

Study Guide # 4

THE EARTH AS A SYSTEM

THE SCIENCE OF PLATE TECTONICS

FROM THE CENTER TOWARD THE WHOLE of Geology

GenSci 102 - Environment Earth

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TOPICS TO BE COVERED **AND GENERAL OBJECTIVES**

During this section we will cover the following topics in lecture and related laboratory investigations:

1. The principles of structural geology.
2. Structure of the earth.
3. The Wilson Cycle.
4. Plate Tectonics and the Plate Tectonic Rock Cycle.
5. Geological Evolution of Virginia
6. The Gaia Hypothesis and the concept of the earth as a total system.

I hope you will gain an appreciation for the extremely dynamic nature of the forces operating on and within the earth, and for the persistence with which these forces have operated throughout geologic time. What is more important is our increasing realization that these forces are not random but have universal patterns at every scale of observation and these reflect some deeper meaning to the history and function of the earth. Furthermore, these patterns can be understood by studying the processes and relationships among specific kinds of rock, and the interrelationship between biological processes and earth processes.

Specifically you should be able to answer questions on the following [some maybe combined into one question on the test.] Also, any of these may be worded as Accept/Reject critical reasoning problems.

THE PRINCIPLES OF STRUCTURAL GEOLOGY

1. Distinguish between **stress** and **strain**.

2. Distinguish between *elastic deformation, plastic deformation, and rupture, by giving a written definition, by illustrating them on a stress-strain diagram, and by giving an everyday example.*
3. Distinguish between ductile and brittle substances and explain how each undergoes rupture.
4. List and explain the ways in which confining pressure, temperature, solutions, and time affect the strength and deformation of materials, and be able to apply these concepts to rock deformation.
5. For the plastic strains in the Earth's crust:
 - A. List and draw a simple sketch of the basic kinds of folds: monocline, anticline, and syncline, and place fold nomenclature [axial plain, crest, flank] on them.
 - B. Distinguish between symmetrical, asymmetrical, overturned, recumbent, and complex folds and arrange them in order of increasing intensity of deformation.
 - C. Define in writing and with a drawing what a plunging anticline and plunging syncline is.
6. For Rupture in the Earth's crust:
 - A. Describe the difference between joints and faults.
 - B. Draw or interpret block diagrams illustrating the differences between: Vertical, Normal, Reverse, Thrust, Right and Left Lateral, [Right and Left Strike-slip], Transform, and various Oblique faults.
 - C. Specifically for thrust faults, draw, label, and/or recognize the two kinds of thrust faults and describe the processes by which they form.
 - D. Draw diagrams of or describe in writing the meaning of the following: horst, graben, and imbricated faults.
7. Draw an example of, and describe the origin and significance of, the angular unconformity, nonconformity, and disconformity.
8. Given a cross section of a portion of the earth's crust be able to arrange the geologic events in sequential order, and/or give the evidence for the order of events.
9. Given a geologic map, be able to draw a correct cross section.

STRUCTURE OF THE EARTH

10. Completely label a cross section of the earth showing the inner core, outer core, lower mantle, asthenosphere, and lithosphere. Be able to identify the rock types associated with each (see *Major Structural Divisions of the Earth's Interior*).

11. Completely label a cross section of the crust and upper mantle of the earth showing all the major divisions [e.g. oceanic crust, continental crust, mantle, asthenosphere, lithosphere, Moho], thicknesses, and rock types typically found in each (see *Structure of the Earth, Lithosphere and Asthenosphere*).
12. Completely label a cross section of the earth's lithosphere illustrating the three types of plate boundaries and all the plate tectonic components and associations listed in the table below. Be able to explain exactly what can and cannot compose a plate (see *The Variety of Plate Boundaries and Inter-Plate Relationships Defined by Plate Tectonic Theory*).

Backarc Basins	Forelands	Subduction zones
Continent-Continent collision	Hinterlands	Suture zones
Convergent boundaries	Marginal Basins	Terranes
Cordilleran Orogenies	Microcontinent	Transform fault
Cratons	Remnant ocean basins	Volcanic arcs
Divergent plate boundaries	Rift plate boundary	
Divergent Continental Margin	Rift valleys	

THE WILSON CYCLE

13. Write a description of the Wilson Cycle, AND/OR
 - A. Given a selected and randomly arranged series of the cross sections from the class handout, arrange them in sequential order.
 - B. Be able to unambiguously label these sketches with the features in the table in the previous question, and in the table below.

Horsts	Blueschist metamorphism
Grabens	Eclogite metamorphism
Batholiths	All types of igneous activity
Metamorphic facies (all)	

PLATE TECTONICS AND THE PLATE TECTONIC ROCK CYCLE

14. For each of the stages of the Wilson cycle we studied in more detail [listed below], do the following:
 - A. Concisely describe the sequence of geologic *processes* occurring, including typical rocks and structures formed.
 - B. Given a blank copy of any drawing used in class, completely label it with the rocks and geologic features created by the processes.

- └ *Volcanic Arc Systems* and *The Origin of Protocontinents*.
- └ *Features of an Intraoceanic Subduction Orogeny*
- └ The Basic Kinds of Orogenies.
- └ History of Divergent Plate Boundaries and the opening of a new ocean basin.
- └ Generation of the ophiolite suite and creation of oceanic lithosphere.
- └ Stages in a Continent-Continent Collision Orogeny

15. Provide a concise, definitive written description of what Plate Tectonic Theory is, and an explanation of how it works, in terms a layman would understand.
16. For a Plate Tectonic Rock Cycle:
1. The rock cycle begins with an assumption that in the beginning the crust of the earth was composed almost exclusively of a mafic parent rock. Explain the basis of that assumption.
 2. Beginning with an original crust of the parent mafic magma, draw a diagram illustrating the Plate Tectonic Rock Cycle sequence by which we were able to evolve the following rocks from an original parent rock:

Igneous	Sedimentary	Metamorphic
Anorthosite	Arkosic sediments	Blueschist [melange]
Felsic	Carbonates	Eclogite
Intermediate	Lithic sediments	Migmatite
Mafic	Quartz sediments	Regional [all facies]
Ultramafic	Shale	

3. Be able to relate any of these rocks or any part of the Plate Tectonic Rock Cycle to the specific Wilson Cycle stages which generate them.¹

Geologic Evolution of Virginia

The geology of the Mid-Atlantic Region and New England is some of the most complex and fascinating in North America. The geology of Virginia in particular contains evidence for one complete Wilson cycle, and parts of at least two others, and all of it is accessible within a two hour drive of Harrisonburg. In our review of this geology we did not begin to explore some of the fascinating things available, but it is enough to realize that geology and earth history is not something that happens somewhere else, it is right here in our own back

¹ In class we related these to specific stages in the Wilson Cycle, but you should be able to relate any part of the Plate Tectonic Rock Cycle, or any rock in the cycle, to any comparable plate tectonic situation. That is, it is not important that you remember that a particular rock formed in "Stage F" of the Wilson Cycle, but that you recognize the processes and rocks associated with particular tectonic situations and be able to relate that to a specific rock.

yards. I do not want to belabor this, but I do want you to have some familiarity with these events.

17. List in order, or recognize, or arrange the sequence of events in Virginia's (and surrounding states) geologic evolution (see *Short Geologic History of Virginia*.)
18. Describe either in plate tectonic terms, or in terms of the Wilson cycle stages, what each of these event in the geologic evolution represents.
19. Explain the processes by which each orogeny occurred, and where the mountain and foreland basin was located.
20. Recognize, or locate the five physiographic provinces on a map, diagram, or photograph.
21. Describe the kinds of rocks and the structural features characteristic of each physiographic province.

THE EVOLUTION BETWEEN LIFE AND EARTH

The earth is a unique planet, and differs dramatically from the other planets in that it is still geologically active, posses abundant liquid water, and is pervaded by life. Is there any relationship among these three features, or are their relationships accidental?

Believe it or not, this is a subject of deep controversy within science with some arguing that these three are only accidently related to each other, and others arguing that they are deeply connected. I learn more toward the latter position than the former, but at this point in time the positions each person holds seems based more on some deep, intuitive feeling than on hard evidence. Oh, each side will be able to give you rationale arguments and evidence, but when it all boils down, we are still too ignorant of the world to make definitive statements with confidence.

So, taking this class from another person would likely give you a very different view and argument. Yet, I am influenced by a systems view of nature, the idea that all things are connected to other things in their environment by a complex system of positive and negative feedbacks, and that these feedbacks have strong influences in both directions. That is, the physical, chemical and biological evolution of the Earth are all connected, and are the way they are today because of their interactions. Today, this is referred to as the Gaia Hypothesis, and even though it is quite controversial, I present it primarily because it does represent a systems view of looking at the earth.

22. Distinguish between fractionating and elaborating evolutionary attractors by describing the properties of each, and giving a definitive example.

23. Compare and contrast the atmospheric compositions, surface temperatures, and atmospheric pressures among Venus, Earth, and Mars.
 24. Describe how the Earth's present atmosphere would change if life were removed.
 25. Understand and present an argument for how Venus and Mars likely lost their early supply of water.
 26. Distinguish between Prokaryotes and Eukaryotes, and between Monera and Protista (Protoctista).
 27. Explain what symbiosis is, and the role it has played in the evolution of life.
 28. Explain what the extremophiles are, where they lie on the universal tree of life, where they live (in the past and present), and how they go about making a living.
 29. For each of the monera organisms listed below (in alphabetical order):
 - L Desulfovibrios
 - L Green and Purple Sulfur bacteria
 - L Precursor Blue Green Algae
 - L Blue Green Algae
 - L Extremophiles (Methanogens)
- Be able to do the following:
- L Arrange them in their evolutionary sequence.
 - L Recognize chemical formulas of their basic biochemical reactions (I will not ask you to reproduce these formulas, but you must be able to distinguish among them and assign them to their proper group.)
 - L State the products they take in and the wastes they produce.

THE GAIA HYPOTHESIS

THE RELATIONSHIP BETWEEN LIFE AND EARTH

30. Explain, describe, recognize, or evaluate what it is that the Gaia hypothesis says, and just as important what it does not say - since there has been much distortion of Lovelock and Margulis's basic concept.) {If you want a nice, straight forward, not too long source of information on the Gaia hypothesis see the web page: }
http://magna.com.au/~prfbrown/gaia_jim.html
31. List or describe some proposed Gaian effects.

32. Explain or recognize the teleological criticism of the Gaia hypothesis, and Lovelock's response to it.
33. Distinguish between Strong Gaia and Weak Gaia.
34. Describe the function of the Daisyworld models.
[A] Be able to read, describe, and interpret any Daisyworld diagram discussed in class.
[B] Describe and explain the factors to which Lovelock attributes the ecological stability of Daisyworld models.
35. Given a "Model of the Archean Before and after life following Daisyworld models," and "Model of the transition from the Archean to the Proterozoic," describe the events and cause-effect relationships described by the model and their importance for the evolution of the earth.

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