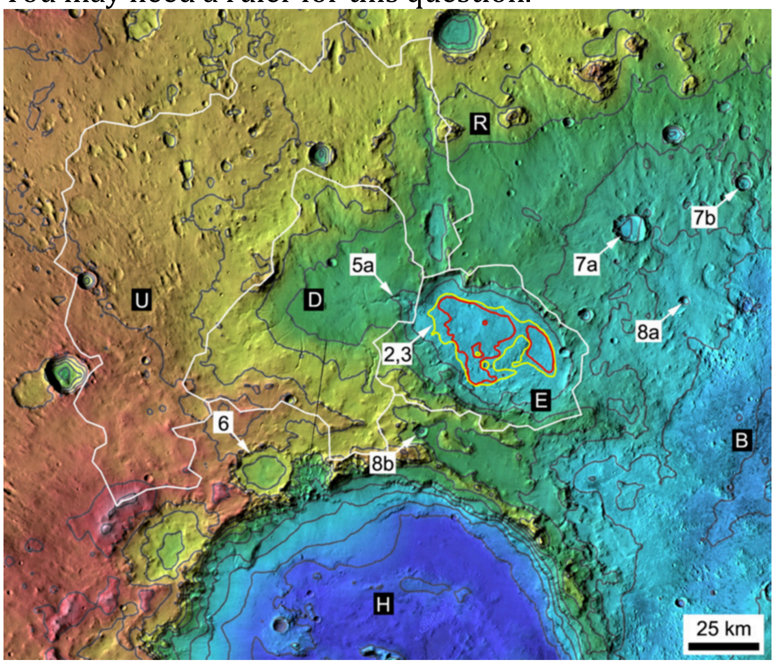
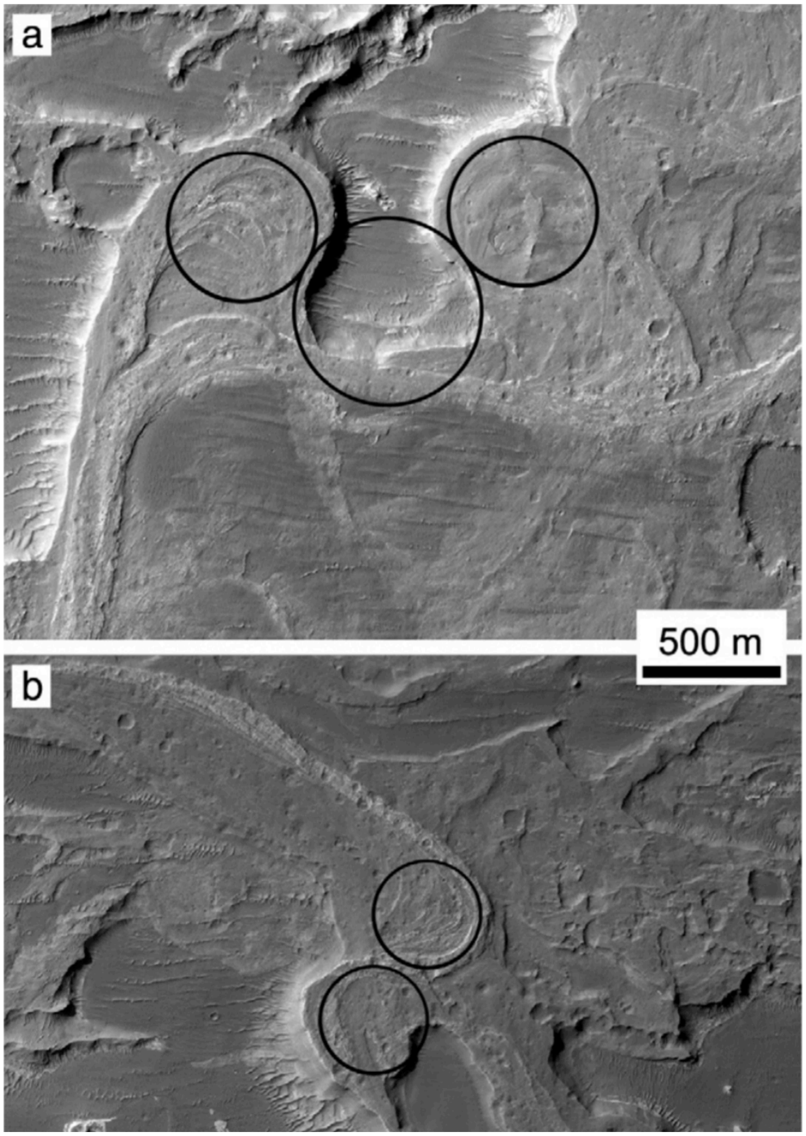
GEOS 22060/32060 – Spring 2019 – Homework 6

Due in class **Tuesday 4 June 9:30a**. No credit will be given for answers without working. It is OK to use e.g. Mathematica, but if you do, please print out the work.

Q1. Eberswalde paleohydrology - minimum duration of lake-forming climates on Mars.
(following Irwin et al., Geomorphology 2015)
You may need a ruler for this question.



On Mars ~3.5 Gyr ago water from the white-outlined catchment area drained into the lake outlined in yellow, forming a delta at the point marked “2,3”. For this delta, we think only one trunk channel was active at any one time.



Use $Q_{1.5} = 0.011\lambda_{\mathrm{m}}^{1.54}(0.62) = 0.0068\lambda_{\mathrm{m}}^{1.54}$
to find bankfull discharge from the two meandering trunk streams shown above. (Remember that wavelength = 2x half-wavelengths).
Assume a sediment:water ratio of 1:1000 (by volume) and a lake evaporation rate of 1 m/yr.

Assuming that the lake level stayed constant during construction of the delta:

What is the total evaporation / yr from the lake (in km^3)?
For how many days/year could the trunk streams have been flowing at bankful discharge?
What is the amount of sediment transported per year?
What is the lake lifetime implied for the measured delta volume of 6 km^3?

Q2. Resurfacing mechanisms on Europa (how to get the oxygen to the ocean)
In class, we discussed the geological evidence that Europa has been resurfaced by liquid water, but did not discuss driving forces for this resurfacing. In this question, you will investigate one hypothesis for resurfacing (optional reading: Manga & Wang, Geophysical Research Letters 2007).

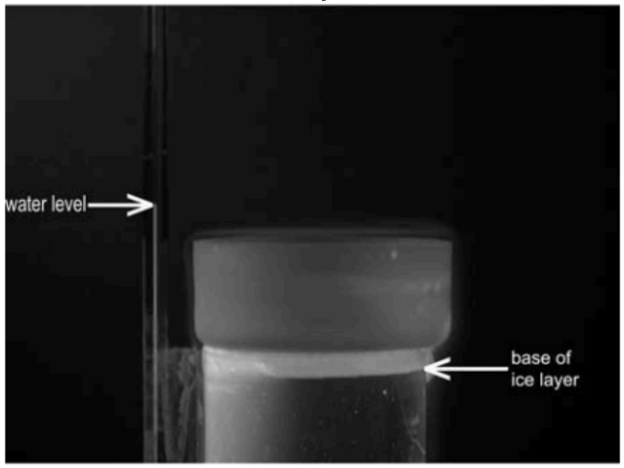


Figure 1. Experiment showing the evolution of pressure in water trapped below a freezing front; water is contained in a cylinder (7.5 cm diameter), open at the top and sealed at the bottom. The small capillary is connected to the cylinder and monitors its pressure. (top) Initial condition before freezing. (middle) Water level in the capillary rises 45 cm (well above the image) after a few mm of ice forms. (bottom) After a crack forms, inferred from acoustic emissions, water pressure returns to close to its original value. Horizontal white line indicate elevation of the water level in the capillary tube.

Manga & Wang, GRL 2007

(a) Assume that Enceladus undergoes heating-cooling cycles every 100 Myr due to the orbital-thermal feedbacks – let's exaggerate and assume that the ice shell goes from almost completely frozen to almost completely unfrozen each cycle. Consider freezing of an initially very thin ice shell. Ocean pressure builds up according to

$$\frac{\partial P_{\text{ex}}}{\partial z} = \frac{3(\rho_w - \rho_i)r_i^2}{\beta \rho_w \left(r_i^3 - r_c^3\right)}$$

(neglecting ice-shell expansion), where z is the ice shell thickness, water density is 1000 kg/m^3, ice density is 910 kg/m^3, and water compressibility (beta) 4 x 10^{-10} Pa^{-1}. r_c is rocky-core radius (the rock is assumed incompressible), and r_i is the radius at the top of the liquid-water ocean (i.e. $r_i = R - z$, where R is moon radius). Let $r_c = R - 200$ km and let R = 1600 km. How thick is the ice when the shell cracks?

(b) Assume that once the shell cracks the overpressured water can erupt onto the surface.[1] Taking into account the length of the heating-cooling cycle, for a typical water molecule, what is the typical wait time after being erupted before being erupted again?

[1] This is controversial; there is suggestive geologic evidence in favor, but theoretical arguments against.