deltas** form in bodies of water that are not affected by waves or tides, this creates a spidering effect at the ends of streams where they split off into several smaller (birdsfoot) deltas
- As a delta continues to deposit sediments it grows outward and eventually creates 3 different layers
 - Bottomset beds - made from fine sediment
 - Foreset beds - as the delta grows it is covered by coarser foreset beds
 - Topset beds - tops everything and is the newly deposited sediment
- **Aeolian and Cross-bedding**
 - Deserts have a lot of sand deposited by wind into sand dunes
 - If sand dunes are preserved as sedimentary rock they can be recognized by their **cross beds**
 - https://courselink.uoguelph.ca/content/enforced/449316-ENVS_1060_DE_W17/units/Unit%20Slides/Unit%208%20-%20Sedimentology/CrossBedding_GL.html
 - Wind carries the sand along by saltation or bouncing and causes ripples to form on the sheltered side of the dune
- There are many types of dunes depending on wind direction, surrounding vegetation and sand supply
 - Barchan Dunes: U shaped dunes with arc pointing downwind

- Parabolic Dunes: U shaped dunes with arc pointing upwind
- Which way is dependent on vegetation holding the sand and sediment down

Marine Clastic Environments

- Marine environments of clastic deposition can be divided into three areas
 - Nearshore and continental shelf
 - **Longshore currents** are created by wind and waves
 - These currents transport the sediment creating beaches, dunes and lagoons
 - Continental slope and continental rise
 - Further offshore and has a steep incline, when there is a sudden drastic increase in the water depth
 - They mark the edge of the continental shelf
 - **Submarine canyons:** sand that falls off the steep cliff from the continental shelf to the abyssal plain
 - Deep ocean floor
 - Most deep ocean floor sediment is very fine grained and is called **ooze**
 - The deep sea sediment is very hard to move
- Main features of marine environment transferring from land to the ocean are:
 - Continental shelf
 - Shelf break
 - Submarine canyons
 - Continental slope
 - Continental rise
 - Abyssal plain
 - *Doesn't really explain what some of these are

Marine Carbonate Environments

- Most carbonate sediments are formed in shallow, warm marine shelves that have few clastic sediments and clear waters
- Carbonate sediments are mainly formed from broken up shells of marine organism which range from large coral reefs to algae
- Waves, winds and currents transport these particles just like other sediment environments
- A good example of this type of environment is the Bahamas

Evaporite Environments

- Occurs when ions in water become too concentrated and evaporate causing the precipitation of minerals

Unit 9 Notes

Paleontology

Introduction

- Paleontology is the study of fossils
- Fossils by definition are:
 - The direct and indirect evidence of past life

- Living organisms evolve through time and these changes are preserved in their fossils
- Relating to last unit, it is observed that different layers of sedimentary rocks contain different fossils
- Fossils are fundamental to geology as they are used to create the geological time scale giving us valuable information about different time periods, giving us perspective on our existence

Introduction to Paleontology

- By definition paleontology is:
 - The study of fossils
 - Fossils are the remain of the ancient animals and plants or can be indirect evidence of their activities
- Very few organisms become fossils after death as most decompose or are eaten and destroyed before they can be preserved
- This means the record humans keep of fossils is very incomplete
- The earliest none organism is called **cyanobacteria** which came from rocks about 3.5 Billion years ago
 - This was the organism that first started producing oxygen in the early atmosphere
- All other organisms have evolved from this
- The main evidence for evolution was the fossil record until genetics were proven and accepting in 1925
- It was noticed that older rocks had different fossils than younger rocks, and major divisions in geological time were based on these fossils, called **index fossils**
- It is important to know that each geological period has a few unique fossils
- Based on **index fossils**, geologists can relates rock layers from different parts of the world
- In order to understand paleontology you need to understand **evolution**
 - **Evolution:** is the changes that occur to a population over time through a process called natural selection
 - **Natural selection:** changes that occur on a genetic level through mutations, some of these mutations enhance the survivability in a given environment and they can pass the beneficial traits to succeeding generation
- Different organisms that share a common environment will develop similar characteristics best suited for that environment, this is known as **Convergent Evolution**
- Alternately, when identical organisms develop in separate environments they start developing different traits to suit those environments, this is called **Divergent evolution**

Fossilization

- Several different ways to fossilize and organism as follows
- **Preservation**
 - There are a few ways organisms can be preserved relatively unchanged
 - Desiccation (drying out like a mummy)
 - Freezing in a glacier

- Being sealed in tar or amber (tree sap)
 - Falling into a bog (swamp type place) with naturally acidic water
- **Petrification (permineralization)**
 - Occurs when porous organic materials like bone or wood are replaced by minerals, usually silica
- **Molds**
 - Form when a buried organism decomposes or is dissolved by moving water leaving behind an organism-shaped cavity in the rock
 - This is the typical shell fossil we see
- **Casts**
 - Building off of molds, if the organism-shaped cavity is filled with sediment or new mineral material then a fossil cast is formed
 - This creates the external shape but the internals are still lost
- **Carbonization**
 - Occurs when plants or animals are buried in fine grained sediments like mud
 - The original organic material decomposes leaving a thin, detailed film of carbon behind
- **Trace Fossils**
 - These fossils are not the organism themselves but traces of their activities like tracks, footprints, trails and burrows
- **Coprolites**
 - Fossilized shit
 - Can teach you a lot about their diet, digestive system and their size

Fossil Identification

- **Stromatolites**
 - Cyanobacteria is the earliest rock forming organism
 - It secretes calcium carbonate to form mounds called **stromatolites**
 - Were the major reef-building organisms in the past
- **Bryozoa**
 - Are marine dwelling colonial organisms
 - Colonial means that many individuals share the same skeleton
 - They have carbonate skeletons
- **Brachiopods**
 - Were the predominant hinged shellfish of the paleozoic era
 - They have bilateral symmetry (can be split down the middle) distinguishing them from modern shellfish
- **Bivalves**
 - The modern shellfish, living in marine and freshwater
 - Can be distinguished from Brachiopods because their shells are not bilaterally symmetrical
- **Tabulate Corals**
 - Ancient corals are marine dwelling colonial with tabulae and are referred to as tabulate corals

- This means that there are shelves inside the corals in a ladder like design
- Shares no common ancestry with modern coral
- **Modern Corals**
 - Most modern corals do not have tabulae
 - Although modern coral looks similar to tabulate corals they have a different structure and evolutionary history
 - They are colonial and the major reef builders of the present time
- **Gastropods**
 - Coiled shell with no internal partitions (divisions)
 - There are different salt and water varieties as well as some that live on land
 - The snail is a common example
- **Cephalopods**
 - Have coiled or straight shells, with internal partitions (divisions)
 - These divisions can be seen as lines on the outside of the shell called sutures
 - The sutures are what define them from gastropods
- **Trilobites**
 - The most common marine arthropod in the paleozoic era but are now extinct
 - They look like the pokemon fossil
 - https://www.google.ca/url?sa=i&rct=j&q=&esrc=s&source=images&cd=&cad=rja&uact=8&ved=0ahUKEwi3w7zHq5bTAhVr4YMKHbXbBqUQjRwIBw&url=http%3A%2F%2Fwww.fossilmuseum.net%2FFossil_Galleries%2FUSTrilobites.htm&psi_g=AFQjCNFDty1ULpgWyo3r3jIMtYQdGWFTxw&ust=1491791771772224
- **Echinoderms**
 - Group of organisms that include crinoids, blastoids and echinoids (probably not important to know what these are)
 - They have 5 sided symmetry
 - The modern example is the starfish
 - “Hello, is this an Echinoderm?”
 - “No...THIS IS PATRICK!”

Unit 10 Notes

Stratigraphy and Time

Stratigraphy

- **Stratigraphy** - The study of layered sedimentary rocks (stratified rocks). This provides us with clues to the history of the Earth
- **Principles of Stratigraphy**
 - **1. Principle of Uniformitarianism**
 - This principle states that “the present is the key to the past”. This means we can interpret ancient rocks on the basis of what we learn from present day processes
 - **2. Principle of Original Horizontality**

- This principle states that most sediments were deposited in quasi-horizontal layers.
 - **3. Principle of Superposition**
 - This principle indicates that in an undisturbed sequence of rock, the lower strata are the older ones. (Meaning upper is younger and lower is older)
 - **Bio-stratigraphic principles**
 - **1. Principle of (Fossil) Identification**
 - This principle indicates that we can recognize and identify fossils within strata
 - **2. Principle of Zonation**
 - This principle indicates that different rock strata in different locations can contain similar fossil assemblages (index fossils)
 - **3. Principle of Correlation**
 - This principle indicates time equivalences between strata exposed at different localities. This correlation is often based on fossils.
 - Stratigraphic records are not complete at every locality because
 - Rocks of a given age may not have formed. (i.e a period with **no deposition**)
 - Rocks that formed may have been eroded away
 - These gaps are called **unconformities**

Unconformities

- **Disconformity:** an erosional surface between **parallel sedimentary** strata.
- **Angular Unconformity:** an erosional surface between a deformed sequence and a younger, less deformed bed.
- **Nonconformity:** occurs when a **sedimentary** rock rests on an **igneous** and/or a **metamorphic** rock.
- **Paraconformity:** indicated by a missing fossil evolutionary link. (ie. a gap in the fossil record).
- **Transgression** - The boundaries between these environments change as relative sea level rises (**transgression**) and fall (**regression**).
- **Transgression related to beaches**
 - Beaches affected by transgression will see fine beach sand deposited further inland, and mud be deposited over the old beach sand. The sedimentary sequence is coarse(on bottom) to fine(on top).
- **Regression related to beaches**
 - Beaches affected by regression will migrate offshore. Beach sand is deposited on top of the deep water mud. The movement of a shoreline seaward may also be related to infilling of the sedimentary basin. The sedimentary sequence is fine(on bottom) to coarse(on top).
- **Stratigraphic Units**

- Local sections are identified first. Then they are subdivided into rock units, and into time stratigraphic units that can be correlated with similar units at other localities.
- The fundamental working rock unit is the **formation**, which is “a group of strata formed under uniform or regularly alternating environmental conditions”.

Oil and Gas Exploration

- To form oil and gas specific environmental conditions must exist
- **Source Rocks**
 - are usually fine-grained **sedimentary rocks** such as shale, which are abundant in **organic matter**.
 - These source rocks must be at an ideal temperature and pressure conditions in order for the organic matter to be **converted into hydrocarbons**.
- **Reservoir Rock**
 - The oil converted by the source rocks migrates into a lower pressure zone (upwards) into more **porous** material such as sandstone. This is known as the **reservoir rock**.
- **Cap Rock**
 - The **cap rock** is a fairly impermeable layer, which traps the oil and prevents it from migrating further upwards.
- **Trap**
 - The structure composed of the Reservoir rock and Cap rock is known as a **trap**. The porous strata allows accumulation of oil, while the impermeable strata keeps the hydrocarbons in.

Concept of Time

- A major goal of Stratigraphy is to establish ages of strata.
- **Absolute Age**
 - Is determined primarily by radiometric dating; this gives us an age estimate in years before present
 - Absolute dates can be determined using weathering rates, the growth rates of lichens, trees and coral, radioactivity, erosion rates and varves.
 - We can't date sedimentary rock **directly by radiometric** methods because their minerals derive from older rocks. (meaning that they can in other ways)
- **Relative Age**
 - Is determined primarily by fossils; this can tell us only if a fossil bed is younger or older than another
 - To accurately determine relative age, an **evolutionary sequence** must first be established. An evolutionary sequence can be determined by applying the **Principle of Superposition**. (Younger fossils will be deposited over older ones in undisturbed sequences of strata)
 - **Index Fossils**

- Fossil records of species that appeared, and changed relatively rapidly over time.
 - Index fossils are widespread and found in many rock types. They are the best indicators of relative time.
 - The Fossil records show the old primitive fossils and the younger more developed fossils.
- **Geological time**
 - The geological time scale was devised in the 19th century before radioactivity had been discovered.
 - The subdivisions mark major changes in the fossil record. Much later absolute ages based on radiometric dating were added.
 - (refer to a geological time scale picture in order to understand what I mean by subdivisions)
- **Relative Dating**
 - The **Principle of Superposition** and the **Principle of Horizontality** are used to determine the order of events in rock outcrops.
 - If sedimentary rocks is undisturbed the lower strata must be older than the strata above it
 - The **Principle of Cross-cutting** relationships is also important.
 - **Principle of Cross-cutting**
 - If two strata are **faulted**. The faulting occurred after the youngest rock affected.
 - If an **igneous** intrusion cuts across strata, then it is younger than the affected rocks. (such as a dike cutting into other older igneous rock)
 - **Stratigraphers** frequently use the knowledge of different principles to determine the relative ages of strata in a rock outcrop and the sequence of events.
- **Absolute Dating**
 - **Rates of Erosion**
 - For instance, by knowing the rate at which a waterfall is cutting back the rock, and assuming the rate has been constant in the past, we can calculate the age.
 - This only works locally. In other words we can't use this kind of dating for things much further in the past. (Dinosaurs etc.)
 - **Rates of Sedimentation**
 - We can calculate how quickly sediments are deposited in deltas or along coasts by observing the thickness of deposits covering archaeological remains.
 - Again like rate of erosion. This only works locally.
 - **Growth rates of Plants or invertebrate animals**
 - For instance, the time of deglaciation in northern areas can be calculated by measuring the size of particular lichen covering boulders, since the yearly growth rate of these lichens is well known

- **Recurring Features**
 - Fossils or sediment that relate to daily, seasonal or multi-year cycles.
 - A good example is a rhythmic yearly sedimentation of silt and clay laminations that form the glacial lakes. The very small silt particles get transported in the summer and then settles to the bottom. The clay however can't settle without stagnant water so when the water gets ice over it it becomes stagnant enough for it to settle. Thus you get a d silt-clay couplet, called a varves, and can determine the lake ages.
- **Radiometric**
 - Radiometric methods are based on the fact that certain **radioactive** elements are naturally unstable.
 - They emit radiation in the form of subatomic particles and in doing so they lose mass and become other elements with different characteristics. This is called **decay**
 - The original element is called the **parent**, and the resulting one is called the **daughter** element.
 - In a rock sample there is a certain number of atoms of the parent element however it is not possible to establish exactly which atom will change (or **decay**) and when this change will occur.
 - It is, however, known that random changes occur at a constant rate and that after a given time interval (**known as the half-life**), half of the parent atoms will have changed into daughters
 - In a subsequent equal time interval, half of the remaining parent atoms will change into daughters. And so on.
 - **By knowing the half-life for a parent element and measuring how much of the parent and daughter exist in a rock sample, we can calculate the age of the rock**
- **Important to know about absolute time and dating**
 - Tree rings provide the most precise method of measuring absolute time. The tree rings are a measure of climate of the year that the tree ring formed.

Unit 11 Notes

Not finished

Structural Geology

- Rocks of the Earth's crust are always in motion.
- During mountain building, seafloor spreading and other plate tectonic processes, rocks of the crust are subjected to stress.
 - **Stress**
 - Directional pressure (force) measured per unit area.
- **Types of stress acting on rocks**
 - **Compression**
 - Causes rock bodies to shorten horizontally and thicken vertically

- Typical of mountain building when two plates **collide**
 - **Tension**
 - Causes rock to be lengthen horizontally and thin vertically.
 - Typical in oceanic and continental rift systems where lithospheric plates are **moving apart**
 - **Shear**
 - Causes horizontal displacement with not a lot of vertical displacement
 - This happens when two lithospheric plates are **neither** converging or diverging but where they **slide** past each other

Folding

- Deep within the Earth under **high pressure** conditions, rocks behave in a **plastic** manner and become **folded**. They deform **permanently** without showing large visible fractures.
-

Unit 12 Notes

Metamorphism

Introduction

- Metamorphism means change
- Metamorphism of rocks is when pre-existing rocks are changed without melting when introduced to different conditions of pressure and temperature
- The degree of change is dependent on these factors

Intro to Metamorphism

- Metamorphism
 - The process through which older rocks, such as sedimentary or igneous, are transformed into metamorphic rocks
- There are three agents of metamorphism
 - Heat
 - Pressure
 - Less commonly - Chemically Active Solutions
- Temperature and pressure increase with the earth's depth because of geothermal gradient (This from unit 2, it is the 30 degree increase for every km of depth) and the weight of overlying rocks
- **Heat** is an important agent of metamorphism and has 2 sources
 - One is an **increase in temp** with the depth caused by the geothermal gradient
 - The other is called **contact metamorphism** which is caused by heat from magma intrusions or lava flows
- **Pressure** is another important agent of metamorphism
 - It generally increases with depth
- **Chemically active fluids** are the 3rd agent of metamorphism
 - Most metamorphism happens without any loss or addition of new materials, this is not the case with chemically active fluids

- Chemically active fluids are **mainly water** with a **lot of dissolved ions**
- Because these waters are under great pressure they can become superheated and carry a lot of material in solution which morphs the rocks

Types of Metamorphism

- Pressure, heat and chemical agents combine to cause metamorphism but depending on the contribution of each agent different types of metamorphism will occur
- **Contact metamorphism**
 - More effect of temperature than pressure
 - Occurs when molten rock comes into contact with the surrounding solid rock
 - Can happen at the base of a lava flow or many kilometers underground
- **Regional Metamorphism**
 - Equal contribution of pressure and temperature
 - Occurs over large areas during the formation of complex mountain regions, where pressure and temp increase together
- **Dynamic Metamorphism**
 - More effect of pressure than temperature
 - Occurs in fault zones where plates move past one another causing enormous pressure
 - This is the zone where pressure is high but temperature is relatively low
 -
- **Metasomatism**
 - If chemically active fluids are present
 - Occurs when chemically active fluids circulate through surrounding rock allowing for the migration of ions
 - A good example of this is in the core of a volcano or adjacent to a large igneous pluton
 - Metasomatism provides many economically important materials such as gold and copper which precipitate out of the fluid

Metamorphic Rocks

- Metamorphic rocks are split into 2 main categories for the purpose of identification
 - Foliated
 - Non-foliated
- **Foliation:**
 - The alignment of platy and/or elongated minerals in metamorphic rock after a directed stress has been applied
 - Before the stress, the grains have a random appearance, after a long period of stress the vertical axis of the grains become aligned and almost parallel
 - It makes the rocks appear layered
 - https://sites.google.com/site/missiontomarsatvssec/_/rsrc/1348642025886/home/mission-background-briefing-students/earth/14-metamorphic-rocks/foliate_press.jpg?height=240&width=400
- Foliated (layered), are identified based on their textures, from fine to coarse (increase in crystal size) they are:

- Slate
- Phyllite
- Schist
- Gneiss
- Migmatite
- **Slate**
 - Is the finest grained foliated metamorphic rock with the individual grain not visible
 - Looks a lot like shale but has a clinking sound when hit, like a dinner plate
- **Note:** phyllite is halfway between slate and schist
- **Schist**
 - Is slightly coarser and covered with visible mica grains
 - Common mica grains are muscovite, biotite and chlorite
 - Often has large crystals
- **Gneiss**
 - Is produced at a higher temp and pressure so there is no mica (crystals)
 - Still shows lines of dark colored minerals
- **Migmatite**
 - The highest grade metamorphic rock
 - The pressure and temp are almost at the melting point of granite so that the quartz and feldspar are just starting to melt and separate from the darker minerals
 - http://blogs.agu.org/georneys/files/2011/08/Migmatite_Callan_2.jpg
- Non-foliated rocks like **marble, quartzite and hornfels** do not show parallel lines even under direct pressure, these rocks are identified by mineral composition over texture

Classifying Metamorphic Rocks

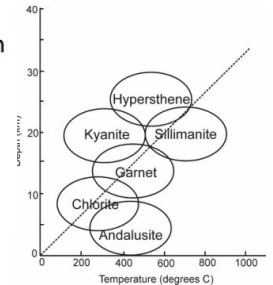
- The most general classification of metamorphic rocks is by **metamorphic grade**
 - This relates to the amount of change in rocks from the original rock to the metamorphic rock
 - **Low grade** is when very little has changed
 - **High grade** is when they have been highly changed under great heat and pressure
- There are only **8** metamorphic rocks you need to know
- To classify them you must first see if they are foliated or not
- If foliated (has visible layers):
 - You classify them based on their texture
 - From fine grained to most coarse and segregated colors : slate, phyllite, schist, gneiss, migmatite
- If not foliated:
 - It is either marble, quartzite or hornfel
 - Marble
 - Made from calcite
 - soft

- Quartzite
 - Hard and could scratch glass
 - Made mostly from quartz
- Hornfels
 - Fine grained, black and baked looking rock

Metamorphic Minerals

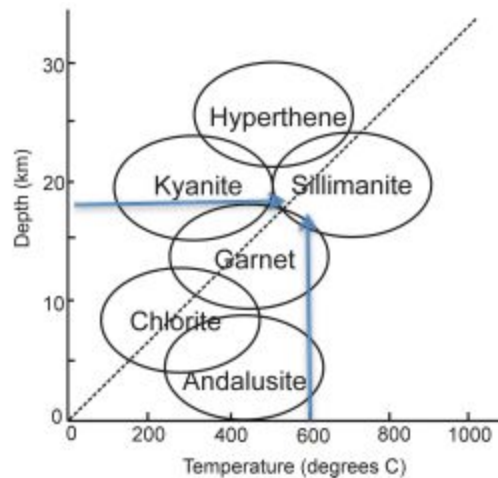
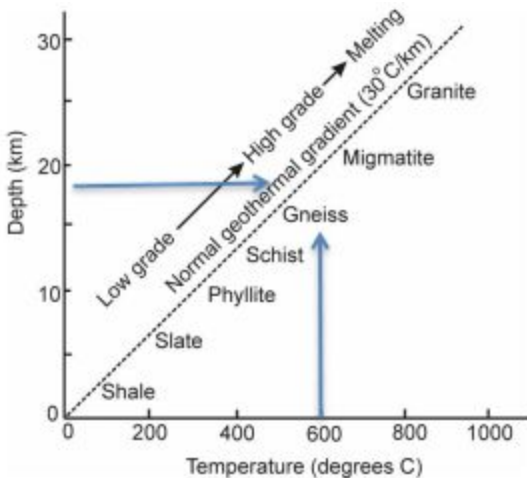
- The reason for studying metamorphic rocks to find out geologic history on an area and for the exploration of a variety of mineral resources
- Some minerals are only formed by metamorphism and are listed above with a graph of conditions needed to form
- Although these rocks form deep underground, due to mountain building they can be exposed to the surface
- Looking at these surface exposed rocks can tell us about what depth and temp they were formed at

- Chlorite (green mica) - low grade metamorphism
- Andalusite - low grade metamorphism
- Garnet - medium grade metamorphism
- Kyanite - medium grade metamorphism
- Sillimanite - high grade metamorphism
- Hypersthene - high grade metamorphism



Paleo-Barometers and Paleo-Thermometers

- Using metamorphic minerals and the graphs below it is easy to figure out at what depth and what temperature they were formed



UNIT QUESTIONS

As suggested by the prof I think we should answer the learning outcomes from each unit here they are: feel free to answer any of these questions at anytime :)

Unit 1 Questions

1. Explain how the composition and structure of planets is dictated by density and gravity.

Its dictated by density and gravity by the number of particles that scattered into space from collisions that were released as heat and melted everything allowing the planets to form.

1. Describe how we experience the Doppler effect in everyday life, and discuss what this phenomenon can tell us about the origin of the universe.

We experience the Doppler effect in everyday life by the sounds we hear either close up or far away, such as, hearing a train. The Doppler effect tells us about the speed and of objects moving further away from us faster. Scientists believed the universe began as a big bang.

1. Define and give the general properties of "black holes", and how they earned their name.

Black holes are a region of space where density of matter and gravity are so great that no matter or radiation (even light) can't escape.

2. Know the estimated age of the universe and how scientists arrive at this figure.

13.7 billion years old

3. Describe how the process of fusion can form new elements, and what conditions are necessary for this to occur.

Two atomic nuclei combine to form a heavier atom under extreme heat. Only occurs naturally in stars, planets are not big enough to produce such heat from transformed kinetic energy

4. Describe a supernova, the factors that trigger its formation and how they played a part in the creation of our solar system.

Stars became unstable, collapsed in on themselves and exploded into supernovas. The supernovas scattered clouds of heavier elements (created from stars). The heaviest, most central cloud generated enough heat for fusion leading to the formation of the sun. Smaller clouds surrounding the central cloud generated enough heat to melt into planets. Even smaller clouds with insufficient heat to melt the entirety became moons and asteroids.

5. Know the age of Earth and the solar system.

4.5 billion years earth & solar system, milky way galaxy 11 billion years

6. Describe the probable composition of Earth's original atmosphere.

Consisted of methane and carbon dioxide, no free oxygen available.

7. Discuss the gases that were added to the original atmosphere when the crust began to form.

Volcanism following the formation of crust led to water vapour, methane, sulphur dioxide and ammonia.

8. Discuss one theory of how the first organic molecules could have formed and how they managed to persist.

Lack of free oxygen in the early Earth made the development and preservation of the first organic molecules possible. Oxygen would have quickly oxidized and destroyed them otherwise.

9. Talk about the earliest known organism and how it changed the Earth's atmosphere.

Cyanobacteria, a photosynthetic single celled bacteria, used solar energy and carbon dioxide to produce free oxygen changing the atmosphere into oxygen-rich.

10. Give the approximate age when complex (multi-celled) organisms began to evolve.

600 million years ago

11. Explain the calculations made by Lord Kelvin and why his estimate of the age of Earth was wrong.

- Assumption: Earth formed by molten rocks cooled from magma to create a crust. This calculation estimates earth at about 40 million years old
- He is wrong because: 40 million years (the calculated age of Earth) is not nearly enough time for such a process to work and produce the numerous living and extinct species that were known to exist

12. Calculate how many calories are required to heat up a given amount of water by a given number of degrees C.

13. Understand the general process involved in fission (atomic) reactions.

The splitting of an atomic nucleus into two lighter daughter particles emitting radioactive decay. Occurs naturally within the earth i.e. U-238

14. Explain what Einstein's formula ($E = mc^2$) means and how it relates to radioactive decay.

15. Compare the amount of solar radiation reaching Earth and what processes it is important for relative to the amount of radiogenic heat reaching the Earth's surface from below.

Unit 2 Questions:

1. Say how seismic evidence can be used to interpret the Earth's internal structure.

It is known that energy waves travel faster in denser mediums and that at boundaries of varying densities there is reflection and refraction of the wave. The amount of time and energy wave takes to reach a receiver (i.e. geophone) from known locations indicates velocities of the energy waves. This can lead to predicting the location of discontinuities.

1. Understand the various layers within the Earth, their relative position, thickness, density and composition.

Crust - (5-50km)

Mantle - (2900km)

Liquid Outer Core - (2270 km)

Solid Inner Core - (1216 km)

1. Describe what S-waves and P-waves are and how they behave within the Earth.

S-Wave: vibrate perpendicular to the transmission like a rope transmits energy from one end to another when one end is fixed. Only through solid

P-Wave: vibrate parallel to the transmission like a slinky compresses and extends to transmit energy. Faster than S and go through solid and liquid.

1. Discuss how the study of meteorites has aided in the study of the composition of the various layers within the Earth.

Meteorites reflect internal compositions of former planets and indicate the internal composition of the Earth. Creating similar proportions of the meteorite with materials from Earth and putting them under conditions mimicking Earth's interior tests this. These are compared with the meteorite.

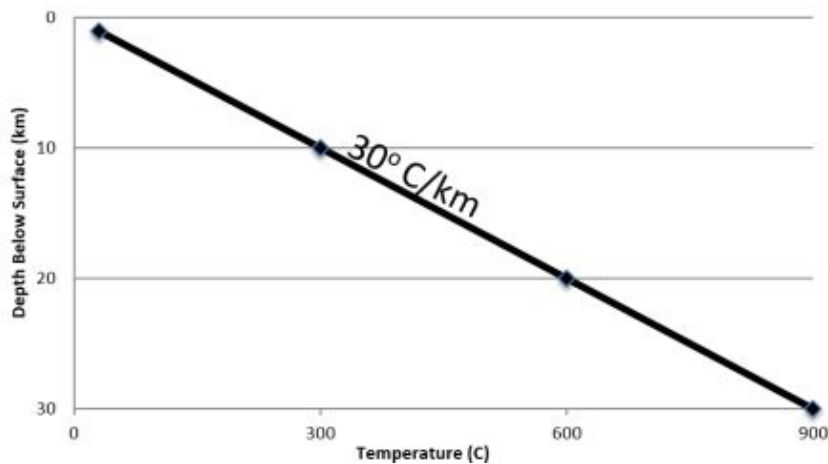
1. Describe the types of meteorites and their important properties.

Iron: metallic iron mixed alloyed with magnesium. Similar to Earth's Core.

Stone: Magnesium and iron silicates. Similar to Earth's Mantle.

- CHONDRITES – contain chondri (small spherical bodies). Similar to whole Earth.
- ACHONDRITES – no chondri and variable composition. Similar to Earth's Crust.

1. Draw a graph showing how temperature increases with depth in the crust and how this varies with geographic location.



Note: near an erupting volcano, this gradient would be considerably higher than the average gradient.

2. Describe convection and conduction and how they relate to heat movement within the Earth.

Conduction – slows down heat carried to Earth's surface through rocks.

Convection – much faster than conduction, transports heat to the surface through hot magma that cools when it gets closer to the surface and heat is lost from the Earth.

Unit 3 Questions:

1. Describe what a mantle (convection) plume is.

Mantle plumes are sections within the mantle that are hotter than the regular mantle causing convection movement. The hot magma rises and the displaced, cooler, denser mantle material sinks. This is the cause behind hot spot volcanoes and bulges on Earth's surface

2. List the major pieces of evidence used to support the theory of plate tectonics (such as similar fossils on both sides of the Atlantic Ocean). You should be familiar with at least four pieces of evidence that support the theory.

Similar rock types in Scotland and North America. Similar fossils in South America and South Africa with no trace of them between the Atlantic Ocean. Climate evidence as cold glacial climates once covered hot and tropical regions such as the Sahara desert. Paleomagnetism shows evidence that there was movement with respect to reversing magnetic poles. Oceanic spreading, as seen with the aging of rocks farther from the Mid-Atlantic Ridge.

3. Explain the mechanism of ocean floor spreading, how it was first discovered and the major pieces of supporting evidence.

WWII submarines brought on the first of deep ocean exploration allowing samples to be taken. Flights over the ocean showed symmetrical stripes about a central line. Fred Vine and DH Matthews put these together understanding that as volcanic lava reaches the surface along the Mid-Atlantic Ridge (central line) it's magnetized according to the current magnetic field showing the change in new rock over time. As time carries on, more rock rises and pushes the original rock farther and farther away

4. Explain the origin and significance of the symmetrical magnetic anomalies on either side of the Mid-Atlantic Ridge.

The pattern reflects the periods of normal and reverse Paleomagnetism. When the Earth was in periods of reversed poles, the iron-rich lava cooled and was magnetized oppositely as to how it does with normalized poles.

5. Look at a plate map of the world and be able to indicate where plates are colliding, where they are moving apart, and where they are sliding past one another. (convergent, divergent, transform)

6. Describe the process of subduction including where and how it happens as well as the processes that go on there.

Subduction occurs between two plates of varying densities. When the plates collide that of higher density is forced beneath that of lower density, for example and oceanic plate forced under a continental plate. At the point of contact, there is initial crushing between the two that yield mountain forms.

7. Explain how slab-pull and ridge-push work.

Ridge-push is work done by gravity and causes plates to slide down and out from the ridge into a subduction zone.

Slab-pull occurs when a crustal plate moving from an oceanic ridge cools and sinks beneath the continental crust in a subduction zone. This creates a force that pulls the rest of the plate downward.

8. Describe the rock cycle and how it can vary from the ideal model.

In the ideal rock cycle, magma first cools and crystalizes into plutonic igneous rock.

Weathering then breaks down the rock and it is transported and deposited downhill as sediment.

Lithification then compacts and cements this into sedimentary rock.

Metamorphism then transforms it into metamorphic rock under intense pressure and high temperature conditions.

Metamorphic rock undergoes melting back into magma under the Earth's surface.

This cycle can vary when steps are bypassed or reversed from altered conditions...

Igneous rock can sink so deep that it goes directly back to the melted lava stage.

Igneous rock can sink and undergo such intense pressure that it forms directly into metamorphic rock.

Sedimentary rock can be uplifted and weathered back into sediment.

Metamorphic rock can be uplifted and weathered back into sediment.

Unit 4 Questions:

1. Define a mineral.

A naturally occurring inorganic solid with regularly repeating internal structure and chemical composition that varies within defined limits.

2. Define electrons, protons and neutrons and their electrical properties.

Proton – positively charged subatomic particle in the nucleus of atoms

Electron- negatively charged subatomic particle in the orbitals of atoms

Neutron – neutral subatomic particle in the nucleus of atoms

3. Describe the difference between atoms, molecules, minerals, and rocks.

Atoms are the smallest division of matter that retain element's characteristics. Molecules are basic building blocks formed from bonded atoms. Minerals are substances formed by molecules joined in an orderly structure. Rocks are solid substance formed an agglomeration of minerals.

4. Write out Bowen's continuous and discontinuous reaction series and know how they relate to temperature of formation and mineral stability.

disContinuous: Olivine, Pyroxene, Amphibole, Biotite, K-feldspar Muscovite
Quartz

continuous: Plagioclase

5. Draw the idealized structure of the atom and how electrons are arranged in the orbitals.
6. Explain what an inert gas is and give several examples.

A gas with all 8 valence electrons filling the outer orbital ie Ne, Ar, Xe, Kr

7. Explain the process of ionization and why it occurs.

Ionization is the charging of an atom that occurs when the atom losses or gains an electron to become stable.

8. Describe an ionic bond, why it occurs, and the major properties of minerals that contain them.

When electrons are transferred from one atom to another an ionic bond occurs. Atoms only one or two valence electrons are likely to donate them in ionic bonding. Minerals containing ionic bonds are generally soft and soluble.

9. Fully explain what a covalent bond is, what types of atoms are covalently bonded and the major properties of minerals that contain these bonds.

The sharing of electrons in the valence shell between two atoms is covalent bonding. This commonly occurs in atoms with half full outer orbitals and is the strongest type of bonding. Minerals with covalent bonds tend to be hard with low solubility.

10. Explain Van der Waals bonds and metallic bonds and the properties of the minerals that contain them.

Van der Waals bonds occur between neutral molecules due to electrostatic force and are very weak. Metallic bonds form between atoms all with freely shared outer electrons. Minerals with metallic bonds have high conductivity and malleability.

11. Say why graphite and diamond are very different even though they are both composed entirely of carbon.

They are polymorphic, meaning that they have the same composition but are distinguished by their structure. Graphite is formed with covalent bonds along the planes of molecules but with Van der Waals bonds between these planes. This gives the graphite a brittle structure. Diamonds, however, only contain strong covalent bonds.

12. Define a cation and an anion as completely as possible.

Cation – positively charged ion occurring from a loss of electrons⁺

Anion – negatively charged ion occurring from a gain of electrons⁻

13. Explain the coordination number of molecules with different shapes. Also you should remember that the most important building block of silicate minerals is the silicon tetrahedron (coordination number = 4)

The coordination number of molecules describes the max number of anions surrounding a cation. A molecule with a coordination of 4 would form a tetrahedron shape. Higher numbers form octahedrons (6), cubes (8), etc. This shape determines the molecule's unit structure.

14. Explain how one cation can substitute for another during mineral formation and how electrical neutrality is maintained.

If a cation is of similar size, it can be substituted during mineral formation. If the new cation has a lower positive charge more cations must be added to neutralize the molecule. This changes composition and structure therefore forming a different mineral. (i.e. different feldspars)

15. Describe the five major ways in which silicon tetrahedra can join together and what structures are produced.

- Island – the silicon tetrahedra are not joined directly but through ionic bonding between $\text{Fe}^{3+}/\text{Mg}^{2+}$
- Single Chain – sharing of silicon tetrahedra corner oxygens, chains join through ionic bonding between $\text{Fe}^{3+}/\text{Mg}^{2+}$
- Double Chain – corner and side oxygens shared between silicon tetrahedra, chains join through ionic bonding between $\text{Fe}^{3+}/\text{Mg}^{2+}$
- Sheet – 3 oxygens of each silicon tetrahedra are shared and form planes
- Framework – all oxygens of each silicon tetrahedra are shared

Unit 5 Questions:

1. Classify the most common igneous rocks based on their colour, texture and mineralogy.

Coarse-Light-High Quartz = Granite

Coarse-Light-Low Quartz = Syenite

Coarse-Dark-No Quartz = Diorite

Coarse-Dark-High Pyroxene = Gabbro

Fine-Light-High Quartz = Rhyolite

Fine-Light-Low Quartz = Trachyte

Fine-Dark-No Quartz = Andesite

Fine-Dark-Lots of Pyroxene = Basalt

Vesicular-Light = Pumice

Vesicular-Dark = Scoria

Glassy = Obsidian

Fragmental = Ash, Tuff, Breccia

1. Describe the main textures of igneous rocks and know how each texture is produced.

Aphanitic (coarse) – microscopic crystals formed from rapid cooling at surface found in volcanic igneous rock.

Porphyritic (fine) – large and small crystals from two-stage cooling found in volcanic igneous rocks.

Phaneritic (vesicular) – large visible crystals from slow cooling at a depth found in plutonic igneous rock.

Fragmental – non-crystallized found from particles thrown from a volcano.

1. Describe the general characteristics of the two main parent magmas, what rocks they produce and how they can be modified as they rise toward the surface.

Basaltic (mafic) – hot and fluid, Si poor, produce volcanic igneous rock.

Andesitic – viscous, Si rich, produce plutonic igneous rock.

1. Describe how subduction is related to the formation of andesitic parent magma.

Generated beneath thick continental crust where subduction occurred. Melted lower continental plate and upper oceanic plate produced magma.

1. Explain crystal fractionation.

Crystal fractionation is the process of liquid magma's composition changing. As minerals crystallize, they use elements like Fe and Mg to do so leaving the liquid with a richer Si concentration. Temperature decreases as minerals continue to form and magma cools. The growing crystalline structures cannot incorporate gaseous molecules so they are forced to bubble out. This ultimately results in a lower liquid content as a result of the forming minerals and regressive "boiling" as a result of the forced release of gasses.

1. Explain how ionized water (OH^-) concentrates in magma and the role it plays in volcanic eruptions.

As more minerals crystallize within magma, the crystalline structure grows more complex and doesn't have room for ionized gasses like OH^- . The gas is thus forced out of the magma and into the free space of the magma chamber. This in turn pressurizes the system eventually causing eruption.

1. Explain why some volcanoes erupt frequently but quietly while others erupt rarely but explosively.

Volcanoes with a thick, solid plug are required to generate mass amounts of pressure to free it, resulting in catastrophic eruptions when it is finally released. Volcanoes with a thin vent require little pressure to erupt and are therefore able to do so regularly in a quiet manner.

1. Describe pyroclastic material and how it forms.

Pyroclastic material is a general term for any broken up or pulverized material ejected during explosive eruptions. Fine grained pyroclastic ash forms tuff and larger pieces solidify into breccia.

1. Explain how a caldera forms.

Following an explosive volcanic eruption, the mountain often experiences fracture. This can lead to the mountain collapsing in forming a caldera.

1. Explain what types of volcanoes occur at different types of plate margin.

Eruptions of basaltic lava (commonly shield volcanoes) occur in areas of oceanic crust where plates diverge. Eruptions of andesitic lava (commonly

strato-volcanoes) occur at convergent plate boundaries where subduction has occurred.

1. Explain why Hawaiian volcanism is a special case and what processes are at work to form the Hawaiian Islands.

The Hawaiian volcanoes are an exception as they erupt basaltic lava formed in the middle of the solid Pacific plate (not an oceanic ridge). The Hawaiian Islands are a result of a trail of volcanic activity as the Pacific plate moved above a stationary mantle hot spot.

1. Describe the two main surface textures of lava and what properties of the lava cause the textural differences.

Aa lava: Appears "blocky" and contains a high volume of gas

Pahoehoe lava: Appears "ropy", contains a low volume of gas

2. Compare and contrast shield volcanoes and stratovolcanoes and the type of eruptions and materials they produce.

Shield volcanoes form as a result of basaltic lava eruptions. They have a wide coned shape due to little pyroclastic material and smooth lava flows.

Stratovolcanoes form as a result of andesitic lava eruptions. They have a cone shape consisting of alternating layer of pyroclastic material and lava.

1. Define special types of volcanic rocks such as welded tuff, pillow lava and columnar basalt.

Pillow lava – small rounded rocks formed from quick cooling when lava comes in contact with water. (Erupted under water or lava slid into water)

1. List the names of the intrusive igneous bodies and how they are defined.

Batholith – largest bodies of intrusive rocks existing deep below crust.

Laccolith – similar to batholith but a bit smaller and shallower, cause bulging of the overlying layers of rock

Dikes – bodies that cut across bedding of host rock in a perpendicular wall

Sills – bodies that cut across bedding of host rock in a parallel sheet

Unit 6 Questions:

1. Describe the main processes involved in mechanical weathering and in what environments mechanical weathering is predominant.

Mechanical weathering is the physical breakdown of rocks without changing the chemical composition. This increases surface area thus allowing chemical weathering can occur more easily. It is prevalent in cold, high altitude, dry regions where rock is composed of stable minerals.

Frost action = water freezes in rock cracks at night, increases pressure causing shattering.

Thermal expansion = repetitive cooling and shrinking from daily heat and night time cooling weakening crystalline bonds.

Abrasion = surfaces scraped when carried by water, wind etc.

Exfoliation = plutonic rocks exposed through erosion peel off as sheets from pressure release.

1. Explain the process of solution and why water is a good solvent.

Polar water molecules disrupt attractive forces in minerals causing them to dissolve. Predominant in ionic bound minerals, like Halite. Water is good because the strong polar bond facilitates disruption.

1. Explain the process of hydration/dehydration and be able to give an example.

The emplacement or removal of water within crystalline structure. For example the hydration of anhydrite to gypsum and vice versa.

1. Explain the process of hydrolysis and be able to give an example.

The reaction of a mineral with water causing them both to break apart. Brucite forms from hydrolysis.

1. Describe the processes of oxidation and reduction, what they mean in terms of loss or gain of electrons, and be able to give an example of both.

Oxidation is the loss of electrons commonly causing rusting. Reduction is the gain of electrons common to waterlogged soil where oxygen is sparse.

1. Explain how CO₂ is related to the precipitation or dissolution of calcite in the oceans. How this process has helped to moderate Earth's climate?

When CO₂ and water react they produce carbonic acid in water that increases the dissolution of calcite. This leads to deposition of carbon in limestone ocean beds regulating the growing temperature.

1. Describe the major properties and processes of deciduous forest soils, grassland soils, arctic soils, poorly drained soils, coniferous forest soils, desert soils, and wet tropical soils.

-Deciduous forest (Brunisolic/Luvisolic soil) = surface layer of enriched organic material, clay particles transported down from horizon A by percolating water.

-Grassland (Chernozemic) = thick, black surface layer w/partially decomposed plants that build up.

- Arctic (crysollic) = perma-frozen except for thin top layer in summer. No horizons, frost action.

- Poorly drained (gleysolic) = thick surface layer of organic matter because decomposition is inhibited underwater. Green/grey colour from reduction of Fe.

- Coniferous (podzolic) = thin upper surface layer over a bleached horizon over a dark reddish Fe/Al rich horizon. Areas of rich quartz parent material.

- Desert (regosolic, solonchic) = no horizons, weathered parent material. Areas of strong erosion along slopes, rates of high decomp in river floodplains.

- Wet tropical (laterite) = deep, reddish colour, soft when wet/hard when dry. Leached elements means low natural fertility. Al rich parent=bauxite.

1. Describe some examples of the way geology can impact human health.

Micro-nutrients that facilitate enzyme activities are transported and stored in elements through weathering. Elements in rocks are released into soil allowing plants to intake them. This can have a negative effect when elements in large concentrations become harmful. For example high concentrations of Zn, Co, Cd, and Fe in Wales are known to cause stomach cancer.

Unit 7 Questions:

1. Define a glacier.

Mass of ice formed from solid atmospheric precipitation(snow), it is capable of moving independently.

1. Describe the major factors affecting the formation, growth, and movement of a glacier.

Formed in areas where the snowline intersects with the Earth's surface. High altitudes and latitudes are conducive to this. Move as a result of gravity and friction against the incline. When these two forces are imbalanced the glacier will move.

1. Explain what the snowline is and how it varies with latitude.

Snowline – the altitude at which snow fallen in winter will stay during summer.

1. Relate at least three possible reasons for global cooling.

Forming glacier creates a microenvironment leading to more snow and further cooling of the surrounding environment. Low levels of carbon dioxide, methane and water vapour that trap heat in the atmosphere. Slight tilt in Earth's axis of rotation affecting the amount of solar radiation being received can also cause cooling.

1. Describe what the two main forces acting on a glacier are, and how a change in the balance between these forces can initiate movement.

Gravity and friction control the movement of a glacier. A thickening glacier can grow to overcome frictional forces. An increase in incline slope can upset equilibrium with gravity. When melting of the glacier is greater than the internal transfer of ice within the glacier imbalanced forces cause movement.

1. Draw on a map of North America the major centers of Pleistocene glaciation and the southern margin of continental glaciation.
2. Explain what is meant by positive and negative budgets and how they relate to the growth of a glacier.

When the melting of a glacier and the internal transfer (ice moving through tubes from accumulation zone to ablation zone) are equal there is a balanced budget. A positive budget refers to when there is an overall addition of snow/ice to the glacier. A negative budget refers to when there is an overall loss of snow/ice to the glacier.

1. Draw a longitudinal section of a glacier showing the main zones of a glacier and how material is transferred from one to another.

Accumulation à Firn line à Ablation

1. Define "pressure melting point" and how it relates to glacier movement.

PMP is the melting temperature of ice at a given pressure. At higher pressures ice will melt at lower temperatures than 0° .

1. Describe the difference between temperate and polar glaciers and their behaviour.

Temperate – water throughout and at the base, the ice temperature is higher than the PMP, water decreases friction allowing active movement

Polar – completely frozen throughout and to base, temperature of ice is lower than PMP, stagnant

1. Describe how ice moves internally and at the surface of glaciers and how crevasses form.

Ice moves in a glacier by internal transfer. Tubes parallel to the surface continually transfer ice from the accumulation zone to the ablation zone.

Crevasses form as a result of different parts pulling away from each other with enough stress in the upper section.

1. Describe the various common landscape features caused by glacial erosion and how they form.

Striation- scratches from the glacier carrying rock/sand over bedrock

Roches moutonnes – ice passing over protruding rock smooths the stross side (pressure causes melting) and plucks the lee side(meltwater freezes to rock and pulls chunks away).

Crag & tail – ice passes over resistant rock and deposits material from the surrounding area on the lee side creating a tail

Fjord – U-shaped valleys made from partially floating glaciers, flooded upon deglatiation

Cirques - form mountains into pyramidal shapes

1. Define a lateral moraine, medial moraine, and transverse moraine and what type of material they are composed of.

Lateral – ridge of debris deposited from valley walls at margins of glacier

Medial – merged ridge of lateral moraines from two valley glsriers

Transverse – merging of all moraines toward the glacier terminus

1. Describe common landscape features formed by glacial deposition and understand how they form.

Drumlins – teardrop shaped hills formed under temperate glaciers

Terminal Moraine deposit – sediment from internal accumulation of a glacier in equilibrium

Recessional Moraine – ridge from fast retreating glacier that built up accumulation in the winter

Esker – well sorted sediment ridges formed from water flowing through tunnels in/under glacier

1. Describe what "till" is and what it is made of.

A till is sediment deposited by a melted glacier.

1. Describe the major types of glaciolacustrine (lake) and glaciofluvial (river) sediments.

Glaciolacustrine – varve (layers of coarse sediment in summer and fine sediment in the winter) pluvial lake (from heavy rain)

Glaciofluvial – outwash plain (run off melt water at the terminus of a glacier deposits sediment), braided stream (coarse sediment carves out)

1. Explain how loess is formed and distributed, its physical structure and importance in agriculture.

A loess is a blanket of fine, silty material deposited by the wind. This produces silt rich soil ideal for agriculture.

1. Discuss the long and recurring history of global climate fluctuations "Greenhouse" to "icehouse" and back again.

A shift from greenhouse (little T difference at equator and poles) to icehouse (large T difference at equator and poles) occurs approximately every 300 million years.

1. Define isostatic rebound, and how it affects glaciated landscapes.

Glaciers cause an immense amount of pressure to the Earth's crust, thus when the glacier is removed the release of pressure results in an upward rising of the crust called isostatic rebound. (3m/century)

1. Describe "permafrost" and some of the effects it has on the landscape.






When soil is continuously frozen for at least two years (with the exception of the active top layer) it experiences freeze-thaw cycles and ice lenses that lead to: angular pebbles, ice wedges, polygonal patterned ground...

1. List the major changes that have occurred on a global scale since the end of the last continental glaciation, especially those which have affected human cultures.

Temperature rising continued from 13 000 years ago to a peak around 9000/5000 years ago. Fluctuation following led to rises and falls of agriculture and populations. Cooling climates forced Vikings to explore farther and led to the discovery of North America.

Unit 8 Questions:

1. Identify a clastic sedimentary rock based on its particle size.

Clastic Texture Particle Size		Sediment Name	Rock Name
Coarse > 2mm		Gravel (Rounded particles)	Conglomerate
		Gravel (Angular particles)	Breccia
Medium 2 – 0.062 mm		Sand (If abundant feldspar is present the rock is called Arkose)	Sandstone
Fine 0.062-0.004mm		Silt	Siltstone
Very Fine < 0.004 mm		Clay	Shale or mudstone

2. Draw and describe the vertical and lateral velocity profiles of a stream.
3. Describe the difference between laminar and turbulent flow, and where they are found in nature.

Laminar flow - low **Reynold number** and is characterized by smooth flowing water with "idealized flow tubes" that are straight and parallel to the channel. Rarely occurs in nature, but instead **quasi-laminar flow** can occur in slow moving water (inside bend of meandering stream)

Turbulent flow - has a high **Reynold number** and occurs naturally in all streams, waves, currents and even winds. An average velocity is found for this flow. Increasing velocity and bed roughness causes it. Turbulent flow and eddies are effective at eroding and transporting sediment.

4. Explain the difference between turbulent subcritical and turbulent supercritical flow. How can you recognize these flows when looking at a river in flood?
5. Describe what ripples, subaqueous dunes, plane beds, and antidunes are, under what flow conditions they form, and what sedimentary structures they produce, when seen in a cross- section.
6. Explain what "settling velocity" of particles is and which particles settle fast and which ones settle slowly.
7. Draw out Hjulstrom's diagram and know how to interpret it.
8. Define suspended load, saltation load, bed load, and solution load of a river.
9. List the major marine environments of clastic sedimentation, the processes at work in each and the sediments and sedimentary structures generated in each one.

10. List the major continental environments of deposition, where they are located, the main processes at work in them, and the sequence of sedimentary structures that are generated in each one. These environments are listed in order from mountainous environments to the sea.
 - Talus fan
 - Alluvial fan
 - Braided stream
 - Meandering stream
 - Delta
11. List the major marine environments of carbonate sedimentation, especially the example of the Bahamas. Know the processes at work and the types of carbonates that are generated.
12. Describe the major environments of evaporite formation and the processes required to generate evaporite rocks.
13. List the sequence of precipitation of evaporite minerals as ocean water evaporates.

Unit 9 Questions:

1. Discuss the five main ways that fossils can become preserved, and be able to give examples.
 2. Explain what a trace fossil is and be able to give examples.
 3. Define convergent and divergent evolution and be able to give examples.
- **Convergent evolution:** different organisms that share a common environment will begin to develop similar characteristics best suited to that environment
 - For example, mammal->dolphin, Bird -> Penguin, Reptile -> ichthyosaur
 - **Divergent Evolution:** when groups of identical organisms are isolated from one another in different environments, they start evolving traits best suited to those environments
 - Example: fish -> amphibian -> reptile -> bird -> mammal
4. Explain how fossil evolutionary sequences can be used to define relative time.
 5. List the important properties of index fossils and know their importance.
 6. Explain the important properties of paleo-environmental indicators and give an example.
 7. Explain how evolution works in a general way.
 8. Describe how fossils are classified, and how this differs from the way in which modern biological specimens are classified.
 9. Identify the most common marine invertebrates using the key for the identification of fossils.
 10. Give a possible historical basis of the biblical story of Noah's flood.
 11. Explain the diluvialism school of thought, and how these discussions contributed to a better understanding of fossils.

Unit 10 Questions:

1. Describe the three main stratigraphic principles and how they can be applied.
 - a. The principle of Uniformitarianism → this principle assumes that the process which form features today function in the now as they did in the past.
 - b. The principle of Original Horizontality → the assumption that all strata layers form in a horizontal pattern
 - c. The Principle of Superposition → this principle states that the lower layers are older than those higher
2. Describe two important bio-stratigraphic principles and their application.
 - a. Identification → used to recognize fossils in the strata which can be used to determine the age of the layer
 - b. Zonation → different rock strata in different locations can contain similar fossil assemblages (Index Fossils)
 - c. Correlation → indicated the time equivalences btwn rock strata exposed at different locations
 - i. Example: Cretaceous-Tertiary (KT) boundary - marks the mass extinction of dinosaurs.
3. Give a good example of a lithostratigraphic marker.
4. Discuss the difference between relative time and absolute time and how each can be measured.
 - a. Absolute Age is determined by radioactive dating giving an age estimate in years before present (y.b.p.)
 - b. Relative Age is determined primarily by fossils and only addresses whether a bed is older or younger than another. The stratigraphic and bio-stratigraphic principles can be used to determine the relative age.
5. Explain what a time line is. ← Is this a real question?
6. Describe the four different types of unconformities.
 - a. Angular Unconformity →
 - b. Nonconformity
 - c. Disconformity
 - d. Paraconformity
7. Describe the properties of a geologic formation, the basic working unit of stratigraphy
8. Define marine transgression and marine regression.
9. Recognize and explain the genesis of a marine transgressive sequence and a marine regressive sequence.
10. Define source rock, mature source rock, stratigraphic trap, and a caprock, and know what rock types each of these are likely to be.
11. Explain the development of a hydrocarbon reservoir from the original sedimentation of plankton, to the economic recovery of oil.
12. Analyze how the theory of relativity and more recent discoveries in subatomic physics have helped in the understanding of the true nature of time.
13. Work out the chronological sequence of events in a geologic cross section.
14. Discuss the Eras and Periods of the geologic time scale and know how the boundaries between major time divisions were decided.

- Describe at least four methods, not including radiometric, of establishing the absolute ages of rocks, and analyze the strengths and weaknesses of each method.
- Explain the way in which radioactive isotopes can be used to calculate the absolute ages of rocks, and know the advantages and limitations of these methods.

Unit 11 Questions:

- Describe under what conditions rocks behave in an elastic, brittle, or plastic fashion.

Plastic - deep within the Earth under high pressure conditions, rocks behave in a plastic manner and become **folded**.

- Define stress in rocks.

Stress: directional pressure (force) measured per unit area

- Say what the deformation caused by the tangential component of stress (shear stress) is called.

A fault.

- Define an anticline and a syncline and be able to draw them correctly.

Anticline: where the beds are bent upwards in an arch

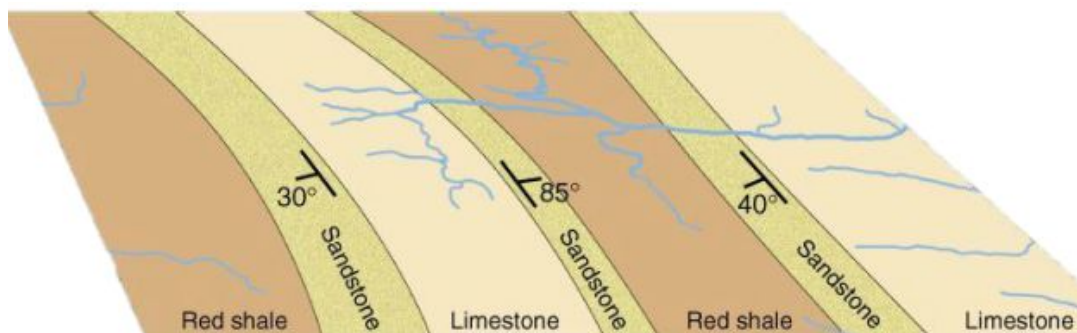
Syncline: where the beds are bowed downwards into a "U-shape"

- Define strike and dip, how they are measured and how they are depicted on a geological map.

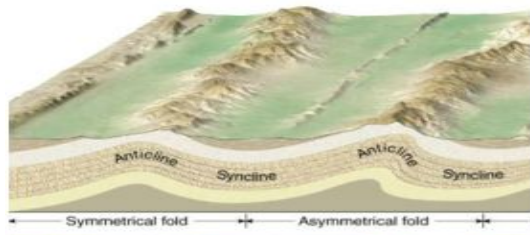
Strike: orientation of a horizontal line on the bedding surface. This is expressed as a compass bearing (eg. NW or SSE)

Dip: always perpendicular to the strike line and is measured in degrees from the horizontal

A structural geologist will measure the strike and dip of the rocks and describe the rocks at different outcrops in an area. Example below:



- Sketch the various types of folding: symmetrical, asymmetrical, isoclinal and recumbent.



Recumbent



Isoclinal Fold

fold axes

Recumbent are U shaped on their side and Isoclinal folds are tight folds.

- Describe the mechanisms involved in normal faulting, reverse faulting and strike-slip faulting, and draw a rough diagram of each type.

Normal faulting - caused by a lengthening (stretching) of the Earth's crust

Reverse faulting - caused by a shortening (or compression) of the crust

Strike slip faults - form where crustal plates slide past each other with very little vertical movement (a good example is the San Andreas fault in California)

- Define a thrust fault and a transform fault.

Thrust faults: are low angle reverse faults formed during mountain building at continental margins

Transform fault: relative motion is predominantly horizontal, in either a sinistral (left lateral) or dextral (right lateral) direction. Most are hidden deep in oceans, but the best known and most destructive are those on land at the margins of tectonic plates.

- Describe in some detail, the four main stages in the life history of a complex mountain chain, and be able to give modern examples of mountain chains in each of the four stages of development.

Stage 1 - development of thick sequences of sedimentary rocks at a passive continental margin. The crust bows downward as sediments collect which allows room for the deposition of sandstones, limestones and shale thousands of metres thick. (Example is Gulf of Mexico)

Stage 2 - begins with plate collision. Volcanism and igneous intrusion cause thickening of crust above the subduction zone near the edge of the continent. Rocks in this zone are subjected to great temperature and pressure and become ductile. This causes them to **fold** rather than fault. The thick, relatively brittle sequences of sedimentary rocks that were deposited on the continental shelf are thrust up onto the continent via a series of large faults. (Example is Peyto Lake, Alberta)

Stage 3 - is when most of the uplift occurs. The downward pull of the subducting plate is now less and the mountains "float" upward in the denser mantle. This produces a lot of normal faulting and a steep mountainous terrain. (Example is Trango Towers Pakistan)

Stage 4 - uplift slows and erosion begins to dominate. The average elevation of the mountain range begins a long slow decline. Eventually a new relatively subdued landscape is formed. The whole cycle of a mountain range takes about 1 billion years to complete. (Example Paint Lake, Canadian Shield Ontario)

Unit 12 Questions:

1. List the three agents of metamorphism and the specific effects of each.

Heat (important) - increase in temp with *depth* (Normal geothermal gradient which averages 30 degrees C/KM) and through *contact metamorphism* from magma intrusions or lava flows.

Pressure - atmospheric pressure at sea level is about 1- bar; plate collision and faulting could increase pressure levels

NOTE: Most metamorphism progresses without any loss or addition of new material except where chemically active fluids are present.

Chemically Active Solutions (less common) - mainly water with many dissolved ions. These waters are under great pressure which can result in them becoming superheated (like a pressure cooker). This carries a lot of material in solution and can enhance the migration of ions and aid in re-crystallization of existing minerals

These fluids can come from groundwater, hydrated minerals or residual liquid from magma crystallization.

2. Describe the four main types of metamorphism, the relative importance of temperature and pressure in each one, and in which environment each occurs.

I) Contact Metamorphism - more effect of temperature than pressure (Tp) occurs when molten rock comes in contact with surrounding rock (earth's surface or at great depths)

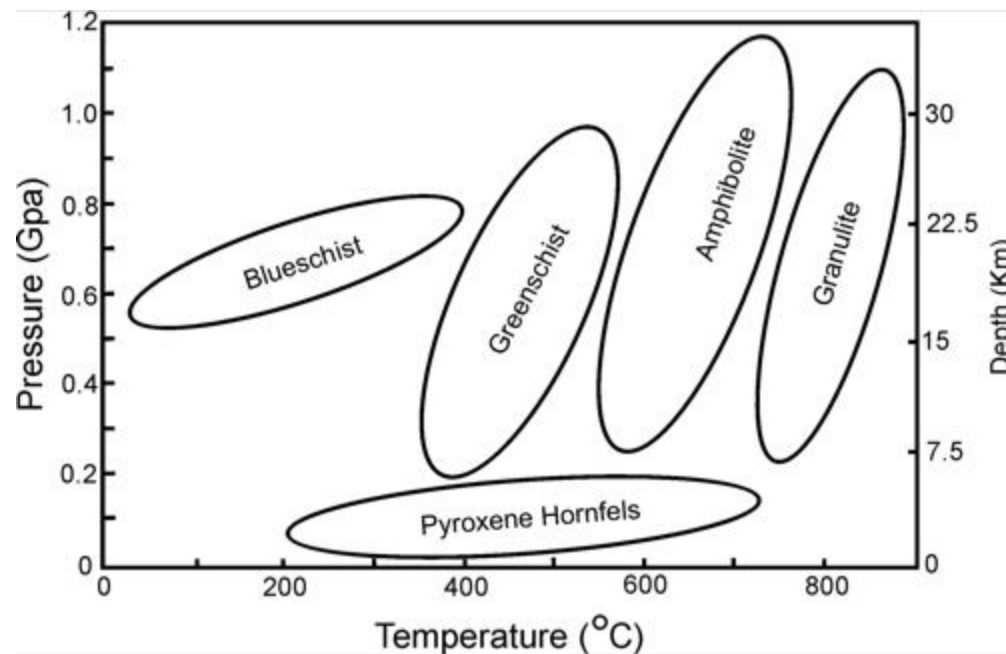
II) Regional Metamorphism- equal contribution of pressure and temp (PT or pt) occurs typically over large areas such as complex mountain regions. High grade rocks at deep depths and high temp & vice versa

III) Dynamic Metamorphism- more effect of pressure than temp (Pt) occurs at fault zones where plates are moving past one another causing immense pressure. Good example would be the san andreas fault which is near the earth's surface and can create a rock called fault breccia

IV) Metasomatism- if chemically active fluids are present; occurs when chemically active fluids circulate through permeable rock allowing for the migration of ions. Typically occurs in core of active or dormant volcano or adjacent to large igneous pluton. Economic metals such as gold and copper are formed this way.

3. Define "**metamorphic facies**," and the temperature and the approximate pressure conditions under which each facies develops.

minerals that are only stable under specific conditions are grouped together to define the so-called metamorphic facies. This allows us to estimate the particular environmental conditions that existed at the type the rocks formed.



Greenschist facies - named for the green mineral chlorite

Blueschist facies - named for the blue mineral glaucophane

Pyroxene Hornfels facies - named for its black pyroxene and "baked" appearance

Amphibolite facies - named for the amphibole, hornblende

Granulite facies - named for its granular appearance

4. Determine the mineralogy of a metamorphic rock knowing only the pressure and temperature of metamorphism and position of the parent rock on the ACF triangle. & Describe the textures of metamorphic rocks (non-foliated, schistose, and so on).

Table 12.1. Common metamorphic rocks and their characteristics				
Name	Texture/fabric	Main minerals	Comments	Original rock
NON-FOLIATED ROCKS				
Marble	Granoblastic	Calcite, dolomite	Reacts with HCl, occurs in all colours	Limestone or Dolomite
Quartzite	Granoblastic	Quartz	Scratches glass, may be any colour but often light shade	Sandstone
Hornfels	Massive	Muscovite, quartz	"baked" looking	Shale, siltstone
FOLIATED ROCKS				
Slate	Slaty, fine grained	Fine grained muscovite and quartz	Individual mineral grains not visible. Good cleavage in one direction	Shale
Phyllite	Slaty, phyllitic	Fine grained muscovite and quartz	Individual mineral grains not visible. Silky sheen	Shale, tuff
Schist	Schistose, Medium grained	Muscovite, biotite, quartz, plagioclase	Individual mineral grains are visible	Shale, tuff
Gneiss	Gneissic, coarse grained	Feldspar, quartz, mica, amphibole, garnet	Individual mineral grains are visible. Coarse light/dark banding	Granite
Migmatite	Wide light/dark banding	Quartz, feldspar, amphibole, biotite	Resembles gneiss but the bands are much thicker	Combination of a metamorphic host and a granitic magma

5) Define what metamorphic grade is and explain how it relates to the metamorphic facies concept.

Degree or grade of metamorphism relates to the successive changes in rocks from non-metamorphic to fully metamorphosed rocks. The grade of metamorphism is related to the temperature-pressure gradients in the Earth's crust. Low-grade metamorphism occurs nearer to the Earth surface, high-grade metamorphism occurs deeper or where temperature and pressure are high.

6) Discuss how the aluminosilicate polymorphs can be used as paleobarometers and paleothermometers.

I don't know

7) Describe how bands of different metamorphic rocks in ancient mountain chains can help in calculating the geothermal gradient that existed there during orogeny.

This means that some minerals developed during metamorphism can be used to determine the range of paleotemperatures and paleo-pressures (ancient temperature and pressure) that once existed.

The normal procedure is to take rock samples and determine their mineral assemblages. This establishes the grade of metamorphism a particular area has undergone in the past. It is found that both in recent and ancient mountain chains, the metamorphic rocks are distributed in bands from the inner to the outer part of the mountain belts. In Japan, the trend in metamorphic grade indicates a stronger influence of temperature than pressure. In British Columbia, the pressure gradient was stronger than the temperature gradient, and in the Scottish Highlands, temperature and pressure played an equally important role