Lecture 1:

What should we be worried about?

- Earthquakes are one of the largest threats
- Where they happen: 2010, northeast of australia, several earthquakes at one spot , small and large
- Earthquakes not just in ocean… Ex. Chile (ocean land transition… 7.0 magnitude)
- Japan, 2011, 9.0 magnitude… so large that it shifted axis of earth by 2 centimeters
    - To tokyo this is a daily threat
- Geology is pattern recognition, external structure of earth can be explained by these patterns
- Earthquakes are on edges of puzzle pieces (tectonic plates) largely around pacific ocean. Edge of puzzle piece is not just where land meets water, it is where tectonic plates, hence why no earthquakes on east coast
- Petroleum fractionation causes earthquakes in the middle of USA
    - No natural
- We observe patterns and try to make maps… in case of earthquakes, safety/hazard map… where is more safe?
- Ottawa is in threat zone
- Danger zones:
    - Ottawa
        - Follow linear trend
        - Fault- displacement along fracture
        - Force far away- this is where it happens to be weakest
        - 15000 was the last glaciation (2km of ice), isostatic rebound
    - Yellowstone- Wyoming
        - Volcano
        - (Outline of creator of red line, ground is super heated from magma)
        - Reasons: movement of molten rock is giving rise to volcanoes (friction of movement causes earthquakes… same as hawaii)
    - New Madrid (faults)
        - 2000 birds fell from sky
        - 80k-100k freshwater fish wash up onshore
        - Behavioural changes during natural disaster
            - (Animal correlation but not death just behavioural changes)
            - Toads left days before earthquake

The science of the solid earth

- Geology is the science that pursues an understanding of planet earth
- Modern approach is to examine earth as a form of systems:
    - Atmosphere
    - Hydrosphere
    - Biosphere
    - Cryosphere
    - Lithosphere

- Modern approach is to examine earth as system: the intellect and practical activity encompassing the systematic study of the structure and behaviour of the physical and natural world through observation and experiment

The nature of scientific inquiry

- Science assumes the natural world is consistent and predictable
- Geology differs from other sciences:
    - 1. Deals with large spatial-scales and complex systems:
        - Controlled experiments are difficult/impossible
        - Observation & description acquire proportionately more importance
        - Ex: minerals to mountain belts, correlation
- Science assumes the natural world is consistent and predictable
    - 2. Deals with time scales that are immense compared to human lives
        - Impossible to observe entire process directly (Only able to view snapshots)
        - Spatial variation can be interpreted as temporal evolution
        - (Principle of Uniformitarianism: Geological processes & natural laws that operate today have acted throughout geologic time)- the rate things occur now are the same as the past… what happens today happened 3.8 billion years ago happened today
            - Oldest continental rock: 4.6 billion years old
            - Extinction of dinos: 65 Ma
            - Evolution of homo sapiens: 500,000 years ago
            - Last glacial maximum 15,000 years ago
            - Average earthquake is less than 10 seconds
        - Therefore… Earth is 4.6 Ga
            - If we were to look at it in terms of 1 year…
                - Jan 1: Formation of Earth
                - Feb 21: Life formed
                - Oct 25: Complex organisms
                - Dec 7: Reptiles evolved
                - Dec 25 Dinosaurs went extinct
                - Dec 31 11:00 pm: Homo sapiens appear
                - Dec 31 11:59:59.97: Columbus discovered Americas
- Science assumes the natural world is consistent and predictable
    - 3. Geologic evidence is fragmented/incomplete
        - Conclusions and models may be non-unique and dependent on intuition and experience
        - Pattern recognition
        - Knowledge+experience = wisdom
        - Emphasis on the collection and interpretation of field data (Discern signal-noise)
        - Art & science of geologizinfg- geocognition
            - Organise % resolve disparate data sources

        - Chemistry
        - Physics
        - Biology
        - Geography
    - Scientists collect “facts” through observation & measurements, but facts are secondary to understanding
    - Goal of science is to discover patterns in nature & use the knowledge to make predictions
    - It’s not what you know, but how you know it
- The nature of scientific inquiry
    - How and why things happen are explained using...
    - Similar to forensic science
        - Inductive (Baconian) method:
            - Early stages recon: collection of data without regard to theory, expect explanation will become apparent from organization and synthesis of large data sets
            - Collecting data without reason… come to conclusion or explanation after data was collected
            - Good for early stages of research
            - Model of evolution came this way from Darwin looking at beaks
        - Deductive (Darwinian) method:
            - Later stages focused: iterative, devised model(s) accounts for set of observations, and used to make predictions about nature
            - Idea, test, not correct, modify idea and try again
        - Hypothesis (model)- a tentative (or untested) explanation--- model: testable, powerful, parsimonious
        - Theory- a well tested & widely accepted view that the scientific community agrees best explains certain observable facts
        - Law- statement based on repeated experimental observations that describes some phenomenon of nature with high degree of confidence (does not always explain why it happens)
    - Deductive scientific method:
        - 1. Collection of scientific facts (data)
        - 2. Development of one or more working hypotheses to explain the facts
        - 3. Development of observations & experiments to test the hypotheses
        - 4. Acceptance, modification, or rejection
        - Ex: Dinosaurs… Cosmic impact, volcano, something biological
            - 250 million years ago 60% extinct. Not just one mass extinction, there is several mass extinctions
- A scientific inquiry
    - Step one: data collection or observations
        - Dinosaurs extinct- 65 Ma
        - Many plankton extinct- 65 Ma

        - Many other organisms went extinct- 65 Ma
        - Extinction was fast … geologically instantaneous
        - Corresponds to unique geochemical anomalies (Ir, S, C) in rock record
            - Iridium (platinum group metal) found in- earth's primordial lavas and the core, meteorites, comets, cosmic dust… Amounts spike
            - Sulfur derived from- Bolide impact on evaporite/carbonate terrain (volatilization of gypsum/anhydrite: SO_4^{2-}), Volcanism releases sulfur (reduced gases, SO_2… oxidized to SO_4^{2-})
            - Carbon (terrestrial C)
    - Step 2: Theory development
        - Comet or asteroid impact created the geochemical anomalies (vs. lava eruptions
        - Testable? Side effects?
            - Craters
            - Dust cloud+fireball= Nuclear winter… instant death
            - (Vs. synchronous numerous and thick lava flows)
    - Step 3: Observations & experiments
        - Test/confirm world-wide geochemical anomalies
        - Test/confirm abrupt end to dinosaurs & plankton
        - Identify crater
        - Identify large lava eruptions
- Shatter cones in sudbury point toward middle of impact
- Chicxulub crater: 65 Ma...pointing toward mexico
    - Dinosaur extinction
    - Geological anomalies
        - tekties(glass balls due to high heat)
    - Step four: Accept, modify, reject?
        - Almost abrupt end to terrestrial & marine life
        - Geochemical anomalies are world wide
        - Anomalies associated ust cloud/fireball
        - Crater
        - Some large lava eruptions