6. Origin of the Earth

I. Planets appear to have come from a disk of matter that circled the early sun **show figure**
   A. particles in the solar nebula clumped together to form planetesimals (small proto-planets)
      1. planetesimals collided to form larger planets – accretion
   B. formation also lead to a "fractionation" of materials among the planets
      1. rocky terr planets form from metals and oxides **Table 3-11 Broecker**
   C. age of planets
      1. oldest rocks on earth ~4.4 by old
         a. dating of zircon grains
      2. planet actually appears to be older - ~4.6 by
      3. this actually tells the time since x'tallization
      4. solar system formed ~10-100 my earlier
      5. time since x'tallization. ≈ age of planets

II. Composition of the early earth
   A. present day earth is layered **show Figure**
      1. liquid outer core and solid inner core - predom. Fe and Ni
      2. mantle - silicate material
      3. crust - continental and oceanic
      4. how did segregation occur?
   B. Planetary formation
      1. initial accretion likely homogeneous
         a. formation of small planetesimals (1- 10 km radii)
         b. non-gravitational forces
         c. weak van der Waal's binding
      2. eventually they start to grow by gravitational attraction
         a. from protoplanets the size of Mercury or Mars
      3. later on – collision of large planetesimals or protoplanets increase planetary size
      4. for Earth some may have been so large as to melt large portions of the early Earth
      5. allowed Ni and Fe to separate and form the core
         a. extensive melting leads to the formation of a terrestrial magma ocean
      6. these processes also played a role in bringing water and other volatiles to the Earth
   C. chemical composition of the Earth and its components shows the evidence of this melting and chemical fractionation and separation **Table 5-3 Broecker**
      1. assume the early Earth started out with roughly the composition of a chondritic meteorite
      2. mantle depleted in Fe
      3. separation of Ni/Fe core during melting
   D. formation of crustal material from mantle leads to additional segregation
      1. partial melting of mantle material
      2. crustal material becomes enriched in Na, Si, and Al **show next Table 5-3**
      3. depleted in Mg
      4. further fractionation for granite than basalt
         a. formation of continental vs. oceanic crust

III. Formation of the crust

A. chemical differences in continental vs. oceanic crust - **show Bowen's reaction sequence**

B. continental crust appears to form from the repeated recycling and partial melting of mantle material and oceanic crust

1. repeated heating, cooling, subsidence, burial and repeated melting
2. leads to a distillation/segregation of lighter granitic material from heavier oceanic crust and mantle
3. also leads to chemical separation of elements

C. age differences as well for these 2 types of crust

1. oceanic basalt generally much younger
2. oldest material ~100 my
3. continental crust is as old as 3.8 by

D. continental crust is also lighter **show my figure**

1. $\rho = 2.7$ g/cm^3 vs. 2.8 for oceanic crust and 3.3 for mantle material
2. recent studies also suggest that heating of continental crust may contribute to its buoyancy

E. age and composition of the oceanic crust controlled by plate tectonics and associated mantle convection cells

IV. Timing **show figure**

A. Major period of accretion

1. first ~10-30 my
2. once thought to be first ~100 millions years
3. recent evidence suggests the planet cooled more quickly
4. water begins to accumulate on the Earth's surface
5. began to form crustal material/features

B. early history of the Earth generally thought to be a period of heavy bombardment by meteorites and small planetessimals

1. up to ~3.8 bybp
2. similar to processes that ultimately formed the moon from the Earth
3. this bombardment continued to bring water and other volatiles to Earth
   a. helped oceans and atmosphere to continue to grow