Plate Tectonics: Grew out of the Theory of Continental Drift, observation by Alfred Wegener in 1915 that some of the continental land masses seemed to fit together, and later drifted apart

- Plate move across the surface of earth at seemingly random directions and at different rate

Significance of Plate tectonics:

1. Almost all earthquakes, volcanoes occur where lithospheric plates are interacting with each other
2. Most of main mineral and hydrocarbon resources occur in specific tectonic settings
3. Plate tectonic process are almost entirely responsible for what happens at the earth surface ex: size and shape of oceans, nature and distribution of landforms and general climatic conditions

Paleogeography: study of evolution of landforms through time

- Subaerial: areas exposed above sea level
- Submarine: covered by very shallow seas

Plate Tectonics: basic concepts

- Oceanic crust is thinner but denser than continental crust
- 3 ways of interaction
  - Divergent boundaries: rift apart
    - Ex: red sea
  - Convergent: move towards
    - When one lithospheric plate pushed down another it is being subducted
    - When oceanic crust is pushed down another plate, large volumes of magma are produced, magma rises to shallow levels in the crust of the overriding plate, and form volcanoes, volcanoes form a linear or more arcuate line (an arch)
    - If the overriding plate is oceanic, than isolated volcanic island(oceanic arc) will be formed
    - If overriding plate is continental, the plate will be thicker and less dense than oceanic plate, so it will be mainly suberial, the arc formed is called continental or Andean-type
    - If continental plate subducted another continental plate, a mountain such as Humalayan forms
  - Transform: sliding along
    - Ex: San Adreas fault
- Mantle Plumes (hotspots)
  - Hotspots from very deep in the mantle produce large volumes of magma that rise to the surface and erupt
    - Ex: Hawaiian Islands

Mantle Convection Model

-is that it is believed that heat from deep in the earth cause large scale convection to occur within the mantle, and caused individual plates to be dragged passively along on top of convection cells

Ridge Push Model

- Alternative model is for mid ocean spreading ridges: that newly formed oceanic crust is thermally uplifited, and that oceanic plates are sliding off this uplifited zone

Slab Pull Model

- When oceanic lithosphere is subducted to considerable depth, the elevated heat and pressure converts the rocks that make up normal oceanic crust, the oceanic crust materla basalt is less dense than the underlying mantle, and therefore floats on it. These are transformed into rock eclogite, which is much denser than the surrounding mantle, it then forms a huge weight on the lower edge of the subducting plate, and as eclogite sinks down into mantle, it pulls the rest of the plate behind it

Current views of plate motion

- Believed to be combination of slab pull and ridge push

Plate Motions in Earth's history

- Magnetic anomalies on the sea floor
    - Critical tool for plate reconstruction is magnetic striping on the ocean floor
    - Magnetic stripes form at spreading ridge, the earth is affected by magnetic field, which changes orientation by 180 every few to tens of million years
    - We can compare the magnetic field that is locked into the rock and when the earth's magnetic field is normal, there will be normal magnetism and vise versa
    - However we can only use magnetic stripes to about 180-190 million years
- Paleomagnetism
    - Use to determine past movements of rocks in N-S Direction, the volcanic lava that flows onto the earth's surface near the equator will preserve the magnetic lines of forces that are parallel to the top and bottom surfaces of the flow
- Hotspot tracks
    - Chains of vaolcanoes produced when a lithospheric plate moves over a fixed mantle plume

Volcanic Activity and Orogeny

- As oceanic crust being subeucted, water is driven off the down going plate, and water passes up into the overlying wedge of mantle material where it causes the mantle material to melt. This rises buoyantly and building volcanoes. This produce chain of isolated volcanoes, theses volcanoes are called composite cones or stratovolcanoes

The principle of Isostasy

- Isostasy: state of gravitational equilibrium or balance between the earth's lithosphere and asthenosphere
- If the crust along a convergent margin becomes thicker, average desnity is decreased, it will cause the crust to float even higher and create a continuous mountain belt

Plutons, batholiths, and mountain ranges

- Not all of the magmas are erupted, most of it ends up cooling and crystalizing, called plutons. A group of adjoining plutons is referred as batholith. This emplacement of plutons inflates the crust with relatively low density rock masses, and so according to isotasy, it will create a continuous mountain belt.
    - Ex: Andes Moutain belt, coast range batholith

Mountain rangers are ephemeral

- Mountain doesn't last very long because materials will being to erode off by rivers, streams and glaciers

Mountain ranges can be long-lived

- Although the mountains continually being eroded, the continued subduction of oceanic crust from the west continues to produce low density magmas that rise, inflate, and thicken the curst from below

Glacial rebound

- Allows portions of the curst to be uplifited when large sheet of ice is removed

Crustal Extension and Orogeny

- Fault is simply an inclined fracture or crack in the earth's surface along which some movement has occurred
- Normal fault is when inclined fault, the hanging wall block is down dropped with respect to the block below the fault foot wall block, the hanging wall block is always the one leaning onto the other, this type of faulting produces a typical pattern of parallel uplifted blocks called horsts and downdropped blocks called grabens, this creates narrow mountain belts
- Ex: basin and range province

Crustal compression and Orogeny

- 3rd way to build mountain is by shortening/compressing parts of the crust, it will cause the hanging wall block to move up with respect to the footwall block.
- Ex: sevier mountains and Canadian rockies

Crust that is being shortened and compressed can be thickening by both reverse faulting and by folding

Terrane: Crustal block or fragment that preserves a distinctive geologic history that is different from surrounding areas and that is usually bounded by faults

Accreted Terranes: terranes that become attached to a continent as a result of tectonic process

Cordilleran belt

- Most of it comprises magmatic arc terrance

Evidence for origins of exotic terrance

- Faunal associations:
    - Ex:everal of the accreted terranes in the Canadian Cordillera contained Jurassic ammonite faunas that were typical of faunas formed far to the south of their present location
- Late Paleozoic macrofossils
    - Using fossils
    - Ex: fossil in the Cache Creek terrane transported into Canadian cordillera from somewhere closer to equator

Plate tectonics and paleogeography reconstruction

- Early to middle Triassic (~240 Ma)
    - Oceanic crust was subducted under the western margin of N.American, producing volcanic arc
- Early Jurassic (~180 Ma)
    - Large terrane called Wrangeilla beginning to move towards the edge of the continent
- Middle Jurrasic(~160 Ma)
    - Southern end of Wrageilla collide with the edge of N.America
- Late Jurrasic(~145 Ma)
    - Wrangeilla continue to collide with N.America, the oceanic plate Farallon plate converging obliquely to the south , so Wrangeila slide woutwards
- Early Cretaceous (~125 Ma)
    - Farallon plate is almost orthogonally to the coast, Wrangeilla began to push against margin, start to create Canadian rocky.
- Mid-Cretaceous (~105 Ma)

    - Farallon plate was converging obliquely to the north, so Wrangeilla begin to pushed slightly north, mountain build and rocky was being formed by crustal thickening
- Late Cretaceous (~85 Ma)
    - Farallon plate split into southern and northern part (Kula plate), Kula plate moving parallel to cost, and farallon plate move obliquely towards the continent
- Cretaceous/Teriary Boundary (~65 Ma)
    - Kula plate still move north, cretaceous sea way gone

Rocky Mountains
- Late Jurassic to Early Cretaceous (145-125 Ma)
    - A lot of strike-slip faulting, terranes that lay west of the rocky moutains were being pushed against and also sliding nothwards
- Mid-Cretaceous (~105 Ma)
    - Rocky still growing, crust compressed and thickened and the area to the east was subsiding, form cretaceous seaway
- End of Cretaceous(~75 Ma)
    - Convergence of oceanic plates from west stopped, rocky began to erod and cretaceous seaway ultimately filled up and gone

Earthquakes
- Surface rupture: disturbance on the surface
- Focus: main release of energy
- Epicenter: surface point above focus
- Liquefaction: loose to moderately saturated, layered sediments are strongly shaken, transforming solid layer to slurry

Tsunami
- Generated when earthquake occurs beneath water

Megathrust earthquake
- Frictional forces along the upper surface of the subducting plate and the pleading edge of the overriding plate cause the thrust fault zone to become locked, no displacement can occur

Evidence of the past
- Tsunami Sands: deposited when tsunami impact a coastline and wash a lot of beach sand far inland into the low-lying coastal areas
- Drowned coastal forests:fir and cedar in coastal swampy areas have been killed due to the sudden influx of seawater
- Oral record
- Last documented giant earthquake in BC occurred in 1700 AD, jan 26, 9pm

Seismic Waves
- Body waves:
    - Primary Waves : similar to attached one end of a slinky spring to wall, stretch the slinky and push the slinky back to wall. The motion would be along the length of the slinky
    - Secondary wave: tying the end of a rope to a wall and quickly shaking the other end of the rope, the motion will be perpendicular to the direction of wave travel
- Surface waves
    - Long waves: like secondary wave,particle motion is perpendicular to the travel direction of the wave

    - Rayleigh waves: are like primary wave that travel along the surface

Summary

- In this Module, we studied the evolution of tectonics and landscape and how these have shaped the Dinosaur's Earth.

- We looked at the interplay between tectonic processes and how that may have affected the western edge of North America through the Mesozoic, as manifested in terms of Paleogeography. We speculated about how this might have impacted the evolution and eventual demise of dinosaurs.

- The Earth's surface is made up of a number of large and small lithospheric plates that are moving independently with respect to one another. Tectonic processes within the Earth are caused by lithospheric plates interacting with one another in various ways.

- Global paleogeography is controlled by plate tectonics! Paleogeography, or the way that landscapes have evolved on the surface of the Earth through time, is a direct result of tectonic processes.

- We have seen how lithospheric plates can interact with each other in three main ways: along divergent, convergent, or transform boundaries. Each of these types of plate boundaries is characterized by specific combinations of magmatism, faulting, and/or mountain building.

- The earlier view that plate motions are driven mainly by large-scale convection in the Earth's mantle has been replaced by the current interpretation that plate motions are driven mainly by slab pull, with a minor contribution by ridge push.

- Convergent margins, such as the one we live on in southern BC, involve the subduction of oceanic lithosphere under either the edge of a continent (as in southern BC) or the edge of another oceanic plate (as in the Marianas or Tongan Islands). In both cases, magmas are generated that rise through the crust and erupt as arc volcanoes.

- When lithospheric plates (either oceanic or continental) move over a fixed mantle plume or hotspot, a chain or isolated volcanoes is produced. These track the motion of the moving plate through time (e.g., the Hawaiian and the earlier Emperor Seamount chains).

- Patterns of magnetic striping on the seafloor and paleomagnetism of ancient rocks can also be used to track past plate motions. Note that magnetic stripes only provide information on plate motions back to about 190 Ma, because this is the age of the oldest preserved oceanic crust.

- Past plate motions can be reconstructed using these and other tools. We must be aware plate constructions are less well constrained the farther back in time you go. Future plate movements may also be predicted. However, these future plate configurations are very model-dependent and wildly speculative!

- Mountain belts exert a major influence on landscapes, climate, and migration patterns of surface-dwelling species. The formation, extent, and nature of mountain belts is entirely controlled by tectonics!

- Most mountain belts form along or near plate boundaries, such as the North and South American Cordilleran mountain belts.

- The Cascade Arc, which is a string of dormant to recently active volcanoes stretching along the western edge of North America from northern California to the Whistler/Pemberton area in southwest BC, formed above an oceanic plate that is being subducted under the edge of the continent.

- Oceanic crust that makes up the floor of the Pacific Ocean basin is being subducted under most of the margins of the Pacific Ocean, producing the circum-Pacific Ring of Fire, which comprises a nearly continuous belt of volcanoes related to convergent margins. Because of this subduction on all sides, the Pacific Plate is actually getting smaller with time.

- Mountain ranges along convergent margins are partially built as a chain of isolated arc volcanoes. These topographically high regions are eventually built up by isostatic uplift caused by emplacement of voluminous low-density plutons onto the crust.

- Linear mountain belts can also be produced by crustal extension. The best example of this is the Basin and Range Province in the southwest U.S.

- Mountain belts along convergent margins can result from arc magmatism, compressional deformation, and/or extensional deformation.

- Some of the largest mountain belts on Earth are produced when two continents collide. A very good example are the Himalayan Mountains, which were produced when the Indian Plate collided with, and started to subduct underneath of the Eurasian Plate.

- The North American Cordillera consists largely of an assortment of terranes, some of which definitely formed far away, and moved large distances into their present position.

- Evidence for large-scale displacement of some terranes in the Canadian Cordillera include:

1. displaced faunas, for example, Tethyan faunas at high latitudes
2. paleomagnetic evidence that indicate terranes are farther to the north of their original position
3. major faults in the Cordillera that have accommodated large amounts of displacements
4. displacements predicted by the relative plate motion between the subducting oceanic plate to the west and the North American plate

- During the Mesozoic, when the supercontinent of Pangaea still existed and was just beginning to break up, western North America faced onto a major oceanic basin to the west.

- From the Early Jurassic until the end of the Cretaceous, several terranes that formed out in the Pacific Ocean basin moved towards and became attached (accreted) to the western edge of N. America.

- Convergence between the oceanic plate to the west and the edge of N. America was oblique, causing some of the accreted terranes to slide to the north or south along the margin.

- Interaction between the oceanic plate and N. America built a substantial mountain range (the Canadian Rocky Mountains) and created an extensive shallow sea (foreland basin) farther inland to the east of the mountain belt.

- By Late Cretaceous time, a continuous mountain belt stretched all the way from western Mexico to Siberia, and a continuous shallow sea (the Cretaceous Seaway) lay to the east of it.

- The bottom line is that the dinosaurs may have ruled in western Canada during the Mesozoic, but that was only possible because plate tectonics had produced suitable landscapes in which they could flourish!

What are the main differences between reverse faults and thrust faults
-Reverse faults have a higher inclination angle than thrust faults.
-Thrusting along thrust faults usually shortens the crust more that faulting on a reverse fault.