EARTH121 Review

# Geologic Time (Chapter 8)

* important periods
  + Eon > Era > Period > Epoch
  + Phanerozoic Eon
    - Cenozoic Era (65.5 mya to today)
    - Mesozoic Era (252.2 mya to 65.5 mya)
    - Paleozoic Era (542 mya to 252.2 mya)
  + Precambrian Eon
    - Proterozoic Eon (2.5 billion to 542 mya)
    - Archean Eon (4.6 billion (earth formation) to 2.5 billion)
  + A Puny Papa Makes Cars (earliest to latest)
* 24 hour clock
  + 4:00 am origin of life
  + 2:08 pm single celled algae
  + 11:58:43 pm humans
* relative dating
  + time of events relative to each other
  + law of superposition
    - what’s on top is probably younger
  + original horizontality
    - sediment is usually horizontal until disturbed
  + lateral continuity
    - sediment extends until it pinches out at the side (think a lake bed)
  + cross-cutting
    - faults or intrusions are younger than the rocks they are displacing
  + inclusions
    - random old rocks in younger rocks
  + unconformities
    - a break in time continuity of rock layers
    - angular unconformity
      * layers get lifted, top part eroded off, exposing middles, new sediment on top
    - disconformity
      * a layer that has a top part that isn’t flat, but somewhat eroded, and other layers on top
    - nonconformity
      * sedimentary rock on top of onto pre-existing igneous or metamorphic rock
  + correlation
    - identification using fossil content (in order of appearance) and “index fossils” or “key beds”
    - index fossils are geographically widespread but existed in a narrow timespan
    - key beds are distinctive layers like coal or volcanic ash that allow for identification in different areas
* absolute dating
  + specific dates
  + radioactivity/radiometric dating
    - measured using half-lives of isotopes and intermediate results of radioactive decay
    - must be a closed system, bad if in high temp environments as intermediate isotopes might be lost, need samples to be fresh and unweathered
    - can use carbon instead of uranium, ratio of C14 to C12, half life of ~5730 years
* engineering time/design life
  + design life – how long it should last
  + radioactive waste has thousands of years of design life
* risk = hazard \* vulnerability
* larger events occur with less frequency than smaller events
  + earthquake deaths > volcano deaths > landslide deaths
* Useful/interesting figures
  + 8.4, 8.6, 8.9

# Minerals (Chapter 2)

* What are they
  + Naturally occurring, inorganic, crystalline solids with specific chemical compositions
  + Consistent and recognizable physical and chemical properties
* Polymorph
  + Chemical composition is the same, but due to arrangement of molecules, physical properties differ (diamond vs. graphite)
* >90% of the crust is from 5 minerals – feldspars, pyroxenes, amphiboles, micas, quartz
  + 97% of the crust is from Oxygen, Silicon, Aluminum, Iron, Calcium, Sodium, Potassium, Magnesium
* Rocks are solid masses of mineral(s)
* Non-silicates (stuff w/o silicon)
  + Carbonate, Sulfate, Sulfides, Oxides, Native (purely one element, like gold)
* Canadian minerals
  + Nickel then gold
  + Cement/stone/sand+gravel together bring in more money than any single metal
  + Export a lot of asbestos, even though it causes cancer because strands of rocks can enter the lungs
* Silicate structures
  + More shared oxygen per tetrahedron = stronger bond (how many corners of the triangle touch)
  + Isolated tetrahedral (none shared)
    - Olivine
  + Chain silicates (2)
    - Pyroxene group (Augite)
  + Double-chain silicates (alternating 2/3)
    - Amphibole group (Hornblende)
  + Sheet silicates (3)
    - Micas
  + Framework (4)
    - Feldspars, quartz
* Properties of minerals
  + Color
    - Ferromagnetics (Iron, Magnesium) are dark coloured (olivine, pyroxene, amphiboles, biotite mica)
    - Non-ferromagnetics are usually light coloured (feldspar, quartz, muscovite)
    - Generally not a good indicator of type of mineral
  + Streak
  + Lustre (How shiny)
  + Hardness
    - 7 Quarts, 5.5 Glass, 2.5 Fingernail
  + Crystal form (naturally grown external geometric form)
  + Cleavage (breakage across flat planes)
    - Quality, direction, angle of intersection of cleavage planes
  + Fracture (irregular breakage)
  + Specific gravity (density relative to water)
  + Magnetism
  + Chemical reaction (to Hydrochloric Acid)
    - Usually only carbonates react
* Rock-forming minerals
  + Oxides (Metals and Oxygen)
  + Sulfides (Sulfur and Oxygen)
  + Halides (Fluoride or Chlorine)
  + Carbonates (Carbon and Oxygen)
  + Phosphates (Phosphorous and Oxygen)
  + Hydroxides (Oxygen and Hydrogen)
* Useful/interesting figures
  + 2.10, 2.15, 2.24

# Igneous Rocks (Chapter 3)

* Igneous rocks created from cooling magma/lava
* Magma is below ground, lava is above
* If magma solidifies under the surface, it creates an “intrusive” rock, above ground is “extrusive”
* Nature of magma
  + Mostly silicon and oxygen with smaller amounts of other elements found in the crust
  + Viscosity is controlled largely by the amount of silicon, and hot magma flows better than cold magma
  + Some water or carbon/sulfur dioxide gases dissolved within the magma
  + Some parts may be solid due to already-crystallized minerals
* Temperature increases with depth of the earth
  + +20/30 C per km until about 3000km, at which the rate of change is lower
    - This is because we start to exit the mantle area (where all the magma is) and enter the core region
  + Heat can be generated by friction of subducting plates, or the heat of other parts of the rock
  + It’s more difficult to melt rocks lower down because the liquid version have more volume, so increasing volume while increasing pressure is difficult
    - This is why sometimes moving rocks up causes them to melt as they’re the right temperature and there isn’t too much pressure – decompression melting
  + Water mixed in helps melt the rocks
    - Usually gets mixed in when plates that have ocean above them get subducted under another plate
* Factors that influence melting
  + Temperature
  + Composition
  + Confining pressure
  + Water content
* Magmatic Evolution
  + The rocks that come out of magma can be quite different due to some minerals crystallizing out first
  + Assimilation
    - Magma melts the stuff around its basin, mixing in those rocks
  + Mixing
    - Two basins join together and mix their contents
* Chemical composition
  + Ferromagnesian silicates (olivine, pyroxene, amphibole, biotite mica)
  + Light colored silicates (quartz, feldspar, muscovite mica)
* Crystallization and Bowes’ Reaction Series
  + Olivine -> Pyroxene -> Amphibole -> Biotite Mica (Discontinuous Branch)
    - Tries to use up all of the stuff in the previous part before moving on to the next part
    - Quick cooling means you can have all of these in one rock
  + Plagioclastic Feldspars (Continuous Branch)
    - Calcium-rich things crystallize first
    - Quick cooling means you can have calcium-rich cores surrounded by sodium rich zones
  + Both trees go to -> Potassium Feldspar, Muscovite Mica, Quartz
  + Both crystallize in this order: ultramafics (almost 0 silicon), mafics (silica <= 50%), intermediates (silica ~60%), felsics (silica ~70%)
    - Things with less silicon crystallize first
* Texture
  + Rapid cooling -> fine grains, aphanitic
  + Slow cooling -> coarse grains, phaneritic
  + Large grains in mostly small grain rock, porphyritic
  + Holes left by gas bubbles, vesicular
  + Very rapid cooling that leaves ions “frozen” are glassy
  + Pyroclastics are rocks ejected by eruption
  + Pegmatitic are very course grained-rocks – crystals >1 cm
* Igneous Intrusions
  + Dykes
    - A form of intrusion that happens when magma is injected into fractures and then cooled
    - Tabular (sheet-like) and discordant (perpendicular-ish to existing rock)
  + Sills
    - Magma injected horizontally between existing layers of rock
    - Tabular (sheet-like) and concordant (parallel with existing rock)
  + Batholith
    - Basically a mega intrusion - >100km surface area
* Interesting/useful figures
  + 3.8, 3.13, 3.14, 3.16

# Volcanoes (Chapter 4)

* Distribution of volcanoes is largely around the “Ring of Fire” which encircles the Pacific ocean
* Zones of volcanism
  + Divergent plate boundaries
    - Plates moving apart – mid-ocean ridges or continental rifts
  + Convergent plate boundaries
    - Plates moving together – ocean-ocean boundary or ocean-continent boundary
  + Intra-plate hotspot
    - Hawaii
* Activity
  + Active – have erupted in human history
  + Dormant – have not erupted in human history, but might again
  + Extinct – have not erupted in human history, and probably won’t again
* Volcanoes are fed by magma reservoirs
  + Molten silicates containing crystals in suspension and dissolved gases
  + 500 C to 2000 C
  + A few hundred to >200k atmospheres
  + 5km to 60 km deep
  + Surface reservoirs usually have more silica, deeper have less
  + Magma rises at 500m to 1 km a day, along a chimney or a dyke
* Comparison of volcanoes
  + Mt. St. Helen’s – 0.24 cubic miles
  + Yellowstone caldera – 600 cubic miles
* Eruption factors
  + Violence of eruption
    - Viscosity
      * More silica = more viscous
      * Higher temp = less viscous
    - Amount of dissolved gases
    - Ease of escape of gases
    - High viscosity and low ability for gases to escape create explosive eruptions
  + The more silica in the magma, the higher the viscosity and the greater gas content, which leads to greater danger and ability to form pyroclastics
* Lava flows
  + Generally flows pretty slowly, easier to avoid than pyroclastics
  + Basaltic “a-a” consists of rouch and jagged surface blocks
  + Less viscous “Pahoehoe” is ropy and wrinkles as it flows
  + Basaltic lava that solidifies underwater makes pillow shapes (pillow lava)
  + Columnar basalt (hexagonal columns) formed by cooling and fracturing of lava
* Pyroclastic materials
  + Dust/ash <2mm
  + Lapilli (which are cinders) 2-64 mm
  + Bomb/block >64 mm
* Anatomy
  + Usually has a crater and a vent at the top
  + Fed by conduit into magma basin
  + Possibly parasitic cones on the side to allow lava to exit from different spots
* Types of volcanoes
  + Shield – low and long, approx. 50 km, Mauna Loa, Hawaii
    - Generally large basaltic flows
  + Composite – tall and medium, approx. 6 km, Mt. Rainier
    - Made through continuous eruptions
  + Cinder Cone – small, approx. 500m, Sunset Crater
    - Made of loose pyroclastic debris
* Fissure eruption
  + Basaltic eruption that’s too viscous to form an actual volcano
* Lava dome
  + Magma can’t go high enough to exit volcano so it builds up at the top and puts a cap on it
  + Instead, might erupt out the side, creating an extremely dangerous avalanche-type flow of magma
* Caldera
  + Hole that is formed after an eruption, where part of the magma basin has been emptied so the land above it sinks downward
* Volcanic hazards
  + Air pollution
  + SO2 acid rain
  + Mud/landslides
  + Lahars (volcanic debris mixed with water to make fast-moving slides)
  + Lava flows
  + Ash falls
  + Blocking and unblocking of rivers
* Volcanic eruption index – from 0 to 8
* Interesting/useful figures
  + 4.5, 4.11, 4.14

# Soils and Weathering (Chapter 5)

* Regolith
  + Layer of rock and mineral fragments that cover the Earth’s land
* Soil
  + Combination of mineral and organic matter, water and air, portion of regolith that supports plants
* Layers
  + O Horizon (Humus)
    - Loose/partly decayed organic matter like leaves
  + A Horizon (Topsoil)
    - Mineral matter mixed with some humus
  + E Horizon (Eluviation Layer)
    - Light-colored minerals that let water and minerals leach down
  + B Horizon (Subsoil)
    - Mostly clay, small/fine particles
  + C Horizon (Regolith)
    - Partially altered parent rock
  + R Horizon (Bedrock)
    - Unweathered parent rock
  + Oh, An Elephant Bakes Cake? Really?
* Soil Formation Factors
  + Parent Material
  + Time
  + Climate
  + Plants and animal in the local environment
  + Topography
* Soil erosion forces
  + Water/Wind/Ice/Gravity
* Weathering
  + Physical breakdown
    - Frost wedging – water freezing in cracks breaks open rocks, create “talus slopes”
    - Unloading – when rocks deep down get brought up, erosion of the overlying surface causes it to expand and separate (fracturing), which may eventually peel off (exfoliation)
  + Chemical breakdown
    - Hydrolysis, mostly
    - Also oxidation and dissolution (dissolving)
    - Susceptibility is the opposite of Bowen’s reaction series
      * Potassium feldspars, muscovite, quartz
      * -> Sodium feldspar -> Calcium feldspar
      * -> Biotite mica -> Amphibole -> Pyroxene -> Olivine
    - The slower to crystallize, the more resistant to chemical weathering
  + Phase relationships
    - Mass and volume of water/air/solid/voids
  + Soil characterization techniques
    - Dry strength – break between fingers
      * Siltier/sandier means easily fractured
    - Knife test – cut with a knife
      * If surface is shiny, it has a lot of clay
    - Teeth test – eat some dirt
      * Gritty – silty, smooth – all clay
    - Particle size/distribution – sieve through mesh
      * Clay < silt < sand < gravel < cobbles < boulders
      * Silt/sand/gravel have fine/medium/coarse prefixes if needed
      * Sorted – how similar are the grains – well sorted means that the grains are relatively similar
      * Graded – how different are the grains – well graded means the distribution of grains is fairly even
    - Plasticity – ability to be changed without breaking
      * Liquid (no strength)
      * Plastic (can bend without breaking)
      * Semi-Solid (acts like plastic for small deformations, solid for big deformations)
      * Solid (all deformations are permanent, usually fracture)
      * Limits determined by Atterberg Limit Test
        + Liquid limit – max water to have plastic behaviour
        + Plastic limit – minimum water to have plastic behaviour
        + Shrinkage limit – no volume change even if we dry the sample more
    - Useful/interesting figures
      * 5.17, the soil triangle figure in the slides, limit graphs, soil particle distribution graphs

# Sedimentary Rocks (Chapter 6)

* Compacted and cemented pieces of rock that have been mechanically or chemically weathered or eroded
* Usually contain evidence of past environments like fossils
* Can also contain metals or petroleum/natural gas/coal
* Pose an engineering challenge due to sliding layers
  + Can either put a large mass at the bottom to prevent sliding or insert large nails to hold the layers together
* Very easy to see faults in sedimentary rock
* Can section a sedimentary rock layer into “facies”, which are sections with differing sets of sediments
* Diagenesis – entire process that turns bits of sediment into sedimentary rocks
  + Occurs within the upper few km of the crust at a temperature of 150 – 200 C
  + Recrystallization – development of more stable minerals from less stable ones
  + Lithification
    - Compaction – pressing things together, reduces void space
    - Cementation – naturally occurring cements glue things together like calcite, silica and iron oxide
* Geographic location determines nature of sediment that accumulate
  + Continental
    - Largely erosion and stream deposition, possibly glaciers and wind
  + Marine
    - Can be either shallow or deep deposition
  + Transitional (shoreline)
    - Tidal flats, lagoons, swamps
* Types of sedimentary rocks
  + Detrital – solid particles of earth material (entire rocks)
    - (classified in order of increasing particle size)
    - Shale – mud compressed into thin layers, clay to silt sized
    - Sandstone – made of sand-sized particles, mostly quartz
      * Can look at composition to tell things about the environment at the time
    - Conglomerate – rounded pebbles or cobbles, usually poorly sorted
    - Breccia – angular pebbles or cobbles
      * Rounded/angular indicates generally how long they travelled for due to erosion

Chemical – sediment that was once part of a solution (things like carbonate or sulfates or broken down plants)

* + - Limestone – mostly calcite with some marine particles (chalk, coral reef, broken shells)
    - Dolostone/Dolomite – formed from broken down limestone
    - Evaporites – leftovers from evaporation, like rock salt of rock gypsum
    - Coal – mostly plant matter
      * Plant material -> Peat -> Lignite -> Bitumous -> Anthracite
* Textures of sedimentary rocks
  + Clastic
    - Discrete fragments and particles (all detrital rocks are clastic)
  + Nonclastic
    - Patterns of interlocking crystals, might look like igneous rocks
* All oil sands are in sedimentary rocks
* Useful/interesting figures
  + 6.3, 6.16, 6.18

# Metamorphic Rocks (Chapter 7)

* Made from transforming other rocks through heat/pressure/fluid chemical activity
* Composition of original rock generally determines composition of final rock
* Generally occurs in convergent plate boundaries, where one of the plates is cold enough such that it doesn’t melt right away, so it gives time to apply medium heat and a lot of pressure on rocks
* Heat increases rate of chemical reactions
* Differential pressure/differential stress/shear stress can cause minerals in a rock to align against plane of least stress, deforming it, perhaps making a new texture
* Even pressure might mean original texture is retained even if minerals recrystallize
* Rocks that have a preferred orientation have “foliation”
  + Granite -> gneiss
* Having fluids also helps reactions go along
  + Water trapped in pores of sedimentary rocks
  + Volatile fluids in magma
  + Dehydration of water-bearing minerals like gypsum that have water within the crystal structure itself
* Grade – intensity of metamorphic transformation
  + Higher grade = more minerals that are stable at higher P/T
  + Often get texture changes with high grade
  + Some minerals exist only in very specific P/T – these are index minerals, help determine the grade
* Like sedimentary rocks, metamorphics can have facies
* Regional metamorphism
  + Occurs over very large area
  + Convergent boundaries drive parts of the plate up, and some deep down, intensifying grade
* Shale -> Slate -> Phyllite -> Schist -> Gneiss -> Migmatite, in order of increasing particle size
* Foliated textures
  + Rocky/Slaty cleavage – horizontal beds get super compressed from the sides, making vertical slats of rock, caused by alignment of grains within the rock itself
* Phyllite
  + Larger grain size than shale or slate
  + Cleavage surface is generally wavy and kind of glossy-looking
* Schist
  + Platy minerals like mica grow to visible size
  + Develop layered structure
  + Similar to porphyritic igneous rock texture, called porphyroblastic
* Gneiss
  + Higher segregation of mafic and non-mafic minerals
  + Foliated, but rarely breaks along the planes of foliation (no paper-like layers)
* Only non-foliated metamorphic rocks are quartzite and marble
* Useful/interesting figures
  + 7.3, 7.4, 7.16, 7.17

# Plate Tectonics (Chapter 12)

* Lithosphere – crust and upper mantle
* Asthenosphere – middle mantle, rocks melted enough to flow
* Uneven distribution of heat moves stuff around in the asthenosphere
* Plate boundaries
  + Divergent (Constructive) – two plates coming together
    - Creates volcanoes, mountains, earthquakes, and metamorphic rocks
  + Convergent (Destructive) – two plate moving apart
    - Decreases amount of crust
  + Transform Fault (Conservative) – Two plates moving in opposite direction, sliding against each other
* Major plates
  + <https://en.wikipedia.org/wiki/Plate_tectonics#/media/File:Plates_tect2_en.svg> for more detailed
  + Pacific plate – moving up and to the left, hitting Indo-Australian plate and Eurasian plate
  + Antarctic plate – Not really moving
  + North American plate – up and to the left, sliding against Pacific plate
  + Eurasian plate – to the right, hitting Pacific plate
  + African plate – moving to the right, away from South American plate
  + South American plate – moving into Nazca plate
  + Nazca plate – moving into South American plate
  + Indo-Australian plate – Moving up and to the right, hitting Eurasian plate
* Pangaea – 200 mya, one giant continent that broke up due to continental drift
  + Shorelines of continents fit together
  + Fossils of same animals in places that are now really far
  + Mountain ranges that seem like they would continue if you pieced together the continents
  + Matching amounts of glacial deposit if it had been one giant piece of land
* Paleomagnetism
  + When iron cools, it points toward magnetic north at the time of cooling
  + Magnetic pole moved over time aka continents moved over time
* Sea floor spreading
  + Divergent boundaries in the middle of the pacific ocean means that it’s pushing the plates apart
  + Showed magnetic poles flipping with known flips of the poles over time
  + Divergent boundaries within land could eventually split the land, creating a river or even ocean
    - This is happened in northeast Africa
    - Sometimes the rifts fail and just make giant rivers instead
* Plate tectonic mechanism
  + Ridge-push slab-pull
    - One part of the plate is pushed up, which pushes the other side down back into
  + Mantle drag
    - Heat moves in circles so plates are kind of dragged like a conveyer belt
* Measuring plate motion
  + Sediment age immediately above oceanic crust divided by distance from spreading ridge
  + Dating magnetic reversals on the seafloor, since we know how long certain magnetic orientation lasted for
  + Satellite-laser ranging techniques
  + Generally from 1.1 to 7 cm a year
* 50 my from now
  + California in Canada
  + New ocean beginning in East Africa
  + Mediterranean Sea beginning to disappear
  + Australia is now on the equator
* Useful/interesting figures
  + 12.2, 12.6, 12.13, 12.21, figures for basic movement of plates and what things look like 50 my from now in slides

# Earthquakes (Chapter 10)

* Sudden slip or rupture on a fault and resulting ground shaking caused by the radiated seismic energy
* Epicenter is not necessarily where greatest damage occurs
* Body waves (waves inside rocks)
  + P-waves
    - Compressional, like a spring, parallel to direction of wave propagation
    - Fast (4-7 km/s)
    - Can pass through all material
  + S-waves
    - Shearing waves, like a sine wave, perpendicular to direction of wave propagation
    - Slower (2-5 km/s)
    - Can only pass through solids
  + Can use p and s waves to figure out material of the core – p waves are refracted by the core, so there are areas where p waves don’t reach
  + S waves just get straight up blocked by the outer core
  + Can detect epicenters of earthquakes through triangulating fast p waves and slow s waves with hundreds of earthquake detection stations
* Surface waves (waves visible on the ground)
  + Slowest type of wave
  + Love waves
    - Side to side motion
  + Rayleigh waves
    - Up and down motions
    - Completely fuck up buildings
* Geological evidence of earthquakes in costal areas
  + Subsidence
    - Areas that were suddenly buried by tidal mud
  + Tsunami
    - Soil overlain with thin sheets of sand from tsunami deposits
  + Liquefaction
    - Sand from underneath soil gets extruded upwards due to lack of structural integrity of soil above
* Size/strength
  + There is absolute energy emitted
  + But there’s also a measure used more closely to link the effects of the earthquake – for example a strong earthquake that doesn’t affect the surface is no big deal for us – Mercalli Intensity Scale
    - 1 – 12 from instrumental to catastrophic
* Notable earthquakes
  + Chile 1960 – 9.5
  + Chile 2010 – 8.8 – megathrust earthquake
  + Alaska 1964 – 9.1
  + Sumatra 2004 – 9.0 – triggered giant tsunami, killing 200k
  + Japan 2011 – 9.0
* Building damage
  + Foundational failure
    - Building stays up but is lopsided because soil beneath it is weak
  + Structural failure
    - Building itself collapses or breaks in some way
  + Prevention
    - Avoid rigid walls, use flexible and lightweight material
    - Flexible cross-reinforcement instead of rectangular open frame
    - Allow for some slippage at joints
* S waves may cause more damage the poorer (the looser) the foundation
* Liquefaction – things that are sturdy when they’re still might fall apart when they’re moving
* Tsunamis
  + Can be caused by earthquakes – waves increase in frequency and height as it approaches the shore
  + Normal faulting – ocean bed far from land drops down, water falls with it, but overcompensates, then rushes back to land as it pulled too far back
  + Reverse faulting – ocean bed far from land raises up, pushing water towards the shore
    - Two plates doing this (faulting upwards) can cause humongous tsunamis
* Pacific ocean has many tide and seismic stations to warn of tsunamis
* Earthquakes can also trigger landslides
* Useful/interesting figures
  + 10.4, 10.7, 10.17, 10.26

# Japan Earthquake

* 9.0 Magnitude, March 14, 2011, 27k dead
* 24 km deep, area of rupture approx. 80000 km^2
* Intersection of Filipino, Pacific, North American, and Eurasian plate
* Due to subduction zone
* Ground displaced up to 4.5 m
* Flooding at such heights went over expected height, damaging nuclear power station’s power systems
* Max 23.6m run-up (water height), 12.2m inundation
* Max tsunami height 7.5m, >8m mean basically everything gets destroyed

# Crustal Deformation (Chapter 9)

* All changes in original form/size/location/orientation of a rock body
* Folding and fracturing
* Vertical stresses are additive (adding pressure from soil + water + atmosphere, etc)
* Compression is pushing together
* Tension is pulling apart
* Shear is moving in two different directions
* Conventional traps – usually used with respect to trapping oil/gas/etc
  + Structural traps – rock has moved overtop (shifting/faults, etc), stopping movement of oil
  + Stratigraphic traps – traps due to the innate properties of the rocks itself – for example oil sands, as the oil is captured within the rock itself, or perhaps there are rocks that aren’t porous and don’t let the oil move
* Elastic strain – strain where rock can move back to its original form
* Plastic strain – rock won’t be able to move back to its original form
* Strike – line of strike is the intersection of a horizontal plane with a rock face
* Dip – angle of maximum deviation from rock face to horizontal plane
  + Dip direction is perpendicular to the line of strike
* Strike/Dip symbol – strike line is the longer line, dip line is direction of dip, angle is dip angle
* Anticline – logical And symbol (upside down U), Syncline – U (think sink-line as middle part sinks)
  + These are usually connected as multiple arches exist
  + Both have an axial plane, and each half a is a limb – these limbs are generally shared
  + Overturned fold is when both limbs fold in the same direction
  + Recumbent folds
    - The plane of symmetry is horizontal instead of vertical
* Faults
  + Hanging wall is where guy hangs light
  + Foot wall is where the guy’s feet are
  + Normal – hanging wall moves down relative to foot wall (compressive stress)
  + Reverse – hanging wall moves up relative to foot wall (tensional stress)
  + Horst is area that is pushed up, graben is area that fell down
  + Strike slip fault – walls moves horizontally, not up and down (differential stress)
    - Transform fault is a strike slip fault
  + Thrust fault – area of rock has been pushed up and over another section, like grabbing a piece of paper by both ends and pushing the ends together
* Joint – a fracture that divides a rock, but the sections haven’t moved much
  + Tensile joints – like what happens when you try to bend your elbow after you’ve scraped it – things come apart
  + Contraction joints – like inside of knee
* Useful/interesting figures
  + 9.2, 9.8, 9.9, 9.10, 9.12, 9.20, 9.22, 9.24, 9.29

# Mass Wasting (Chapter 14)

* Downhill movement of masses of bedrock/rock debris/soil due to gravity
* With planning, easily most avoidable of all major geologic hazards
* Factors
  + Slop Angle
  + Amount of Water
  + Slop materials and vegetation (possibly)
  + Earthquakes
  + Heavy rains or rapid snow melt
  + Human activity
* Slopes have shear strength through internal friction of soil/rock grains
  + Shear stresses degrade the slope’s stability
* Factor of Safety (FS) = Resisting Force (R) divided by Disturbing Forces (D)
  + When FS <= 1, the slope fails
* Huascaran, Peru (1970) – 5k deaths from landslide flow
  + Caused by an offshore earthquake
  + Cemetery Hill was the only part to survive
* Concerns
  + Railway lines may be damaged
  + Marine habitats due to landslides into bodies of water may be affected
* Prediction methods
  + Shuttle Radar Topography Mission (200)
    - Digital elevation map of entire earth’s surface
  + Landsat 7
    - Pictures of entire world’s surface without any cloud
  + ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer)
* Recent (1899+) landslides in North America have generally always occurred on the west coast
  + Hope Slide 1963 in BC basically filled in an entire lake
* Movement monitoring
  + Which parts are moving and how fast? Are there ways to control the movement?
  + Signs of movement
    - Visual (surface cracks, split/angled trees)
    - Comparison of old and new photographs
    - Measurement of surface movement
    - Subsurface deformation of boreholes (put in a bendy stick, how much has it bent in the last month?)
    - Satellite observations
* Classifications
  + Flow – moves kind of like a liquid
    - Creep – super slow movement
    - Debris flow
      * Earthflow – debris moves downslope, like a liquid, usually on steep hills
      * Mudflow – mix of debris and water, usually down a channel
      * Debris avalanches – extremely fast moving (several hundred km/hr)
    - Rock avalanche
  + Slide – a chunk actually breaks off and slides downward
    - Rock slide (bedrock moving)
    - Debris slide (stuff on top moving)
  + Fall – rocks that broke off cliffs
    - Debris fall
    - Rock fall
* Defences
  + Fences or wire net screens
  + Dams
  + Channels to direct flow
  + Rock sheds on top of areas where we expect rock falls to happen
  + Rock bolting
  + Cementing over the slope
  + Straight up just remove the hill itself
  + Block the bottom of it so it can’t slide
  + Drainage to let water through but not solid

# Shorelines (Chapter 19)

# Running Water (Chapter 15)

* 1.36 billion cubic kilometers of water
* Anatomy of stream
  + Head = source
  + Bank = sides
  + Bed = bottom
  + Mouth = exit into larger water
  + Levee = artificial bank
  + Channel = artificial bed
* Biggest rivers
  + Amazon
  + Congo
  + Yangtze
* Laminar flow is smooth, straight flow
* Turblent flow is intermixing, all direction (this is the majority of a stream’s flow)
* Drainage basins
  + Total area drained by stream and its tributaries
  + Tributary – smaller river that enters this one
  + Divide – strip of high ground that divides one drainage basin from another
  + Continental divide – separates streams -> Pacific and streams -> Gulf of Mexico
* Drainage patterns
  + Dendritic
  + Radial
  + Rectangular
  + Trellis
* Discharge = velocity \* area
* Sediment transportation (called alluvium)
  + Suspended – things flowing with water itself
  + Bed/Saltation load – things that roll or skip along the bed
  + Competence – biggest thing a stream can carry
  + Capacity – most things a stream can carry at once
* Graded stream – smooth bed, as the rate of sediment transportation is the same as erosion
* Base level – lowest level of erosion (impossible to erode below sea level)
* Alluvial deposits
  + Stratified
  + Greater permeability in horizontal directions
  + Linear/sinuous geometry
  + Good sources of gravel/sand
  + Bad foundations
* Flood mechanisms
  + Regional (weather-related, like snowmelt)
  + Flash flood (local intense rainfall)
  + Ice jam (build up of ice fragments blocks flow)
  + Constructed dam failure
  + Natural dam formation/failure
  + Floods described by statistical return period – so a 50-year flood has a 2% chance of occurring each year
* Flood control
  + Artificial levees
  + Flood control dams
  + River channelization/floodways

# Groundwater (Chapter 16)

* 0.6% of water is groundwater
  + Needed for agriculture and plant life
* In Canada
  + 94% of freshwater is groundwater
  + 40% Ontario, 100% PEI
  + 80% waterloo
* Zones
  + Infiltration zone
  + Capillary zone
  + Water table
  + Saturated zone
  + Finer grains of sand mean water can rise higher
* Pores can be filled with water/gas/oil
* Specific Yield = Drainable Volume/Total Volume
* Retention = Undrainable Volume/Total Volume
* Groundwater storage mitigates runoff/erosion
* Streams can be created/destroyed if the water table is high enough/low enough, as water either exits the ground or goes further down into it
* Perched water tables are ones that are higher up than the main one, usually due to some difference in the rocks below it, not allowing it to move further down
* Artesian well
  + Aquitards on top and bottom of water, usually flows downhill
  + Better to put well downhill where the pressure surface is likely to be higher than the height of the well
* Flow rate factors = Conductivity \* Gradient \* Area
  + Gradient (steepness)
  + Permeability (flow capacity)
  + Viscosity
  + Area (flow cross-section)
* Hydrostatic/static/hydraulic head
  + Height of liquid above measuring point, regardless of shape or path of the sealed tube
* Cone of depression
  + Cone formed by draining too much of the water table at one spot
* Contamination
  + Landfills, dumps, septic tanks
  + What type of contaminant? In what ways is it able to flow through the water table? Does it go through the unsaturated zone? How diluted or dispersed are the contaminants?
* Walkerton May 2000 EColi outbreak
  + Manure application on a farm close to a well with highly fractured rock zone
* Treating groundwater
  + Pump and treat
  + Monitored Natural Attenuation
    - Watching exactly where the contaminant is
  + Dig and dump
  + Permeable Reactive Barriers
    - Nets that kill contaminants
  + Introduce safe bacteria or chemicals that can kill contaminants
  + Sparging
    - Pumping air in to oxidize contaminants

# Testing Rock Properties

* Rocks are used in building materials, foundations for engineered structures, and underground construction
* Important to understand properties of the rocks you use to prevent failure or accidents (
  + ex. Hungary aluminum refinery reservoir dam broke)
    - Released 12-foot high wave of refinement waste
  + Leaning Tower of Pisa
    - Foundation is bad, tried to rectify it in the middle of building it by putting more material on one side
* Properties of Rocks for foundations of buildings
  + Density
  + Strength
  + Compressibility
  + Stiffness
  + Permeability
* Site investigation
  + Surface conditions
    - Slopes, bedrock outcrops, springs
    - Done in office (maps, pictures) or in the field
  + Subsurface conditions
    - Depth to bedrock, water levels inside, what types of bedrock, quality of rock masses
    - Done through ground penetrating radar or drilling
  + Obtain rock samples for testing (drill core samples)
  + Conduct tests on load bearing and shear stress, etc, at site itself
  + Install instrumentation to monitor change if necessary
* Rock classification
  + Rock quality designation (RQD)
  + Relates number of fractures with the length of the core itself
  + Basically, drill out a bunch of cores, count how many are longer than twice the diameter, add up the length of those ones, then take that as a percentage of total length of the core
  + Very Poor (0-25%) < Poor (25-50%) < Fair (50-75%) < Good (75-90%) < Excellent (90-100%)
  + How do we know how many samples (geo-mechanics units, GMUs) is enough? Too few is risky, too many wastes money
    - Generally just a judgment by the engineer/professional in charge
  + There’s intact rock (no fractures) and rock masses (lots of fractures), both of which are used to test different things
    - Intact
      * Specific gravity
      * Unit weight
      * Porosity
      * Compressive (crushing, uniaxial compressive strength UCS)/tensile (pulling)/shear strength (across different planes), experts not in agreement about how exactly to define “strength”
    - Rock masses
      * Really dependent on what geologists want to look for
      * Fracture orientation, joint roughness, groundwater conditions
      * Classification
        + Geomechanics System of Rock Mass Rating
        + Norwegian Q
        + Geological Strength Index
* Case study
  + 1963 Viaont Dam Disaster
    - Rockslide caused flood and waves 200m high, killing 2000+
    - Dam was built, groundwater mixed with the shale below, increasing their size and becoming slippery
    - Slope failure due to slippery shale, causing a rockslide into the water in the dam
    - Dam itself survived, but wave destroyed Longarone

# Global Climate Change

* Factors
  + Sun’s output
  + Earth’s orbit
  + Drifting continents
  + Volcanic eruptions
  + Greenhouse gases
* 97% agreement by climate scientists
* Climate change is additional change caused by humans on top of normal climate fluctuations
* Greenhouse gases help the atmosphere trap in additional heat, like heat in a car in the summer
* Important greenhouse gases
  + NO2
  + CO2
  + Methane
  + Water
* CO2 has been steadily increasing, way over the natural variation, and global mean temperature has been increasing the last 140 years, increased 1 degree since 1960 (the majority of the earth is anywhere from 0 to 2 degrees higher than normal)
* 10 warmest years have been in the last 17 years
* Ocean’s temperature has been steadily increasing as well
* Canada is 3rd place in terms of CO2 emission per person
* Arctic sea ice is decreasing as well
* Importance
  + Sea levels rise, killing beaches and wetland habitats, some island nations may disappear
  + Higher temp = better for mosquitos who hold dangerous diseases like malaria
  + Ground-level ozone pollution worsens, more respiratory diseases like asthma
  + Deaths from heat waves
  + Animals/plants go extinct
  + Changes in weather could affect agriculture and our ability to produce food
  + Loss of forests and wildlife species
  + Billions of dollars in property/crop damage from higher sear levels and worse storms
  + Worst case temperature increase could be +7 degrees by 2100. Best case is +1.5 degrees.
* Affect number of dangerous tornados, larger hurricanes
* Challenges
  + Nature of the climate system itself
    - It’s difficult to predict something with so many variables in it
  + Needs for research
    - Improve data, theory, models, and separate naturally-occurring fluctuations from human effects
  + People
    - Needs cooperation
* Possible changes
  + More fuel-efficient vehicles
  + Less vehicle use (more public transport)
  + Improve energy efficiency in buildings and manufacturing
  + Increase usage of nuclear and other renewable sources of energy
  + Plant trees/reduce deforestation
  + Improve soil management strategies