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Overall course learning goals for GEOL 1010: 1st draft (June 1, 2007)

Attitudinal Goals

A1. Students will appreciate the wonder of the habitable and evolving Earth.
A2. Students will appreciate that Earth (and the materials that compose it) can be studied using the scientific method.
A3. Students will appreciate the power of geologic events and hazards.
A4. Students will appreciate the role of geology in society and in everyday life, particularly with regard to use of geologic resources and the environment.
A5. Students will appreciate the impact of humans on the Earth.

Content goals (The Big Ideas)

B1. Students will apply geologic knowledge to everyday life, identify geologic features in the field, and interpret relationships and processes of geologic features.
B2. Students will understand how Earth materials and landforms provide a record of Earth's history.
B3. Students will comprehend the scope of geologic time and the principles of absolute and relative dating.
B4. Students will understand the recurrence intervals and rates of geologic processes.
B5. Students will understand the rock cycle and plate tectonics (distribution of geological features and materials).
B6. Students will understand the composition and structure of Earth.
B7. How elements are organized into minerals and rocks.
B8. Students will understand the forces that drive surficial processes, and how surficial processes shape landscapes and create and transport sediment.
B9. Students will understand the driving force of internal processes and their effects.
B10. Students are able to explain the distribution of Earth's major features (distribution of resources?)

Scientific Thinking goals

C1. Students will understand and appreciate what geologists do.
C2. Students will understand how geologic data are used to evaluate hypotheses.
C3. Students will relate time, distance, and rate of geologic processes.
C4. Students will comprehend graphical representations of geologic data.
C5. Students will be able to convert units commonly used in geology.
C6. Students will be able to reduce 3D information to 2D representations, and vice versa.
C7. Students will be able to understand and apply the scientific method in geology.
C8. Students will be able to evaluate scientific claims relating to fundamental concepts in geology.

Topic-level learning goals for GEOL 1010 - 1st draft (June 1, 2007)

Plate tectonics

1. Students will understand the 3 types of plate boundaries (and sub-types) and how they relate to the distribution and type of mountain ranges/trenches, earthquakes, and volcanoes.
2. Students will understand how heat generated by radioactive decay drives plate tectonics.
3. Students will understand how the history and development of the theory of plate tectonics is a model of the scientific method [how science works].
4. Students will be able to understand and produce calculations of past and current plate motion.
5. Students will understand that the Earth's outer layer comprises a dozen or so mostly rigid plates that move relative to one another and are recycled and renewed over geologic time by subduction and sea-floor spreading.

Earth materials and the rock cycle

1. Students will understand the fundamental makeup of matter, and how matter is organized into Earth materials.
2. Students will understand what an isotope is and how it is used in the study of geology.
3. Students will relate atoms, minerals, and rocks to each other.
4. Students will understand the formation of the three major types of rocks (igneous, sedimentary, and metamorphic) and the processes by which they form, relating them by the rock cycle.
5. Students will understand how mineral assemblages (rocks) form at characteristic temperature and pressure conditions and from characteristic chemical compositions.
6. Students will understand how and why rocks and minerals are distributed on and in Earth (particularly felsic and mafic rocks).
7. Students will recognize that minerals are important in everyday life – important resources

Earth structure and internal processes

1. ID and describe primary layers of Earth and their properties including differentiation of crust mantle and lithosphere& asthenosphere
2. Describe tools and methods used to investigate the interior of the earth.
3. Origin and nature of Earth's magnetic field and how it is recorded in rocks.
4. Describe where and why earthquakes occur and how energy from the quakes is transmitted trough the earth.
5. Describe formation and differentiation of Earth (includes gravity)
6. Define primary Earth structures and their associated stress fields.
7. Primary modes of rock deformation and how these are controlled by temperature, pressure, water, and composition.
8. How P, T, density, vary in the Earth
9. How earthquakes are measured, located and characterized
10. Density and how related to global topography of lithosphere, density and buoyancy.
11. Understand the diversity of volcanoes and volcanic processes and its relationships to magma composition and plate tectonic setting

Geologic time and history/formation of Earth

1. Understand how the solar system formed and the reasons for Earth's uniqueness (hydrologic cycle, life, plate tectonics, etc.)
2. Define and apply relative and absolute dating techniques to determine geologic history
3. Appreciate and understand that rocks provide a record of Earth's history, and that many of today's processes have operated in the geologic past.
4. Comprehend the significance of geologic time and development of geologic time scale

Surficial processes

1. Students will understand the water cycle including reservoirs of water storage and fluxes between them; differentiating between fresh and salty water.
2. How does water flow through stream networks, including erosion/transport/sedimentation and flooding.
3. Understand processes of chemical and physical weathering and soil formation, and how they vary with bedrock and climate
4. Role of erosion in shaping Earth's surface and recycling of Earth materials through erosion and sedimentation
5. Linkage between glacier mass balance and climate, including terrestrial and marine records of variations; understand the fundamental relationships between major controls on global climate, sea level, and ice extent (include global warming?).

Lecture-level goals defined and utilized by:

Matt Pranter, Becky Flowers, Lon Abbott,
Karl Mueller, Shemin Ge, Greg Tucker (50% of the course)

- Major headings reflect chapter titles, but because instructors are free to use whatever text they prefer, the major headings may not correspond to a particular text.
- Words in italics are the action verbs that describe what the students should be able to do
    - These verbs reflect cognate levels of thinking (N.B - most usages require only lowest levels of cognate thinking)
    - Verbs in *brown* are vague and do not really specify cognate level expected
- No independent cross checking has been done to see if stated goals are indeed aligned with lecture, classroom activities, home works, or exams.

A. Introduction

1. *Describe* the forces that drive various geologic processes
2. *Become* familiar with the basic interior structure of the Earth
3. *Know* the three rock types
4. *Describe* the basic elements of plate tectonics such as plate motion, and plate boundary types
5. *Develop* a preliminarily comprehension of the immensity of geologic time
6. *Describe* how scientists think the solar system, earth, and moon formed.

B. Earth's Interior and Geophysical Properties

1. *Define* lithosphere, asthenosphere, moho, tectonic plate
2. *Describe* how the 3 main layers of the Earth differ in terms of thickness, density, temperature, seismic velocity, and composition.
    a. Know the basic chemical structure of the earth: crust, mantle, core.
3. *Describe* the direct and indirect types of information geologists use to understand the Earth's interior
    a. *Distinguish* seismic wave reflection and refraction
    b. *Describe* seismic shadow zones (P and S wave shadow zones)
    a. *Explain* how the properties of seismic waves are used to determine Earth's major boundaries (interior structure)?
    b. *Explain* how we know of the core's existence
    c. *Describe* how we locate the Moho
4. *Describe* the methods and data that geologists use to investigate the upper part of the Crust.
5. *State* the scale of Earth's topography (the maximum relief on Earth's surface). Explain the concept of isostasy
6. *Apply* isostasy to explain glacial rebound, crustal uplifting
7. *Relate* isostatic equilibrium/disequilibrium to gravity anomalies
8. *Explain* lithostatic pressure and compute pressure at any given depth
9. *Describe* the Earth's magnetic field, its origin, reversals, and anomalies
10. *Describe* geothermal structure, sources of heat, heat flow anomalies

C. Plate Tectonics (and Ocean Floor)

1. *Describe* the origin of the ocean (basins, water, and salts)

1. *Define* tectonic plate.
2. What are the differences between oceanic and continental crust?
3. *Describ*e what plate tectonics theory is.
4. *List* the 3 main types of plate boundaries and describe how the plates move relative to each other.
    a. *Name* and *describe* 3 types of plate boundaries.
    b. *Give* some modern examples of the 3 major plate boundaries.
5. *Describe* geologic features/processes associated with these boundaries
    a. *Compare and contrast* passive and active margins
    b. *Identify* examples of active and passive margins
    c. *Describe* mid ocean ridges
6. *Describe* the lines of evidence used by Alfred Wegener to support the idea that present-day continents were once joined together into a single large continent (continental drift hypothesis).
    d. *Describe* Wegner's continental drift hypothesis
    e. *Discuss* the supporting evidence for continental drift
    f. *Explain* why the continental drift idea failed to gain acceptance (until data from ocean basins became available after World War II.)
7. *Explain* the seafloor-spreading hypothesis and the initial data used to support it.
    g. *Discuss* the age patterns of the sea floor
    h. *Describe* the main features of the sea floor
    i. *Describe* the process of sea floor spreading
8. *Explain* how iron-rich minerals in some rocks become magnetized and aligned with Earth's magnetic field (how they become fossil compasses).
    j. *Explain* how geologists use Earth's magnetic field to define a geographic location (how far north or south, and direction to magnetic north pole).
9. Use information from magnetized rocks to *determine* the movement of continents through time.
10. *Describe* how reversals in Earth's magnetic field are recorded in rocks of the oceanic (geomagnetic reversals).
    k. *Explain* how evidence from geomagnetic reversals further supported the seafloor-spreading hypothesis.
    l. *Explain* how the age and thickness of the seafloor supports the seafloor-spreading hypothesis.
    m. *Discuss* marine magnetic anomalies and fracture zone, and how they support the idea of sea floor spreading
11. *Calculate* the rate of seafloor spreading given a map of seafloor age (i.e., given age and distance between marine magnetic stripes)
    n. *Predict* the age of sea floor at a given distance and a spreading rate
12. *Analyze* plate motion direction and rate from the age of seamounts
13. *State* the range of plate motion rates measured today.
    o. *Know* modern rates of plate motion
14. *Describe* the primary forces that drive tectonic plate motion.

p. *Discuss* various mechanisms for driving plate motion
q. What drives plates?

15. *Describe* how density and temperature differences cause motion in Earth's interior.
16. *Explain* the evidence that supports or refutes different models for motion of Earth's tectonic plates and mantle.
17. *Define* the components of a spreading ridge and how they interact to allow new oceanic lithosphere to be formed.
18. *Define* how the bathymetry of ocean floors can be used to constrain the chemical and thermal structure of the lithosphere.
19. *Explain* how aseismic ridges (e.g. Hawaii) are formed
    r. *Describe* how atolls formed
20. *Describe* the three types of convergent boundaries.
21. *Describe* the evidence for subduction.
22. *Define* the features of subduction zones, why they form and how their relative position can be used to define how convergent plates sink or override one another.
23. *Describe* how lithospheric density differences determine the type of convergent boundary (which plate subducts, why subduction terminates when chunks of continental lithosphere collide)
24. *Summarize* (define) how plate tectonics became an accepted model and what information was critical in its development.
    s. *Comprehend* the development of plate tectonics theory in the context of how the scientific method works
25. *Relate* the occurrence and locations of earthquakes and volcanoes to different types of plate boundaries
    t. *Relate* plate tectonics (plate boundary types) to global distribution of earthquakes and volcanoes
    u. *Explain* distribution of earthquakes in fracture zones
    v. *Describe* the shape of Earth's surface,
26. *Distinguish* plate boundaries from geographic boundaries
27. *Distinguish* ocean margins from plate boundaries
28. *Relate* the breakup of Pangaea to the supercontinental cycle and the processes that contribute to this process.

D. Minerals

1. *Compare and contrast* how geologists define the terms "mineral" and "rock"
    a. *Describe* the relationship between "mineral" and "rock".
    b. *Explain* difference between rock and mineral.
    c. *Distinguish* between what geologists define as minerals and other substances (non-mineral).
    d. *Define* what is a mineral
2. *Describe* the relationship between atoms, elements, minerals, and rocks.
    a. *Review* atomic structure, nucleus (protons, neutrons), electrons
3. *Distinguish* between mineral and crystal.
4. *Describe* the primary ways in which crystals form.
5. *Explain* the relationship between external crystal form and internal atomic structure.
6. *Explain* how a mineral's crystal form can be used to help identify the mineral.

7. *Explain* how physical properties (e.g. color, hardness, luster, etc.) are used for mineral identification
    a. *Describe* some diagnostic mineral properties
8. *Describe* how geologists divide minerals into different groups or classifications.
    a. *Identify* common non-silicate minerals and describe their uses.
    b. Name five common rock-forming mineral groups
9. *Explain* how silicon and oxygen atoms combine with other atoms to form the variety of minerals of the main mineral group (silicates).
    a. *Distinguish* five different structures of silicate minerals
10. *Describe* how minerals form different chemical bonds (ionic, covalent, metallic, and Van der Waals)
    a. *Relate* bonding strength to mineral properties
    b. *Describe* how the different bond type and strengths (e.g. covalent, ionic, and metallic) between atomic elements can result in different physical properties.
11. *Explain* how physical properties (e.g. color, hardness, luster, etc.) are used for mineral identification
    a. *Describe* how you could identify a mineral based on hardness
    b. *Explain* why minerals tend to break along flat and planar or very irregular surfaces and how this is used to identify minerals.
    c. *Describe* how mineral's color, weight, reflected light, and crystal form are useful for mineral identification.
    d. *Compare and contrast* physical properties of different types of common rock-forming minerals that have a silica-oxygen tetrahedron as their building block.
12. *Discuss* examples of minerals in your daily life

E. Igneous Rocks

1. *Describe* the rock cycle
2. *Describ*e geothermal gradient and *calculate* temperature at any given depth given a gradient
3. *Define* magma, and explain where on Earth it comes from.
    a. *Describe and explain* what changes the composition of a magma
    b. *What* is magma?
    c. *Know* how magma is generated, and which mechanisms are likely in different tectonic settings.
4. *Describe* conditions permitting rocks to melt (and igneous activity to occur) and explain how these conditions relate to plate tectonic setting.
    a. *How* do rocks get melted?
    b. *Understand* how rock gets melted to form magma.
5. *Define* viscosity, and explain how silica content of magmas influences magma viscosity.
6. *Describe* (*understand*) how igneous rocks form.
7. *Compare* igneous rocks that form below Earth's surface with those that form above Earth's surface.
8. *Explain* how cooling rate affects the resulting crystal size of minerals within igneous rocks.
9. *Define* igneous texture.

10. *Explain* what factors contribute to the resulting texture of an igneous rock.
    a. *Describe* how cooling rate influences igneous rock texture.
11. *Describe* and identify the common igneous rock textures and explain how they form.
12. Describe the basis (texture, composition) for igneous rock classification
    a. *Describe* how igneous rocks are named based on their texture and composition (minerals that make up the rock).
    b. *Distinguish* extrusive and intrusive on the basis of texture and composition
13. *Compare and contrast* mafic, intermediate, and felsic igneous rocks. List examples of each.
14. *Identify* common igneous rocks based on a description of their texture and composition.
    a. *Classify* the different types of igneous rocks
    b. *Know* 3-6 igneous rocks and what they tell you about the environment in which they formed.
15. *Explain* the roles that heat, pressure, and water play in causing a rock to melt.
16. *Explain* how an initial magma of a given composition could produce a wide variety of igneous rocks with different compositions.
17. Describe how Bowen's reaction series predicts the order of crystallization of minerals in igneous rocks, and explain how the order of crystallization relates to mineral composition of igneous rocks.
    a. Apply Bowen's reaction series diagram to explain the sequence of mineral melting and crystallization
18. *Recognize* the structural features of intrusive igneous rocks
19. *Appreciate* the important events in earth's history that can be deduced simply through identification of a particular type of igneous rock
20. *Relate* igneous rock (location and silica content) to plate tectonics
    a. *Understand* how melting of rock relates to plates and hotspots

F. Volcanoes and Other Igneous Activity

1. *List* and *describe* materials extruded from a volcano (flowing on land or under water; airborne).
    a. *Be familiar with* two common volcanic hazards (pyroclastic flows and lahars)
    b. *Describe* characteristics of typical basaltic lava flows.
    c. *List* and describe pyroclastic materials extruded from a volcano.
2. *Compare* the shape and size of the three major types of volcanoes, and explain how each are produced.
    a. *Be familiar with* the 3 main volcanic landforms, and why they differ
3. *Relate* lava composition to the size and shape of volcanic landforms
    a. *Contrast* the shape and size of the three major types of volcanoes, and *explain* how each are produced.
    b. *Understand* where stratovolcanoes are likely to form, and why they are particularly hazardous
    c. *Describe* the general features of a volcano and volcanic landforms.
4. *Compare* intrusive igneous features and *explain* how you could identify them.
    a. *Distinguish* between intrusive igneous features: dike, sill, laccolith.
5. *Describe* the factors controlling the explosivity or violence of volcanic eruptions
    a. *Describe* how viscosity controls the nature of a volcanic eruption.

b. Relate eruption behavior to magma composition and magma viscosity.
c. *Understand* why do volcanoes vary in eruptive style?

6. *Relate* geographic locations of volcano to plate tectonics
    a. *Where* do most volcanoes occur?
7. *List and describe* ways impending volcanic eruptions are monitored.

G. Weathering

1. *Define* weathering, erosion, differential weathering
2. *Distinguish* between weathering and erosion concepts
    a. *What* controls erosion versus sedimentation?
3. *Describe* the role of weathering in the formation of sedimentary rocks
4. *Describe* the key factors that control weathering (e.g., parent rock properties, time, soil, topography, etc.).
5. Distinguish physical and chemical weathering
    a. Describe how mechanical and chemical weathering relate to each other
    b. Be familiar with the main types of physical and chemical weathering.
    c. Understand how these processes turn rock into sediment.
    d. *Understand* that we can distinguish between physical and chemical weathering processes.
    e. *Understand* how physical and chemical weathering differ, and how they interact
    f. *Compare and contrast* the major processes and effects of chemical and mechanical weathering, and *describe* how they interact.
    g. *Be familiar with* a few common examples of physical and chemical weathering processes:
6. *Explain* how rocks disintegrate to form sediment by physical (mechanical) weathering processes.
7. *Describe* how the composition of rocks/minerals is changed by chemically reacting with water, CO2, oxygen, etc.
    a. *Describe* how some minerals chemically react with water, CO_2, or oxygen to alter the minerals.
    b. *Illustrate* how chemical weathering works using oxidation, dissolution and hydrolysis as examples
8. *Describe* the products of chemical weathering of common minerals.
9. *Discuss* factors that affect weathering rates
    a. *Know* the controls on weathering rates
    b. *Explain* how climate and rock type affect weathering rates.
    c. Apply Bowen's reaction series to explain why some minerals are more resistant to weathering than others
    d. *Identify* environments and materials in which different types of weathering would tend to be faster or slower.
10. *Evaluate* how weathering, environment, and human activities are linked

H. Soils

1. *Describe* how soils form
    a. *How* does soil form?
2. *Describe* the main constituents of soil and where they come from.

    a. *What* is soil made of?
3. *Identify* the three major soil horizons, describe and illustrate their characteristics
    a. *Why* is soil layered?
4. *Describe* the characteristics of the three primary types of soil, and explain important factors in the formation of each type.
5. *List* the factors influencing soil formation
    a. *Identify* conditions that promote slow versus rapid soil development.
    b. *Identify* conditions (climate, parent material, time, topography) associated with different degrees of soil development.
    c. *What* controls soil thickness and composition?
6. *Explain* the importance of soil for human societies, and *describe* how human activities affect soils.

What controls soil thickness and composition?

I. Mass Wasting

1. *Define* mass wasting
2. *Describe* the types of mass movement by rate of movement, type of material, and mode of movement
    a. *Be familiar* with the three forms of mass movement and the conditions that promote one or the other.
3. *Describe* gravity force (shear force, normal force)
4. *Describe* resistant force
5. *Analyze* how slope angle and the different type of forces affect slope stability
6. *Discuss* the role of water in slope stability
    a. Understand the role of slope, grain size, and water content (including saturated versus unsaturated) in controlling slope stability.
7. *Discuss* the different types of interventions (measures) used to prevent landslides

J. Sedimentary Rocks

1. *Explain* the main processes (and their order in the rock cycle) that are related to how loose sediment is transformed into a hard (rigid) sedimentary rock.
    a. *Summarize* the processes necessary for formation of a clastic sedimentary rock.
2. *Describe* clastic and chemical sediments and be able to distinguish between the two types
    a. *Know* that sedimentary rocks come in two flavors: clastic and chemical, and that the chemical flavor comes in two types, biogenic and non-biogenic.
3. *Understand* that sedimentary rocks form where transport power decreases *describe* geologic situations where transport power decreases.
4. *Describe* the processes of sediment transport and deposition
    a. *List* different types of sediment transport agents
    b. *Interpret* sediment shape and size in terms of transporting agent
5. *Describe* how loose sediment is transformed into a hard rock.
    a. *Define* lithification
    b. *Describe and differentiate* processes of compaction, cementation
    c. *Synthesize* the processes of sedimentary rock formation
    d. *Understand* how sediment turns into rock (compaction, cementation).
6. *Describe* the basis for how geologists classify and name sedimentary rocks.

    a. *Describe* the textural characteristics of clastic sediment, and identify rock type using texture.
    b. *Describe* and identify some common types of sedimentary rocks.
    c. *Contrast* the most important properties for naming clastic and non-clastic rocks.
7. *Compare and contrast* the formation of the non-clastic sedimentary rocks limestone, coal, chert, and evaporites (rock salt and rock gypsum).
8. *Characterize* sedimentary rock structures
9. *Relate* the common types of sedimentary rocks to the settings in which they form.
10. *Explain* how various rock characteristics are used to interpret how sedimentary rocks formed.
    a. *Be able to recognize* and *describe* common sedimentary environments and the type of rock associated with them.
11. *Interpret* sedimentation environments from sedimentary rocks to infer sources and locations of deposition
12. *Know* the basic sedimentary rock types (sandstone, conglomerate, shale, limestone) and the type of environment they represent.
13. *Relate* sedimentary processes to tectonic plate boundaries

K. Metamorphic Rocks

1. *Classify* metamorphic rocks
2. *Summarize* the processes producing a metamorphic rock.
    a. *What* are the causes of metamorphism?
3. *Understand* and *sketch*, how temperature and pressure vary with depth beneath the Earth's surface.
4. *Describe and distinguish* the roles of temperature, pressure, and fluid in metamorphism.
    a. *Describe* the sources of heat, pressure, and chemically active fluids that change the form of a rock (density; grain size, shape, and arrangement; composition) without melting it?
    b. *Understand* what processes metamorphose rocks
5. *Describe* how the size, shape, and arrangement of grains in a rock changes during metamorphism.
6. *Describe* the types of metamorphism
7. *Describe* the types of foliated textures and how they form.
    a. *What* does the texture of a metamorphic rock reveal?
8. *Describe* the main environments in which metamorphic rocks form.
9. *Explain* how the composition of the "parent rock" (a rock before it is exposed to metamorphism) determines what happens during metamorphism.
10. *Define* how different mineral assemblages can be used to estimate pressure and temperature conditions in metamorphic rocks.
    a. *What* is the concept of metamorphic grade?
    b. *Explain* how the texture and mineralogy of a metamorphic rock reflects the environment in which it formed and the grade of metamorphism.
    c. *What* are common types of metamorphic rock and their associated grade?
11. *Recognize* how to use metamorphic rock classification to determine parent rock type and past tectonic environments

L. Geologic Time

1. *Describe* the concept of uniformitarinism
2. *Explain* how the concept of uniformitarianism is used to interpret geologic history.
3. *Define* what geological relationships are used to define relative age constraints
4. *Describe* how the order of geologic events can be determined
5. *Apply (use)* relative ordering principles to *determine* the order of geologic events from a diagram or picture of a rock sequence.
    a. *Apply* Steno's principles to *interpret* a sequence of events, for example in a block diagram or photograph.
6. *Define* the three different types of unconformities (gaps in the rock record)
7. *Describe* how each of these types of unconformities form
8. *Describ*e how geologists recognize gaps in the record of rocks, and *interpret* what process(es) likely caused a gap.
9. *Recognize* an unconformity in a diagram, and *understand* that it indicates an interval of erosion.
10. *Describe* how geologists determine the relative ages of rocks in widely separated places
11. *Describe* how geologists correlate rocks in widely separated areas
12. *What* is an isotope?
13. *Explain* the process of radioactive decay, and describe how radioactive isotope abundances change over time
    a. *Describe* radioactive half-lives and decay rates
14. *Define* the concept of half-life
    a. *Understand* the relationship between fraction of parent isotope remaining and time elapsed
15. *Understand* the assumptions you make when you apply a radiometric method such as U238-Pb206
16. *Apply* the concept of half-life to determine the age of a rock, given modern isotopic abundances of a radioactive element and the half-life for decay of that element
    a. *Derive* an age from a daughter-to-parent ratio (and vice versa)
    b. *Compute* rock ages from radioactive decay data
17. *Explain* why isotopic methods can be used to date some rocks but not others
18. *Distinguish* relative and absolute ages
19. *Define* the Geologic Time Scale and *explain* how and why it was first created.
    a. *Describe* the major subdivisions of the geologic timescale
    b. *Comprehend* the geologic time scale, its history and use
20. *Explain* the relationship between extinction events and era boundaries
21. *State* the age of the Earth?
22. *Explain* how we know the age of the Earth
    a. How do we know the age of the Earth?
23. Combine relative and absolute dating techniques to *unravel* the geologic history of a region

M. Structural Geology (Crustal Deformation)

1. *Define* stress and strain.

2. *Describe* the three main types of differential stress (compression, tension, and shear), and how they affect a rock body.
3. *Describe* the main types of (strain) deformation (elastic, plastic, brittle, contraction, extension, shear)
4. *Calculate* stress, strain (under simple and ideal conditions)
5. *Describe* the factors that affect if and how a rock deforms.
6. *Explain* how those features cause deformation
7. *Relate* strain to stress (what strain is produced by what stress)
    a. Interpret the stress and strain involved in producing folds and faults
    b. *Describe* how Earth's crust breaks (faulting) and the geologic features that develop due to tensional stress (pulling apart), compressional stress (pushing together), and shear stress (rocks sliding past each other).
8. *Explain* how to measure the orientation of deformed rocks
    a. *Explain* the meaning of strike and dip (angle and direction)
9. *Describe* the shapes of folded rocks.
10. *Describe* the different types of faults
    a. Contrast normal and reverse faults
    b. Distinguish right-lateral and left lateral faults
11. *Describe* how geologic maps and cross sections are made
12. *Describe* what geologic maps show
13. Interpret geologic structures from maps and geologic cross sections
    a. *Extract* information from geologic maps
    b. *Recognize* different geologic structural features (folds, faults)

N. Earthquakes

1. *Know* what an earthquake is
2. *Describe* what causes earthquakes.
    a. *Describe* why earthquakes occur.
3. Describe the mechanism of earthquakes with elastic rebound theory
4. Relate earthquakes distribution and plate tectonics
    a. Define why the magnitude of the largest earthquakes that occur in a particular region varies relative to heat flow and the types of faults that form in different plate boundaries
    b. *Describe* the distribution of earthquakes.
    c. *Describe the* depth and location of earthquakes (as a function of plate boundary type)
5. *Distin*guish earthquake epicenter and focus
6. *Explain* why earthquakes occur as seismic cycles
7. *Describe* what seismic waves are.
8. *Compare and contrast* the types of seismic waves produced by an earthquake.
    a. *List* the different types of seismic waves
    b. Compare the differences between body wave and surface wave
    c. Compare the difference between P wave and S wave
    d. Compare the travel speeds of surface wave, P wave, and S wave
    e. *Understand* the types of waves released by an earthquake

9. Use seismic wave travel times to *determine* an earthquake location (location where the earthquake begins).
    a. Know how earthquakes are located and what their distribution is
10. *Describe* what earthquake intensity measures.
    a. *Describe* how earthquakes are measured
11. *Compare* the Mercalli intensity scale with the Richter magnitude scale.
    a. *Comprehend* the two ways that earthquake size is measured.
    b. *Compare (contrast)* an earthquake intensity scale with an earthquake magnitude scale.
12. *Describe* how seismograms can be used to locate where earthquakes have occurred
13. *Interpret* seismogram data to locate earthquakes (three circle method)
14. *Use* seismic wave information to *calculate* Richter magnitude.
    a. *Calculate* the different magnitudes of shaking between units of the Richter scale
15. *Describe* the effects of earthquakes
    a. Compare ground motion and energy associated with earthquakes of different magnitude
16. *Describe* the relative effects of ground motion in different types of material
    a. *Understand* the factors that influence the amount of damage earthquakes do
17. *Relate* earthquakes to other hazards they trigger
    a. *Relat*e the occurrence of tsunamis to large earthquakes
18. *Define* how small earthquakes can be triggered by mankind
19. *Explain* how geologists try to make long-term predictions of earthquakes
    a. *Define* how scientists forecast the location of future large earthquakes
    b. *Know* how geologists are working toward the goal of being able to predict earthquakes
    c. *Discuss* human impact/effects of earthquakes & earthquake prediction

O. Streams / Running Water/ Surface Water

1. *Name* the Earth's sources of water
2. *Describe* and illustrate the water (hydrologic) cycle.
3. *Descri*be the processes of water flow in the hydrologic cycle
    a. *Be familiar* with relative sizes of reservoirs (e.g., what percent in ocean? ice? groundwater?)
    b. *Understand* how water circulates among land, oceans, atmosphere, and roughly how much.
    c. *Understand* basic processes that move water around the planet.
    d. *State* how much of global precipitation on land goes into ET versus runoff?
4. Describe the concepts of a water budget/balance
    a. *Understand* and be able to calculate a basic water balance (precipitation = ET + runoff)
    b. *Calculate* runoff, precipitation, or ET if you know the other two.
5. *Define* drainage basins, drainage divides, and drainage patterns
    a. *Name* Colorado's major river basins
6. *Identify* the boundaries of a drainage basin on a topographic map
7. *Describe* how the channel gradient (slope), shape, size, and roughness change downstream and affect stream velocity.

    a. Describe how channel shape and roughness influences stream velocity
    b. *Be familiar with* typical changes in discharge, depth, width, velocity.
8. *Understand* how water gets into streams, and why many streams flow when it's not raining
9. Explain why streams become wider, deeper, and flow faster downstream.
10. *Define and calculate* stream gradient and discharge
11. *Calculate* drainage density.
12. *Convert* discharge into runoff or vice versa.
13. *Describe* base level and its relationship to stream erosion, transport, and deposition.
14. *Define and compute* discharge and explain how it changes downstream.
15. *Contrast* the three types of sediment load (bed, suspended, dissolved)
    a. *Describe* the primary types of sediment load that streams transport.
    b. *Compare and contrast* bedload, suspended load, and dissolved load
    c. E*xplain* how bedload, suspended load, and dissolved load moves in the water of a stream.
16. *Describe* how streams are able to pick up and move sediments.
    a. *Understand* how transport power is related to stream properties.
    b. *Understand* how changes in flow properties influence a stream's ability to pick up and move sediment.
17. *Describe* stream-erosion mechanisms: abrasion, hydraulic lifting, dissolution
18. *Relat*e stream velocity & sediment size to erosion, transport & deposition
19. *Describe* sediment transport by traction, saltation and suspension
20. *Describe* why streams deposit sediments and the types of deposits that form.
21. *Describe* the features related to stream deposition
22. *Identify* locations of likely erosion or sedimentation based on information about topography and/or stream properties.
23. *Describe and illustrate* the shape and major features of a stream;
24. *Compare and contrast* (*describe*) the 3 main types of streams (stream channel patterns) and their associated characteristics.
    a. *Illustrate* their major features
    b. *Explain* the factors influencing channel pattern.
25. *Be able to recognize* different river patterns from a map or photo
26. *Describe* how a meandering stream develops over time
    a. *Predict* (roughly!) the migration direction of a meandering river bend.
27. *Understand* how natural levees form.
28. *Understand* what a stream terrace indicates about the stream's history.
29. *Describ*e the processes of V-shape stream valley development
30. *Be familiar* with where and why deltas form.
31. *Describe* a flood
32. *Describe/define* the meaning of recurrence intervals.
    a. U*nderstand* the concept of recurrence interval
    b. *Understand* the definition of, for example, a 100-year flood.
    c. *Be able to identify* a flood of given return period from a plot of frequency versus discharge.
33. *Discuss* how urban development changes flooding
34. *Discuss* some basic tools used for flood control

P. Groundwater

1. *Define* groundwater and describe where it resides in the ground.
    a. *Predict* where groundwater exists
    b. *Describe* where ground water is stored
2. *Describe* how rock characteristics influence groundwater storage capacity and flow through the rock.
    a. *Define* porosity, permeability, hydraulic conductivity
    b. *Understand* the difference between porosity and permeability, and how these are related to groundwater storage and movement.
4. *Distinguish* the saturated from unsaturated zone
5. *Contrast* aquifer and aquitard, confined and unconfined aquifer
    a. *Describe* the different types of aquifers.
6. *Describe* how the water table relates to surface topography.
    a. *Relate* the shape of water tables to topography
7. *Describe* how streams interact with ground water
8. *Describe* how the water table changes in response to rainfall and climate.
9. *Trace* the ways that water is exchanged between the ground and the surface
    a. *Identify* how a change in a particular water delivery process to/from groundwater (e.g., rainfall infiltration, pumping, ET, seepage) will influence water table height.
    b. Understand how gaining and losing streams relate to the water table and water budget, and the type of climate/geography that each might be associated with.
10. *Describe* how geologists determine the rate and direction of groundwater flow.
11. *Define* hydraulic gradient, *compute* hydraulic gradient from water levels
12. *Describe* Darcy's law
13. *Apply* Darcy's Law to compute ground water flow rate
    a. *Define* why groundwater flows from some regions to others
    b. *Describe* what drives ground water flow
    c. *Comprehend* how and where groundwater flows
    d. *Predict* the direction of groundwater movement given information about the water table height at 2 or more points.
    e. *Calculate* the groundwater flow speed given hydraulic gradient and permeability.
14. *Describe* the keys to finding ground water
15. *Analyz*e a water budget by comparing recharge and withdrawal
16. *Explain* how pumping affects the water table, groundwater flow, and the ground surface.
    a. *Understand* the various effects of groundwater withdrawal
    b. *Explain* what happens when groundwater is removed from water wells
    c. *Relate* how rapidly groundwater resources can be depleted relative to human timescales
    d. *Define* why and how flow of groundwater can be changed by and for human activities
    e. *Describe* negative impacts of over pumping
    f. *Understand* how a pumping well influences the geometry of the water table.
17. *Describe* problems associated with groundwater, including overuse, subsidence, and contamination
    a. *List* sources of ground water contamination

b. *Describe* how contaminants in ground water are transported
c. *Track* the implications of groundwater contamination

18. *Recognize* the landscape features created by groundwater activity (karst topography)
19. *Relate* the processes that occur in geysers to their periodic (e.g. cyclic) eruptions.
20. *Relate* ground water to karst and oil/mineral deposits

Q. Glaciers and Glaciation

1. *Define* glacier (valley versus continental).
2. *Recognize* the types of glaciers that exist
3. Describe the processes involved in forming glaciers
4. *Describe* how glaciers can shrink (ablation).
5. *Explain* how ice moves within a glacier (consider the brittle interval at the top, "plastic" flow with depth, and sliding).
    a. Understand how and why glaciers recede or advance (shorten or lengthen)
    b. *Comprehend* how glaciers form, how they move, and how they erode the landscape
    c. Explain how glaciers flow
    d. Describe the driving force for glaciers movement
6. *Compare* the characteristics of advancing and receding glaciers
7. *Analyze* ice budget by examining accumulation and ablation
8. Describe the velocity profile within a glacier
9. *Describe* why valley glaciers "advance" or "retreat".
    a. When it retreats does the glacier move up the glacial valley?
10. *Describe* how glacial landscapes (erosional and depositional) form and the corresponding features (see above) that develop.
    a. *Recognize & explain/describe* the landforms created by glacial erosion
    b. *Recognize & explain/describe* the landforms created by glacial deposition
    c. *Define* the processes that produce landforms that develop in response to either erosion or deposition to glaciated regions
    d. *Characterize* glacial landforms in Rocky Mountain National Park and how they can be used as a record of past ice ages
11. *Determine* the direction of ice (glacier) movement from glacial features.(roche moutonnée and drumlins.
    a. These features look similar to each other from a distance (their shapes); so, what else would you need to know about them before you could determine the direction of ice movement?
12. *Describe* how significant periods of glaciation affect global sea level.
13. *Describe* how the Milankovitch hypothesis addresses how high-frequency glacial and interglacial cycles form.
14. *Describe* how to figure out where and when glaciations occurred
15. *Explain* the glacial rebound phenomenon

R. Global Climate Change

1. *Understand* the major driving forces that shape earth's climate and how they interact with each other in the integrated climate system
    a. *Explain* the three primary factors that control earth's climate

    b. *Explain* how plate tectonics influences climate
2. *Describe* the natural causes of climate change and if they explain long-term versus shorter term changes in climate.
3. *Describe* how the buildup of greenhouse gases (like carbon dioxide) can change the earth's climate
    a. *Describe* the greenhouse effect (in general terms).
4. Describe Milankovitch cycles
5. *Describe* how the Milankovitch hypothesis (cycles) addresses how high-frequency glacial and interglacial cycles form.
    a. Explain why the Earth has had periods of much colder climate that produced large ice caps (and the so-called ice ages).
6. *Trace* the climate changes of the geologically recent past and discuss the tools geologists use to reconstruct that climate history
    a. *Describe* how we know how Earth's climate has changed over the last 2 million years (climate change proxies)
    b. *Describe* how we know how Earth's climate has changed over the last 100,000 years.
7. *Explain* how the ratio of the stable oxygen isotopes [oxygen 18 (^{18}O) and oxygen 16 (^{16}O)], vary in the oceans (in foram shells) and in ice records with changes in global climate (colder vs. warmer climates).
    a. Relate oxygen isotope ratio change to glacial and inter-glacial periods
8. *Describe* some anthropogenic causes of climate change.
9. Apply your knowledge of the earth's climate system to *project* the likely trajectory of climate change in the near future
10. *Recognize and contemplate* the impacts of climate change on humans and ecosystems

S. Geologic Resources

1. *List* the different type of geologic resources
2. *Distinguish* "reserve" from "resource"
3. *Contrast* renewable and nonrenewable resources
4. *Describe* the origin and distribution of petroleum (oil, gas, ….)
5. *Describe* the origin and distribution of coal
6. *Predict* the impact of using fossil fuel on the environment
7. *Describe* the alternatives to fossil fuel consumption