Description of the Final Exam

The final will be a 3-hour closed-book, closed-note take-home exam. Calculators are allowed, but probably not necessarily. If you wish to type the exam, that is fine, but other files on your computer are still closed; note that there is some sketching involved, so work out a way to draw figures on-screen before you do an all-digital exam.

It is due Friday, December 14, 2007, at 5:00 PM (Pacific Standard Time) in **Paul's** mailbox (not Brian's). I will distribute it by e-mail Friday 12/7. If you are at AGU, you may turn it in to Paul on Wednesday December 12 before 5 PM on the AGU message board in Moscone West or in person.

The test will be graded out of 180 points; each question counts toward your score in proportion to the number of minutes allocated to it. The test consists of three sections:

- Very short answer: definitions of terms or distinctions between two terms; 15 questions at 3 minutes each.
- Medium answer: More problem-set-like questions, asking you to draw a figure, prove a theorem, or solve a problem; 6 questions at 9 minutes each.
- Essays: Open-ended opportunities to show how much you have learned about the major topics of the course, writing in sensible paragraphs and complete sentences; 4 questions at 20 minutes each.

The test tries to emphasize concepts rather than memorization. In deciding how many equations to memorize, for example, see whether you think they would be needed to come up with good answers to the following review questions.

Review Questions

These questions are deliberately broad to encourage you to consider deeply how much you know or need to review as well as how the various topics relate to one another.

What are the processes that form the stable isotopes up to mass 56 in the chart of the nuclides? What is the stellar evolution that accompanies this formation? How are the heavier elements formed? Why are certain combinations of neutrons and protons favored over others?

Why are chondritic meteorites in general, and carbonaceous chondrites in particular, thought to be useful indicators of the bulk composition of the Earth? In what ways is this general presumption demonstrably false?

What are the four most abundant elements in the solar system? What are the four most abundant elements in the Earth? Why are they different?

What are four independent lines of evidence for the existence of an Fe-rich core in the earth?

What controls the geochemical behavior of each element? Why are some elements concentrated in the core (don't just say because they are siderophile…the question is why)? Why are some elements highly enriched in the continental crust (don't just say because they are very incompatible…the question is why)?

How do we know the upper mantle is depleted in incompatible elements relative to chondrites, and what do we know (and how) about the age of this depletion?

Name the five types of radioactive decay. What distinguishes nuclei that tend to undergo each mode of decay?

Why is the K-Ar date of a metamorphic rock usually younger than the Sm-Nd age?

Why are $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ in terrestrial basalts anticorrelated? How do the Nd isotope compositions of primitive, depleted, and enriched reservoirs evolve over time?

How was the presence of live nuclei of the now extinct isotope ^{26}Al at the time of meteorite condensation established?

How old is a coral fossil in which the activities of ^{230}Th and ^{238}U are equal to within 1 part in 32?

What is the Concordia plot and what is it good for?

In thermodynamics, what is the difference between a *phase* and a *component*? What is the Phase Rule and what does it tell you?

Why is Gibbs Free Energy more useful than Internal Energy? What is chemical potential and who cares? How can you tell what the partial derivatives of a potential function are by looking at the expression for its total derivative?

Distinguish the melting behavior of minerals with and without solid solution. Remind yourself what solidus and liquidus mean and how to read simple phase diagrams.

What is the relationship between chemical composition and mineralogical structure? Why is the continental crust dominated by framework silicates and sheet silicates, the oceanic crust by framework silicates and chain silicates, and the mantle by chain silicates and isolated tetrahedra silicates?

Propose two exceptions each to the stratigraphic principles of superposition and original horizontality. What characteristics make particular rock horizons good stratigraphic markers? What characteristics make particular fossils good biostratigraphic markers? Remind yourself what a cross-cutting relationship is in stratigraphy.

Why were Kelvin and the 19th century physicists wrong about the age of the Earth? (two reasons) How do we know the age of the earth today?

How are mantle convection and plate tectonics different from a bottom-heated pot of water on the stove (at least three major reasons)? What are the characteristic physical and chemical properties of earth materials that determine how the Earth's internal heat engine leads to the observed mechanisms of geology?

Why are there magnetic lineations on the seafloor: how are they generated and what do they reveal?

What is the characteristic stratigraphy of ophiolite complexes and what process in the formation of oceanic crust does each layer represent?

Why (physically and chemically) do most petrologists consider that the melting process under mid-ocean ridges is approximated by fractional melting?

Why do mid-ocean ridges whose axes are at relatively shallow depths in the ocean tend to be associated with thick oceanic crust, high Fe contents and low Na contents (after fractionation correction and regional averaging)?

What are the stages in growth of a Hawaiian volcano? What are the stages of development of a continental flood basalt province? Is there any similarity between these sequences?

What is the difference between similar and parallel folds? Which kind of folds tend to form in the relatively shallow crust?

Why do faults often come in conjugate sets ~60° different in orientation?

In rock fabric development, what is the difference between lattice preferred orientation and shape preferred orientation?

Why don't intersecting joint sets cross-cut each other?

Why is a balanced (or retrodeformable) cross-section a good thing?

What factors determine the change in the height of a land surface near the top of a mountain? What factors determine the change in the height of a land surface on a low-elevation plain? How do the topographic profiles of hillslopes and river channels evolve?

Explain isostasy.

How do we measure the rates of evolution of geomorphic features?

What is the significance of hydrothermal venting and alteration near mid-ocean ridges?

Why does volcanism develop above subduction zones, even though these are the coldest parts of the mantle? Why might the volcanic front occur globally at a nearly constant depth above the Benioff zone?

Why do continental margin arc volcanoes form steep-sided cones and why do they tend to erupt explosively?

Explain the origin of the brittle-ductile transition in the mechanical behavior of continental crust. How are the mechanical properties of oceanic lithosphere different? Can you imagine what kind of continental region might actually be as resistant to deformation as oceanic lithosphere (and why)?

What's the difference between metamorphic zones and metamorphic facies? How do metamorphic petrologists reconstruct the peak metamorphic conditions experienced by a rock? What makes some metamorphic reactions good thermometers and other reactions good barometers?

What is the general sequence of reactivity for mineral dissolution during weathering? Describe how you can evaluate the extent of chemical and physical weathering of a geologic region. How do chemical and physical weathering interact?

Explain the significance of chemical weathering in regulating global climate.

What are the minerals associated with the major sedimentary rock types? What are the processes that govern how a particular mineral assemblage becomes a sedimentary rock? What are the typical depositional environments for the main types of sedimentary rocks?

What is an unconformity? What is base level?

How do you recognize a transgressive succession of sedimentary facies? Is it necessarily associated with a rise in eustatic sea level?

How many mechanisms can you come up with for driving changes in relative sea level at some particular location?

What do you learn by measuring a virtual magnetic dipole preserved in an ancient, stratified rock?

What are the four types of continent-ocean margin [not the three types of plate boundary, but the four types of continental margin], and in what sequence has California most recently passed through all four? Describe the causes and kinematics of the transition from subduction to strike-slip motion along the California coast.

Why does one sometimes plot an isotope ratio versus the reciprocal of concentration of the element in question (e.g. $^{87}Sr/^{86}Sr$ vs 1/[Sr]) ?

Review the concepts behind setting up a simple box model of a geochemical system. What is a residence time? What does it mean to be at steady state?

Briefly explain the origin of equilibrium and kinetic stable isotope fractionations.

Why is high-latitude precipitation isotopically lighter than low-latitude precipitation? What is the relationship between δD and $\delta^{18}O$ in various natural waters on earth?

What processes are reflected in the record of $\delta^{18}O$ of marine carbonate fossils? Why do ice-core records give a different picture of climate from marine sediment cores; what are the advantages and disadvantages of each kind of record?

Explain the origin of the oceanic thermocline. Why are North Pacific deep ocean waters so old?

Draw the oceanic concentration-depth profiles of: phosphate (a nutrient), lead (a particle-scavenged element) and chloride ion (a conservative species). Why do they look the way they do?

Compare and contrast the distribution of carbonaceous, siliceous, and pelagic sediment on the ocean floor.

Why is there a pole to equator temperature gradient on earth? What processes act to reduce this gradient?

Explain the significance of chemical weathering and of sedimentary accumulation in regulating the abundance of oxygen in the atmosphere.

What do atmospheric chemists mean when they group molecules into families like O_x, NO_x, HO_x, etc? What is a *radical* species?

Why does the abundance of ozone peak in the middle stratosphere, at about 25 km altitude?

What do we know, geochemically, about the lower mantle? What facts can be established independent of model assumptions, and what is a matter of opinion? How do noble gases, trace element ratios, isotopic compositions, and mass balance arguments constrain mantle structure?

What is the relationship between the enrichment of Pb in continental material and the origin of the HIMU component of oceanic basalts?

Why is it so much easier to make good measurements of He isotopes in rocks, compared to all other noble gases?

How do ^{3}He and ^{4}He, respectively, suggest at least partial layering of mantle convection?

What do Xe isotopes tell us about the history of the atmosphere?