Lab #7 — Astronomy 184L — Life in the Universe

Grand Canyon

Field trip on Saturday, October 24, 2009

Lab due by Tuesday, November 3, 2009, by 3 pm

There are four main scientific goals of this lab: (1) Learn about the history of the Grand Canyon and the Colorado Plateau; (2) Learn about fluvial (river) processes from real life examples; (3) Learn about the timescales and scope of erosional processes; and (4) Learn about analogies on other planets of the Grand Canyon and its processes.

The assignment is described below, and is due in my office or my mailbox by 3 pm on Tuesday, November 3. For this assignment, please work in pairs, and please work with someone you have not worked with before. You can turn in just single lab for your pair. Naturally, you need to show all your work.

The assignment

Question 1: What is the total amount of geologic time represented by the sedimentary stack at the Grand Canyon? (Do not count the igneous basement.) In other words, how long did it take to lay down these layers? Also: what is the total thickness of the stack? Given these, what was the average deposition rate? This calculation ignores a number of nuances, but that's okay, for our purposes.

How long did it take for the Colorado River to cut the Grand Canyon? What is the average downward erosion rate? How does it compare to the average deposition rate? Which is a more powerful, faster process – deposition or erosion?

Question 2: It takes about seven days (or so) to raft down the Colorado River from Lee's Ferry to Diamond Creek. What is the flow rate of the river?

Valles Marineris is Mars' "Grand Canyon," but it's quite a bit bigger, actually: around 4,000 km from end to end, 100 km across, and up to 10 km deep. How long would it have taken for a river like the Colorado River to have eroded this giant canyon on Mars (if indeed it was created by river erosion)? How long would it take for water to flow from one end to the other, if water did so?

There is a topographic dichotomy on Mars: most of the southern hemisphere is rocky highlands and most of the northern hemisphere is low, smooth plains. The difference in average elevation between the two hemispheres (this is called the boundary scarp) is around 4 km. It has been proposed that the entire northern lowlands area on Mars was once a single, giant ocean. What is the volume of this ocean? You can assume that the northern lowlands cover 50% of Mars' surface. If a typical rainstorm delivers around 1 cm of rain per hour, how much time would it take to cycle all of Mars' (former) ocean through the Mars water cycle, if you assume it is raining on Mars half of the time?

Another idea concerning Mars' previous water cycle is that gigantic floods delivered the water across the surface. If the entire volume of Mars' oceans flooded through Valles Marineris at the same flow rate that you found above for the Colorado River, how long would it take to fill the northern lowlands and make Mars' (former) ocean?

Mars may no longer have an active water cycle (who knows?), and certainly some Martian water is sequestered in Mars' polar caps, each of which is round with radii around 700 km and height around 2 km. If these polar caps are 75% water ice (the rest would be CO_2 ice, probably), and if Mars' total water reservoir is equal to the volume of the former northern ocean, what percent of Mars' total water is sequestered in the polar caps?

The remaining Martian water reservoir would have to be stored in a permafrost layer (a permanently frozen layer of ground just below the surface of the planet; the Arctic tundra has a permafrost layer.). A permafrost

layer might be 50% ice and 50% rock/dirt/sand (percentages by volume). How thick would this layer be? Assume its top is only a few meters below the surface of Mars.

On the Earth, the temperature increases 15 K for every 1 km you go down into the Earth (this is called the *geothermal gradient*). Mars' surface temperature is around 220 K. If you assume that Mars has the same geothermal gradient that the Earth does, is there any portion of the Martian subsurface permafrost layer which is liquid?

Two formulae you might find useful for this problem are these: The volume of a cylinder is given by $\pi r^2 h$ where r is the radius of the cylinder and h is the height of the cylinder; and the volume of a spherical shell is given by $4\pi r^2 \Delta r$ where r is the radius of the sphere and Δr is the thickness of the shell. This second equation is only valid when Δr is much, much smaller than r.