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 what we mean when we say something is a "system." System has become a buzz word these days: "It's, . . . the system." "You can't beat, . . . the system." "You haf'ta play, . . .the system." Likewise, text books and courses have begun to acquire names like, "The Earth System." We are going to study the Earth as a System, so we need to be clear about what we mean** *(. . . science is philosophy, and as often as not philosophy - what we believe to be true - constricts our thinking rather than expands it).*

- **The origin of geologic ideas about the Earth, its origin and history** *(. . . science is also history, and if you do not know where ideas have come from it is easy to think we have always believed as we do today).*

- **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 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 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.

PREPARATION FOR TESTS

A few 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.
- ***SEE SAMPLE TEST*** . . . on the course web page
  http://geollab.jmu.edu/fichter/Geol230/Geol230.html.
- ***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 FINAL 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 way their special significance for the Earth's origin, history and/or present conditions.
    A. Be able to compare the Earth's uniqueness compared with other planetary bod(ies) (including the moons of other planets) as a basis of comparison.
2. Describe the mechanisms of origin of our solar system by relating its origin to what we understand about the history of other stars and solar nebula.
    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 a gas/dust cloud into a solar nebula and finally a solar system.

One of the major questions we must answer this semester is how evolution takes place. There are two main mechanisms: fractionation and elaboration. Each will be explored in turn, but we began by introducing evolution by fractionation.

3. Describe what "fractionation" is (the how of the mechanisms we will explore all semester).
4. Compare/contrast the following fractionations in the origin of the solar system and Earth.
    A. Cosmic abundances vs solar spectrum.
    B. Solar spectrum vs Jovian planets.
    C. Solar spectrum vs Earth's composition.
    D. Earth's lithosphere vs Earth's core.
6. Explain the mechanisms by which the terrestrial planets developed a different composition from the Jovian planets.
7. 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 a homogeneous mass formed by the accumulation of planetismals to a stratified body with a liquid iron core, mantle, and crust.)

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1 This course changes every time I teach it, sometimes a little, sometime a lot. If changes are made I will tell the class when that happens so you can keep track of what is going on. One way or another, the study guide is just a guide. When in doubt about what to study rely on your notes. When I make up tests I go through my notebook to remind myself of what I have talked about this semester, and compose questions from there.

8. Explain the current theory for the origin of the Earth-Moon system, and how that has affected the structure and composition of both the Earth and the Moon.
9. Explain the mechanism by which the Earth became stratified, and describe that stratification.
10. Compare the Moon's composition with that of the Earth, and explain those differences.
11. Compare/contrast the Earth's current atmosphere with those of Mars and Venus.
12. Explain the origin of the Earth's Stage One atmosphere, and the mechanisms by which it might have evolved from the composition of volcanic outgassing to an equilibrium state (such as possessed by Mars or Venus.)
13. Detail the processes by which the Earth's present atmosphere evolved by fractionation—and out of equilibrium—through Stages Two, Three, and Four.
14. Describe the final fate of the Earth and how we deduce that fate. Be able to follow the trajectory of a star's history on the Hertzsprung-Russel diagram and relate it to the history of a solar system.

SYSTEMS THINKING, AND THE EARTH AS A SYSTEM

*When we see the Earth from space what we see is a single entity, a ball of rock (**lithosphere**) covered with a very thin veneer of water (**hydrosphere**) surrounded by a slightly thicker **atmosphere**, and pervaded by a **biosphere**. From space these four great systems look like a unity, a whole, a **system**. But, that is not the way science studies the Earth. Instead we divide the Earth up into parts: biologists study the biology part, meteorologists study the weather part, geologists study the geology part, . . . and so on. What is more, these different scientists don't often talk with each other. This division of labor represents the traditional way science is structured, and its reductionist strategy for understanding the world. Even geologists, who tend to be scientists with the widest training, are handicapped when it comes to understanding what a system is.*

Considering how pervasive and important systems are, why is it we seem to know so little about them? How come we are not taught them? There are at least three reasons. First, the systematic study of systems is relatively new; only a couple of decades old, and sometimes much less. Second, academic divisions. Someone may be a well trained biologist, but know very little about other disciplines. You must be specifically educated to look outside your discipline, and look for systems connections—and for the most part that is not done. Third, for philosophical reasons classical (Newtonian) science has found the study of systems phenomena inexplicable, even abhorrent, because of their unruly behavior and shun them.

Nonetheless, the term system is showing up more and more in scientific investigations, especially those involving multidisciplinary and interdisciplinary studies. Plus, just in the past 5 years or so a flurry of popular books have been published dealing with the kinds of systems we are interested in, so the subject is not as obscure as it has been.

But, the Earth and everything on and in it is a system. And, for better or worse out task as Earth scientists is to understand that system not only as it exists today, but as it has existed in the past, and as it might exist in the future.

15. Know what the following terms mean, and know how to use them correctly.

A. Closed System
B. Dissipative structure
C. Equilibrium
D. Non-equilibrium
E. Feedback (-)
F. Feedback (+)
G. Open system

13. List, or recognize the evidence that tells us the Earth is an open, dissipate, non-equilibrium system, or conversely, that the Moon, Venus, and Mars are closed systems.

The Problem of Problems and the 2nd Law

14. State or recognize the three ***laws of thermodynamics***.
15. State the two definitions of ***entropy***—thermodynamic and logical—with specific examples of each.
16. Describe the "***problem of problems***" and its relation to the 2nd law.
17. Write a definition of ***teleology***.
18. Describe the core position of ***Vitalism***, knowing how *chi*, *prana*, and/or Henri Bergon's *elan vital* relate to it.
19. Describe the core position of ***Finalism***, including examples from William Paley's Watchmaker argument, and Teilhard de Chardin's alpha/omega argument.
20. Describe the core position of ***Naturalism***, including how the principles of Newtonian Science, and Adam Smith's "invisible hand" argument fit into it.
21. We encounter on our journey a number of individuals who have had something important to say about evolution or evolutionary systems. You need to be able to recognize the arguments each of these individuals has made, or state their basic argument.

- Bak, Per
- Barabasi, Albert-Laszlo
- Bergson, Henri
- de Chardin, Teilhard
- Feigenbaum, Mitchell
- Lorenz, Edward
- Mandelbrot, Benoit
- Paley, William
- Smith, Adam
- Zipf, George Kingsley

What is Required for a System to Evolve?

Our study of evolution is somewhat involved and complex, using a variety of concepts and mathematical models to explore what systems are and how they evolve. The study guides below follow them in the order we studied them in class, but you should be able to connect them all together as a system of principles by which we understand evolutionary systems.

14. Distinguish between empirical and theoretical evolution.
22. ***Self Organized Criticiality*** - although Bak modeled SOC systems in the computer, and others studied real sand piles for SOC, the core concept of an evolutionary system is captured in the sandpile model. Be able to explain this model to another person, including its implications and applications.
23. **Models** are one of the most powerful tools we have, and they are universally used. Memorize the definition of a model, explain why we need models, and discuss the values and uses, and the limits and conditions of models. Give examples of different kinds of models (you may use examples from ones we study in class, or others as you choose).
24. ***The Bak-Sneppen evolutionary model*** is an "ecosystem" in which the fitness of each "species" changes because of its relationships with other "species," following two simple rules; it is a SOC model.
    A. State the rules for the Bak-Sneppen model.
    B Explain each of the following: How the model *works*.
    C How the model *behaves* including the role of the threshold fitness line.
    D What an *avalanche* is, where it begins and where it ends.
    E Why and how random processes result in self organized criticality.
25. Fascinating conclusions and implications come out of the Bak-Sneppen model, and we explored some of them in class. Be able to talk knowingly about answers to these questions.
    A. Watch the species above the threshold. How stable are they?
        1. How much are they able to change on their own?

2. How much do they contribute to raising the threshold line to the next level?

B. Get personal. Pick out one species above the threshold line and identify with it; imagine it is you.
1. How safe are you in this avalanche prone world?
2. How much control do you have over your destiny? Why or why not?
3. Are there any innocent victims?
4. Is there any way to protect yourself in such a world?

C. Is there any part of this ecosystem that is isolated from the rest, sitting in a protected niche, independent and self sufficient.

26. ***Logistic Model (X_{next} Equation)***
A. Reproduce the X_{next} equation, and explain the role of each term in the model, e.g. X, X_{next}, r, (1-X).
B. Define or use correctly the following terms.

C Bifurcation (Diagram)	C Logistic
C Deterministic	C Predictable
C Iterate	C Recursive

27. Describe the successive changes in behavior of X_{next}, OR recognize on a bifurcation diagram the changing behavior of X_{next}, OR be able to put in order a random group of time-series diagrams that represent increasing values of r (rate of growth).

Universality

"The principle that the underlying properties and behaviors of a large class of problems are essentially the same, and therefore, can be studied in principle without delving into the particular details of each system."

I am arguing that systems that may not seem at all related—e.g. social, political, chemical, biological, geological—behave according to the same principles and mechanisms. We get some clue that this might be true by comparing the sand pile with the Bak-Sneppen model, but it is the universality properties that really lead to the conclusion.

28. Describe ***Euclidean geometry***. Describe ***fractal geometry***. Explain in ways a layperson would understand the most salient distinguishing features between them.
29. Distinguish between geometric self-similarity and statistical self-similarity.
30. Explain what a ***DLA*** (diffusion limited aggregate) is, how it is generated, why it is fractal, and why the model is important.
31. Be able to recognize and identify any characteristic fractal object.
32. ***Feigenbaum Ratio*** Explain what this is, what it means, and why it is important.
33. ***Sensitive Dependence (butterfly effect)***. In terms of X_{next} and for Bak-Sneppen explain how sensitive dependence arises and leads to bifurcations.
34. Explain why ***sensitive dependence*** is important for systems behavior.
35. Give or recognize some real world examples of sensitive dependence.
36. ***Power-Law Relationships***. Explain or recognize in graphic form (log-log, linear, time series graphs [pink/white noise], etc.) what a power-law relationship is.
37. Explain how power-law relationships are expressed and what they mean in Bak-Sneppen, DLA, Earthquakes, extinction events, Zipf's Law, or any other system.
38. **Attractors (Strange and Otherwise).**
A. In mathematical terms, describe what an attractor is, including a definition or drawing illustrating a phase space.

B. Describe, define, illustrate, recognize, and give examples of Fixed Point, Limit Cycle, and Strange attractors.
C. In vernacular (non-mathematical) terms, describe what an attractor is and give or recognize any example.
D. Describe in terms a lay person would understand what makes a strange attractor strange.

Classical and Complex Systems Science

Some have the impression, or the belief, that science is objective Truth. Nothing could be farther from the Truth. Like every other human endeavor, science is a groping attempt to make sense out of a universe we really don't understand. True, science is supposed to be objective, but it is also influenced by philosophy, social values, and a host of other factors.

39. Compare and contrast classical and complex systems science for the following:
    A. Reductionism vs Holism
    B. Linear vs Non-Linear
    C. Clear Boundaries vs Diffuse Boundaries
    D. Discrete Solutions vs Qualitative Solutions
    E. Centralized Control vs Interconnected Systems
40. Be able to relate these concepts to any model or example we used.

Cellular Automata and Self Organization

Still, the question remains, how do systems self-organize, but what rules, what mechanisms, what processes—how does order arise out of a disordered state, in seeming violation of the second law of thermodynamics. In science we must have explainability—a logical series of steps that show how the natural world works. The closest Adam Smith could get to an answer was the "invisible hand." He observed what was going on, but was unable to provide the explainability. Cellular automata allow us to "see" self-organization taking place. It is perhaps no easier to explain, but we can sure see it happening. Adam Smith would have loved it.

41. In terms a layperson would understand, describe or explain what a ***cellular automata*** is, including the principle of ***local rules/global behavior***.
42. Given a set of rules and a CA grid with starting conditions, be able to calculate a two dimensional cellular automata (on a test this will probably show up as a set already calculated; you will just have to decide if the given outcomes are the correct ones.)
43. In terms a layperson would understand, describe or explain the relationships which exist between information flow and the emergence of complex or interesting patterns in cellular automata.

A Systems Definition

We constructed, through these discussions, step by step, a system definition (Clarification One through Clarification Seven). "A naturally occurring group of interacting, interrelated, or interdependent elements forming a complex whole, existing far from equilibrium, that have evolved together through time (self-organized by bottom-up processes), forming a dynamic network where everything is connected to everything else by positive and negative feedback, such that a change in one component affects the states of the other components, exhibiting sensitive dependence, fractal organization, and avalanche behavior that follows a power-law distribution."

44. I am not going to ask you to memorize this definition, but I do want you to be able to:
    A. Explain any part of the definition, why it is important, or what it means.
    B. And, identify for each phrase in the definition the model we used to add that phrase to the definition.

GROWTH OF HISTORICAL GEOLOGY AS A SCIENCE

45. Characterize the changes which have occurred over the past four hundred years in our scientific knowledge of the Earth by doing the following:
    - A. Contrast the "myth of the eternal return" with Judeo-Christian views of time.
    - B. What is Deism, when did it arise, and what are its precepts?
    - C. Explain the importance that fossils played in the development of current concepts of Earth history.
    - D. The history of any discipline is messy and complex, involving a lot of individuals and ideas in a great historical mix. There are many things to be gained from the study of history. For our purposes they include: 1. Coming to know that we cannot presume that how we think today has any bearing on how people thought or believed in the past—you cannot impose present thinking on the past. Instead you must strive to *get inside* their heads. 2. You cannot judge how good a scientist someone is/was just by their ideas—especially when judging them in hindsight. People must be judged in how they responded to conditions during their lifetime. 3. The success and acceptance of a scientist in their own day is not a good measure of how lasting their contributions will be.

      In any event, for each of the individuals below you need to be able to recognize their arguments and positions and explain their contribution to the history of theories of the Earth.

Ardunio	Hook	Smith
Buffon	Hutton	Steno
Burnet	Lyell	Thompson
Cuvier	Murchinson	Ussher
d'Orbigny	Paley	Werner
Darwin	Sedgewick	Whewell

    - E. 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).
    - F. List and describe the quintessence of each of Stephen J. Gould's eternal metaphors, and why they are important.
    - G. 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.
    - H. 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.
    - I. Explain how the eternal metaphors affect the way we look at scientific progress.

So far everything we have talked about concerns how—philosophically and historically—to think about the history of geology and the history of the Earth. Below we get into the nitty-gritty of interpreting the rock record. A dramatic shift.

THEORIES OF SEDIMENTARY ROCK CLASSIFICATION

B. Write a statement designed to convince a skeptic that "How you classify something is how you think about it."

C. List and discuss the criteria a good classification should fulfill. Be prepared to give examples to illustrate your points.

D. 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.

E. Be able to discuss, or solve a problem, concerning when a classification should emphasize similarities and when it should emphasize differences.

SEDIMENTARY ROCK CLASSIFICATION

F. ***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.

G. ***Carbonate classification***. Given any rock name in the Folk system be able to "deconstruct" it and describe the composition of the rock.

H. 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

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

SEDIMENTARY STRUCTURES AND SEQUENCES

J. For the study and interpretation of sedimentary structures:
  - A. Distinguish among the following:
    - A. Laminar and turbulent flow
    - B. Mass and traction transport
    - C. Saltation
    - D. 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:
    - A. Describing or defining what these terms connote.
    - B. Giving examples demonstrating:
      - A. Bedforms which have corresponding internal structures.
      - B. Bedforms which do not have the corresponding internal structures.
      - C. 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 " Linguoid = small trough cross laminations " Lunate = Large Trough x-beds " Oscillation (Symmetric)	EROSIONAL STRUCTURES " Channels " Scours " Sole markings 6 Groove 6 Flute 6 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 Ø combine Ø 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:
    A. Listing and explaining the processes of formation of the sedimentary structures commonly found in:
        A. Turbidites [submarine fans] (Bouma Sequence),
        B. Meandering rivers (Point Bar Sequences),
        C. Storm shelves (Hummocky Sequences).
        D. Braided rivers (L-Bar/T-Bar Sequences).
    B. Draw appropriate strip logs of each.
    C. Be able to solve problems similar to the critical reasoning problems assigned in class.

SEDIMENTARY TECTONICS

50. 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 the 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:
            A. Stable craton
            B. Recycled orogen (collision orogeny)
            C. Block faulted continent
            D. 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.
        1. Short and long systems.
        2. Sediment location on a QFL.
        3. Typical environments present.
        4. Typical strip logs representing environments present.

CHEMICAL/BIOCHEMICAL (INCLUDING CARBONATE) ROCKS

51. 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

52. 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:
        1. The way in which the Periods were <u>initially</u> defined and named.
        2. The work of Ardunio, Werner, Sedgewich and Murchinson.
        3. 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.

53. 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).
54. 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.
55. 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
        1. Eustasy
        2. Onlap (transgression)
        3. Offlap (regression)
        4. 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.

56. 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"
- Key beds
- Position in sequence
- Electrical logging
- Radioactive logging (gamma)
- Seismic reflection profiling

57. 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.

58. 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.

59. Define, describe, or recognize on a strip log a Parasequence. Be able to describe an explanation of the mechanism(s) by which they form.

60. Explain the 3 processes we discussed for diastem formation, including the drawing or interpreting of any diagrams necessary.