

Natural Disasters

Midterm Review

LESSON 1-INTRODUCTION

What is a natural disaster?

- **Natural Disaster:** natural event which large amounts of energy is released in a short time, resulting in a catastrophic impacts on life or environment
 - usually has high casualties, destruction of infrastructure, disruption of society, economic loss, media coverage, gov't involvement
 - big focus on if it disrupts society

Natural Hazards

- **Natural Hazards:** source of potential hazard that exists in the environment that have the potential to cause harm (eg rock slides)



- **Vulnerability:** likelihood that a community will suffer injuries, deaths or property damage from a hazardous event
- **Resilience:** reduction in likelihood for community suffering by taking various steps (eg burying power lines)

Metrics

- **Frequency:** number of occurrences of similar events per unit of time (eg Caribbean storms affect Atlantic Canada 4x per year)
- **Return Period:** length of time between similar events (eg severe hurricanes occur in the US about every 6 years.)
- **Magnitude:** amount of energy fuelling a natural disaster event (eg force of hurricane winds, or of an earthquake.)

Origin of the Solar System

1. Formation of Solar Nebulla

- **gravity:** force of attraction between masses m & m_2 separated by a distance of r
- turbulent cloud filled with dust particles that attract each other and eventually becomes a disk by moving in the same direction (gravity flattens it)

2. Planetary Accretion

- accretion into planetestimals
- planets
 - collisions between a small number of large bodies in final stage—>impact body
 - controlling T° as you move from the sun
 - closer: merc, venus, mars, earth—>rocky
 - further giants: jup, saturn, uranus, nep—>icy

- other very far: comets, stable, water/ice
- 3. Differentiation of Earth
 - caused by gravity causing denser materials to gradually migrate to the centre of the planet
 - centre is hot because of radioactive decay

Global Trends

1. Man-made disasters decreasing in recent years
 - emerging health and safety, economics
2. # of great natural disasters increasing with time
 - geological disasters staying constant (earthquakes, tsunami)
 - weather related going up (drought, flood etc)
 - result of climate change??
3. # of natural disaster fatalities increasing with time
 - communities are more vulnerable (higher populations, degradation of ecosystems, over reliance on technology)
4. Economic losses rising

Canadian Trends

1. natural disaster #s increasing overtime
 - is climate increase responsible?
2. # of fatalities decreasing
 - improved engineering
3. economic loss most due to weather

Risk and Mitigation

Risk: product of **hazard x vulnerability**

Response: immediate actions taken after a disaster has occurred to put event under control

Recovery: middle-term activities to put situation back to normal (not always possible/desireable to return exactly as it was before)

Mitigation: long term actions to reduce risk

- structural: building retrofitting, etc
- non-structural: land use policies, severe weather warnings

Preparedness: planning for disasters by putting in place resources to cope with them when they occur

LESSON 2: GUEST SPEAKER MATTHEW GODSOE

What makes a disaster?

- **disasters:** a social phenomenon that results when a hazard intersects with a vulnerable community in a way that overwhelms that community's ability to cope
- Vulnerabilities
 - Structural
 - old buildings
 - critical infrastructure (oil, gas)
 - urbanization
 - unsustainable land use planning

- Social
 - health, age and gender of population
 - language
 - aboriginal community considerations

Emergency Management

- focus on managing emergencies and deciding whether it is a disaster later
 - 4 pillars
 - Prevention/Mitigation
 - Preparedness
 - Response
 - Recovery
 - all hazards emergency management
 - common response to multiple disasters

LESSON THREE: IMPACTS WITH SPACE OBJECTS

Extraterrestrial Debris

Meteoroids: extraterrestrial debris orbiting the sun (potential impactor)

Asteroids: small rocky body orbiting the Sun (primary source)

- most frequently hit earth
- impactor larger than 100m
- Main Asteroid Belt
 - most asteroids are in the belt
 - range from tiny pebble to massive (more than 900km)

Near Earth Asteroids: asteroids crossing the orbits of earth or mars (only 1/1000 the number as the belt)

- Apollo and Atens asteroids cross Earth's orbit (2 contact points each)

Comet: small object composed of ice and rock debris moving through outer space (secondary source)

- very far from the Sun, Mostly past Neptune
- "dirty snowballs", famous for having a beautiful tail with passing near the sun
- Halley's comet: 76 year orbit. Fringe of Solar System to right near the sun

Impact Scenarios

- Meteoroids are classified according to size
 1. Cosmic Dust (0.001-1mm)
 - pass through atmosphere unchanged
 - settles on Earth's surface
 - mass gains 10^5 - 10^6
 2. Shooting Stars (~1mm)
 - melt when entering atmosphere because of friction
 - blaze=1s, 100km above ground
 - tiny glass spheres fall on the Earth's surface
 3. Meteorites (1mm-100m)
 - pass through atmosphere and fall to earth's surface

- can split into fragments mid air
- 2 definitions
 - impactor 1mm-100m
 - impactor that hits the ground
- upon entry, exterior melts and is stripped away
- Classification:
 - Stony Meteorites (primitive) [95%]
 - composition similar to Earth's mantle
 - Chondrules are solidified droplets of matter from the solar nebulla
 - Iron & Stony-Iron [2-3%]
 - composition similar to Earth's core
 - stony more rare as they are harder to find
- Measuring Density
 - density provides clues about source body
 - 3D laser imaging to determine volume
- 4. Asteroids (<100m)
 - not slowed by atmosphere
 - explode on contact with surface
 - 160 craters on earth (low number due to rain erosion)

Mid-Air Explosions

- Tunguska, Siberia 1908
 - massive fireball in the sky, blast heard 1000km away
 - barometric anomalies recorded worldwide
 - 80 million trees fallen
 - no crater ever found
 - no scientists visited site before 1928
 - 50m diameter, exploded 6km above ground
- K/Pg boundary event (K=Cretaceous, Pg=Paleogene)
 - major extinction, 65% of all species extinct in short time
 - 1980 Alvarez asteroid impact theory
 - discovery of a worldwide iridium rich layer at boundary event
 - rare element on earth, meteorites are rich in iridium
 - usually associated locally at impact sites
 - asteroid of 10km diameter need to generate enough iridium to completely disrupt environment
 - additional stress on life from flood basalts (volcanos in india)
 - likely a combination of impact and volcanos, unable to find site at the right age until Riviera Maya, Mexico. Right by shore. 1/2 on land and 1/2 underwater
 - return period ~100Ma

LESSON FOUR: IMPACT TOURS

Impact Craters

Astrobleme: synonym for impact crater

- Distinctive Features
 - 1 Circular Feature
 - 2 Crater is steep sided and closed
 - 3 Rim rocks tilted away from crater
 - 4 Shattered rocks on crater floor
 - 5 larger angular clasts of rock scattered around
 - 6 presence of meteorite fragments
 - 7 shock minerals
 - 8 **shatter cones:** conical fragments of host rock fractured by shock wave generated in the impact
- Simple Craters: small impacters
 - diameter >5km
 - raised rim, no central uplift
 - concave bottom, would look here for meteorites
- Complex crater
 - <5km
 - collapsed rim
 - central uplift, no meteorites

Canadian Impact Crater Tour

1. Sudbury, ON (1850 +/- 3Ma)
 - largest and oldest
 - heavily deformed by regional movements along faults (was originally a complex circular crater, not an elliptical structure)
 - nickel already present in area, and heat helped to concentrate metals
 - DF: circular, shatter cones
2. Wanipetoi, ON (37 +/- 2Ma)
 - lies within limits of sudbury crater but is much younger
 - located under Lake Wanapetoi (revealed by gravity survey)
 - measuring gravity done a gravimeter, requires very precise field measurements, very expensive
 - interpreting gravity data processed to map heterogeneities
 - low gravity values=cavity
 - high gravity values=high rock concentration
 - DF: circular
3. Brent, ON (396 +/- 20Ma)
 - stony meteorite 150km in diameter, velocity=20km/s
 - crater now=simple 3km crater, 2 kidney shaped lakes
 - 12 boreholes drilled in crater in 1950-60s
 - DF: semi-circular, crater is steep-sided, shattered rocks on floor, large angular blocks of rock scatter around crater
4. Charlevoix, BC (357 +/- 15Ma)
 - north shore of St Lawrence river

- heavily eroded
 - differs from regional topography
 - associated with earthquake activity (impact scars act as zones of weakness in earths crust
 - DF: semi-circular, shatter cones
5. Eau claire, QC (290 +/-20Ma)
 - double impact site
 - binary pair (2 bodies closely bound by gravity→asteroid + little moon bound by gravity)
 - 32 km and 22 km
 - DF: circular
 6. Manicouagan, QC (214 +/- 1Ma)
 - originally 100km, now 75 km)
 - hydroelectric reservoir since 1960s, flooding revealed crater structure, complex crater
 - DF: shock minerals, circular.
 7. Haughton, NU (23.4 +/-1Ma)
 - shatter cones found 1974
 - mars analog (place on earth that looks and feels like mars)
 - DF: semi-circular, shatter cones
 8. Pingualuit, QC (1.4 +/- 0.1 Ma)
 - aerially found in 1943
 - simple crater, 3km, rim ~160 above water, 250m deep
 - *impacticide*: glassy material produced by partial fusion of host rocks by the heat generated from impact, rich in iridium, terrestrial rocks.
 - one of the deepest freshwater lakes in World, water pure and transparent, water stays ~330years.
 - QC Provincial park,
 - DF: circular, crater is steep sided, shock minerals
 9. Whitecourt, AB (0.036 +/- 0.001Ma)
 - youngest in Canada
 - discovered 2007, with iron meteorites (only one in canada)
 - almost perfect bowl shape, only 36m D, 6m deep
 - DF: circular, steep-sided, presence of meteorite fragments

Crater Counting

- Absence of radiometric data, surface dated using 'crater counting' (older surface=more craters)
- method has been calibrated with lunar data from which radiometric data is available
- knowing crater rate, age can be estimated
- assumptions
 - geological record has been preserved
 - N/A to Earth cause of plate tectonics, N/A to Venus due to complete resurfacing effect
 - little of no erosion

LESSON FIVE: PLATE TECTONICS

Layered Earth

Differentiation of Earth; gravity causes denser material to migrate to centre

Layers based on 1. Density of 2. Physical Properties

1. Density Layers

- inner core: solid iron
- outer core: liquid iron
- Mantle: Iron and Magnesium
- Crust: silicone and oxygen
- less dense material 'floats' on top of denser material
 - continental crust has lower density than oceanic crust
 - mantle is supported by the very dense core

2. Strength Layers

- gaseous atmosphere
- liquid hydrosphere (mostly ocean)
- rigid *lithosphere*: thicker than crust, ~ first 100km thick, rigid solid that when put under pressure will crack
- plastic *asthenosphere*: solid but more like toothpaste, from 100-350km, slippery and moves a bit
- Plastic *mesosphere*: more viscous than asthenosphere

Before "Plate Tectonics"

Early Hypotheses

- Aristotle (384-322BC)
 - earthquakes caused by underground air escaping explosively after being heated by central fire
- Kircher, Athanasius (1602-1680)
 - witnessed active volcanos in Italy
 - Drew early cross-sections of earth
 - fire in core inflame subsurface reservoirs feeding volcanos
- Catastrophism (17-18C)
 - earth's landscape shaped by great catastrophes (based on Christian thinking at the time)
- James Hutton (1726-1797)—Uniformitarian's
 - natural processes operate with the same intensity and under same set of physical constraints with now as geological past
 - based on erosion rate, concluded Earth was much older
 - "Present is key to the past"
- End of 19C
 - earth's internal structure understood
 - radiates heat
 - basic geology of continents known
 - recycling earth material through Rock Cycle
- Rock Cycle
 - describes process by which older rocks are made into new rocks

- **Igneous Rocks:** form by cooling from molten liquid called magma
- **Sedimentary Rocks:** by erosion and compaction of rock fragments or by precipitation
- **Metamorphic Rocks:** form by alteration of existing rocks by heat and/or pressure
- theory fails to describe distribution of rock types and processes on Earth's surface
- Alfred Wegener & Continental Drift Theory
 - hypothesis largely correct but with incorrect details
 - continents are in motion, not fixed
 - supercontinent Pangea broke apart starting 200Ma ago
 - estimated drift rates of 3-10m/year (real=2-10cm/year)
 - matched rock types, mountain ranges and fossils across Atlantic
 - Paleoclimatic evidence
 - fossils of tropical plants found in arctic zones
 - BUT was unable to provide an explanation for HOW
 - suggested low density continents has moved laterally through denser mantle (impossible!)

Tectonic Cycle

Tectonic: related to deformation forces acting on Earth's lithosphere and responsible for creation of mountain ranges and faults

Tectonic Cycle: episode of large scale deformation of Earth's cycle, one cycle= \sim 250ma)

Plate Tectonics

- continents move laterally, as part of rigid lithosphere plates that slide over plastic asthenosphere
 - lithosphere: continental and oceanic crust and rigid upper mantle
 - asthenosphere: convecting upper mantle (convection in asthenosphere is the driving force)
 - **subduction:** process which a lithosphere plate descends beneath another, pulled down by gravity
 - less dense plate=overriding plate
 - denser plate=subducting plate
 - avg plate descends at $\sim 45^\circ$
 - subducting plate gradually melts into asthenosphere

Magnetization Patterns on Seafloor

Internal Geomagnetic Field

- liquid iron outer core creates field
- Earth's rotation, heat transfer by convection at outer-inner core boundary
- **Magnetic Lines of Force:** theoretical representation of the force acting on a small magnet
 - resembles bar magnet
 - equator: horizontal lines of force, parallel to earth surfact
 - magnetic poles: vertical
 - not constant over time
 - polarity reversal every 0.1 Ma, poles wander every few years

Paleomagnetism

- as lava cools, magnetic minerals align in direction of Earth's magnetic field

Seafloor Spreading

- underwater surveys (50-60s) revealed patterns of normal and reversal magnetized seafloor

Age of Ocean Basins

- 200 Ma
- oceanic crust constantly being recycled
- no crust older than ~200Ma
- travels, dragged by the loop and dives
- close to spreading center are new, get older as you move away

Bathymetry

Bathymetry: depth measurements at various places in a body of water

- **Mid-Oceanic ridges:** shallow water above ridges
- water is gradually deeper away from ridges (rocks increase in density as they cool and sink)
- **Deep Trenches:** subduction zones

Earthquake Hypocentres and Epicentres

Hypocenter: point of origin of an earthquake in the subsurface

- distribution
 - relation between hypocentre and subduction process
 - shallow earthquakes in overriding and subducting plates
 - intermediate & deep quakes in subducting only
 - no earthquakes below ~600km

Epicenter: point on earth's surface directly above hypocentre

- locations outline plate boundaries

Our Tectonic World

- Active on earth ~2Ga
 - before 2Ga there was a higher internal T◦
 - smaller plates, shorter the cycle
- unique to earth
 - mars=1 plate planet, Venus resurfaces ~500Ma
- Circum-Pacific PLate
 - largest
 - 80% earthquakes
 - 75% active and dormant Vol
- Mediterrean and trans-Atlantic belt
 - 15% of quakes
- largest continent-continent collision: Himalayas
- North American Plate
 - Eastern Boundary: along mid Atlantic ridge
 - Western boundary:
 - north: subduction of the Juan de Fuca plate under NA plate
 - South: Na plate and Pacific plate moving alongside each other

LESSON TEN: PEOPLE AND INFRASTRUCTUREWhat do people feel during an earthquake?

Intensity: measure of the effects on an earthquake on people and infrastructure

- Mercalli intensity scale (Mercalli 1902, modified by Richter 1956)
 - Descriptive and subjective scheme based on:
 - Eyewitness accounts and damage to infrastructure

Magnitude: total amount of energy released during fault rupture

- There can be only ONE magnitude versus several intensity measurements per earthquake
- Results summarized in intensity reports and isoseismal maps which are contour maps of Mercalli intensity

Shakemaps: map of modified Mercalli intensity generated automatically using data from networks of seismograph stations

- Inputs ground motion data, knowledge of regional geology
- Outputs computed intensity
 - Can be completed minutes after quake
 - Helpful for first responders

Earthquake Damage

Controlling Factors on damage

1. Magnitude
 - Higher mag, higher intensity
 - More energy released during quake, higher potential for damage
2. Epicenter location
 - Greater damage in densely populated areas
3. Distance from epicenter
 - General rule; closer to the epicenter, higher the intensity (but local geology also plays a role in propagation of seismic waves)
 - Area of felt area is not a good indicator of magnitude
4. Hypocenter Depth
 - Shallow quakes are particularly dangerous
 - Seismic waves propagate for a short distance are less attenuated, causing greater ground motions
 - Hypocenters of megathrust earthquakes are relatively shallow
5. Duration of Shaking
 - Longer shaking, higher destruction potential
 - **Aftershocks:** main earthquakes that follow the largest shock in an earthquake sequence
 - **Mainshock:** largest shock
 - **Foreshocks:** small, precursor quakes before mainshock
 - longer the mainshock, larger and more number of aftershocks and will continue for longer periods of time
 - aftershocks can damage already weakened buildings
6. Foundation Materials

- **Soil:** top layer of earth's surface, consisting of rock and material particles mixed with organic material
 - *Top 0-30m* have major impact on ground motion
 - **Natural Frequency:** mechanical system (eg. Guitar string, building) is characterized by a particular natural frequency (frequency at which system oscillates when disturbed)
 - Soft sediments <1Hz
 - Hard rock >1Hz
 - **Resonance:** phenomenon by which a system experiences very large oscillations when it is disturbed by a forcing function of frequency equal to its natural frequency. The energy of the forcing function is added to the system so that the oscillations are reinforced (oscillations grow larger and larger until object breaks)
 - **Local Site Amplification:** seismic waves act as forcing functions of foundational materials
 - hard rock are amplified by body waves
 - soil amplified by surface waves –more dangerous
 - **Liquefaction:** phenomenon in which the strength of soil is reduced by rapid and violent shaking or loading
 - Occurs in saturated soils in which the space between the particles are filled with water
 - Liquidified soil behaves like a liquid and does not have the strength to support a load

7. Building Style

- Different materials behave differently when subjected to external deformation forces as well as the type of external force (tension, compression, shear)
 - All materials have an elastic limit; When an object passes the limit
 - Some materials fail abruptly
 - a. Higher hazard: total collapse (eg.. brick and stones)
 - Some materials undergo plastic deformation before failing
 - b. Less hazard: potential partial collapse (eg wood and steel)
- Resonance: seismic waves act as forcing functions on foundation materials and building
 - Soil and building frequency affect damage

LESSON ELEVEN: MASS MOVEMENTS I

Slope Intensity

Mass Movement: collective name for a variety of processes for the downslope movement of earth's materials under direct influence of gravity

- The driving force is the component of gravity parallel to the slope
- The resisting force is proportional in inertia and friction and counter acts the driving force

External Conditions on Slope Intensity

Conditions decreasing stability

1. Adding mass high on slope
2. Steepening on slope
3. Removing support at base of slope
 - a. Eg wave erosion

Internal Conditions on Slope Intensity

Conditions decreasing stability

1. Presence of weak material
 - Material that deforms plastically under stress
 - Crumbly=poor consolidated material
 - Lubricants eg clay
 - *Friction*: force that restricts motion between 2 surfaces in contact
2. Fractures in Rock
 - Fractures oriented in slope direction are particularly stable
 - Fractures exist at different scales
 - Regional, local, hand sample and microscopic
3. Internal roles of water
 - Adding weight to porous Earth materials
 - Dissolving cement binding materials
 - Erosion in subsurface (creates network of caves)
 - High pore pressure
 - *Congelifaction*: disintegration of rock due to several cycles of freezing and melting

Role of Clay

Composition of Earth's Crust

- Silicone and oxygen account for ~75%
- 8 elements form 98%
 - Elements combine to form minerals (400 known, 25 common)
 - Minerals=building blocks of rocks

Geochemistry

- Studies structures of silicone and oxygen
 - Basic building block is the silicone-oxygen tetrahedron molecule
 - Tetrahedron combines to form rings, chains, sheets
 - *Silicates*: group of minerals containing Si and O combined with one or more other elements
 - *Clay*: general term used to describe a variety of complex sheet silicates
 - Sheet surface=neg. charged
 - Attracts water molecules and positively charged ions
 - Swelling clays
 - Clays that tend to swell when exposed to water

- Accompanied by loss of strength..becomes a lubricant
- Sensitive Clay
 - Clays that can change internal structure almost instantaneously
 - (a) Presense of salt is key
 - (b) Clay closes strength when they change from flocculated to dispersed structure
 - *Flucculated Structure*: strong and stiff, salt binds that sheets and salt together

What Triggers Mass Movement?

Rock Cycle: process by which old rocks become new rocks

- Mass movements occur in all rock forms (igneous, sedimentary and metamorphic) but most often in sed.
- Triggers
 - Quakes, volcanic activity and erosion
 - Water
 - Construction work, tunnelling

Classification of Mass Movements

Classified according to 3 categories:

1. Types

- Falls
 - Rapid free fall mass movement
 - Bouncing, rolling, end over end motion
 - Fragments ranging in size from small grains to large blocks
 - Develops in material weakened by fractures
- Slides
 - Mass movement involving motion along a failure surface
 - Material remains a block
 - Classified according to the nature of the failure surface
 - Planer surface—transitional slide
 - Carved surface—rotational surface
 - *Transitional Slide*: slide which earth material moves parallel to planer failure surface
 - Material unconsolidated? Debris or earth slide
 - Bedrock? Rock slide
 - *Lateral Spreads*: special trans. Slide in which movement of Earth material results from liquefaction of subjacent material. Related to distinct geological conditions

Steps in Lateral Spreads

1. Marine clay deposited in glacial regions (flocculated by salt in sea)
 2. Glacials melt. Uplift of earth's surface(now clay=above water level)
 3. Clays are leached by fresh water from rain and snow melt
 4. Clay instantly changed to dispersed structure
- Movement occurs without warning and failure is progressive

- Material flows rapidly even on very gentle slopes

1971 St. Jean Vianny lateral spread

- Retrogressive spread in sensitive clays
- 7.6 million cubic m displaced
- Created a crater

LESSON TWELVE: Mass Movements II

- *Rotational Slides*: slide which failure occurs on an over steepened slope, along a concave rupture surface
 - Multiple blocks often fail due to natural or human factors
- Flows: Mass movement that involves continuous internal deformation of the moving material (Main differences between flows and slides= slides have little deformation of moving material)
 - 2 Types depending on velocity
 - Slow-Creep
 - Fast-Rock, debris or earth flow
 - *Creep*: gradual, slow moving, earth or debris downfall
 - *Rock, debris or earth flow*: mixture of rock fragments, soil and water flowing downslope as a viscous fluid
 - *Gelification*: type of flow in Northern regions, linked to the melting of the top layer of permafrost. Soil always frozen but in summer top layers melt and creates flows down gentle slopes

Subsidence

Subsidence: sinking of land surface

- Causes:
 - Rapid subsidence: surface collapse of underground cavities
 - Man-made: abandoned excavated cavities
 - Natural: sinkholes
 - Slow subsidence: removal of subsurface fluids (water, oil, natural gas), decomposition of organic soils
 - *Sinkholes*: circular area of subsidence caused by collapse into subterranean void
 - Typically occur in soluble sedimentary eg limestone
 - ~10m diameter
 - Cover subsidence

v

cover collapse sink holes

LESSON THIRTEEN: Snow Avalanches

Cohesion: property of particles of a material to stick together

- *Low Cohesion Snow*: fresh "powder" snow, 95% void space

- *Cohesive Snow*: wet snow; liquid water particles between ice particles. Compacted snow; snow particles densely packed and tightly bound

Weak Layers, formed in 3 ways

1. When wind is increasing during a storm
2. Depth Hoar
 - *Hoar*: relatively large crystals formed by deposition of water vapour into ice (often grow on existing crystals, some are feather-shaped)
 - when hoar crystals grow, the density of the snowpack decreases
 - hoar crystals tend to not gain strength as they are compacted within the snowpack (hoar remains relatively weak layers)
 - *Depth Hoar*: commonly found at base of shallow snowpacks following periods of cold weather
 - Formation
 - (a) Vapour from underlying soil deposits
 - (b) Hoar crystals grow
 - (c) Density of the lower level of snowpack decreases
3. Surface hoar
 - *Surface Hoar*: form on cold, clear nights
 - Vapour from the atmosphere deposits on the surface of the snowpack

Mechanics of Snow Avalanches

Main Parts

1. Start Zone: most volatile part of slope where unstable snow begins to slide
2. Track: path followed by avalanche moving downhill
3. Run out zone: where snow and debris stop and are deposited (most likely spot for victim to be buried); snow can be hard as cement

Size Characteristics

1. Relatively harmless
2. Could bury a person
3. Bury/destroy a car
4. Railway
5. Destroy village/forest

Point Release and Slab Avalanches

Point Release Avalanches

- Often develop in low-cohesion snow
- Inverted V shape
 - Develop from single point
 - Trigger additional snow during downslope movement
- Many similarities with *FLOWS*

Slab Avalanches

- Involve several layers of cohesive snow

- Fracture first develops on the perimeter of the slab
- Avalanche starts when fracture spreads to a weak layer at the base
- Usually larger and more dangerous (greater force of impact)
- Similarities with *SLIDES*

Conditions Decreasing Density

1. Low Friction
 - Several potential failure surfaces
 - Melt-freeze crust: might develop between snowfalls
2. Presence of weak materials
 - Weak layers (cannot support weight)
3. Slope angle of start zone
 - >50-frequent point release and sluff
 - 25-50-infrequent large dry slab avalanches → rec use
 - <25-slab avalanches
4. Uploading of slope
 - Wind shifts snow to certain areas
 - *Cornices*: snow structure formed by wind drifting snow on the downwind side of an obstacle, often a mountain ridge line
5. Fractures
 - Gravity causes snowpack to creep downslope
 - Top of snowpack moves faster than bottom
 - Shear stress induces fracture