

Study Guide #1
Geology 230 - Evolution of the Earth

THE ROCK RECORD

(ITS ORIGIN AND ORDERING)

Lynn S. Fichter, Professor
Department of Geology and Environmental Science
James Madison University

Topics to be Covered and General Objectives:

During this first third of the semester we will cover the following topics in lecture and related laboratory investigations:

- ☺ **The origin and first one billion years of earth history, trying to discover how the earth's gross structure was achieved and why it differs from other planets in the solar system (. . . out of a swirling cold cloud of dust and gas to a seething red-hot ball . . .)**
- ☺ **In terms of evolutionary processes in the solar system, explore the probable long term fate of the earth (. . . it will be burned to a crisp).**
- ☺ **Explore the meaning of "science" as an intellectual activity, and a process of seeking truthful knowledge, and review the development of the science of historical geology from its beginnings in the 16th century, especially the origin of the rules and assumptions which underlie modern scientific and geological thinking (. . . human history is complicated and the mind a powerful instrument, for exploring the universe, but still requires great knowledge and intelligence.).**
- ☺ **The importance of the rock record and how it preserves earth history (. . . its all in the rocks).**
- ☺ **The several methods used to interpret and arrange the rock record in logical sequential order (. . . conceptually its simple, just figure out their ages and put them in order . . .).**

I hope you will gain an appreciation for the unique nature of this planet we live on, compared to the other planets in our solar system, and the influence that has had on its evolution. This uniqueness includes the development not only of a stratified internal structure and ongoing internal heat source, which has maintained a surprising constant level of geologic activity for four billion years, but also the presence of abundant, liquid water. This liquid water, in combination with the geologic activity, has produced large quantities of two rock types (sedimentary and regional metamorphic) that are otherwise rare or nonexistent in the rest of the solar system (Mars has some sedimentary rocks, but they are very ancient).

But in addition, I hope you will gain an appreciation for our developing ability to understand and interpret the significance of the various rocks found on and in the earth. This includes especially the

growing realization of the enormous amounts of time recorded in the rocks and the various concepts and methods needed to measure that time and organize the rocks into a logical sequence. With our ability to do these two things, interpret the origin of individual rocks and place them in their proper time chronology, we will have much of the knowledge necessary to interpret the history of the earth.

PREREQUISITE KNOWLEDGE WHAT YOU NEED TO KNOW ALREADY

Geology 110 (Physical Geology) is a prerequisite to this class and means that all of you have had a broad introduction to the basics of geology. To a large extent, therefore, this class will not repeat that knowledge but rather expand on it and as well introduce new subjects more appropriate to historical geology. For many of these new subjects your physical geology background will be useful, but not essential since the new ideas will be developed in detail. In other cases your physical geology background will only be the beginning for a more technical and detailed study.

I expect you to be in touch with your physical geology knowledge, but if during class I mention some term or process you don't understand ask me. If I can answer it quickly there I will do so. If not I will answer it after class for you. One of the few things that makes me angry is when someone does not understand something and does not ask, or does not understand but acts as if they do.

PREPARATION FOR TESTS

Afew suggestions which past students have found successful:

- ☺ **KEEP UP WITH THE STUDY GUIDE.** Read the guide statements likely to be covered in each lecture and while taking notes mark the information in your notes pertinent to each statement in the guideline.
- ☺ **WRITE OUT ON INDEX CARDS** complete answers to each statement in the study guide, including detailed, fully labeled illustrations and keep up with it lecture by lecture. This allows preparation of good answers while it is still fresh in your mind. Also, it makes review easy, just flip through the cards, and as you learn them pull out the known cards so you will not waste time reviewing what you already know.
- ☺ **MOST IMPORTANT** . . . before the exam get together with 2 or 3 others and quiz each other. Verbalizing not only finds flaws in your answers it also "sets" the information making it much easier to remember.
- ☺ And last . . . be sure you understand what I look for when reading and grading answers; see the syllabus. It would be unfortunate to lose points because you did not know what is important to me.

THE ROCK RECORD STUDY GUIDE QUESTIONS

You should be able to demonstrate your understanding of our developing scientific knowledge and its application to solving problems about the earth by specifically answering the following ¹:

NOTE: In a test question two or more of these may be combined in one question. Also questions may be drawn from the critical reasoning problems, or any assigned readings.

NOTE 2: Most of the guides below are stated as if you should be able to do something. This is in fact a good way to study; if you can explain your understanding clearly and succinctly then you probably do understand it - even though the test exists in a computer graded format.

EARLY HISTORY AND FATE OF THE EARTH

1. List and explain the ways the earth is uniquely different from other planets in the solar system, and describe for each their special significance for the earth's origin, history and/or present conditions.
2. Outline the earliest hypothetical stage of earth history prior to 4 billion years, and before the beginning of the rock record, by doing the following:
 - (A) Draw a time-temperature diagram for earth history and on the time axis show the major phases of earth history.
 - (B) List and explain the mechanisms which transformed the early earth from its initial cold state (inherited from the gas cloud) to a molten state.
 - (C) Write a description of what the earth was like during its earliest stages, and explain the way in which it is believed the earth underwent planetary differentiation (i.e., was transformed from an homogeneous mass formed by accumulation of planetesimals to a stratified body with a liquid iron core, mantle, and crust).
 - (D) Explain why, after planetary differentiation, the earth underwent a period of rapid cooling and general slowing down of geologic activity.
 - (E) Explain the mechanism used to explain why after planetary differentiation the earth has maintained an almost constant rate of geologic activity over the past several billion years.
 - (F) Briefly describe what the final fate of the earth will be and how we know.
3. Describe the early history of the earth's atmosphere and oceans by doing the following:

¹ The following list of things you must know may change as lectures sometimes get rewritten in the course of a semester. IF deletions are made from the list below they will be announced in class and posted on the course web page. IF statements are rewritten, or new ones added, they will be typed and handed out in class, and/or posted on the course web page.

- (A) Outline the way(s) in which the earth's present (Stage III) atmosphere contrasts with and is uniquely different from the other planets, and rest of the solar system.
- (B) List the Stage I and Stage II compositions and time ranges of the earth's atmosphere and explain the proposed origins of each.

NATURE OF SCIENCE

- 4. For the history and development of science:
 - (A) List 5 or 6 ideas we said are not science and convince a skeptic why not for each.
 - (B) Science - The Psychological Element: distinguish between right brained and left brained thinking and how these, through the cognitive imperative, result in the formation of concepts.
 - (C) Define or distinguish among mythical, empirical, and analytical truth.
 - (D) Define or distinguish between induction and deduction.
 - (E) Describe or give an example of a syllogistic (deductive) argument. Distinguish between validity and truth is a deductive (syllogistic) argument.
 - (F) Greek contributions - distinguish between **Aristotelianism** (Realism) and **Platonism** (Idealism).
 - (G) The **Scholastics** - briefly explain the fates of Plato's and Aristotle's ideas during the Middle Ages.
 - (H) What is the way of the two truths?
 - (I) **Francis Bacon** and the Modern Inductive Method. What was Bacon's modern inductive method and how is it related to black magic and white magic?
 - (J) **Newton** and Induction Science - what is the assumption of Newtonian induction science, and how does it decide when Truth has been found?
 - (K) **David Hume** (Treatise of Human Nature, 1788) said induction science was both logically and psychologically flawed. What are these flaws, and how do the effect induction as a method of finding truth?
 - (L) **Karl Popper** (The Logic of Scientific Discovery, 1959) not only restated Hume's argument that induction science was logically flawed he said, "it is neither a psychological fact, nor a fact of ordinary life, nor one of scientific procedure." What is the basis of this criticism?
 - (M) **Karl Popper** (Conjectures and Refutations, 1963) provides an alternative to induction which is a central tenant of modern scientific procedures. Explain what this ideas is.

- (N) **Jacob Bronowski** (Science and Human Values) provided a "To and Fro" model for how science is done by humans. We recast his description into a flow diagram.

Diagram, analyze, and/or explain our flow diagram of Bronowski's depiction of the scientific processes showing the relationships among inductive processes (observation → imagination → etc.), deductive processes (theory → hypothesis → prediction, etc.), and the testing of scientific ideas for truth and validity.

- (O) Be able to define any of the terms (handout "Some Definitions") used in the description of science in Bronowski's model.
- (P) List and briefly describe the **Guiding Principles** of science.
- (Q) What is the nature of **T**ruth and **t**ruth in science.

GROWTH OF HISTORICAL GEOLOGY

5. Characterize the changes which have occurred over the past four hundred years in our scientific knowledge of the earth by doing the following:
- (A) Explain the importance that fossils played in the development of current concepts of earth history.
- (B) Explain the significance of the principles developed by **William Smith** in England and **George Cuvier** in France to our ability to study earth history.
- (C) Briefly characterize the beliefs of the following schools of thought: CATASTROPHISM (epitomized by G. Cuvier) NEPTUNISM (epitomized by A. Werner) and PLUTONISM (epitomized by Hutton and Lyell).
- (D) List and describe the quintessence of each of Stephen J. Gould's eternal metaphors.
- (E) Describe the differences in assumptions and opinions between the two great late 18th and early 19th century British schools of CATASTROPHISM and PLUTONISM (UNIFORMITARIANISM), and discuss how the differences were finally resolved.
- (F) Explain how the eternal metaphors affect the way we look at scientific progress.
- (G) Illustrate how the eternal metaphors have varied through geologic history by demonstrating or explaining their shifting history in the Catastrophist, Uniformitarianist, contemporary creationist, and contemporary geological paradigms.
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THEORIES OF SEDIMENTARY ROCK CLASSIFICATION

6. Write a statement designed to convince a skeptic that *"How you classify something is how you think about it."*
7. List and discuss the criteria a good classification should fulfill. Be prepared to give examples to illustrate your points.
8. What are some of the problems which make it difficult for a sedimentary classification system to fulfill the criteria of a good classification. Be able to give definitive examples.
9. Be able to discuss, or solve a problem, concerning when a classification should emphasize similarities and when it should emphasize differences.

SEDIMENTARY ROCK CLASSIFICATION

10. Siliciclastic classification. Given any rock name be able to plot it on the ternary diagrams we used. Or given a ternary diagram with a specimen plotted be able to properly name it.
11. Carbonate classification. Given any rock name in the Folk system be able to "deconstruct" it and describe the composition of the rock.
12. Be able to write a statement, or solve a problem, relating the amount of information a rock name carries and our confidence in its precision, accuracy, vulnerability, and usefulness.

DEPOSITIONAL SYSTEMS

13. Define or distinguish among the following. Where appropriate:
 - ✧ Give definitive descriptions, make a sketch, recognize on an illustration, or give specific examples, and/or
 - ✧ Understand, demonstrate, or solve a critical reasoning problem about typical interrelationships.
 - ☞ Sourcelands
 - ☞ Basins of deposition
 - ☞ Clastic dominated systems
 - ☞ Carbonate dominated systems
 - ☞ Dip-fed systems (identify all specific examples)
 - ☞ Strike-fed systems (identify all specific examples)
 - ☞ Long systems (describe typical tectonic conditions and list the ideal complete environmental sequence)
 - ☞ Short systems (describe typical tectonic conditions and list two or three ideal typical environmental sequences)
 - ☞ Terrestrial, transitional, marine epicontinental, and oceanic marine environments

SEDIMENTARY STRUCTURES AND SEQUENCES

14. For the study and interpretation of sedimentary structures:
- (A) Distinguish among the following:
- ✧ Laminar and turbulent flow
 - ✧ Mass and traction transport
 - ✧ Saltation
 - ✧ Unidirectional, combined, and oscillation flow
- (B) In terms of fluid dynamics, and with the aid of illustrations, explain the processes by which sedimentary structures (for example, a ripple) form.
- (C) Describe, with the aid of drawings, the relationship between ripples and cross-beds. Be able to accurately pinpoint following:
- | | | | |
|---------|-------------|----------|-------------|
| " stoss | " crest | " trough | " foreset |
| " lee | " slip face | " topset | " bottomset |
- (D) Distinguish between bedforms and internal structures by:
- (1) Describing or defining what these terms connote.
 - (2) Giving examples demonstrating:
 - ✧ Bedforms which have corresponding internal structures.
 - ✧ Bedforms which do not have the corresponding internal structures.
 - ✧ Internal structures which do not have corresponding bedforms.
- (E) Sketch, recognize in an illustration, and/or interpret the environmental meaning (e.g., processes of formation, special environments of formation, energy conditions and/or changes) of the following sedimentary structures:

SEDIMENTARY STRUCTURES		
RIPPLES AND CROSS BEDS " Current (Asymmetric) " Straight = Planar cross laminations and beds " Linguloid = small trough cross laminations " Lunate = Large Trough x-beds " Oscillation (Symmetric)	EROSIONAL STRUCTURES " Channels " Scours " Sole markings - Groove - Flute - Tool	BIOTURBATION " Tracks and trails " Root traces " Pellets
BEDDING " Plane bed " Laminar bedding " High Velocity " Parting lineations " Hummocky " Graded " Lenticular " Wavy " Flaser " Herringbone	DEFORMATION STRUCTURES " Rock Falls (talus) " Slumps " Debris (mud) Flows " Convolute Bedding " Load " Pillow and Ball " Mud Cracks " Rain Drop Impressions	EVAPORATIVE " Salt hoppers and casts

- (F) List and illustrate the unidirectional flow regime sedimentary structures in sequential order of formation from low energy to high energy.

- (G) Make distinctions among unidirectional ↔ combine ↔ oscillatory flow, and describe the kinds of sedimentary structures which form in each.
- (H) Illustrate how sedimentary structures are commonly associated in, and can be used to interpret different depositional environments by:
- (1) Listing and explaining the processes of formation of the sedimentary structures commonly found in:
 - ☞ Turbidites [submarine fans] (Bouma Sequence),
 - ☞ Meandering rivers (Point Bar Sequences),
 - ☞ Storm shelves (Hummocky Sequences).
 - ☞ Braided rivers (L-Bar/T-Bar Sequences).
 - (2) Draw appropriate strip logs of each.
 - (3) Be able to solve problems similar to the critical reasoning problems assigned in class.

SEDIMENTARY TECTONICS

15. For the study of Sedimentary Tectonics and knowledge of how sedimentary rocks evolve:
- (A) Given a blank version, or any portion thereof, of the chart "The Evolution of Depositional Environments, Sedimentary Rocks, and Rock Sequences" be able to label it as done in class.
- (B) Given a blank version, or any portion thereof, of the chart "The Multiple Cycle Evolution of Sedimentary Rocks" be able to label it as done in class.
- (C) Discuss or answer questions about the evolution of sedimentary rocks:
- (1) List as many systematic changes which occur downstream in an ideal short and/or long system.
 - (2) How does source rock composition affect a sedimentary rock?
 - (3) Define what is meant by the term sediment maturity, and briefly explain why maturity is a relative measure of the evolution of a sandstone.
 - (4) On any clastic ternary diagram identify the maturity of any plotted composition.
 - (5) On any clastic ternary diagram draw arrows indicating the direction of increasing maturity of a sediment as it evolves.
 - (6) On a QFL diagram indicate the compositional fields associated with each of the tectonic regimes listed below, and write a rational argument explaining and justifying why each field is located where it is on the QFL:
 - ☞ Stable craton
 - ☞ Recycled orogen (collision orogeny)
 - ☞ Block faulted continent
 - ☞ Volcanic island arc
- (D) Given any stage in the Wilson Cycle, illustrated in both the first chapter of the lab manual and the notebook of lecture drawings, be able to identify, distinguish between, solve a critical reasoning problem about, or predict the following.

- ✧ Short and long systems.
- ✧ Sediment location on a QFL.
- ✧ Typical environments present.
- ✧ Typical strip logs representing environments present.

CHEMICAL/BIOCHEMICAL **(INCLUDING CARBONATE) ROCKS**

16. For Chemical/Biochemical rocks:
- (A) List the general conditions necessary for the formation of both chemical and biochemical carbonates.
 - (B) Explain the special environmental and/or climatic conditions in which oolites, flat pebble conglomerate (intramicrite), chert, dolomite, halite (rock salt) and gypsum form (including, where appropriate, complete, lucid illustration and explanation of the Sabkha model).
 - (C) Given an illustration of an ideal Carbonate Dominated System, be able to label the depositional environments, and list typical rocks and/or sedimentary structures formed in each environment.

SEDIMENTARY FACIES AND TIME

17. Understand the origin of the Geologic Time Scale by doing the following:
- (A) Describe the historical processes by which the Modern Relative Geological Time Scale came into being. Include:
 - ✧ The way in which the Periods were initially defined and named.
 - ✧ The work of Arduenio, Werner, Sedgewich and Murchinson.
 - ✧ The historical processes by which the periods of the time scale came into being and were defined.
 - (B) List Steno's Principles and how they were used to organize the developing Geologic Time Scale.
18. Reproduce the Modern Geologic Time Scale, including the eras, periods and epochs (including the absolute ages of all the Period Boundaries) (see copy in Notebook of Lecture Illustrations).
19. Understand the way in which the physical geologic record is subdivided by doing the following.
- (A) Explain the origin of the term Formation (including the idea of "layer cake" stratigraphy) and the kinds of criteria by which it is defined.
 - (B) Distinguish between the Group, Formation, Member and Bed when applied to sedimentary rocks.
 - (C) Define or describe what is meant by the local section.
20. Understand the relationships among the physical geologic record and the record of time preserved in those rocks by doing the following.

- (A) Distinguish among these concepts
 - ✧ Eustasy
 - ✧ Onlap (transgression)
 - ✧ Offlap (regression)
 - ✧ Progradation (regression)
 - (B) Explain how formations can be time transgressive by a definitive written explanation and/or by drawing a fully labeled illustration showing the processes and sequence of rocks deposited during a transgressive sea, and a regressive sea.
 - (C) Write the two definitions of the Facies concept we are using and giving an example(s) of each.
 - (D) Modern Stratigraphic Concepts. Define, recognize and/or distinguish among Time Units (Era, Period, Epoch, Age), Time-Rock Units (System, Series, Stage) and Rock Units (Group, Formation, Member), including examples or lucid descriptions of each.
 - (E) Define and/or describe the meaning and significance of a Type or Standard Section in how it relates to time stratigraphic units and rock units in places other than the type section.
21. Understand correlation by doing the following:
- (A) Explain what is meant by correlation, and listing and describing the three kinds of correlation we discussed.
 - (B) Distinguish between lithologic and biostratigraphic (chronostratigraphic) correlation.
 - (C) List the following methods of ***lithologic correlation***, and describe and/or explain in ways a layman would understand how they work (use illustrations to aid your explanations).

◇ "Walking out"	◇ Electrical logging
◇ Key beds	◇ Radioactive logging (gamma)
◇ Position in sequence	◇ Seismic reflection profiling
22. For ***biostratigraphic (chronostratigraphic) correlation***.
- (A) Describe the underlying principle which allows us to correlate rocks with the use of the fossils they contain.
 - (B) Define what, in terms of stratigraphy, a zone is.
 - (C) Define what an index fossil is, and list the three characteristics which make a good index fossil.
 - (D) List and describe the different kinds of zones, and recognize and interpret them in a diagram.
23. Explain the origin, nature, and significance of gaps in the geologic rock record by doing the following:
- (A) Distinguish between diastems and unconformities.
 - (B) Recognize the three kinds of unconformities and explain the historical processes by which each forms.

24. Define, describe, or recognize on a strip log a Parasequence. Be able to describe an explanation of the mechanism(s) by which they form.
25. Explain the 3 processes we discussed for diastem formation, including the drawing or interpreting of any diagrams necessary.
26. ***And Finally: Questions concerning any of the readings assigned during this part of the course may show up on the test.***