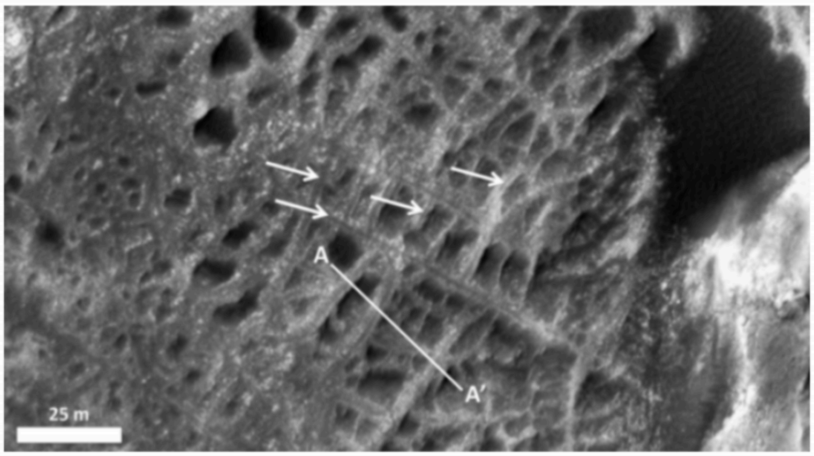
GEOS 22060/32060 – Winter 2020 – Homework 5

Due Thursday 5 March, 5pm

Q1. Mars boxwork and groundwater circulation.

Mars Reconnaissance Orbiter has found "boxwork" structures along the future path of the *Curiosity* rover. These light-toned ridges are interpreted as preferentially-cemented halos around dark central fractures formed during a past episode of groundwater flow (the rocks have since been wind-eroded, and the cement resists erosion). The scale bar on this image is needed to answer this question.

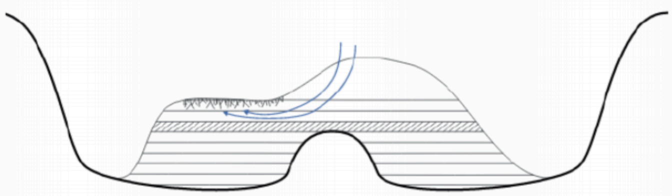


a) Assume the haloes form by chemical diffusion at a diffusivity of 10^{-17} m^2 s^{-1}. What is the formation time of the haloes?

b) Now assume that the haloes formed by infiltration of cementing fluids through a network of pores (pores not resolved from orbit). Model the network of pores as a cubical matrix of tubes – equation given in lecture 4, slide 34. Assume lattice spacing 0.1 mm and pore diameter 0.005 mm. What is the permeability? How long did the haloes take to form? (There is no need to do a complicated calculation for formation time; dimensional reasoning is acceptable.) You may ignore the feedback of cementation on permeability, and you may assume (for this part of the question) that the dark central fractures have very high permeability.

c) Discuss (quantitatively, with at least two examples) the dependence of formation time on pore spacing and on pore diameter. Which factor is more important?

d) Assume the boxwork once contained 30% pore space that is now completely occluded by cementing minerals. Assume water migrated vertically as it passed through the boxwork layer, had salinity 1 wt%, and that all salts were precipitated out to form the boxwork. Boxwork thickness is estimated at 40 m. Assume the pressure driving fluid flow corresponds to a water-table difference of 1 km over a baseline of 20 km, and an effective fracture (dark central features) permeability of 10^{-7} m^2 s^{-1}. What is the duration of subsurface fluid flow needed for boxwork formation?



From Siebach & Grotzinger 2014.

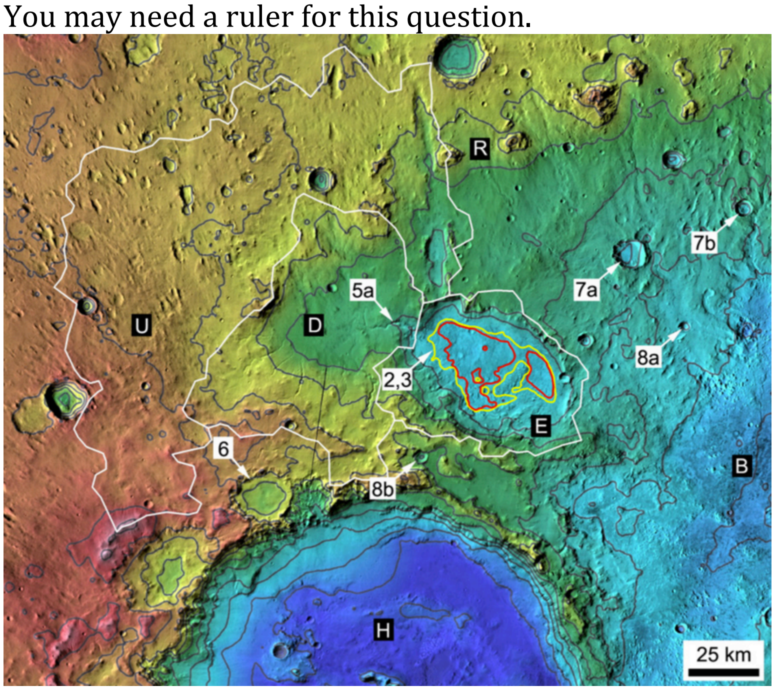
e) Would you direct a paleolife-seeking rover to sample the boxwork?[1] To which of the above assumptions and parameters is your decision most sensitive?

[1]: $10 mn (amortized) for in-situ sampling; >$100 mn for return to Earth.

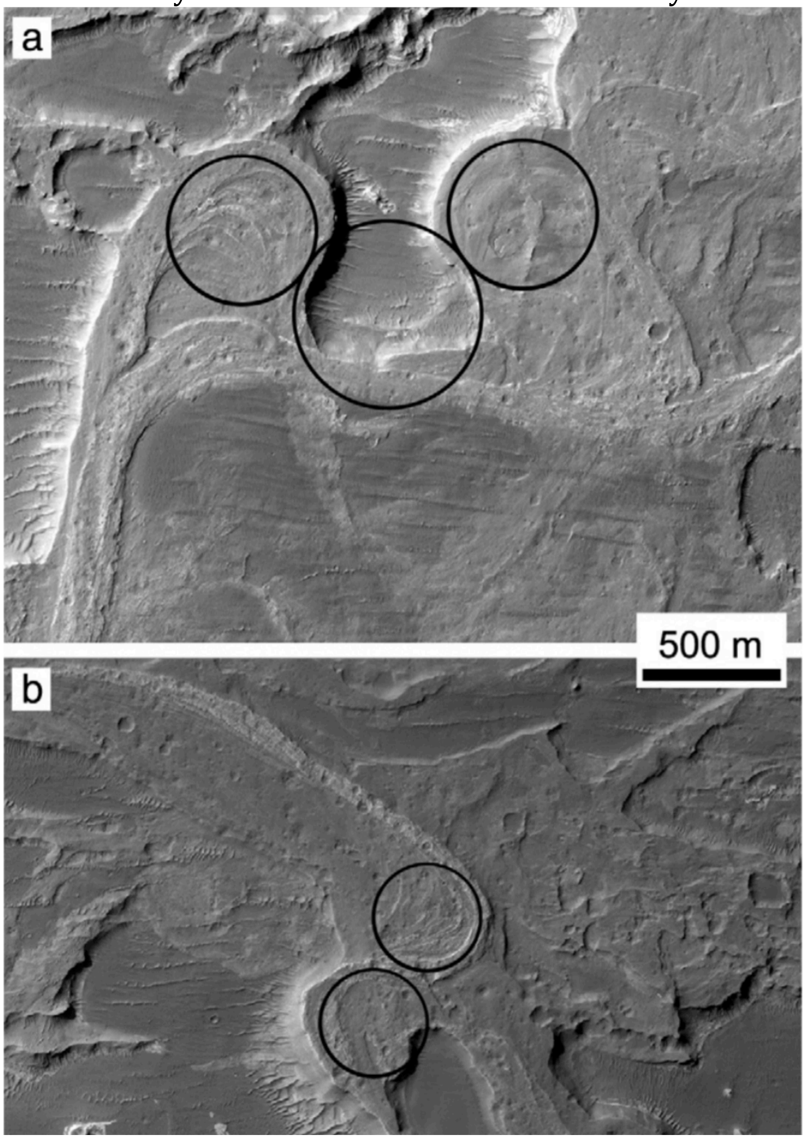
Q2. Eberswalde paleohydrology - minimum duration of lake-forming climates on Mars.

(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 $Q_{1.5} = 0.011\lambda_m^{1.54}(0.62) = 0.0068\lambda_m^{1.54}$, where λ_m is wavelength, 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?