12.007 Geobiology

Final Exam

Tuesday, May 20, 2003
9:00 am – 12:00 pm

Honor Statement

I, _____, promise not to share information with others or make use of any reference materials during this exam. I will work alone and not discuss the exam with anyone who is taking it or will take it at a later time.

Signature Date

Instructions: You will have three hours to complete the exam. Please read it through completely to make sure you understand the questions. Make your answers concise.

Have a great Summer!

Part 1: Answer five (5) of the following eight (8) questions. Plan to spend up to 15 minutes per answer. Each answer is worth 10 points out of an exam-total of 100 points. (I.e., Part 1 of the exam is worth 50% of the total.)

1. Eons of Earth history are Hadean, Archaean, Proterozoic and Phanerozoic. In general terms, describe their ages, characteristic surface features and biologies. What kinds of biogeochemical changes mark the transitions between these eons?

2. Name and describe three major extinction events or boundaries. Choose one event to elaborate on the biological consequences, theories about the causes and how these theories were arrived at.

3. How are stable isotopic ratios measured? How do stable isotopes become fractionated in natural systems. In round terms, what are the general values for the ratios of carbon isotopes in the atmosphere, ocean, biological materials and rocks.

4. Describe the pathways of carbon fixation in photosynthetic organisms. What are the isotopic consequences of these pathways?

5. C4 photosynthesis denotes physiological and anatomical aspects of a particular type of plant. Elaborate on this statement and include a discussion of the likely evolutionary drivers and geobiological consequences.

6. What are some of the main divisions of photosynthetic organisms. What are their capabilities, when did they appear (include evidence) and what were the environmental and evolutionary consequences.

7. What are biomarkers?

8. Give equations for the two end stage redox reactions in organic matter remineralization. Describe the organisms (MPA and SRB), where these reactions take place, linkages and what determines their spatial distributions. Describe some of the overt natural manifestations of these important biogeochemical processes.

Part 2: Answer all questions. Part 2 of the exam is worth 50% of the total (i.e., 50 out of 100 total exam points).

9. **Climate and CO_2 (10 points).**
Discuss the connection between carbon dioxide and climate. Why is it believed that past climate fluctuations have resulted from carbon dioxide fluctuations? Discuss three examples from the geologic record (e.g., periods of time and climate regimes) that support a connection between CO_2 and climate. Be sure to describe the evidence used to infer the climate regime and atmospheric CO_2 levels.

10. **Oxygen isotope systematics (5 points).**
Describe three processes that can cause oxygen isotope fractionation in surface seawater. What can be inferred from changes in oxygen isotope ratios ($\delta^{18}O$) in marine carbonates? What can be inferred from $\delta^{18}O$ changes in polar ice cores?

11. Climate Forcings and Feedbacks (10 points)
(a) Climate change mechanisms operate on a variety of time scales, from 10^0-10^9 years. Discuss five (5) processes that influence climate change on a different time scale. Provide examples from the geologic (or instrumental) record of climate regimes when each process is thought to have played an important role.

(b) The climate system contains many positive and negative feedbacks. Give one example of a positive feedback and one example of a negative feedback in the climate system. Describe how these feedbacks may influence climate in the next century assuming greenhouse gas emissions continue to increase at the current rate.

12. Isotopic Mass Balance (10 Points).

Fossil fuels are depleted in ^{13}C ($\delta^{13}C$ = -27 ‰) relative to dissolved inorganic carbon in the ocean. Over the next 100 years, assume that 500 Gt of fossil fuel carbon will be taken up by the ocean (as CO_2 from the atmosphere), and that the added carbon gets evenly mixed throughout the ocean. Today, the $\delta^{13}C$ value of the ocean is 0‰ and the ocean contains 39,000 Gt of dissolved inorganic carbon.

(a) (1 point) In the year 2100, will the $\delta^{13}C$ value of the ocean be higher or lower than it is today?

(b) (6 points) Write the mass balance equation(s) required to solve this problem.

(c) (3 points) Solve the equation(s) in (b) for the $\delta^{13}C$ value of the ocean in the year 2100. (Show all work.)

13. The Milankovitch Theory (10 Points).

The Milankovitch Theory maintains that changes in Earth's orientation and orbit around the sun cause climate change on Earth.

(a) (1 point) By what mechanism can changes in Earth's orientation and orbit influence climate ?

(b) (1 point) What are the three orbital parameters that change?

(c) (1 point) What is the period of each of the three orbital parameters?

(d) (1 point) What causes the seasons to occur?

(e) (1 point) Is increased or decreased seasonal contrast conducive to the growth of Northern Hemisphere ice sheets?

(f) (2 points) Describe an ice growth and an ice decay configuration of the three orbital parameters.

(g) (3 points) Benthic foraminifera in sediments indirectly provide a time history of changes in Earth's orbital parameters. Explain the link between Earth's orbital geometry and calcium carbonate microfossils on the seafloor.

14. **Planetary energy balance (5 points).**

(a) Describe each of the terms (σ, T_{eff}, S, A) in the planetary energy balance equation:

$$\sigma T_{eff}^{4} = S/4*(1-A)$$

(b) What is meant by the term "energy balance" in this equation?

(c) Why is S divided by four?

(d) Why is A subtracted from one?

(e) Provide reasonable values for T_{eff}, S, A today.

(f) What is the difference, if any, between T_{eff} and surface temperature?