Unit #1 ES 100 lecture outline and related internet links.
Introduction to Earth Science and Chapters 2 and 3

For this unit read the introduction and chapters 2 and 3. Start with the chapter summaries. Learn the key terms and answer the review questions at the end of each chapter. Keep in mind that I get some of my weekly quiz material from these questions. The readings are required before class. The lectures and films augment and clarify the readings. The ends of chapter questions are in order of the material presented in the text. The CD Rom at the back of the book has additional material to help you.

Films:

Please view the Earth Revealed videos before class.

1. Down to Earth
Surface conditions of the planets Venus and Mars are compared with those of Earth, and scenes of Earth's living landscapes lead into a discussion of how unique Earth truly is. Major topics addressed in the series, including plate tectonics, natural resources, seismology, and erosion, are introduced in this program.

Read the questions first. Then answer them while watching this episode of "Earth Revealed".

1. What environmental conditions make life possible on earth?
2. What is the goal of the study of geology?
3. Describe earth's internal and external heat engines.
4. How do these two heat engines work together to shape the planet?
5. What new theory makes this an exciting time to study the earth?
6. What are the four natural resources mentioned in the film?
7. Discuss some of the issues which relate to groundwater usage.
8. What is the main factor which leads to soil erosion?
9. How do geologists attempt to predict volcanic eruptions?
10. What are the three goals of the Parkfield experiment?
11. Summarize steps we can take to prepare for earthquakes.
12. What earth process is more destructive than volcanoes and earthquakes?
13. Where are many of the earth's major population centers?
14. What is the dual challenge and obligation of modern earth scientists?
15. Why is geology the most important science?

12. Minerals: The Materials of Earth (unit #1)
Minerals have been indispensable to human civilization. This program looks at the variety of minerals, their atomic and crystalline structures, and their physical properties such as hardness and luster. Petrologists' methods of sectioning rocks are shown, and gems, precious metals, ore excavation, and the value of silicates are discussed.

Read the questions first. Then answer them while watching this episode of "Earth Revealed".

1. What five characteristics are required for a substance to be considered a mineral?
2. What are rocks?
3. How are minerals like fossils?
4. What are some of the common rock forming minerals?
5. How can the growth of a mineral be compared to the construction of a block wall?
6. Why is quartz harder than steel?
7. What is cleavage?
8. How does the cleavage of feldspar differ from the cleavage of mica?
9. What is one easy way to distinguish calcite from quartz?
10. What happens when you drop acid on a carbonate mineral (or rock)?
11. What is luster (this is very important)?
12. What is streak?
13. How deep in the crust were the granitics of the Whipple Mountains formed?
14. Discuss diamonds and graphite. What makes them so different?
15. Discuss hydrothermal solutions and the precipitation of metallic minerals.
16. What is the origin on most hydrothermal solutions?
17. Discuss the formation of ore minerals.
18. Discuss the importance of the silicate minerals (also very important)

14. Intrusive Igneous Rocks (Unit #1)
Most magma does not extrude onto Earth's surface but cools slowly deep inside Earth. This magma seeps into crevices in existing rock to form intrusive igneous rocks. Experts provide a graphic illustration of this process and explain the types and textures of rocks such as granite, obsidian, and quartz. Once again, plate tectonics is shown to be involved in the process.

Read the questions first. Then answer them while watching this episode of "Earth Revealed".

1. What factors contribute to the formation of magmas?
2. Discuss in detail the differences between mafic, intermediate, and felsic magmas.
3. How does cooling history relate to the texture of the resulting rock?
4. How do textural variations within the dike illustrate the effect of cooling history?
5. Discuss cooling and the formation of phaneritic, aphanitic, and glassy textures.
6. What is Bowen's Reaction Series and how does it describe magma crystallization?
7. How does water content affect the temperature of crystallization?
8. How does differentiation relate to the evolution of magmas?
9. How does magma composition relate to plate boundaries?
10. Describe the formation of intermediate (andesitic) magmas in subduction zones.
11. Describe granitic (felsic) rocks.
12. What are xenoliths and what do they represent?
13. Discuss the classification of intrusive igneous bodies.
14. Describe the formation of a batholith.
15. How does the study of igneous rocks help in our interpretation of earth history?
16. Compare and contrast igneous rocks found on the continents and ocean floor.
17. What can geologists learn from the study of intrusive igneous rocks?

17. Sedimentary Rocks: (Unit #1)
The Key to Past Environments (Unit #1 and #4) This program returns to the Grand Canyon: its exposed layers of sedimentary rock allow scientists to peer into the geologic past. The movement of sediment and its deposition are covered, and the processes of lithification, compaction, and cementation that produce sedimentary rocks are explained. Organic components of rock are also discussed.

Read the questions first. Then answer them while watching this episode of "Earth Revealed".

1. How many years of earth history are represented in the Grand Canyon?
2. What are sedimentary rocks?
3. How are sediments formed?
4. How do weathering and erosion influence the composition of sediments?
5. Describe mechanical weathering and the formation of clastic sediments.
6. Describe chemical weathering and the formation of solutions.
7. How can sediments be transported?
8. How does energy relate to the transportation and deposition of sediments?
9. Why do you usually find sand at the beach?
10. What is sorting?
11. What are "facies changes" and how do they relate to sedimentary rocks?
12. Describe the process of lithification.
13. Describe chemical sedimentation, and how it takes place in the ocean.
14. What are sedimentary structures, and why are they important?
15. What is a bedding plane, and what do they represent?
16. How is cross-bedding used by geologists to interpret geologic history?
17. Describe the formation of symmetrical and asymmetrical ripple marks.
18. How are sedimentary rocks important to economics?
19. Summarize the geologic history of the Grand Canyon.

18. Metamorphic Rocks (Unit #1)
The weight of a mountain creates enough pressure to recrystallize rock, thus creating metamorphic rocks. This program outlines the recrystallization process and the types of rock it can create — from claystone and slate to schist and garnet-bearing gneiss. The relationship of metamorphic rock to plate tectonics is also covered.

Read the questions first. Then answer them while watching this episode of "Earth Revealed".

1. What happens during metamorphism?
2. What is a protolith?
3. What temperature and pressure ranges are common in metamorphic environments?
4. What is directed pressure and what usually causes it to occur?
5. What happens to minerals as temperature and pressure increase?
6. What is foliation?
7. Why are foliated rocks often unstable when exposed at the surface?
8. Describe temperature increases and recrystallization.
9. What are migmatites and how are they formed?
10. What changes in composition often occur during the metamorphic process?
11. What factors affect the specific changes which take place during metamorphism?
12. Describe contact metamorphism.
13. Describe regional metamorphism.
14. How is metamorphism like cooking (called an "isochemical" process).
15. What are metamorphic facies, and how are they used to decipher geologic history?
16. Describe how metamorphism is a process of continual change.
17. Describe progressive regional metamorphic stages, using claystone as the protolith.
18. Why aren't metamorphic rocks 'unmetamorphosed' as temperatures drop?
19. What types of information are preserved in metamorphic rocks?
20. What is the assumed rate of growth of snowball garnets, and what does this suggest about the metamorphic process?
21. Why are most metamorphic rocks associated with plate boundaries?

Lecture Outlines

Introduction

Earth Science
Learning Objectives:

- List the sciences traditionally included in Earth Science.
- Summarize the early evolution of Earth.
- Describe Earth's "spheres."
- Discuss Earth systems science and earth as a system/
- Summarize some of the relationships between people and the natural environment.
- Describe the nature of scientific inquiry.

Jacob Bronowski
"science is the acceptance of what works and the rejection of what does not"
Scientific Method

Observation
Hypotheses
Test
Acceptance or rejection

Map Review (lecture)
Introduction to Earth Science

I. Earth science
A. Encompasses all sciences that seek to understand
1. Earth
2. Earth's neighbors in space
B. Includes
1. Geology - literally the "study of Earth"
a. Physical geology examines the materials composing Earth
b. Historical geology is the study of the origin and development of Earth
2. Oceanography
a. Not a separate and distinct science
b. Oceanography integrates
1. Chemistry
2. Physics
3. Geology
4. Biology
3. Meteorology - the study of the atmosphere and the processes that produce weather
4. Astronomy - the study of the universe

II. Early evolution of Earth
A. Origin of Earth
1. Most researchers believe that Earth and the other planets formed at essentially the same time from the same primordial material as the Sun
2. Nebular hypothesis
a. Solar system evolved from an enormous rotating cloud called the solar nebula
b. Nebula was composed mostly of hydrogen and helium
c. About 5 billion years ago the nebula began to contract
d. Assumes a flat, disk shape with the protosun (pre-Sun) at the center
e. Inner planets begin to form from metallic and rocky clumps of substances with high melting points
f. Larger outer planets began forming from fragments with a high percentage of ices - water, carbon dioxide, ammonia, and methane
B. Formation of Earth's layered structure
1. As Earth formed, the decay of radioactive elements and heat from high-velocity impacts caused the temperature to increase
a. Iron and nickel began to melt and sink toward the center
b. Lighter rocky components floated outward, toward the surface
2. Gaseous material escaped from Earth's interior to produce the primitive atmosphere

III. Earth's "spheres"
A. Hydrosphere
1. Ocean – the most prominent feature of the hydrosphere
a. Nearly 71% of Earth's surface
b. About 97% of Earth's water
2. Also includes fresh water found in streams, lakes, and glaciers, as well as that found underground
B. Atmosphere
1. Thin, tenuous blanket of air
2. One half lies below 5.6 kilometers (3.5 miles)
C. Biosphere
1. Includes all life
2. Concentrated near the surface in a zone that extends from the ocean floor upward for several kilometers into the atmosphere
3. Influences other three spheres
D. Solid Earth
1. Based on compositional differences, it consists of
a. Core
b. Mantle
c. Crust
2. Divisions of outer portion based on how materials behave
a. Lithosphere - rigid outer layer
1. Crust
2. Uppermost mantle
b. Divisions of Earth's surface
1. Continents
2. Ocean Basins

IV. Earth system science
A. Earth is a dynamic body with many separate but highly interacting parts or spheres
B. Earth system science studies Earth as a system composed of numerous parts, or subsystems
C. System - any size group of interacting parts that form a complex whole
1. Closed systems are self contained (e.g. an automobile cooling system)
2. Open systems - both energy and matter flow into and out of the system (e.g. a river system)
D. Feedback mechanisms
1. Negative feedback mechanisms resist change and stabilize the system
2. Posit feedback mechanisms enhance the system
E. Earth as a system
1. Consists of a nearly endless array of subsystems (e.g. hydrologic cycle)
2. Sources of energy
a. Sun – drives external processes
1. Weather and climate
2. Ocean circulation
3. Erosional processes
b. Earth's interior – drives internal processes
1. Volcanoes
2. Earthquakes
3. Mountains
3.Humans are part of the Earth system

V. People and the environment
A. Environment
1. Surrounds and influences organisms
2. Physical environment encompasses
a. Water
b. Air
c. Soil
d. Rock
3.Term "environmental" is usually reserved for those aspects that focus on the relationships between people and the natural environment
B. Resources
1. An important focus of the Earth sciences
2. Include
a. Water
b. Soil
c. Minerals
d. Energy
3. Two broad categories
a. Renewable
1. Can be replenished
2. Examples include
a. Plants
b. Energy from flowing water and wind
b. Nonrenewable
1. Fixed quantities
2. Examples
a. Metals
b. Fuels

C. Population
    1. Population of the planet is growing rapidly
    2. Rate of mineral and energy usage has climbed more rapidly than the overall growth of population
  D. Environmental problems
    1. Local, regional, and global
    2. Human-induced and accentuated
        a. Urban air pollution
        b. Acid rain
        c. Ozone depletion
        d. Global warming
    3. Natural hazards
        a. Earthquakes
        b. Landslides
        c. Floods
        d. Hurricanes
    4. World population pressures

VI. Scientific inquiry
  A. Science assumes the natural world is
    1. Consistent
    2. Predictable
  B. Goal of science
    1. To discover patterns in nature, and
    2. To use the knowledge to predict
  C. An idea can become a
    1. Hypothesis (tentative or untested explanation)
    2. Theory (tested and confirmed hypothesis)
    3. Paradigm (a theory that explains a large number of interrelated aspects of the natural world)
  D. Scientific method
    1. Gather facts through observation
    2. Formulate
        a. Hypotheses
        b. Theories
  E. Scientific knowledge is gained through
    1. Following systematic steps
        a. Collecting facts
        b. Developing a hypothesis
        c. Conduct experiments
        d. Reexamine the hypothesis and
            1. Accept
            2. Modify
            3. Reject
        2. Theories that withstand examination
    3. Totally unexpected occurrences

Chapter 2 Minerals: Building blocks of Rocks
Learning Objectives

- Explain the difference between a mineral and a rock.
- Describe the basic structure of an atom and explain how atoms combine.
- List the most important elements that compose Earth's continental crust.
- Explain isotopes and radioactive decay
- Describe the physical properties of minerals and how they can be used for mineral identification.
- List the basic composition an d structures of the silicate minerals.
- List the economic use of some nonsilicate minerals.
- Distinguish between mineral resources, reserves and ores.

Minerals: Building Blocks of Rocks

I. Minerals: the building blocks of rocks
  A. Mineral definition
    1. Naturally occurring
    2. Inorganic
    3. Solid
    4. Possess an orderly internal structure of atoms
    4. Have a definite chemical composition
  B. Mineraloid - lacks an orderly internal structure
  C. Rocks are aggregates (mixtures) of minerals

II. Composition and structure of minerals
  A. Elements
    1. Basic building blocks of minerals
    2. Over 100 are known
  B. Atoms
    1. Smallest particles of matter
    2. Have all the characteristics of an element

III. How atoms are constructed
  A. Nucleus, which contains
    1. Protons B positive electrical charges
    2. Neutrons B neutral electrical charges
  B. Energy levels, or shells
    1. Surround nucleus
    2. Contain electrons B negative electrical charges
  C. Atomic number is the number of protons in an atom's nucleus
  D. Bonding of atoms
    1. Forms a compound with two or more elements
    2. Ions are atoms that gain or lose electrons
  E. Isotopes
    1. Have varying number of neutrons
    2. Have different mass numbers B the sum of the neutrons plus protons
    3. Many isotopes are radioactive and emit energy and particles

IV. Minerals
- A. Properties of minerals
  1. Crystal form
  2. Luster
  3. Color
  4. Streak
  5. Hardness
  6. Cleavage
  7. Fracture
  8. Specific gravity
  9. Other properties
     a. Taste
     b. Smell
     c. Elasticity
     d. Malleability
     e. Feel
     f. Magnetism
     g. Double refraction
     h. Reaction to hydrochloric acid
- B. A few dozen minerals are called the rock-forming minerals
  1. The eight elements that compose most rock-forming minerals are
     a. Oxygen (O)
     b. Silicon (Si)
     c. Aluminum (Al)
     d. Iron (Fe)
     e. Calcium (Ca)
     f. Sodium (Na)
     g. Potassium (K)
     h. Magnesium (Mg)
  2. Most abundant atoms in Earth's crust are
     a. Oxygen (46.6% by weight)
     b. Silicon (27.7% by weight)
- C. Mineral groups
  1. Rock-forming silicates
     a. Most common mineral group
     b. Contain the silicon-oxygen tetrahedron
        1. Four oxygen atoms surrounding a much smaller silicon atom
        2. Millions join together in a variety of ways
     c. Groups based upon tetrahedron arrangement
        1. Olivine B independent tetrahedron
        2. Pyroxene group B tetrahedron are arranged in chains
        3. Amphibole group B tetrahedron are arranged in double chains
        4. Micas
           a. Tetrahedron are arranged in sheets
           b. Two types of mica
              1. Biotite (dark) and
              2. Muscovite (light)
        5. Feldspars
           a. Three-dimensional network of tetrahedron
           b. Two types of feldspars
              1. Orthoclase and
              2. Plagioclase

6. Quartz B three-dimensional network of tetrahedron
d. Feldspars are the most plentiful mineral group
e. Crystallize from molten material
2. Nonsilicate minerals
a. Major groups
1. Oxides
2. Sulfides
3. Sulfates
4. Halides
5. Carbonates
6. "Native" elements
b. Carbonates
1. A major rock-forming group
2. Found in the rocks limestone and marble
c. Halite and gypsum are found in sedimentary rocks
d. Many have economic value
D. Mineral resources
1. Reserves are already identified deposits
2. Ores are useful metallic minerals that can be mined at a profit
3. Economic factors may change and influence a resource

Chapter #3 Rocks: Materials of the Solid Earth

Learning Objectives:

- Diagram and discuss the rock cycle.
- List the geologic processes involved in the formation of each rock group.
- Briefly explain crystallization of Magma.
- List the criteria used to classify igneous rocks.
- List the manes, textures, and environments of formation for the most common igneous rocks.
- Discuss the origin of materials that accumulate as sediment.
- List the criteria used to classify sedimentary rocks.
- Explain the difference between detrital and chemical sedimentary rocks.
- List the names, textures, and environments of formation for the most common sedimentary rocks.
- List the common features of sedimentary rocks.
- Describe the agents of metamorphism.
- List the criteria used to classify metamorphic rocks.
- List the names, textures, and environments of formation for the most common metamorphic rocks.
- Discuss metallic and nonmetallic mineral resources.

Rocks: Materials of the Solid Earth

I. Rock cycle
- A. Shows the interrelationships among the three rock types
- B. Earth as a system: the rock cycle
  1. Magma
     - a. Crystallization
  2. Igneous rock
     - a. Weathering
     - b. Transportation
     - c. Deposition
  3. Sediment
     - a. Lithification
  4. Sedimentary rock
     - a. Metamorphism
  5. Metamorphic rock
     - a. Melting
  6. Magma
- C. Full cycle does not always take place due to "shortcuts" or interruptions
  1. e.g., Sedimentary rock melts
  2. e.g., Igneous rock is metamorphosed
  3. e.g. Sedimentary rock is weathered
  4. e.g., Metamorphic rock weathers

II. Igneous rocks
- A. Form as magma cools and crystallizes
  1. Rocks formed inside Earth are called plutonic or intrusive rocks
  2. Rocks formed on the surface
     - a. Formed from lava (a material similar to magma, but without gas)
     - b. Called volcanic or extrusive rocks
- B. Crystallization of magma
  1. Ions are arranged into orderly patterns
  2. Crystal size is determined by the rate of cooling
     - a. Slow rate forms large crystals
     - b. Fast rate forms microscopic crystals
     - c. Very fast rate forms glass
- C. Classification is based on the rock's texture and mineral constituents
  1. Texture
     - a. Size and arrangement of crystals
     - b. Types
       1. Fine-grained B fast rate of cooling
       2. Coarse-grained B slow rate of cooling
       3. Porphyritic (two crystal sizes) B two rates of cooling
       4. Glassy B very fast rate of cooling
  2. Mineral composition
     - a. Explained by Bowen's reaction series which shows the order of mineral crystallization
     - b. Influenced by crystal settling in the magma
- D. Naming igneous rocks
  1. Granitic rocks
     - a. Composed almost entirely of light-colored silicates - quartz and feldspar
     - b. Also referred to as felsic: *fe*ldspar and *si*lica (quartz)

c. High silica content (about 70 percent)
d. Common rock is granite

2. Basaltic rocks
a. Contain substantial dark silicate minerals and calcium-rich plagioclase feldspar
b. Also referred to as mafic: *ma*gnesium and *f*errum (iron)
c. Common rock is basalt

3. Other compositional groups
a. Andesitic (or intermediate)
b. Ultramafic

III. Sedimentary rocks
A. Form from sediment (weathered products
B. About 75% of all rock outcrops on the continents
C. Used to reconstruct much of Earth's history
1. Clues to past environments
2. Provide information about sediment transport
3. Rocks often contain fossils

D. Economic importance
1. Coal
2. Petroleum and natural gas
3. Sources of iron and aluminum

E. Classifying sedimentary rocks
1. Two groups based on the source of the material
a. Detrital rocks
1. Material is solid particles
2. Classified by particle size
3. Common rocks are
a. Shale (most abundant)
b. Sandstone
c. Conglomerate
d. Siltstone

b. Chemical rocks
1. Derived from material that was once in solution and precipitates to form sediment
a. Directly precipitated as the result of physical processes, or
b. Through life processes (biochemical origin)

2. Common sedimentary rocks
a. Limestone B the most abundant chemical rock
1. Coquina
2. Chalk
3. Travertine

c. Microcrystalline quartz (precipitated quartz)
1. Chert
2. Flint
3. Jasper
4. Agate

d. Evaporites
1. Rock salt
2. Gypsum

e. Coal
1. Lignite
2. Bituminous

F. Produced through lithification
    1. Loose sediments are transformed into solid rock
    2. Lithification processes
        a. Compaction
        b. Cementation by the materials
            1. Calcite
            2. Silica
            3. Iron oxide
G. Features
    1. Strata, or beds (most characteristic)
    2. Bedding planes separate strata
    3. Fossils
        a. Traces or remains of prehistoric life
        b. Are the most important inclusions
        c. Help determine past environments
        d. Used as time indicators
        e. Used for matching rocks from different places

IV. Metamorphic rocks
A. "Changed form" rocks
B. Produced from preexisting
    1. Igneous rocks
    2. Sedimentary rocks
    3. Other metamorphic rocks
C. Metamorphism
    1.Takes place where preexisting rock is subject to temperatures and pressures unlike those in which it formed
    2. Degrees of metamorphism
        a. Show in the rock's texture and mineralogy
        b. Types
            1. Low-grade (e.g., shale becomes slate)
            2. High-grade (causes the original features to be obliterated)
D. Metamorphic settings
    1. Contact, or thermal, metamorphism
        a. Near a mass of magma
        b. Change is driven by a rise in temperature
    2. Regional metamorphism
        a. Directed pressures and high temperatures during mountain building
        b. Produces the greatest volume of metamorphic rock
E. Metamorphic agents
    1. Heat
    2. Pressure (stress)
        a. From burial (confining pressure)
        b. From differential stress during mountain building
    3. Chemically active fluids
        a. Mainly water and other volatiles
        b. Promote recrystallization by enhancing ion migration
F. Metamorphic textures
    1. Foliated texture
        a. Minerals are in a parallel alignment
        b. Minerals are perpendicular to the compressional force
    2. Nonfoliated texture

a. Contain equidimensional crystals
b. Resembles a coarse-grained igneous rock

G. Common metamorphic rocks
1. Foliated rocks
a. Slate
1. Fine-grained
2. Splits easily
b. Schists
1. Strongly foliated
2. "Platy"
3. Types based on composition (e.g., mica schist)
c. Gneiss
1. Strong segregation of silicate minerals
2. "Banded" texture
2. Nonfoliated rocks
a. Marble
1. Parent rock B limestone
2. Large, interlocking calcite crystals
3. Used as a building stone
4. Variety of colors
b. Quartzite
1. Parent rock B quartz sandstone
2. Quartz grains are fused

V. Resources from rocks and minerals
A. Metallic mineral resources
1. e.g., Gold, silver, copper, mercury, lead
2. Concentrations of desirable materials are produced by
a. Igneous processes
b. Metamorphic processes
3. Most important ore deposits are generated from hydrothermal (hot-water) solutions
a. Hot
b. Contain metal-rich fluids
c. Associated with cooling magma bodies
d. Types of deposits include
1. Vein deposits in fractures or bedding planes, and
2. Disseminated deposits which are distributed throughout the rock
B. Nonmetallic mineral resources
1. Make use of the material=s
a. Nonmetallic elements
b. Physical or chemical properties
2. Two broad groups
a. Building materials (e.g., limestone, gypsum)
b. Industrial minerals (e.g., flourite, corundum, sylvite)