GEO1115 F15

Week Two: Tuesday, September 22, 2015. TECTONICS AND DATING

Brief History:

- 13.7 Ga: Big bang
- ~5 Ga: Solar nebula contracts and rotates
- ~4.5 Ga: Moon forms, earth differentiates shortly after its formation.
- 4.28 Ga: Oldest dated rock (Northern Quebec)

(Where Ga → 1 billion years, giga annum)

Our Planets:

- Terrestrial Planets: small, dense, and rocky. ie. Mercury to Mars
- Jovian Planets: large, gaseous (less dense). ie, Jupiter to Neptune

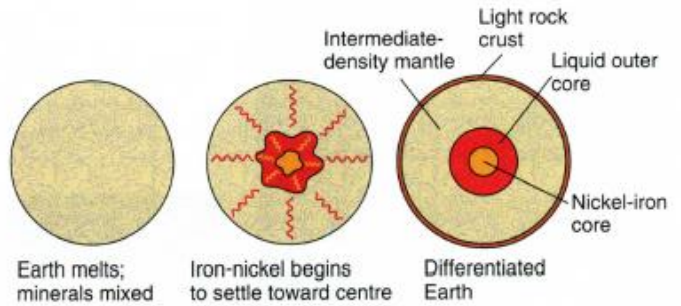


FIGURE 1.8
Differentiation of the Earth.

Differentiation of the Earth: (f. 1.8)

- heaviest (Ni, Fe) → core
- lightest (Si, O) → crust

Structure of the Earth:

Compositional Divisions (lower → denser)

- Crust: Light elements (Si, O, Na, K, Al)
  - Continental ~40km
  - Oceanic ~7km
- Mantle: rich in Fe and Mg
  - source of magma
- Core: heavier elements (Fe, Ni)
  - extremely dense

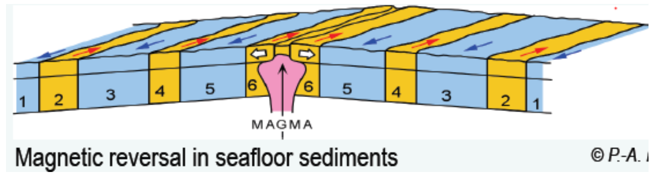
Mechanical (Rheologic) Divisions (ranked by solid/liquid/plastic layers)

- lithosphere (solid)
- asthenosphere (plastic)
- mesosphere (solid)
- outer core (liquid)
- inner core (solid)

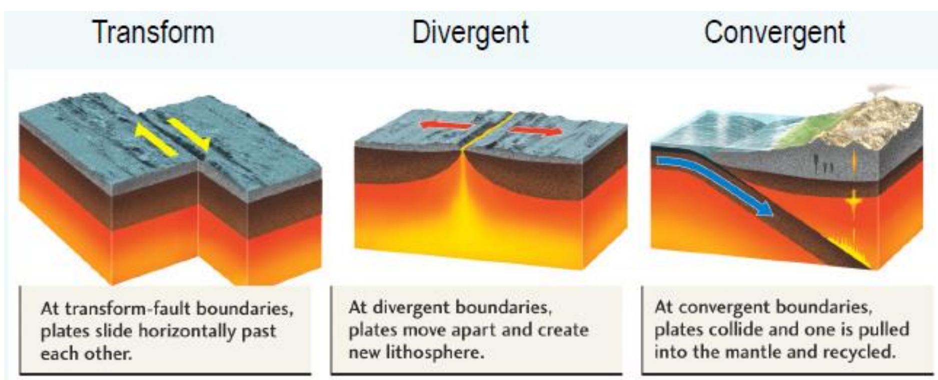
Lithosphere:

- solid, oceanic crust and rigid part of upper mantle
- deforms brittly, ie. plate tectonics.

Plate Tectonics:

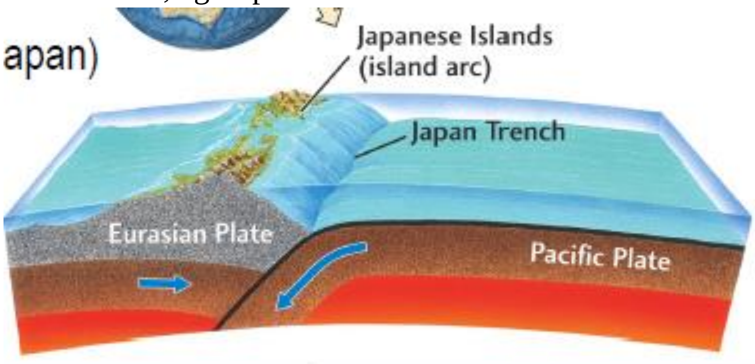


- continental drift: 4 lines of evidence
  - continental fit (ie. South America and Africa)
  - matching (non swimmer) fossils
  - geology
  - glaciations
- Proposed in 1912, but with no explanation for *how* the continents had drifted. 50 years later, plate tectonics offers a driving mechanism for this concept (as shown in above figure). Revolutionized geology in the 60s – explains/brings together numerous geological theories.
- Formal definition of plate tectonic theory: “Tectonic plates are rigid/brittle lithospheric slabs that float above a deformable/ductile asthenosphere.”
- Phenomenon explained by this unifying theory:
  - origin of volcanoes – help map plate boundaries.
  - earthquakes
  - formation of mountains
  - rock deformation
- Rate of movement of tectonic plates is between 10s of mm, to 10s of cm.
- Identification of plate boundaries is made simple by the mapping of volcanoes, mountains, earthquakes.
- Tectonic boundaries: (NOT fixed eternally!)



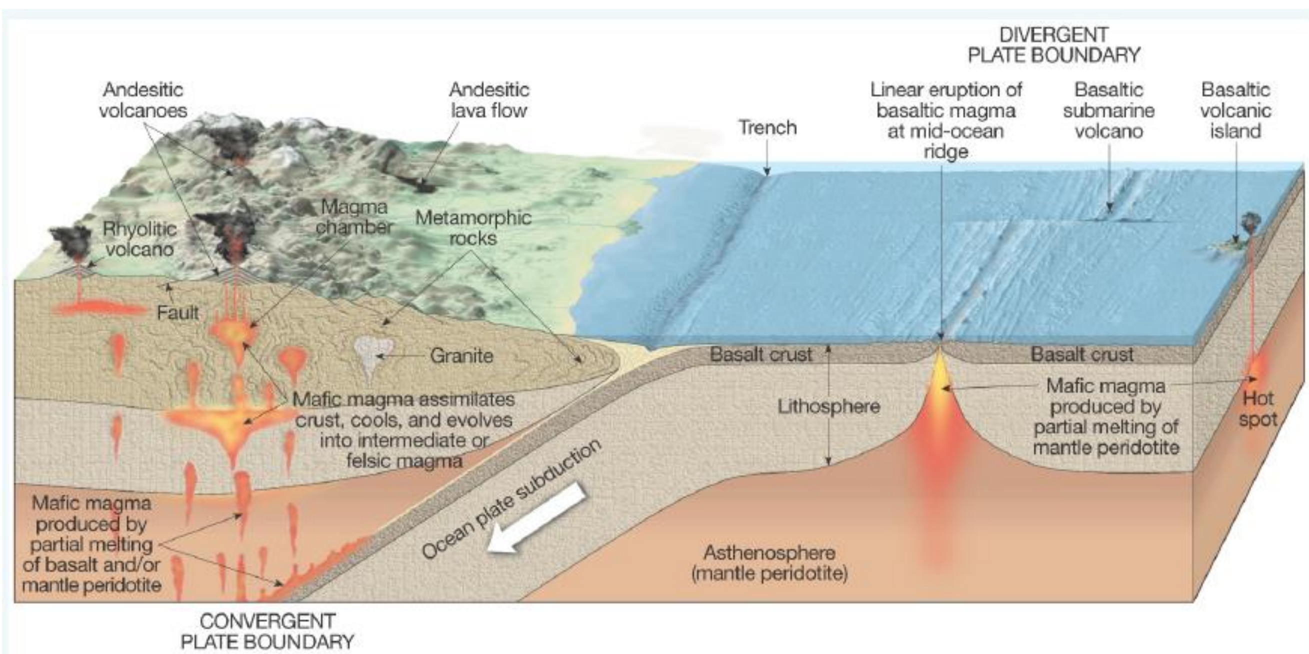
- Divergent: moving away, tensional stress.
  - ie. atlantic ocean – ‘mid-atlantic ridge’, can happen on land as well: creating faults, ie. Iceland.
- Transform: moving parallel, shear stress.
  - ‘kinks in linear features,’ ie. rivers with sudden large fault, making it ‘wonky’
  - ie. San Andreas fault. Earthquakes, very populated area, so studied extensvely.
- Convergent: moving together, compressional stress.
  - Three kinds:

- ocean-ocean, eg. Japan



  denser plate subducts (sinking under the other one)
  portion of plate melts, magma interacts with closer surface rocks, and a line of volcanoes is formed.
- ocean-continent, eg. Andes
  similar to o-o, but different geological makeup, different kind of rocks.
- continent-continent, eg. India and Eurasia – Himalayas.
  Indian-Australian plate subducting under Eurasion.
  Eventually, the plate will stop subducting, and will weld with Eurasia.

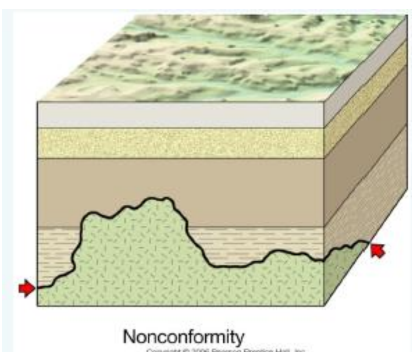
• Summary:



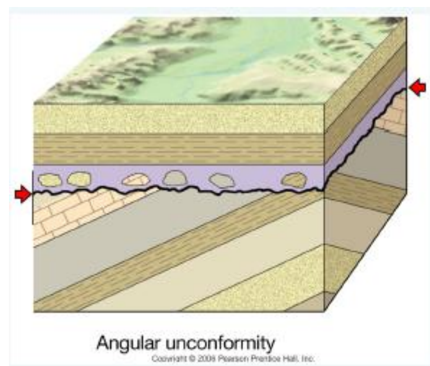
• Mechanism driving plate motion? Still controversial. Some theories:
  - Mantle convection, heat rising, cooling, lowering, repeating. Convection is moving slower than the plates move. So another theory:
  - Gravity acting on lithospheric slabs but pushing and pulling them together, ie. a plate with a slope on plastic material, it will slide and be pulled down, like a conveyor belt.

Geological Time:

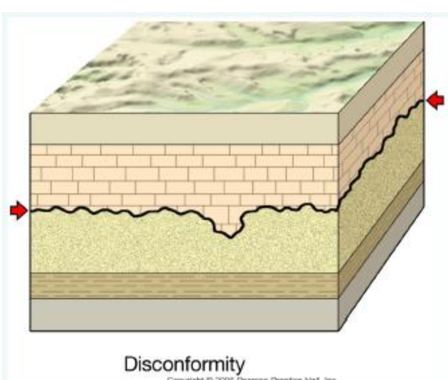
- How to date geological events?
    - Relative dating: (For our labs!) observation and placing events in sequence.
    - Absolute dating: precise age determined by analysis of radioactive elements, ie. measuring their decay process.
- Relative dating based on 6 basic principals:
    1. Original horizontality: Sediment layers were deposited in horizontal position. ie. When did deformity occur?
    2. Lateral continuity: Deposits are laterally extensive. ie, D past A
    3. Superposition: oldest at the bottom and youngest at a top.
    4. Inclusions: inclusions pre-date the formation in which they are found. ie. chunks over O from C.
    5. Cross-cutting: cross-cutting unit is younger. ie. A is cross cutting. H is cross cutting E, P, L, C, etc.
    6. Unconformities: mappable surfaces of regional extent.
- Unconformity: “a surface marking a substantial break or gap in the geological record; marks a major period of erosion or non-deposition.” 4 Types:
    - Nonconformity: Not sedimentary below.



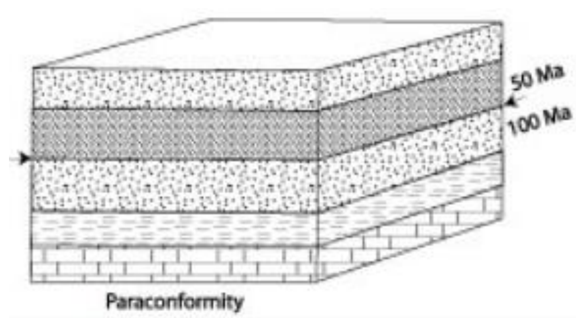
    - Angular unconformity: angled.



    - Disconformity: Visually obvious.



    - Paraconformity: not visible.



- Exercise: top to bottom: para, disc, disc, angular, non.

Week Three: Tuesday, September 29, 2015. PRECAMBRIAN AND PALEOZOIC

Divisions:

- From largest to shortest: eon, era, period, epoch.
- Epoch: ends in '-cene.' subdivisions of Cenozoic periods.
- Periods: names based on specific areas extensively studied.
- Precambrian represents around 90% of earth's history.
- Time boundaries based on fossil records, ie. mass extinctions.
- Approx. Time boundaries:

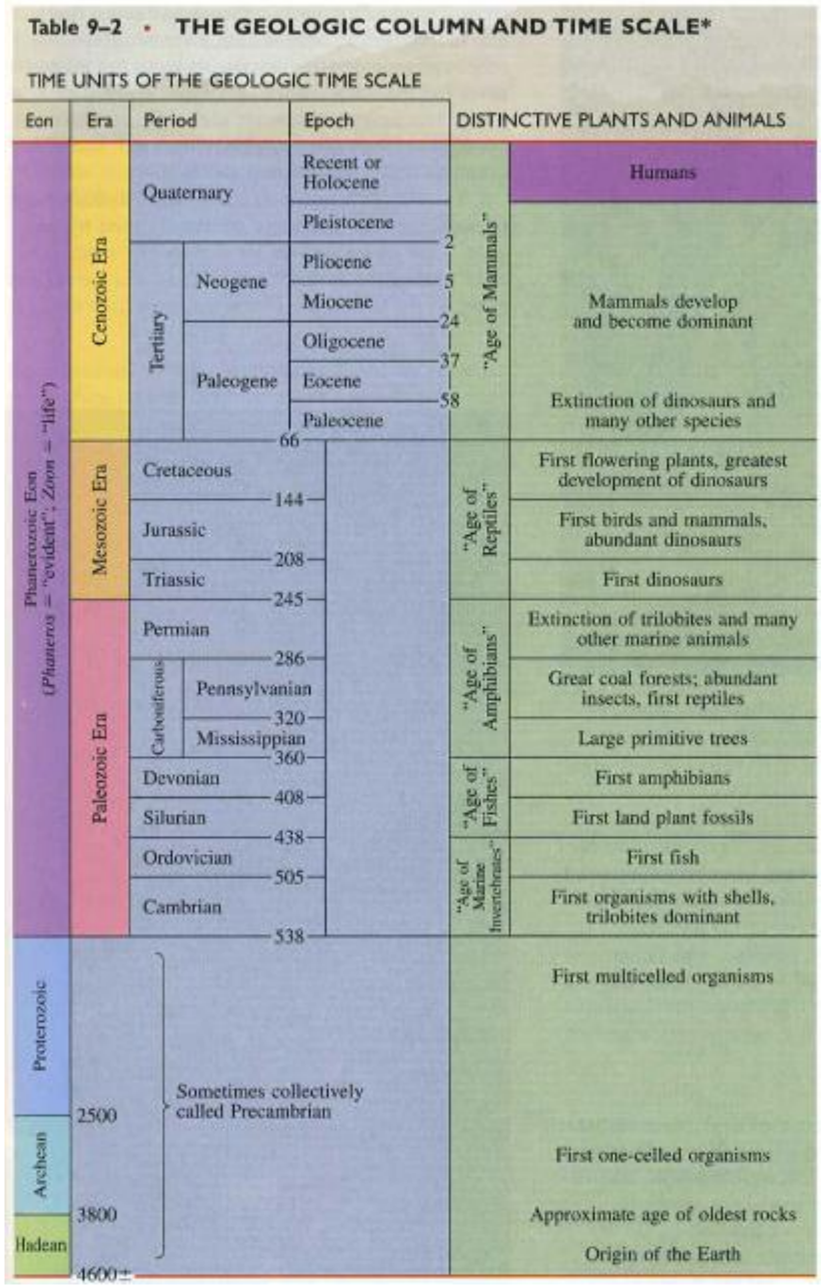


Table 9–2 • THE GEOLOGIC COLUMN AND TIME SCALE*

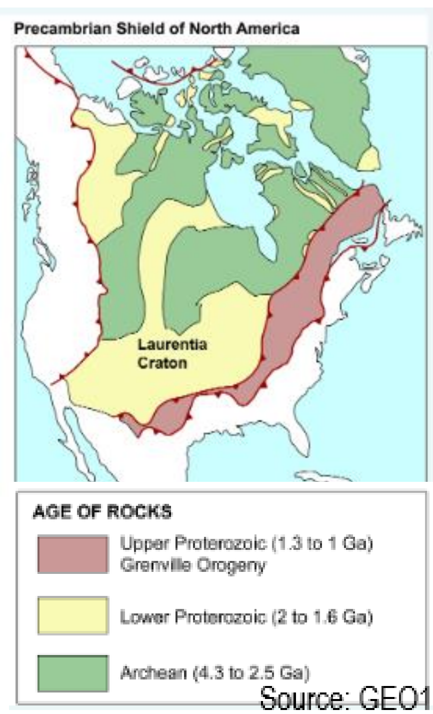
TIME UNITS OF THE GEOLOGIC TIME SCALE

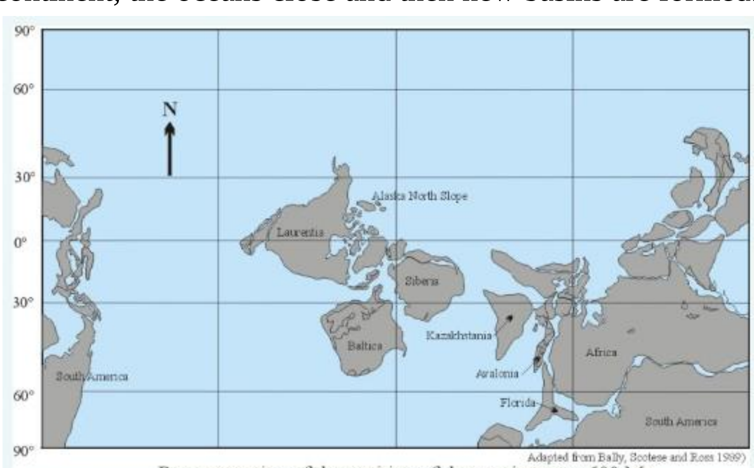
Eon	Era	Period		Epoch			DISTINCTIVE PLANTS AND ANIMALS
Phanerozoic Eon (*Phaneros* = "evident"; *Zoon* = "life")	Cenozoic Era	Quaternary		Recent or Holocene		"Age of Mammals"	Humans
		Quaternary		Pleistocene	2		Mammals develop and become dominant
		Tertiary	Neogene	Pliocene	5		
		Tertiary	Neogene	Miocene	24		
		Tertiary	Paleogene	Oligocene	37		
		Tertiary	Paleogene	Eocene	58		
		Tertiary	Paleogene	Paleocene	66		Extinction of dinosaurs and many other species
	Mesozoic Era	Cretaceous			144	"Age of Reptiles"	First flowering plants, greatest development of dinosaurs
		Jurassic			208		First birds and mammals, abundant dinosaurs
		Triassic			245		First dinosaurs
	Paleozoic Era	Permian			286	"Age of Amphibians"	Extinction of trilobites and many other marine animals
		Carboniferous	Pennsylvanian		320		Great coal forests; abundant insects, first reptiles
		Carboniferous	Mississippian		360		Large primitive trees
		Devonian			408	"Age of Fishes"	First amphibians
		Silurian			438		First land plant fossils
		Ordovician			505	"Age of Marine Invertebrates"	First fish
		Cambrian			538		First organisms with shells, trilobites dominant
Proterozoic		Sometimes collectively called Precambrian			2500		First multicelled organisms
Archean					3800		First one-celled organisms
Hadean					4600±		Approximate age of oldest rocks
							Origin of the Earth

In Ottawa region, there are rocks from Precambrian (eon) (gneiss), Paleozoic (era) (Nepean sandstone) (today's lecture these two), and Quaternary (period). Rocks from other periods were not preserved, they were eroded or just not created in this area. The only way to find the full geologic time scale is to find evidence from localities all over the world, and piece it together.

Precambrian: (4600 – 544 Ma)

- Definitions:
  - Craton – stable portion of the earth's crust. Largely of Precambrian age. Composed of shield of platform portions. Continents build around this.
  - Shield – exposed portion of the craton (central domal portion)
  - Platform – sediment-covered portion of the craton (margins)
- When early life developed in the form of bacteria. Stromatolites (Hog's back park trip). First multicellular animals (soft bodies), and a few fossils, mostly trace fossils. Since organisms were soft bodied with no hard parts, their remains do not leave fossils, they just decompose.
- Orogeny – Mountain building process. Possible mechanism: accretion (addition) of exotic terranes (lithosphere fragment).
- Grenville was the last orogeny of the Precambrian. The mountains were even higher than the Himalayas are today, but are now rolling hills.
- Oceanic crust is pushed towards land, and eventually is recycled. The oceanic crust is about 200 million years. This indicates that every 200 million years, there is a super continent, the oceans close and then new basins are formed.





Reconstruction of the position of the continents at 600 Ma

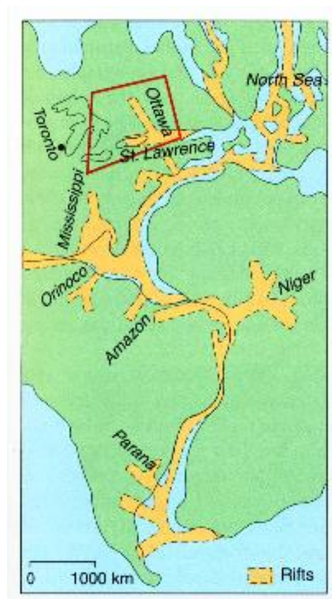
Paleozoic: (544 – 245 Ma)

- Appearance of hard shell organisms. Abundant life, the Cambrian explosion. Very important: in the early Paleozoic, life is restricted to oceans. In the middle to late Paleozoic: insects, plants, amphibians. Appalachian Mountains created. Late Paleozoic: mass extinction due to climatic conditions.
- Early Paleozoic:
  - fragmentation of super continent Rodinia, and opening of Iapetus ocean. This broke up the grenville mountain belt, ‘sending’ them all over the earth.
  - locally, marine invasion in Ottawa embayment, a small basin of the Iapetus. This creates early Paleozoic sedimentary rocks eg. the Nepean sandstone. (During Ordovician)
- Beginning of accretion of the maritimes. Fluctuating sea level, but the general trend is transgression. Late ordivician ends with mass extinction caused by glaciation.
- Maritimes: 200 million years ago in Mesozoic era, Pangea begins to disassemble creating the Atlantic Ocean.

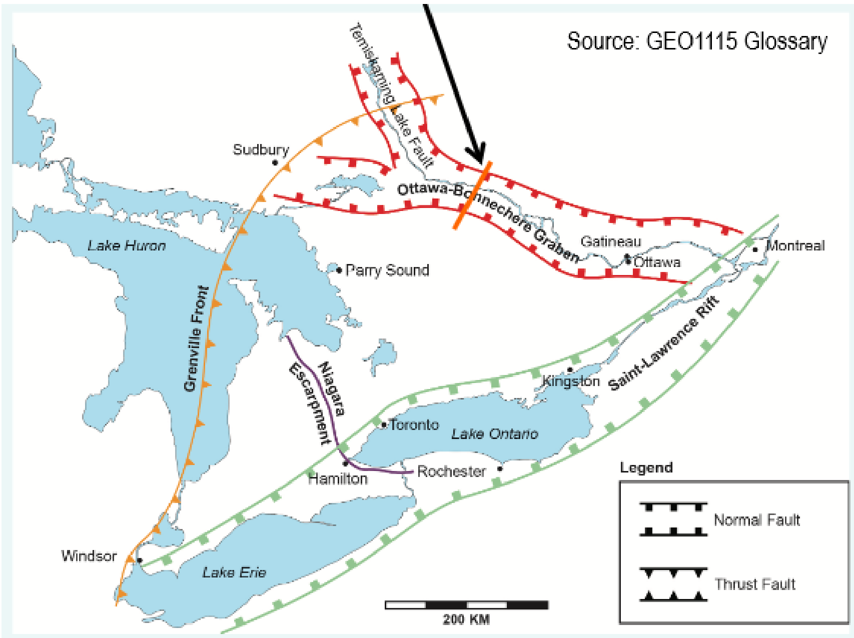
Reconstruction of the position of the continents at 255 Ma

Mesozoic (245 – 65 Ma)

- Dinosaurs, birds, mammals. Breaking up of Pangaea (above), opening of atlantic ocean.
- Rifting (breaking up of lithosphere), volcanic activity, faulting.
- Ottawa-Bonnechere Graben.
- Rocky mountains added to western margin of continent. (youngest mountains in Canada). North America migrates north.
- Locally:
  - Rifts: thinning out and creating brittle failure. Some areas have a rift during the fragmentation of pangaea that does not result in an ocean, ie. the red sea and the gulf of aden: the failed rift is the east african rift zone, a depression.
  - Similarily and locally, during the formation of the atlantic, the failed rift arms extending into ottawa and st. lawrence created rivers (among others around the world)

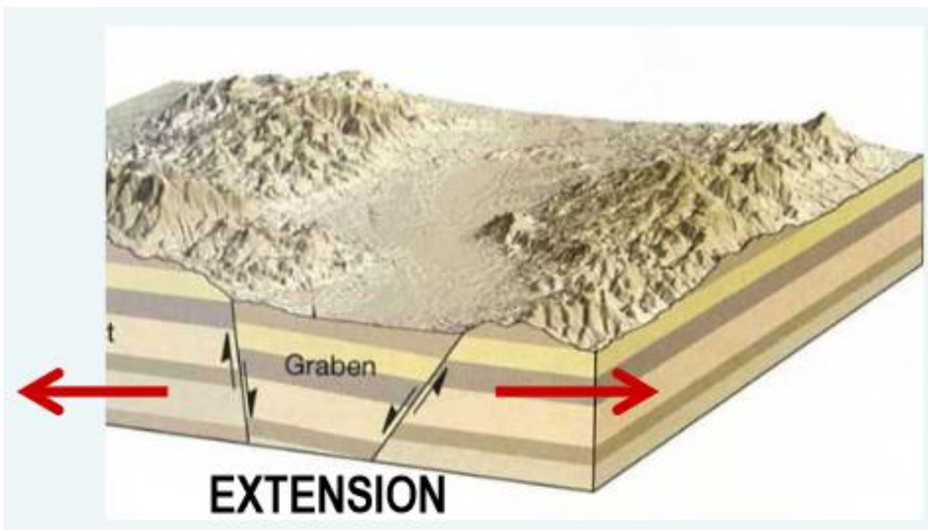


BOX 2.6 ■ FIGURE 1



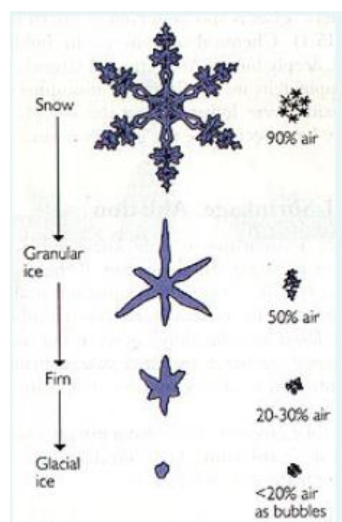
Graben – an elongated trough of basin, bounded on both sides by high-angle normal faults that dip toward the interior of the trough.

Rift – a regional scale graben.

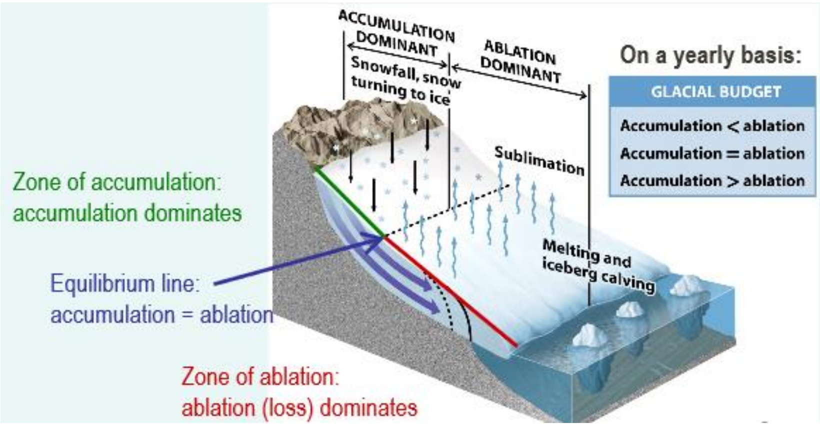


Week Four: Monday, October 6th, 2015.   GLACIERS

- Glacier – A thick, naturally accumulated ice mass formed over 100s or 1000s of years, and deforms under the force of its own weight. A few kilometers in height. Dome-like shape.
  - Impacts on lithosphere because of massive weight.
  - Part of the cryosphere (?)
  - 80% of earth's freshwater is in glaciers (freshwater is only ~2% of the hydrosphere) (and the rest of freshwater is ground water, in the pores of sediments).
- Effects of glaciers seen in Canada/USA, ie. drumlins, sculpted bedrock, etc. Sediments left/reworked by the passing of glaciers. This makes them glacial features (individually, not in general)
- Benefits of glaciers: as a preservation agent (artifacts, mummies, etc.), ripping apart of rocks via melt water jets making construction easier.
- In figure: arrows represent ice flow vectors. Numbers are centres of mass – note the vectors flow *away* from mass. Dotted line represents glacial maximum. Focused on the Laurentide ice sheet. This is a part of the Wisconsinian glaciation, 18000 years ago.
- Glacier Formation
  - Snowfall, and preservation of snowfall through the melt season.
    - Happens at high latitude because of lower solar radiation due to the tilt of the earth (equator 0, poles 90), high elevation/altitude (ie mountainous, lower amount of oxygen, depressurized, less dense air, water vapour is key to making air warm, so lower amount of water vapour means cooler air).
  - Snow falls and compacts other snow further and further until there is only ice crystals. Intermediate between snow and ice called 'firn.' Porosity decreases.

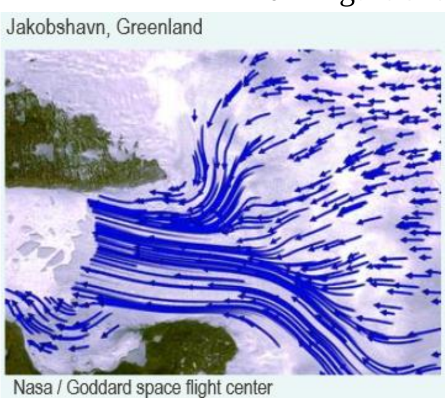


- Glacial Budget
  - ie. must accumulate more than lose (ablation)
  - accumulation > ablation = glacier advance (more snow added)
  - accumulation < ablation = glacier retreat (melting, sublimation, calving)
  - Calving – pieces of ice detach and float away, called icebergs.

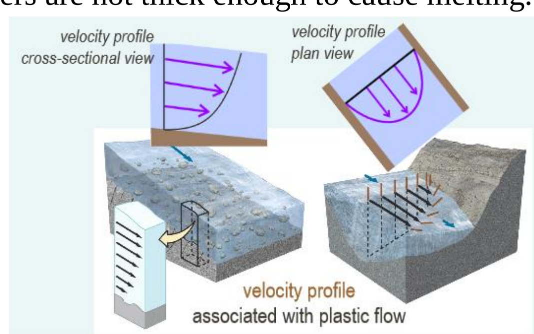


  - Calving – once one goes, many more go. Creates massive waves because of displaced water as the ice temporarily sinks.
  - Cause by fractures at surface

- Ice as a fluid:
  - Fluid NOT THE SAME AS liquid. A fluid flows under sheer stress. The Glaciers evidently deform, ice can behave as a fluid. Even on the microscopic level, ice crystals deform.
  - Figure shows glaciers move similarly to rivers, increasing in velocity as they reach a smaller area to go through. They are like "slow motion" rivers.



  - Move becase of their weight being effected by gravity. (ie. physics of something on a slope, gravity pulling down which is parallel and perpendicular and therefore pulls them along)
  - Ice deforms under stress, and display plastic and brittle deformation. Brittle at surface (ie calving), and plastic below.
  - If ice is compressed enough, it becomes water, as that is more compressed. If there is meltwater below a glacier, it will act as a lubricant and the glacier will slip.
  - If there is no meltwater below, they are called dry based glaciers. Happens in colder climates, or if the glaciers are not thick enough to cause melting.
- Glacial Movement
  - Speed:
    Min. observed, 2 m/yr, a dry base. (Antarctica)
    Max. observed, 8.3 km/yr, a wet base. (Greenland)



- Glacial Classification
    - Based on size and morphology.
    - Continental-scale: thick, flow radially from center (95% of present day ice volume)
        - Ice sheet - >50,000km^2
        - Ice cap - <50,000km^2
        - Ice shelf – portion of ice sheet/cap extending over the ocean
    - Valley glacier: discharge of ice into deep bedrock valleys, ie high altitude. (5% of present day ice volume)
        - Like rivers or streams.
- Evidence
    - Erosional (negative evidence)
        - large-scale features: polishing, grooves and furrows, striations, chatter marks, rat tails, flutes, potholes.
        - Tool marks are created when some kind of debris effects the bedrock, ie. striations, chatter marks.
        - Note: Rat tail notes in these notes, p. 33
    - Depositional features – glacial sediments
        - gravel, sand, silt, etc. May be sorted by size (sorted/stratified) (caused by melt water), or Till (unsorted and unstratified) (caused by ice).
        - Called drift (all deposits, either stratified/unstratified)
        - Stratified: Can read the amount of dark/pale pairs, each are one year of sediments deposited in the glacial lake.
            - Esker: a tunnel of meltwater through a glacier depositing sediments. sediments may be deposited in a convex way, filling the tunnel.
            - Eskers are groundwater resevoirs.

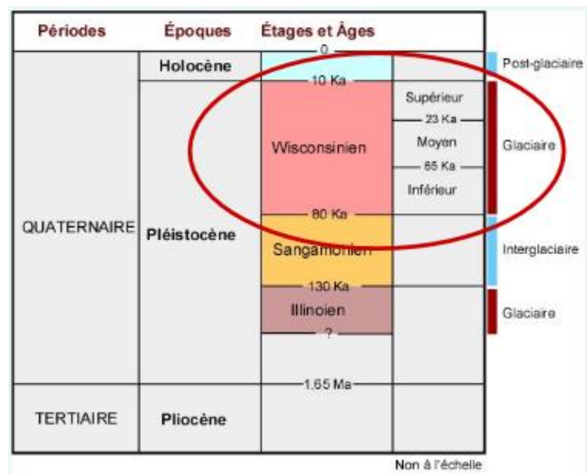
Week Five: Wednesday, October 13, 2015. Quaternary

(Glaciers CONT'D)

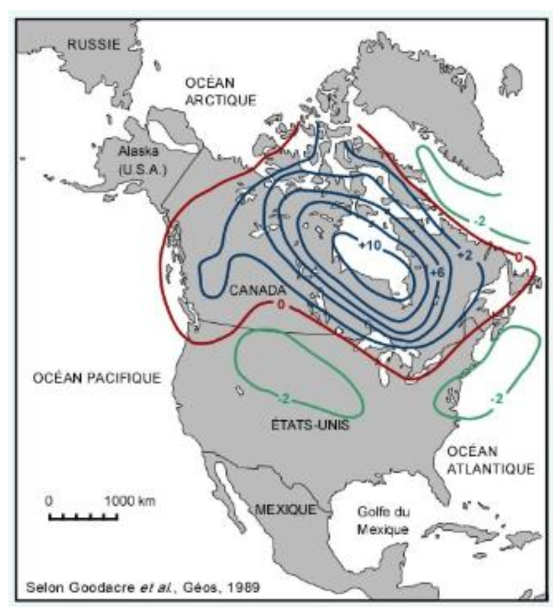
- Glacial deposits
    - Eskers
        - Continuous ridges of sand deposited in glacial tunnels.
        - Many ground water resources can be found in these porous resevoirs.
    - Drumlins
        - Distinctive shape, often in fields all pointing in the same direction. Narrow end is down flow, tear drop shape. Made of stratified gravel and sand – indicates something about melt water
    - In Ottawa:
        - Glaciers retreated, Champlain Sea invaded, sediments from melt water exit into Champlain Sea forming a subaqueous fan. Finer sediments further away from output. (Cantley Quarry)

Quaternary:

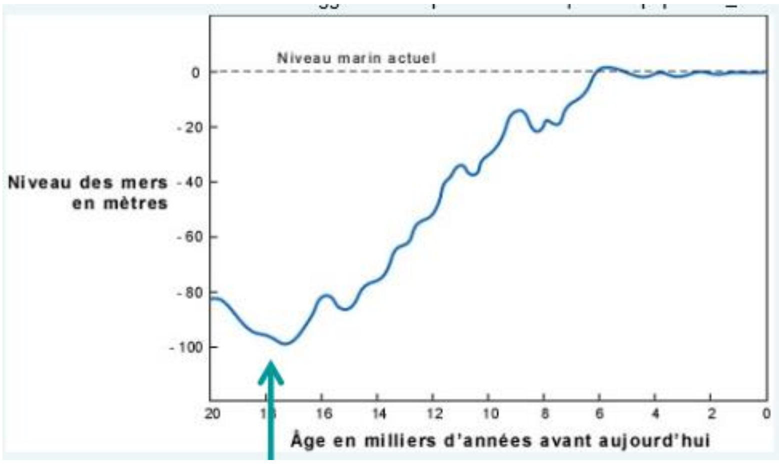
- Most recent/current period. Many glaciations.
- Glacial maximum – largest extent of glacial ice sheet. Most recent 18000 years ago, the Laurentide ice sheet.
- Cenozoic Era: 65 Ma to present
    - Tertiary – Eocene
        - India not yet with Asia, Australia moving north, Atlantic not yet as open as today.
    - Quaternary – 2Ma
        - Pleistocene – 2Ma to 10k years ago (Numerous glaciations)
        - Holocene – 10k to present (NON glacial)
            - Improved/higher climate, non-glacial. Unknown whether an interglacial or post-glacial.
- Glacial Periods
    - Glaciation – formation and deconstruction of continental ice sheet.
    - Glacial period – collection of glaciations.
    - Most recent glaciation easiest to see, as its features are superimposed on previous.
    - Ocean sediment cores record temperature fluctiations, since ice floats, the sediments underneath are preserved.
    - These ocean cores find about 20 glaciations, as opposed to four.
    - Continent assembly/break up and volcanic activity, may effect climate cycles, but are much more complex.



- Consequences of Laurentide
    - lithosphere (rigid, floating on __sphere which is fluid, ie buoyancy) adjusting position, called isostatic adjustment (for either movement). Isostatic rebound or uplift for upward motion, subsidence or isostatic depression for downward motion.
    - Map on right, mm per year of isostatic adjustment. Where thickest ice/centre of mass, lithosphere was most depressed, and now is rising most. Some parts are sinking. Explanation: lithosphere sunk so much at centres of mass, it pushed other areas upwards, and today they are sinking. Map is from 1989.

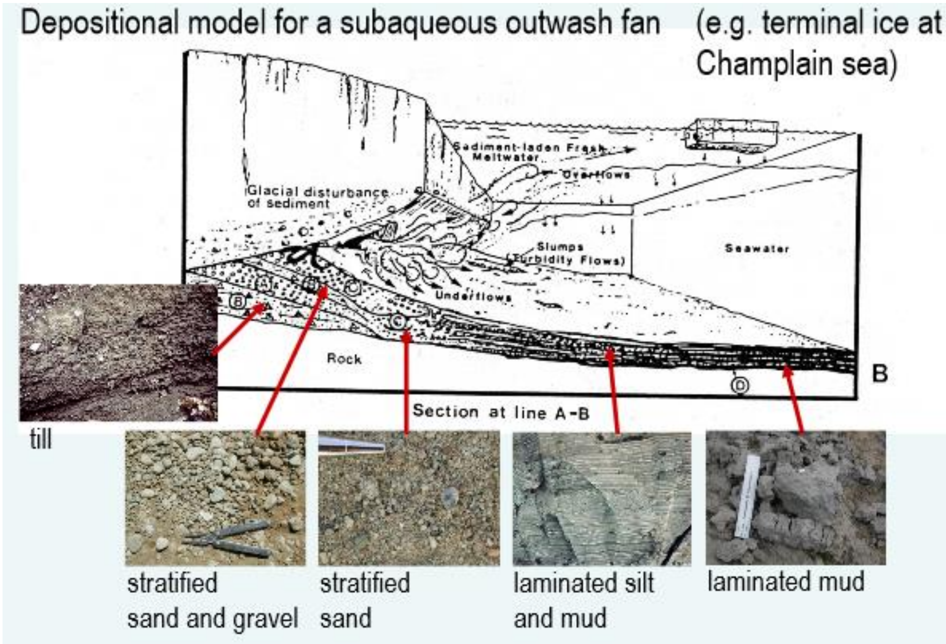


- Lithosphere trying to reach equilibrium by responding to weight above it.

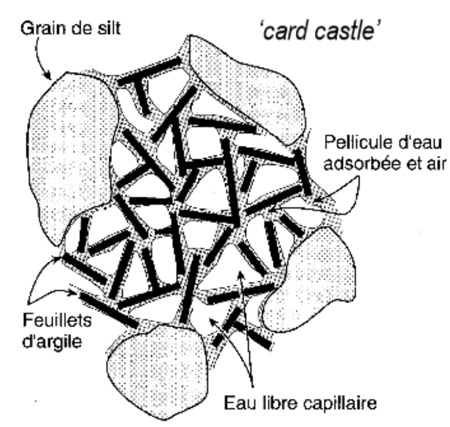


- Sea level vs. 1000s of years ago
- Glacial maximum at arrow.
- Takes much longer to form a large glacier than to dismantle. Lithosphere has much longer to sink, and rises much faster as there is suddenly (geologically) much less weight.

- Wisconsinan Ice Sheet Progression (Locally)
  - Drainage of glacier towards the south west. Pooling of melt water right infront of ice margin, as lithosphere is depressed (only recently melted).
  - Current drainage is eastward.
  - Champlain Sea invades (short lived) – salinity diluted by addition of freshwater. Freezing cold. Much more evolved marine life from Iapetus. Shrinks within 2000 years because of uplift.
  - Tyrrel Sea, an ancestor of Hudson’s bay.
  - Cantley – northern edge of champlain, next to fresh water.
- Glacial deposits
  - Glaciers are erosion agents which create small particles:
    - Gravel >2mm
    - Sand 0.062 – 2mm
    - Silt
    - Clay <0.004mm
  - If particles are deposited from being frozen in ice, they are not stratified, and poorly sorted. No neat layering. Called mixed grade size, unstratified, unsorted.
  - Particles deposited from energetic glacial lakes, as it loses energy, coarser particles drop. This continues to happen as the energy changes, so the deposits are sorted and stratified.
  - Ice deposits called till, which is unstratified drift.

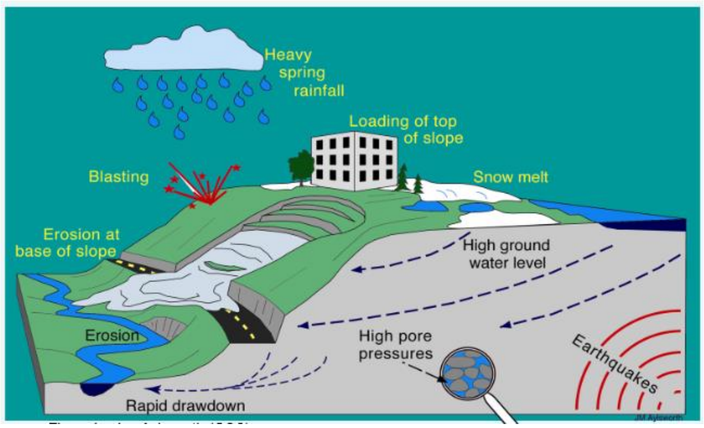


- Leda 'clay' at Lemiuex landslide. (laminated mud)
  - clay <0.004mm
  - Minerals – phyllosilicates. 'Layered silicate.' Silicate and oxygen dominate in the crust. For example, micah.
  - Leda Clay – dominantly silt. Around 10/20% phyllosilicates, 80/90% quartz and feldspar. Not actually clay by minerals or grain size!
  - Sensitive or Quick Clay: undisturbed clay is 30x stronger than remoulded clay.
  - Conditions to from quick clay:
    - glacial origin – particles broken down from glacier.
    - *deposited in marine water
    - *deposited in high sediment concentration – will not have time to organize, pack up in unstable way.
    - little compaction (would force them to organize)
    - high fraction of non-clay minerals.

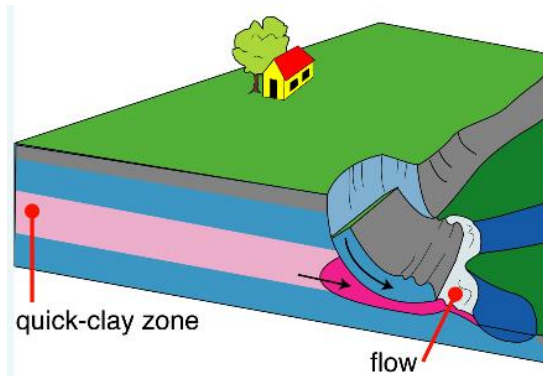


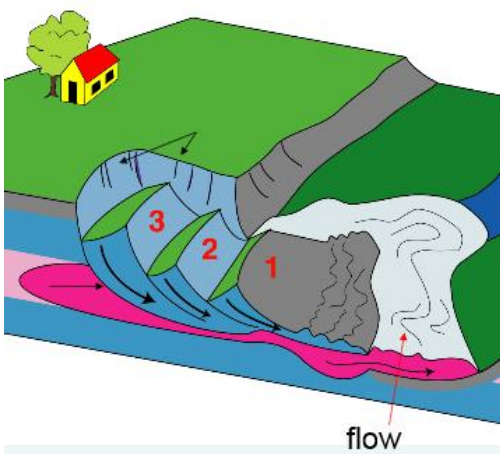
- Sheet silicates in unstable formation. Water in pores. Like a card castle, the sheets will form a more stable configuration if energy is introduced.
- Marine water, Na+ adds electrostatic stability by binding negatively charged sheets.
- After Champlain, the Proto Ottawa River (fresh water) replaces water in pores flushing out salts. Weakens the configuration.
- This destabilizes the sediments. Clay loses strength and remoulds. Landslide in 1993.

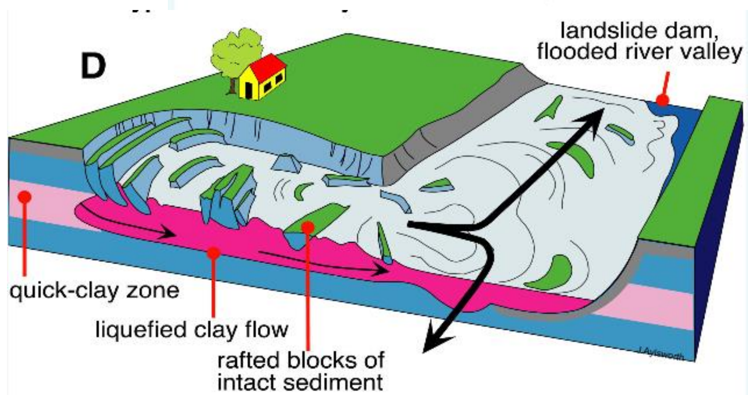
- Landslide
  - Destabilized by:



    - Saturation: water added in pores, dilating matrix, easing movement of grains. Water added by rapid snow melt, excessive rain, spring conditions.
    - Earthquakes: shake/move structure. (or even a mechanical vibration induced from construction such as dynamite)
    - Add Weight: exceed strength of clay – add buildings.
    - Increase slope: erosion of base.
  - On right: clay can no longer hold up crust. Retrogressive failure: inland, from edge of river basin. Sequentially in slices of land. A 'domino' effect.
  - Clogs river, creates inundation upstream.





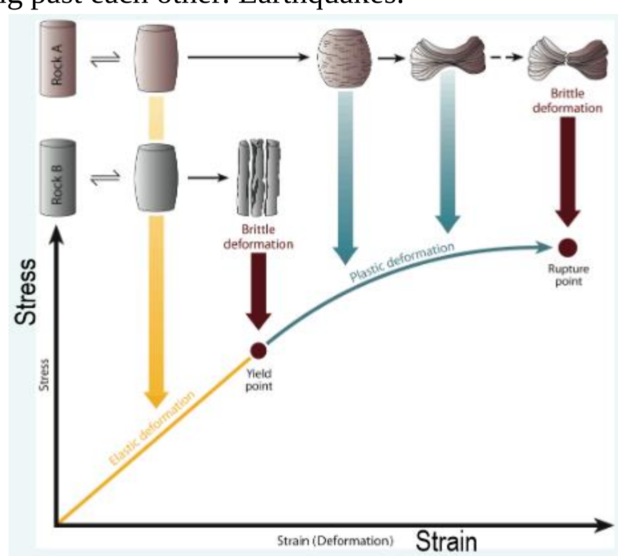


- Lemieux Impact
  - Some debris flowed 1.5km up and downstream. River didn't move for 4 days. Flooding for 25km upstream, and the river level higher for years. No deaths.
  - A success – 20 years earlier at St. Jean there was 31 deaths, a landslide hit during the night.

GEO1115 F15

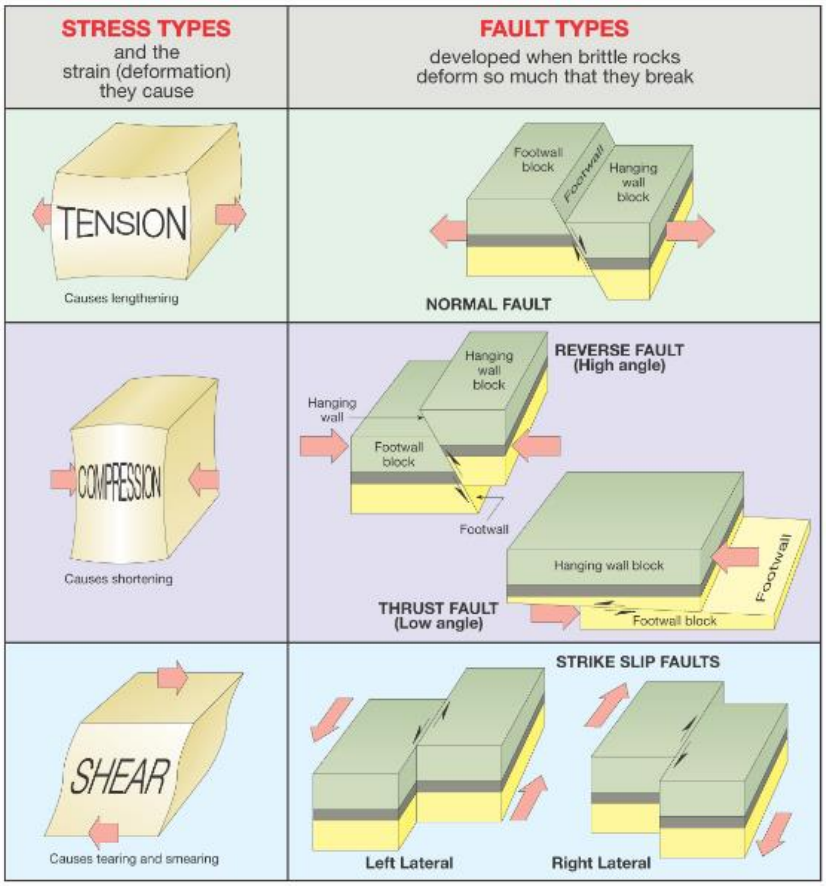
Week Six: Tuesday, October 20, 2015. Rock Deformation

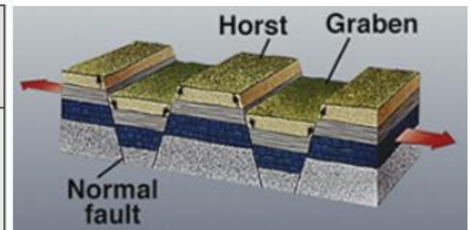
- Geologic Structures: patterns in rocks or sediments generated by tectonic forces. Large scale forces.
- Structural geology: study of these patterns and the forces that cause them.
- How to rocks deform? A large amount of force, over a long period of time. When this happens:
    - Bend/fold
    - Break/brittle deformation. Fracture.
    - Flow
- Most rock deformation occurs at plate boundaries.
- Forces:
    - Compression, reduced horizontally, moves vertically. Folding/faulting due to loss of horizontal space. Convergent boundaries, higher elevation.
        - Local example: Gneiss at Grenville orogeny.
    - Tension, thinning of vertical dimension, horizontal dimension elongated. Fractures and faulting in crust as a result.
        - Local example: Ottawa Bonnechere graben (Ottawa valley)
    - Shear, transform plate boundary, plates moving past each other. Earthquakes.
        - (No local example) San Andrea fault



- Definition:
    - Stress: force/area (N/m^2)
    - Strain: deformation due to applied stress.
- Deformation:
    - Elastic: reversible, rock can go back to initial shape when stress is gone.
    - Brittle: rock fractures, exceed strength of material. Hit rupture point, irreversible.
    - Plastic: Change shape without breaking. Permanent deformation, irreversible, but will become brittle eventually.
    - Confining pressure: caused by weight of rock above, below surface of earth. Lithostatic pressure. Even on all sides.
- Under lithospheric pressure, rock will favour plastic deformation since brittle deformation is more difficult. Under regular pressure, will fracture.
- Factors effecting rock deformation:
    - Pressure (brittle vs. ductile)
    - Heat (a horseshow)
    - Time (an old bookshelf)
    - Composition (eg. chatter marks at sandstone, not on marble)

- Definition:
    - Faults are fractures in rocks along which appreciable displacement has taken place.
        - Faults –
        - Joints –
    - Drag folds: pulling of strata along fault. Local plastic deformation, indicating direction of fault.
    - Graben: downdropped block. Faults converge towards interior.
    - Horst: uplifted block. Faults diverge towards interior.





- More definitions:
    - Folds: during crustal deformation, rocks are often bent into a series of wave-like undulations called folds.
    - Most folds result from compressional stresses which reduces horizontal and increases vertical.
    - Plunging: non horizontal plane. Strata moving upwards or downwards, from surface it is W or M shaped.
    - Ancline a peak, syncline a valley.
    - Magnetic declination: difference between geographic (axis of earth rotation) and magnetic (convergence of magnetic field) pole.

    - Attitude: the orientation of a structural element (plane or line) relative to a horizontal plane.
        - Plane: expressed by strike and dip.
        - Line: expressed by trend and plunge.

Week Seven: Tuesday, November 3, 2015. Minerals

- Minerals are the building block of rocks, ie. granite is made up of quartz, feldspar, hornblende.
- Rocks are composed of one or more minerals. Single mineral rocks are dominated by only one mineral, and are monomineralic.
- Definition of a mineral: (5 criteria)
    - solid
        - ice!
    - natural
        - non-synthetic (not formed in a lab)
    - inorganic
        - coal – organic because it has hydrocarbons (sometimes it is ?? but technically organic)
    - crystalline structure
        - fixed chemical composition does not guarantee order. Quartz can be interally ordered (crystalline) or amorphous (disorganized manner, cooled too fast)
    - fixed chemical composition
        - Same chemical components in the same ratio to create the same mineral. ie. olivine = Fe, Mg, Si, O – can have variation so long as there are two MgFe. Mostly minerals are not as varying.
- Known minerals: 4000 (>95% of earth: 12), known insects: 1.3 million. Feldspar is 50% or earth's crust. We are learning 22 minerals.
- Most of earth's crust is made up of: (right)
- Si + O = silicates. Tetrahedral structure with centre Si, and O on the corners.
    - Si and O are lighter, migrated to the surface. Ni and Fe heavier, at core.

O	46.6 %	Fe	5 %
Si	27.6%	Ca	3.6 %
Al	8.1%	Na	2.8%

Grouping:

- Isolated (eg olivine): not connected, sheltered by other elements.
- Single chain (eg pyroxene): sharing one oxygen.
- Double chain (eg amphibole): two attached single chains
- Sheets (eg mica): sheets separated by other minerals
- 3D framerwork (feldspar):

- Single chain will break preferentially at two planes of 90dg to each other. Double will break at 60 / 120.
- Sheet grouping minerals such as mica will peel. Weak bonds along Potassium ion layers.
- In 3d, only Silicates, does not fracture along weak planes as there are none.
- Minerals are classified by their defining anions.
- Physical properties are intricately linked to the chemical composition and nature of chemical bonds between the elements that constitute the mineral. Macroscopic expression of microscopic making.

Physical Properties:

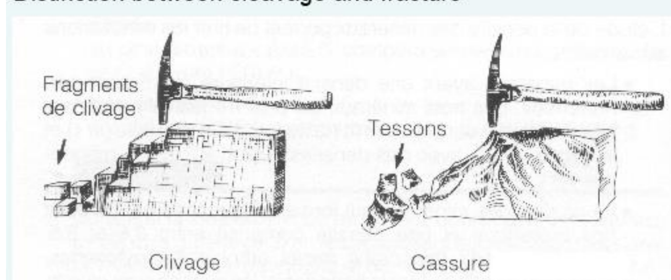
- Colour: not always diagnostic! Light reflected by / transmitted through crystals or masses.
- Streak: color of the powdered mineral. Stable for all varieties of the same mineral. Good for metallic luster minerals.
- Luster: appearance of light reflected from mineral. Metallic means light is almost entirely reflected, non-metallic (with subjective qualifiers).
- Transparency: capacity to transmit light. Not diagnostic. Transparent, translucent or opaque.
- Hardness: easiness with which mineral surface can be scratched. Non-linear scale.
- Relative density: unitless number defined as ratio of mineral's density compared to density of an equal volume of water. Diagnostic if it is 'unexpected' weight, heavy or light.
- Crystalline form: crystals of mineral grow with specific shapes bounded by planar crystal faces. Different crystalline shapes exist, hexagonal, cubic, rhombohedric etc.

HARDNESS

scratched by your nail	1	**Talc**
	2	Gypsum
scratched by a penny	3	**Calcite**
scratched by a knife	4	**Fluorite**
	5	**Apatite**
scratches glass	6	K-Feldspar
	7	**Quartz**
	8	**Topaze**
	9	Corundum
	10	Diamond

- Cleavage: tendency of a mineral to break along flat planar surfaces. If present, very well / well / moderate / poorly developed. Number of planes, angles. If absent, there is an irregular fracture along non-planar surface. Can be conchoidal, acicular, etc.

Distinction between cleavage and fracture



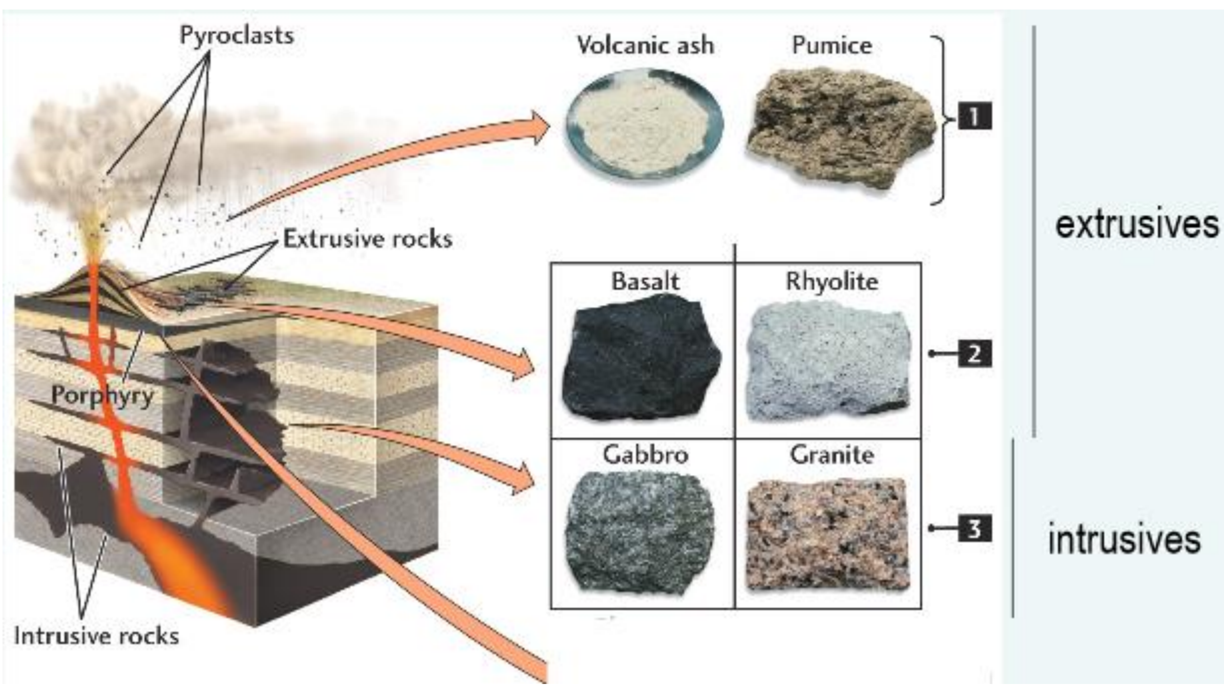
Other Properties:

- Magnetism (magnetite)
- Effervesence (calcite, fizzes at acid)
- Taste (halite, salty)
- Smell (sulfur, activated in golina with acid)
- Touch (talc, very soft, flakes, sheet silicate)

Week Eight: November 10th, 2015. Igneous Rocks

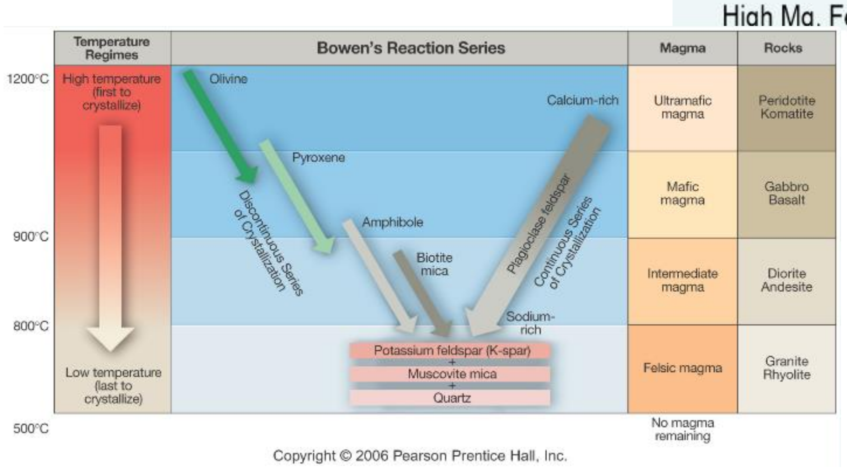
Igneous Rocks:

- From the crystallization of magma. (Moving from liquid to solid)
- Most of the Earth's crust is made up of metamorphic and igneous rock.
- Magma shows up at plate boundaries,
  - heated up lithosphere bulging up instigating tension initiating divergent plate boundary.
  - Convergent boundary with oceanic plates
  - Subduction zone between ocean and continental plate. Part of subducted plate melts creating magma. Nature of different crusts means different melting point, different magma. Thicker and more explosive. More dangerous.
  - Hot Spots:
    - Not a plate boundary! Intraplate volcanism, eg. Hawaii (no boundary). Temperature anomalies in mantle generating magma, called hot spots. Happen on oceanic or continental. Oceanic is thinner, so easier to heat up there. Hot spot is consistent in its placement, but the crust moves. As it moves, hot spot creates new volcanoes over and over linearly.
- Categories of igneous rocks:
  - extrusive (volcanic): cooling at surface.
  - intrusive (plutonic): cooling at depth.

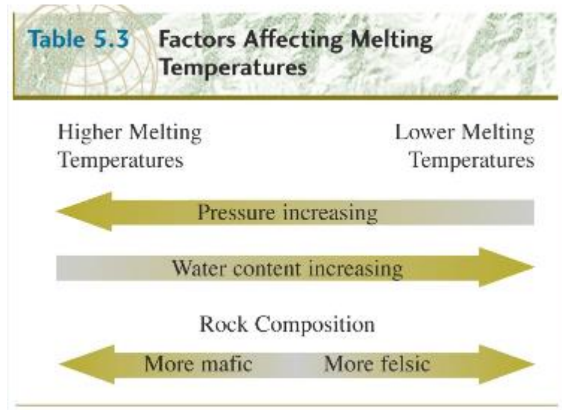


- Crystal size will differ depending on where it cools. Intrusives have larger crystals, so cooling time is slower, because underground is warm.

- Intrusive:
    - Large bodies: plutons.
        - Batholith > $100km^2$
        - Stock < $100km^2$
    - Dyke: crosscuts existing fabric.
    - Sill: parallel to existing fabric.
- Extrusive:
    - Lava: fluid magma at surface
    - Pyroclastics: volcanoes erupting fragments, being shot up, lava cooling in air and falling as rock.
    - Volcanic edifice: volcanoes made up of successfive layers of cooled lava from eruptions, creating a conical shape.
- Magma vs. Lava?
    - Magma: molten or partially molten rock. Mix of liquid (molten), solid (chunks), gas (water vapor, CO2, sulfur dioxide, etc.).
    - Lava: Extrusive magma (on the surface of the earth).
- *** If magmas originate from the mantle, why don't all igneous rocks have the same composition? ***
    - Crystallization and fusion temperatures vary from one mineral to another.
    - Scenario 1: gradual lowering of temperature. From molten rock → solid rock. Called fractional crystallization.
    - Scenario 2: gradual increase of temperature. From solid rock → molten rock. Partial melting.
- Scenario 1:
    - "Fractional crystallization": sequential crystallization of minerals according to their melting temperature.
    - High Mg, Fe, Ca solidify first. Since those minerals go away first, the last to solidify are high in other minerals.



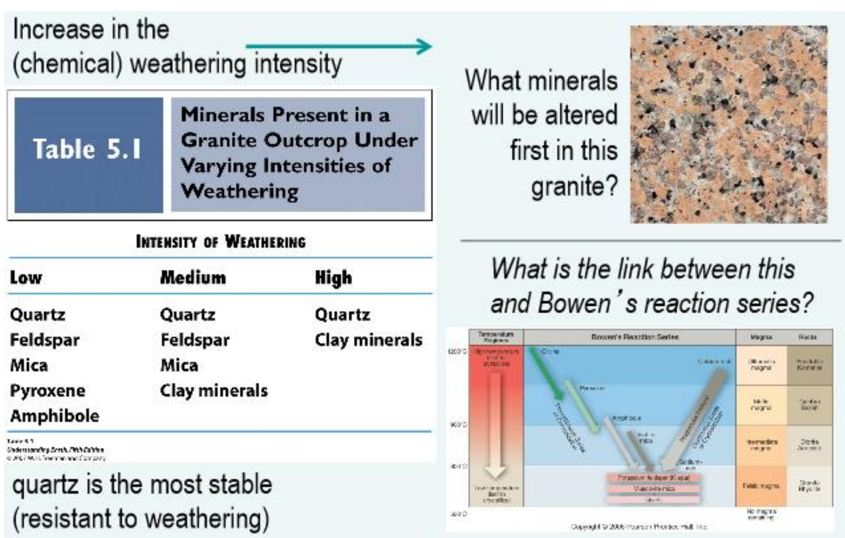
- Scenario 2:
  - Generating magma by melting rocks, “partial melting.” This process also happens in a predictable sequence.
  - The low temperature cooling minerals, ie the ones who became solid last from scenario 1, will melt first.
- Factors that will influence melting temperatures:
  - Pressure ‘impedes’ melting, since it needs more ‘space’ to melt. At depth, fusion temperature will increase. <u>Pressure will affect fusion temperature.</u>
  - <u>Composition will affect fusion temperature.</u>
  - <u>Presence of volatiles decreases fusion temperature</u>, ie gases, present in magma will make things melt more easily.



- Sedimentary rocks which are hydrated, ie have sea water, getting pushed under crust will create magma more easily because of presence of volatiles.
- Decompression melting ?? less pressure in hot spot something
- Classification:
  - High temperature minerals are “mafic” (Mg, Fe): Olivine, pyroxene, amphibole, biotite. Higher Mg, Fe are ‘ultra mafic.’
    - Mafic are dark in colour (not necessarily ultra). Olivine is green.
    - Low viscosity magma which flows easily, less <u>explosive</u> (can’t accumulate pressure), oozing.
  - Low temperature minerals are “felsic” (feldspars, silica): quartz, muscovite, feldspars (potassium, sodium plagioclase).
    - Pale
    - Explosive
- Textures of igneous rocks: (crystal size and appearance)
  - “phaneritic” – magma cools slow below surface intrusively, forming large crystals.
    - “pegmatitic” – crystals > 1cm. intrusive.
  - “aphanitic” – magma cools above surface extrusively, formation of small crystals.
  - “porphyritic” – cools slowly for a while, then rises and cools much faster. Two differing crystal sizes, two differing cooling periods. Can be both instrusive and extrusive or both extrusive.
  - “glassy” – cools *very* fast, has not time to organize itself. Must be extrusive.
  - “vesicular” – Like an aerobar. Also aphanitic, so extrusive. Vesicles were gas pockets trapped in the magma as it crystallized.
  - “pyroclastic” – angular fragments formed by violent eruptions. Various sizes of particles, deposited very rapidly. Large clasts broken from inside of volcano. Magma that does not flow easily, higher in felsic elements. High viscosity.

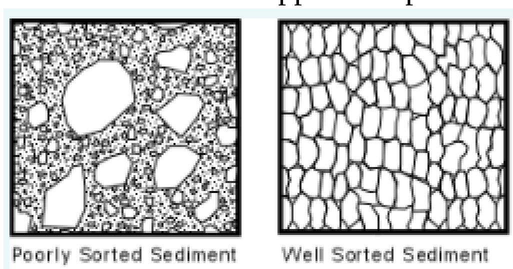
Week Nine: November 17, 2015. Sedimentary Rocks

- Sedimentary rocks:
  - a thin layer of sedimentary rock accounts for ~75% of all rocks exposed on land.
  - (not really past the surface, as we know, igneous and metamorphic make most of the planet deeper down)
- Importance:
  - hosts gas and oil, coal. Mineral deposits of gold, etc.
  - Aggregate: (lab 1) use sediments like sand/gravel for cement, bricks, concrete, etc.
  - Evaporite: salt, gypsum. form through process of evaporation. Salt for roads, food.
- Characteristics:
  - formed under low temperature and pressure. Maximum a few 100 degrees, few kPa.
  - Made of sediment. Sediments are loose, solid particles originating from:
    - weathering/erosion of pre-existing rocks. Dominant. Smaller pieces of pre-existing rocks. Weather weakening rock to create particles.
    - chemical precipitation from solution. Such as salt water evaporating, salt will stay behind. This is still sediment.
  - Sediment is accumulated in layers, ie stratified. Fossils, relative dating, sense of time can be garnered from this.
- Processes related to formation of sediment/sedimentary rocks:
  - Weathering
    - breaking down of rock to produce sediment particles. Anything that breaks down or weakens the rock.
    - Physical: mechanical processes, no change in chemical composition.
    - Chemical: minerals in rock are chemically altered or dissolved.
    - Related to Bowen's reaction series.Last minerals to crystalize are more resistant.

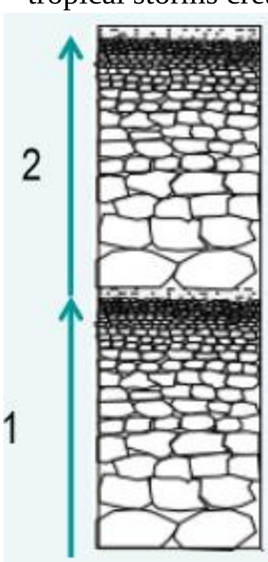


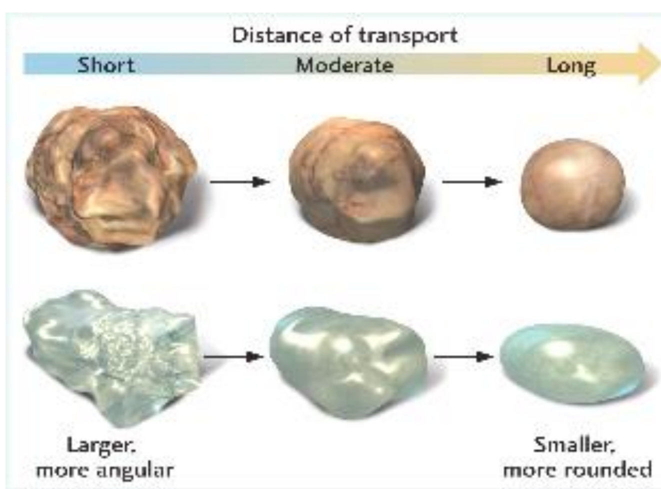
Intensity of Weathering		
Low	Medium	High
Quartz	Quartz	Quartz
Feldspar	Feldspar	Clay minerals
Mica	Mica	
Pyroxene	Clay minerals	
Amphibole		

- Erosion
  - Erosion is weathering *and* transport/movement. Moved with **water** (main!!), wind, ice moving downhill or downstream. Gravity governs direction of transport.
- Transport
  - Direct relation between particle size and flow velocity. ie, a boulder in a small stream won't move. Grain size can be related back to how fast the flow was which brought it to its place. Found through "experimental sedimentology," reproducing nature in the lab.
  - Sorting: range of particle size in a deposit. Can tell than well sorted sediment has had a long distance of transport. As flow fluctuates, larger sediments will be dropped. All particles will be of similar size.



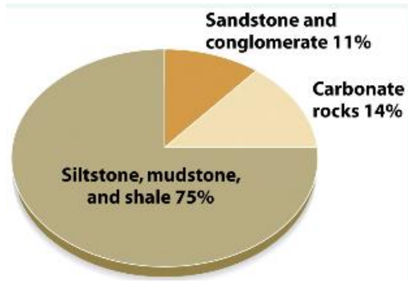
  - Grading: Called 'normal' because it is seen the most. Each bed is deposited in one event. High energy initially, then energy decreases and finer particles are deposited. as second event begins, energy has sharp increase, and the process is repeated.
  - For example, Lac Des Fees had normal graded beds, from a marine setting – tropical storms created the energy.





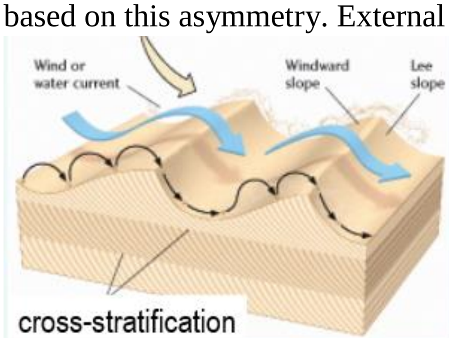
  - As distance of transport increases, particles become smaller and more rounded.
- Deposition

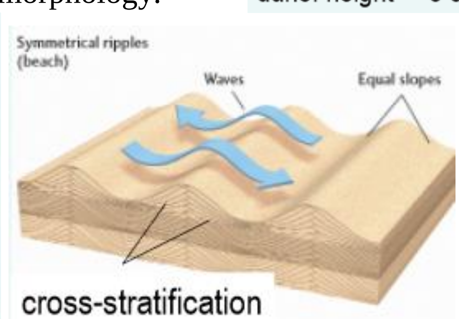
    - settling of particles into sediment sink, due to a decrease in energy agent. OR: decrease in solubility, or super saturation. Precipitation from solution of minerals.
  - Lithification (compaction/cementation)
    - conversion of unconsolidated sediment into a coherent solid rock. Mostly by compaction and cementation, also crystallization.
    - Compaction (from continuous accumulation sediments are buried and compacted by the weight of overburden) + cementation (precipitation of cements into the pore space) = lithification (rock)
- Classification of sedimentary rocks:
  - Clastic (detrital): Made of broken rock, sediments. Named according to grain size.
    - fragments of pre-existing rocks. 10x more abundant thatn chemical sediments. (eg. sandstone, shale.)



  - Chemical/Biochemical: Made of precipitated sediments. Named according to mineralogy.
    - consists of the minerals that are dissolved in the process of chemical weathering and either:
      - Chemical: precipitated from solution. (eg. salt)
      - Biochemical: extracted from solutions by organisms and later deposited in the form of shells, and other organically derived material. Often from shallow warm water. (eg. fossiliferous limestone)
- Chemical Sedimentary rocks:
  - Rock Salt: composed of NaCl, halite. Rock Gypsum, also an evaporate.
  - Conditions favouring high evaporation:
    - Arid Climate: both low precipitations, high temperature.
    - Marine Water isolated from dilution from fresh water or normal salt water.
- Sedimentary Structure: (large-scale features from which we can infer a genetic process that can be linked to a depositional environment. 4 Categories:
  - Depositional (ripple, dune, bed)
    - Steep ridge is down flow. Can find flow direction based on this asymmetry. External morphology.

ripples: height ≤ 5 cm
dune: height > 5 cm





        - Wave ripples are symmetrical. Flow direction changes due to waves, which form this morphology. (Picture on right above). Shore is parallel to crests.
    - Erosional (tool marks, scour marks)
    - Deformation (folding, mud cracks)
    - Biogenic (trace fossils, stromatolites)

Week Eleven: December 8th, 2015. *Review*

Lecture One:

- Earth materials in our every day lives, ie. construction materials.

Two:

- ‘beginning of time’ to beginning of earth.
- Layers/structure of the earth: crust floating on more malleable, asthenosphere – implying movement of brittle layers, separating into different plates and interacting with each other. Plate tectonics explain volcanoes, mountains, earthquakes, big scale geological events.
- plate boundaries, transform/divergent/convergent
- rock cycles and three rock types (in general) constantly being effected by processes, transforming them into other rock types.
- relative dating principles, unconformities and chronology of rock diagrams. observing relationships and deducting history. (puzzle)

Three (local history)

- Precambrian to middle Ordovician, and quaternary sediments / rocks; opening of atlantic in Mesozoic – Ottawa/Bonnechere graben.
- Grenville orogeny 1Ga, Rodinia assembly (precambrian)
- (Paleozoic) Rodinia disassembly, tensional forces from opening of Iapetus ocean → Ottawa embayment, a marine invasion. marine invertebrates, because of warm waters. (know these rocks and their chronology)

Four

- glacial budget, equilibrium line, snow metamorphism, dry base / wet base, melt water
- glacial features (evidence): rat tail, subaqueous fan (coarse to fine), leda clay (finest sediments, mud and silt from champlain sea) (marine condition, silt with some clay, vulnerable to landslides, sensitive)

Five

- Champlain sea, major landslides in area, all within basins.

- Wisconsinan glacial period, in Pleistocene with numerous other glacial periods. continental evidence shows three or four, but there were many more, each glaciation reworks previous evidence. *glacial dates / maximum ??
- Retrogressive failure, various triggers for sensitive clay, loses strength and cannot carry weight above it. sediments above are no longer supported, and fails in block retrogressively from edge of escarpment to inland. 600m of retrogressive failure at Lemieux
- stress/strain plots. temporary deformation, brittle failure, plastic and permanent failure.

Six:

- faulting types, tension/compression/shear
- syncline/anticline/terminology, strike/dip.

Lab Seven

- maps, geographic coordinates.
- scale, vertical exaggeration.

Lecture Seven: minerals

- solid, natural, inorganic, crystalline, fixed composition.
- silicate tetrahedral, **p. 37 chart. predicts cleavage, etc., structure. **vs bowens, ie. isolated are first to solidify, 3d are last, weathering (olivine easily)
- colour, streak, luster, transparency, hardness, density, crystalline form, cleavage.

Eight: igneous

- intrusive classified by size. extrusive are formed from lava flow, pyroclastics (ash etc), volcanic edifice (apron of sediment around volcanic site, the cone)
- bowens reaction series