**Physical Geology Exam 4 Study Guide**

**Inclusion** is a fragment of one rock type enclosed within another rock type. Relative dating: The included rock must be older than the surrounding rock.

**Group** – A lithostratigraphic unit containing two or more Formations.

**Formation** – A body of rock strata that consists dominantly of a certain lithologic type, or combination of types. It is the fundamental lithostratigraphic unit.

**Member** – A unit consisting of a specially developed part of a Formation.

**Unconformities** - Layers of rock deposited sequentially without interruption are **conformable**. A break or gap in the geologic record, such as an interruption in the normal sequence of deposition of sedimentary rocks. During this period, erosion removes some of the rock record. 

3 **TYPES:**  
**Angular Unconformity** - An unconformity in which younger sediments rest upon the eroded surface of tilted or folded older rocks.

**Disconformity** - An unconformity between beds that are parallel. This term is usually applied to erosional breaks that are represented elsewhere by rock units of at least one Formational rank.

**Nonconformity** - An unconformity between stratified rocks above and unstratified igneous or metamorphic rocks below.
**Correlation** - demonstration of the equivalence of two or more geologic phenomena in different areas (it may be lithologic or chronologic).
Correlation over short distances – locate the unit of interest in relation to other units above and below; identify characteristic features.
Correlation over long distances is usually accomplished by using **fossils**.

**FOSSIL DEFINITIONS**

**Petrification** – organic matter is converted to rock by the infiltration of water containing dissolved inorganic matter ($\text{CaCO}_3$, $\text{SiO}_2$) which replaces the original organic material, sometimes retaining the original structure.

**Permineralization** – the original hard parts of an animal have additional mineral material deposited in their pore spaces.

**Replacement** – the substitution of inorganic material for the original organic components of a plant or animal.

**Mold** – an impression made in the surrounding earth or rock by the exterior or interior of a fossil shell or other organic structure.

**Cast** – Secondary rock or mineral matter that fills a natural mold, thus producing a replica of a fossil shell or skeleton.

**Carbonization** – The slow decay under water of organic material, resulting in a concentration of carbon as a film showing the form and structure of the original tissue.

**Impression** – If the film of carbon is lost from a fossil preserved in fine-grained sediment, an impression (replica of the surface) may be evident.

**Trace Fossils** - A sedimentary structure consisting of a fossilized track, trail, burrow, or tube resulting from the life activities of an animal.

(These are dinosaur footprints from Late Triassic – Early Jurassic redbeds in Connecticut).

**Burrows** – tubes in sediment or rock left behind by a burrowing animal.

**Gastroliths** – polished “stomach stones” from extinct reptiles.

**Coprolite** – fossilized animal feces.
FOSSIL PRESERVATION
Certain environmental conditions favor fossil preservation.
1. **Rapid burial** – prevents organism from being either eaten by scavengers or decomposed by bacteria.
2. **Hard parts** – hard parts of an organism (shells, bones, teeth) are more likely to become fossilized.

In the late 1700’s and early 1800’s English engineer **William Smith** (1769-1839) observed that different layers of rock contained different fossils. He first worked at Mearn’s Pit (coal), then worked as a surveyor for a canal company. His travels and interests led to him develop a large fossil collection, and the nickname “**Strata Smith**”.

Principle of Fossil Succession: Fossil organisms succeed one another in a definite and determinable order. Any time period can be recognized by its fossil content.

**Index Fossil**: A fossil taxon (usually a Genus, rarely a Species) that identifies and dates the strata in which it is found. Typically, an index fossil is limited to a short span of geologic time.

**Radiometric dating** – Calculating the age in years for geologic materials by measuring:
- the presence of a short-life radioactive element such as carbon-14;
- a long-life radioactive element plus its decay product, such as potassium-40/argon-40.
Radiometric dating allows geologists to evaluate the dates of formation of very old materials.

**Radioactivity** -The emission of energetic particles and/or radiation during radioactivity.

**Radioactive decay** – The spontaneous disintegration of the atoms of certain nuclides into new nuclides, which may be stable or undergo further decay until a stable nuclide is finally created.

**Nuclide** – A species of atom characterized by the number of neutrons and protons in its nucleus.
The initial isotope, prior to radioactive decay, is called the **parent element**. The isotope that forms following radioactive decay is called the **daughter element**.

**Examples:**
- Parent – Uranium 238 is the parent element of lead 206
- Daughter – radon is the daughter element of radium

**Alpha Emission** – alpha particles (2 protons, 2 neutrons) are emitted from the nucleus.

**Beta Emission** – A beta particle is an electron. Therefore, emission of a beta particle results in no mass change, but the atomic number increases by one (the electron comes from a neutron, thus changing one neutron to a proton).

**Electron capture** – If an electron is captured by a nucleus it will combine with a proton to form a neutron, resulting in no mass change, but the atomic number decreases by one as one proton is converted to a neutron.

**Half Life**

The time required for half of the nuclei in a sample to decay. When parent-to-daughter is 1:1, then one half-life has passed. When parent-to-daughter is 1:3, then two half-lives have passed. When parent-to-daughter is 1:7, then three half-lives have passed.
**Rb-Sr Dating**
Rubidium has 32 isotopes (naturally occurring Rb$^{85}$ (72.2%) and radioactive Rb$^{87}$ (27.8%). Different minerals in a given geologic setting can have a distinctly different ratio of strontium-87 to strontium-86 ($^{87}$Sr/$^{86}$Sr) as a consequence of different ages, original Rb/Sr values and the initial $^{87}$Sr/$^{86}$Sr.

If the initial amount of Sr is known or can be extrapolated, the age can be determined by measurement of the Rb and Sr concentrations and the Sr$^{87}$/Sr$^{86}$ ratio. The dates indicate the true age of the minerals only if the rocks have not been subsequently altered.

**Carbon 14 Dating**
Stable isotopes: C12, C13
Unstable C14 is produced in the upper atmosphere by cosmic ray fluxes. Cosmic rays bombard gas atoms, releasing neutrons which are absorbed by nitrogen atoms (N=7, mass = 14), causing each nucleus to emit a proton (N=6, mass = 14) and create C14. The C14 circulates and is incorporated into living matter. While alive, organisms maintain constant C14 to C12 proportions. Upon death, C14 decreases by decay to N14 (beta emission). Comparison of C14 to C12 allows estimation of age. C14 dating is good for wood, charcoal, bones, flesh, cotton fabrics.

**MASS WASTING**
Gros Ventre Landslide (Kelly, Wyoming)
On June 23, 1925, one of the largest fast-moving landslides in generations occurred near the village of Kelly, Wyoming. In just three minutes, huge amounts of rock and debris cascaded down the north slope of Sheep Mountain, changing the area forever. Hurling down the slope at 50 m.p.h., the mile-wide slide carried 50,000,000 cubic yards of debris. The mass rode 300 feet up the opposite slope, blocked the Gros Ventre River, and formed a five-mile long body of water known today as Lower Slide Lake. The piles of debris seen today contain large chunks of Tensleep Sandstone, along with remnants of the original forest.

**CAUSES**:
- Heavy rains and rapidly melting snow saturated the Tensleep Sandstone, causing the Amsden Shale rock layer on Sheep Mountain to become exceptionally slippery;
- The river, cutting through the sandstone, produced a “free side” with no extra support holding it in course;
- Swampy pools with no outlets, on top of the mountain, indicating water-saturated soil.
- Earthquake tremors (which were occurring) added to these already unstable factors and could have precipitated a landslide.

Mass Wasting - The downslope movement of soil, regolith, and rock material under the influence of gravity. The most spectacular examples of mass wasting occur in newly formed, rugged mountains. These regions are rapidly eroded by rivers and glaciers into regions of steep and unstable slopes.

**Factors**:
Gravity, Saturation of soil or rock materials, Slope oversteepening, Removal of vegetation, Ground vibrations (earth quakes)
**Saturation** – The degree to which the pores in a rock contain oil, gas, or water, generally expressed in percent of total pore space.

**Angle of repose** – The maximum slope or angle at which loose, cohesionless material remains stable (typically between 33 and 37 degrees). Larger, more angular fragments maintain the steepest slopes.

*Activities leading to oversteepened slopes:*
- a stream undercutting a valley wall
- wave action on a cliff face
- manmade slopes (retaining walls, etc.)

**Effects of Vegetation**
- Raindrops hitting the soil surface can seal the soil particles and make a crust that prevents infiltration and creates runoff.
- Trees and shrubs intercept precipitation before it hits the soil surface.
- Most of the intercepted precipitation evaporates back into the atmosphere, and the moisture that drips off the plants causes little soil damage because it has less force.
- Roots physically reinforce soils, resist erosion, and increase infiltration of water into the soil.
- Roots form physical pathways that help water infiltrate the soil.
- Vegetation actively decompacts soil through the expansion of the root systems and the addition of organic matter to the site. Water absorbs more readily into uncompacted soil.
**Earthquakes**
An earthquake and subsequent aftershocks may often serve as a trigger for a mass wasting event.

**Soil liquefaction** is a phenomenon whereby a saturated soil substantially loses strength and stiffness in response to an applied stress, and behaves like a liquid. Earthquake shaking or other sudden changes in stress conditions cause soil liquefaction.

**Landslides**
Landslides may occur without obvious trigger events.

The long-term effects of weathering, moisture retention and other physical processes reduce slope stability to the point where failure occurs in an apparently random fashion.

**Old Man of the Mountain, New Hampshire**
For decades, the Old Man was the official symbol of the state of New Hampshire. After thousands of years in the making, the rock formation was "discovered" by white settlers at the beginning of the 19th century. The profile was formed by several ledges of granite, and in a cubist manner the representation is striking. The face was only about 40 feet high. It was set on a cliff 1,000 feet above the valley floor.

Freezing and thawing opened fissures in the Old Man's forehead. By the 1920s, the crack was wide enough to be mended with chains, and in 1957 the state legislature passed a $25,000 appropriation for a more elaborate weatherproofing, using 20 tons of fast-drying cement, plastic covering, and steel rods and turnbuckles, plus a concrete gutter to divert runoff from above. A team from the state highway and park divisions kept the patchwork up to date each summer. Nevertheless, the formation collapsed between midnight and 2 a.m., May 3, 2003. The Old Man of the Mountain is no more.

**Mass Wasting Processes**
Types of mass wasting are classified based on the material involved, and the kind and velocity of movement.

**Material** – soil, regolith, rock

**Motion** – fall [talus slopes], slump/slide [rotational and translational], flow [lobes or tongues of material]

**Rate** – fast [avalanche], slow [creep]

**Slump**
Movement of a mass of material along a curved, concave rupture surface. Slump is considered a rotational slide. Causes:
- oversteepened slopes.
- overloaded slopes (weaker clays beneath sandstone for example).
Rock/Debris Slide
Rock and debris slides are *translational slides*. A moving mass of rock fragments, soil, and mud, with more than half of the particles being larger than sand size.
Speed: slow [1 m/year] fast [160 km/hr = 100 mph]

Debris flows tend to occur frequently in semiarid mountainous regions.

Lahar (fast) A mudflow of pyroclastic material on the flank of a volcano.

Creep (slow) The gradual downhill movement of soil and regolith.

Solifluction (very slow) The slow (0.5 to 5.0 cm/yr) downslope movement of waterlogged soil. Solifluction is common in areas where water cannot infiltrate soils, and in areas of *permafrost*.

Permafrost permanently frozen soil or subsoil. Permafrost underlies about 1/5 of the Earth’s land area!
Red River flooding, MN/ND
During the spring of 2001, major flooding occurred for the second time in four years on the Red River of the North and its many tributaries in eastern North Dakota and western Minnesota.
Unlike the 1997 floods, which were the result of record-high snowpacks region-wide and a late spring blizzard, the 2001 floods were the result of above-average soil moistures in some areas of the basin, rapid melting of above-average snowpacks in the upper basin, and heavy rainfall that swept across the region on April 7, 2001.
In the fall of 2000, soil moistures varied across North Dakota and Minnesota.
Before freeze-up in November 2000, a series of storms saturated the upper portions of the soils preventing further infiltration of moisture and leaving many parts of the Red River Basin with 1 to 2 feet of snow.
Along the Red River, the 2000-2001 snowfall was above average but was less than the record 1997 snowfall.
Temperatures began to warm during the end of March and caused the flooding to start in the upper Red River Basin.
A massive storm system that brought heavy rains and high winds moved through the upper plains on April 6 and 7, 2001.
The upper part of the basin received 1 to 2 inches of rain that added to the flooding problem. Rainfall continued periodically throughout April in parts of the Red River Basin.
Fargo/Moorhead
• On April 14, 2001, the peak stage of the Red River at Fargo, N. Dak., was 36.63 feet, which is 3.09 feet less than the record set in 1997, and the peak discharge was 20,300 cubic feet per second.
Grand Forks/East Grand Forks
• High discharges continued downstream on the Red River. On April 14, 2001, the peak stage of the Red River at Grand Forks, N. Dakota, was 44.87 feet, which is 9.48 feet less than the record set in 1997. The peak discharge was 55,800 cubic feet per second, which occurred on April 11, 2001.

Hydrologic Cycle – The process of water evaporating from oceans, plants, and soils; condensing and falling as precipitation; percolating through soil and eventually returning to the ocean.

Infiltration – The process by which water enters the ground.

Evaporation – The vaporization of a liquid occurring only at the surface of the liquid.

Transpiration - The loss of water vapor from parts of plants (leaves, stems, flowers, roots).

Evapotranspiration - The sum of evaporation and plant transpiration from the Earth’s land surface to atmosphere.
**Stream** – water that flows in a channel. **Synonyms**: branch, brook, beck, burn, creek, "crick", gill, kill, lick, syke, bayou, rivulet, streamage, wash, run or runnel.

**River** – a stream that carries substantial amounts of water and has numerous tributaries.

**Drainage Basin** - The tract of country that contributes water to a particular stream channel or system of channels, or to a lake, reservoir or other body of water.

**Watershed** - The terms “watershed” and “drainage basin” are often used interchangeably in North America. In Great Britain, however, “watershed” is used to denote a drainage divide.

**Drainage Divide** - A drainage divide is the boundary between drainage basins.

**Stream Flow**

- **Laminar flow** – Water flow in which the stream lines remain distinct.
- **Turbulent flow** – Water flow in which the flow lines are confused and mixed.

**Flow Velocity**

Factors influencing stream flow velocity:
- channel slope or gradient (v/h);
- channel size and cross-sectional shape;
- channel roughness; and
- the amount of water flowing in the channel.

**Measuring Flow Velocity**

Gaging stations equipped with current meters are used to measure flow velocity.

**Calculating Flow Rates**

A basic flow rate equation:

\[ Q = VA \]

- \( Q \) = flow rate (cubic meters per second, or m³/sec)
- \( V \) = velocity (m/sec)
- \( A \) = area (m²)
For a rectangular open channel:
\[ Q = VBh \]
- \( Q \) = flow rate (cubic meters per second, or m\(^3\)/sec)
- \( V \) = velocity (m/sec)
- \( B \) = channel width (m)
- \( h \) = depth of flow (m)

For Channel B
\[ Q = VBh \]
- \( Q \) = flow rate (cubic meters per second, or m\(^3\)/sec)
- \( V \) = velocity (m/sec) - let's say 5 m/sec
- \( B \) = channel width (m) - 5 m
- \( h \) = depth of flow (m) - 2 m

\[ Q = (5 \text{ m/sec})(5\text{m})(2\text{m}) = 50 \text{ m}^3/\text{sec} \]
The flow rate is also known as **discharge**, or the volume of water flowing past a point over a given unit of time.

**Stream Profile** - A cross sectional view of a stream from its source to its mouth.

**Erosion Ability**
When in a channel, the erosional power of flowing water is related to the stream slope and discharge.
The rate of erosion is dependent on the bank and bed materials.

**In bedrock:**
- **Quarrying:** removal of blocks from the stream channel
- **Abrasion** – sediment grains entrained in the flow abrade the channel. Example: **potholes**
- **Corrosion** – a chemical weathering/dissolution process, typical of carbonate rocks.

**Dissolved Load** – That part of the total stream load that is carried in solution.

**Suspended Load** – The part of the total stream load that is carried for a considerable period of time in suspension, free from contact with the stream bed. Typically consists of clay, silt, sand.

**Bed Load** – The part of the stream load that is moved on or immediately above the stream bed, such as the larger or heavier particles (boulders, pebbles, gravel) rolling and saltating along the bottom.
Stream Channels

**Bedrock Channels**

**Alluvial Channels**

-- wide bends, primarily suspended load transport of silt and clay, sand, and fine gravel.

**Associated terms:**

- **Cut bank** – outside bank of a meander, zone of erosion.
- **Point bar** – inside bank of a meander, zone of deposition of coarser material.
- **Cutoff** – short circuit of the channel through a narrow neck of land separating two adjacent segments of the channel.
- **Oxbow lake** – An abandoned meander bend.

**Alluvial Channels**

- **Meandering Channels** – a complex network of converging and diverging channels. They form when a stream load is primarily coarser sand and gravel. Typical at the end of glaciers.

**Braided Channels** – a complex network of converging and diverging channels. They form when a stream load is primarily coarser sand and gravel. Typical at the end of glaciers.

**Oxbow Lake** - A crescent-shaped body of standing water situated in an abandoned channel of a meander.

**Base Level** - The theoretical limit or lowest level toward which erosion of the Earth’s surface constantly progresses, but seldom, if ever, reaches. The ultimate base level is sea level. Local or temporary base levels include lakes, resistant layers of rock, rivers, and dams.
**Formation of Valleys**

Valley deepening occurs when:
1. there is a steep stream gradient; and
2. the channel is well above base level.

*The result is a V-shaped valley.*

*Valley widening* begins to occur when:
1. down cutting decreases; and
2. the stream becomes *graded*. A stream is graded when the stream channel characteristics are such that it is able to maintain the minimum velocity to transport the material supplied to it.

Continued lateral erosion results in:
1. a meandering channel; and
2. development of a floodplain.

**Terraces** - A relatively level bench or step-like surface breaking the continuity of a slope. Fluvial terraces are remnants of a former floodplain.

**Deltas**

A fan-shaped fluvial plain that forms at the mouth of a river. Deltaic sediments are deposited as three types of beds:

**Foreset** - coarse particles that settle almost immediately when the flow rate decreases. Foreset beds slope downcurrent from the delta front.

**Topset** – thin, horizontal, coarse sediments deposited during flood stage.

**Bottomset** – finer sediments (silt, clay) that settle away from the mouth of the river in nearly horizontal beds.

**Incised Meanders** - Incised meanders typically form in response to changes in base level.
**Alluvial Fans**
Fan shaped deposits of coarse *alluvium* deposited by a stream especially in arid or semi-arid regions where a stream flows out of a narrow canyon.

*Alluvium* – detrital deposits made by streams on river beds, flood plains and alluvial fans.

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**Drainage Patterns**

**Dendritic** – streams branch randomly at almost any angle; like tree branches. Cause: relatively uniform bedrock.

**Radial** – streams diverge from a central area. Typically develops on volcanoes and areas of dome-like uplift.

**Trellis** – parallel main streams with right-angle tributaries. Cause: forms along edges of alternating hard and soft rock outcrops.

**Rectangular** – drainage pattern with many right angle bends. Cause: highly jointed bedrock.
**Water Gap** - A deep pass in a mountain ridge, through which a stream flows. The stream may be either an antecedent, or superposed/superimposed stream.