Geophysics 150: Homework 3
(Due January 31 2005)

1. We will do some quick calculations on the heat and mass balance of plate tectonics. Seafloor spreading produces a surface area of 3 km^2 yr^{-1} of oceanic crust. Subduction returns an equivalent area back into the mantle.

a. The surface area of the Earth is 510×10^6 km^2. How long does it take seafloor spreading to generate an area equivalent to that of the Earth?

b. The Earth is 40% continents and 60% ocean basins. How long does it take seafloor spreading to generate an area equivalent to the ocean basins? What does this say about the expected age of oceanic crust.

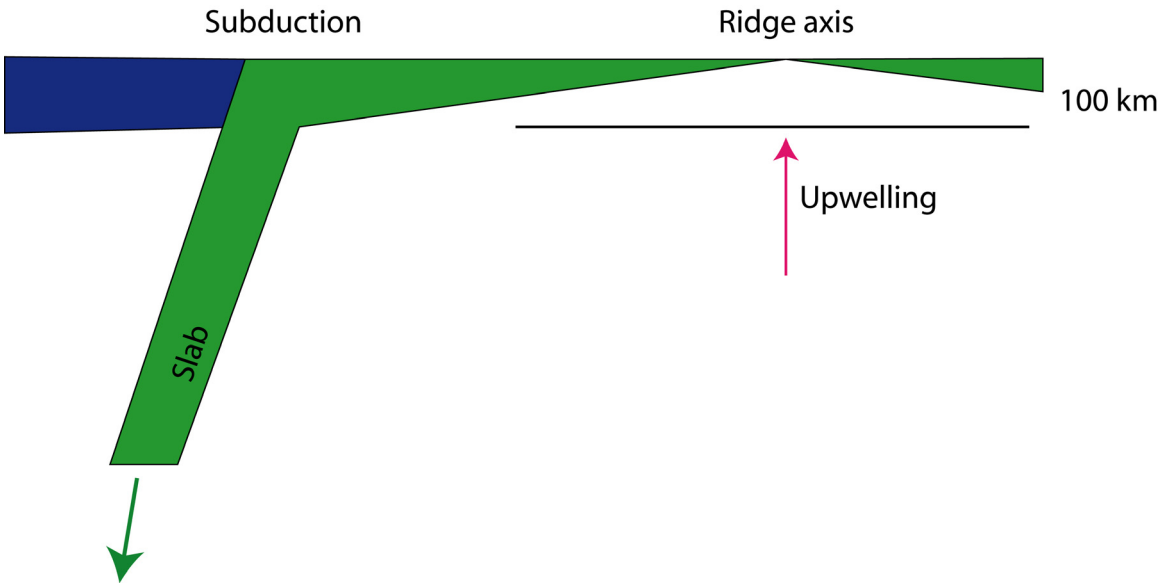
c. The heat flow in the ocean basins is 0.5 W m^{-2} divided by the square root of age in million years. Assume that all the oceanic crust gets subducted at the expected age that you computed above in part (b). What is the average heat flow in the ocean basins? Hint $\int 1/\sqrt{t}\, dt = 2\sqrt{t}$ where t time the age of the crust.

d. Repeat using the time you got in part (a) for seafloor spreading to replace the entire surface of the Earth

2. We will now consider the 1-dimensional average of the process. The oceanic lithosphere is ~100 km thick when it gets subducted. The material in the lithosphere upwells at the ridge axis. The volume of material that goes done in lithosphere each year is 100 km times 3 km^2. Use later: The thermal conductivity of the mantle is 3 W m^{-1} K^{-1}. Volume specific heat is 4×10^6 J m^{-3} K^{-1}. The radius of the Earth is 6371 km. The material at great depth is 1300°C and it is 0°C at the surface.

a. Compute the velocity of the global average upwelling at 100 km depth. Ignore the small area where slabs downwell. You will want m s^{-1} later.

b. Compute the scale depth κ/v for the upwelling. What is the convective heat flow at 100 km depth?



3. We will do a bit more mass balance.

   a. The base of the upper mantle is 670 km down. Assume that all the slabs get subducted into the lower mantle. How long does it take plate tectonics to turn over the upper mantle? You can use volumes here. Densities would be better.

   b. How long does it take to cycle the volume of the mantle down to 2900 km through the ridge axis and subduction?