

May 1999 Version: Study Guide # 3

THE ROCK CYCLE: PART TWO

THE CENTER OF GEOLOGY

(SEDIMENTARY AND METAMORPHIC ROCKS, AND THE ROCK CYCLE)

*GenSci 102 - Environment: Earth
Lynn S. Fichter
Department of Geology and Environmental Sciences
James Madison University*

GENERAL OBJECTIVES:

In The Rock Cycle - Part One (Minerals and Igneous Rocks) the foundation was laid that the earth is the result of the cyclical transformations of MATTER by the dissipation of ENERGY. In Part Two we continue this theme in the study of Sedimentary and Metamorphic rocks. Again we see that what is important for scientific understanding is understanding *processes*, the transformations which take place through the positive and negative feedback in the system. It is a theme that we explore all semester.

As a preparation for this section you should return to Study Guide: Part One and review the Topics to be Covered and General Objectives. Those concepts need to be clear in your mind in order to understand and appreciate the framework in which our continuing study takes place.

TOPICS TO BE COVERED

The main focus of this section is the study of sedimentary and metamorphic rocks. With these rocks we span the extreme of conditions and processes from those at the earth's surface where we are comfortable, to those deep inside the earth where we would be very uncomfortable.

We end with the Rock Cycle, the central theory in geology. It describes how all the earth's minerals and rocks are related and can be transformed from one to the other. It also contains all the

percepts (observations) and concepts which explain how all these transformations take place, and how all this has been demonstrated to be scientific truth (small "t", mind you).

Specifically you should be able to:

On the exam you should be able to demonstrate your understanding of sedimentary and metamorphic processes and the rock cycle by intelligently providing answers to the questions below. Note that in a test question two or more of these may be combined in one question.

Note that these guides are often stated as if you should be able to do something, write something, explain something. This is in fact a good way to study. If you can understand these ideas well enough to explain them, as if to someone else if not yourself, then you will do ok. Also, remember that test questions commonly ask you to identify, recognize, or interpret diagrams and illustrations in the Lecture Notebook.

SEDIMENTARY ROCKS

PRINCIPLES OF SEDIMENTARY ROCK INTERPRETATION

1. Understand the quintessential characteristics of sedimentary rock interpretation by doing the following:
 - A. State the basic principle of mineral/rock stability which is the basis of rock formation and interpretation.
 - B. Reproduce the Simple Ideal Model for the Origin of Sedimentary Rocks. Include a definitive written explanation of the processes operating at each stage of the model to result in three end member weathering products (attractors), deposited in separate environments.
 - C. Explain the simple ideal model in terms of complexity theory and attractors.

ROCK WEATHERING

2. Outline the weathering processes and their products by doing the following:
 - A. List the mechanisms of **mechanical weathering** including a brief [but definitive] explanation of how each works, and the products which result.
 - B. List the mechanisms of **chemical weathering** (solution, oxidation, dissolution, hydrolysis) giving an example of each (you should be able to recognize the chemical formulas we discussed, and the type of weathering they represent) (*note that, as always, on a test you can assume that any formulas I give you are correct; part of a test is not evaluating whether a formula is technically correct, but recognizing what it represents is*).

C. Be able to answer the questions in the lecture handout The Bulk Chemistry of Rocks explaining the fate of the following cations and anions produced during weathering:

- | | | |
|--|---|---|
| <input type="checkbox"/> Silicon [Si] | <input type="checkbox"/> Potassium [K] | <input type="checkbox"/> Calcium [Ca] |
| <input type="checkbox"/> Aluminum [Al] | <input type="checkbox"/> Ferrous iron [Fe ⁺²] | <input type="checkbox"/> Magnesium [Mg] |
| <input type="checkbox"/> Sodium [Na] | <input type="checkbox"/> Ferric iron [Fe ⁺³] | |

3. Sedimentary Fractionation Processes: be able to place the various weathering cations and anions on Bowen's Reaction Series, and explain how the weathering/ transportation processes lead to fractionation (see *The Fractionation of Sedimentary Rocks Through Weathering and Transportation*.)

Sedimentary Rock Classification

4. List, briefly explain, and justify to a skeptic the criteria of a good classification.
5. For the Ternary Classification of Siliciclastic rocks do any of the following.
- A. Plot any composition on any ternary diagram, **OR** list the percentage composition of any given point on any ternary diagram.
 - B. Describe and explain the strategy by which sedimentary rock names are constructed from the empirical observations of their composition.
 - C. Given a blank ternary QFL, or Sand¹/Silt/Clay, or Quartz/Feldspar-lithic/Matrix (Q/FL/M) diagram [i.e. only the apexes are labeled]:
 - ☛ Illustrate the basic classification of clastic rocks by naming and describing the composition of any rock of any composition plotted in any or every field of the ternary diagram,
 - ☛ OR, given a written description or name of any sedimentary rock accurately plot it on an appropriate ternary diagram.

The Multiple Cycle Evolution of Sedimentary Rocks

6. Given any part of the evolutionary diagram *The Multiple Cycle Evolution of Sedimentary Rocks* from the notebook, be able to plot out, or recognize, the evolutionary transitions on any of the diagrams beginning with any starting percent composition and ending with any other percent composition.

¹ Remember that the sand apex of the triangle can also be a conglomerate or breccia apex depending on the composition of the rock.

7. Define sediment maturity, identify the maturity of specific rock types by name or on a ternary diagram, and explain how and why sediment maturity fits into our concepts of attractors.

DEPOSITIONAL ENVIRONMENTS

8. Explain the characteristics of depositional environments by doing the following:
- A. Explain what, in geological terms, a depositional environment is [e.g. not a place or thing].
 - B. Explain the kinds of energy depositional environments dissipate, and how specifically gravitational and solar energy is distributed among different depositional environments.
 - C. Recognize on, or label a diagram showing the source-land to basin location and proximal to distal relationships among the common depositional environments² [alluvial fan, braided river, meandering river, delta complex, beach [+barrier island/lagoon], tidal flat, shelf, submarine fan [including the feeder channel], and basin].
 - D. Describe the typical energies being dissipated in each environment.
 - E. Distinguish between **short** and **long** depositional **systems** providing or recognizing typical examples of each, including the tectonic regimes in which each typically forms.

SEDIMENTARY ROCK EVOLUTION AND ITS TECTONIC SIGNIFICANCE

9. Given a blank version of the model *The Evolution of Sedimentary Rocks and Depositional Environment*, be able to fill it out showing the position of rock types and depositional environments at each stage in the model.
10. Discuss or answer questions about the model for *The Evolution of Sedimentary Rocks and Depositional Environment*, including:
- A. The changes which occur in a sediment as it is transported downstream, and the processes of change.
 - B. The influence of source rock composition on the evolution of a sediment.
 - C. Sediment maturity, how it is measured [be precise and accurate], examples of rocks of different maturity, and how sediments evolve from one maturity to another.

² You must be sure to have the proximal [close to the source land] to distal [far away from the source land] sequence of environments in the right order. The environmental sequence is never rearranged so that an environment farther downstream comes before one normally upstream of it in the sequence. It is possible, however, for environments to be missing from the sequence; in fact this is a common occurrence.

- D. The relationships between sediment rock evolution and depositional environment evolution.
- E. Being able to use, interpret or draw the variety of ternary diagrams associated with the model for the evolution of sedimentary rocks to show how sediments evolve on a ternary diagram during their transport downstream.
11. On a Q/FL/Matrix ternary diagram:
- A. Plot the position of typical phaneritic mafic (e.g. gabbro) and felsic (e.g. granodiorite) igneous rocks.
- B. Illustrate and/or explain in writing the weathering/transportation evolutionary history of these rocks.
- C. Discuss the processes occurring in terms of sediment maturity and attractors.
12. Identify on a QFL diagram the distribution of sedimentary rocks associated with the tectonic regimes listed below. Be able to argue why each field plots where it does by arguing the composition of the sourceland rocks, and the processes by which the sediments from those sourceland rocks got their position on the QFL.
- Craton Block faulted continent
- Volcanic arc Recycled orogen

METAMORPHIC ROCKS

DIAGENETIC AND METAMORPHIC PROCESSES

13. Describe the underlying principle responsible for the processes of diagenesis and metamorphism? [It's the same principle as for weathering].
14. Describe or define what diagenesis is and discuss the processes by which it occurs.
15. Describe or define what metamorphism is.
- A. List and describe the processes and mechanisms by which metamorphism occurs, including:
- ⇒ Heat, and its various sources.
 - ⇒ Pressure, the different kinds, and the effects of each.

- ⇒ Chemically active fluids. Fluids are particularly important, so be able to discuss their significance relative to the following:
- ☞ Pores and intergranular fluids.
 - ☞ Under prograde conditions.
 - ☞ Under retrograde conditions.
- B. Migmatites are particularly instructive about the processes of both metamorphic and igneous rock generation.
- ☞ Define or describe what a migmatite is.
 - ☞ Describe the conditions necessary for their formation and the processes by which they form.
 - ☞ Describe the significance of migmatites for igneous processes.
- C. In your discussions of the above processes use or apply where appropriate the following concepts:
- | | |
|--|---|
| <input type="checkbox"/> Geothermal gradient
<input type="checkbox"/> Directed stress
<input type="checkbox"/> Hydrostatic stress
<input type="checkbox"/> Country rock | <input type="checkbox"/> Metamorphic grade
<input type="checkbox"/> Prograde metamorphism
<input type="checkbox"/> Retrograde metamorphism
<input type="checkbox"/> Fractional melting |
|--|---|

Kinds of METAMORPHISM

16. Distinguish among Zeolite, Contact, Barrovian, Blueschist, and Hydrothermal metamorphism by doing the following:
- A. Given a T/P phase diagram label the distribution of each, and provide a written description of the conditions under which each occurs.
- B. In your discussions of the above use or apply where appropriate the following concepts:
- | | |
|--|---|
| <input type="checkbox"/> Geothermal gradient
<input type="checkbox"/> Metamorphic grade
<input type="checkbox"/> Metamorphic facies
<input type="checkbox"/> Kilobars | <input type="checkbox"/> Country rock
<input type="checkbox"/> Prograde metamorphism
<input type="checkbox"/> Retrograde metamorphism |
|--|---|

Classification of METAMORPHIC ROCKS

17. Metamorphic rock classification is particularly difficult, and it is very hard to satisfy the criteria of a good classification. List, describe, or recognize why metamorphic rock classification is difficult.
18. Metamorphic rocks can be initially divided into two categories, Foliated and Non-foliated. Be able to write a statement or solve a problem clearly distinguishing between these. In your discussions use or apply where appropriate the following concepts:
- | | |
|--|--|
| <input type="checkbox"/> Parent composition
<input type="checkbox"/> New metamorphic minerals generated | <input type="checkbox"/> Varieties of Texture
<input type="checkbox"/> Typical examples
<input type="checkbox"/> Types of metamorphism |
|--|--|
19. One of the most important aspects of foliated metamorphic rocks is their textural response to the processes of metamorphism. Be able to describe, define or distinguish among the following.
- | | |
|---|--|
| <input type="checkbox"/> Foliation
<input type="checkbox"/> Slaty cleavage | <input type="checkbox"/> Schistosity
<input type="checkbox"/> Mineral banding |
|---|--|
20. For Regional [Barrovian] metamorphism be able to intelligently discuss or answer questions for each of the following parent rocks:
- ▶ 1 Shale, 2 Mafic igneous rock, 3 Felsic igneous rock.
 - ⇒ The sequence of textural changes beginning with the parent and ending with a magma.
 - ⇒ The sequence of mineral changes, underscoring [where appropriate] the index minerals [be able to list them in order].
 - ⇒ **Metamorphic zones** [where appropriate; be able to list them in order from low to medium to high].
 - ⇒ **Metamorphic facies** [why do we use two measures of metamorphism, facies and zones?].
 - ⇒ In your discussions of the above be able to use or apply where appropriate any of the other metamorphic concepts in the guides above necessary to explain the processes occurring.

22. For Hydrothermal metamorphism be able to discuss or answers questions:
- The various conditions under which it occurs.
 - The effect on mafic rocks.
 - Metasomatic mineralization

METAMORPHISM AND TECTONICS

23. Given a cross section of a portion of the earth's crust, identify the locations various kinds of metamorphic processes are typically found [see The Geological Circumstances Under Which Various Kinds of Metamorphism Occur in lecture notebook]. Be able to relate this to the T/P phase diagram.

The Rock Cycle

24. Be able to draw a complete Rock Cycle showing all the major steps in the cyclical evolution of the earth's rocks, and write [in terms someone who thinks your crazy for taking this class would understand] a quintessential, brilliantly clear description of what is happening at each step.
25. Write a statement or answer questions which explain or describe the rock cycle in terms of chaos/complexity theory, dissipative structures, local attractors, evolutionary attractors, and the history of the earth.

F 😊 I 😊 N 😊 I 😊 S