The science of landscapes: Earth and planetary surface processes
Winter 2019
Problem set 1 - due in class Wed 22 Jan, 10:30am.

All homeworks must be typeset. Printing out the text of your answer and then marking up equations by hand on the printout is OK. Homework can be submitted by email (kite@uchicago.edu), or in my mailbox on the first floor of the Hinds building, or in class.

Question 1. How can topography and gravity measurements be combined to determine the compensation state of surface features? [McSween et al. question 8.5].

Question 2. Lucy's targets. The "Lucy" spacecraft (named after the hominin fossil), now under construction, is a mission to the Trojan asteroid swarms. The largest target is the binary minor planet Patroclus-Menoetius. The members of the binary are 141 km (Patroclus) and 112 km (Menoetius) in diameter. For uniform density and water-ice composition what is the central pressure inside Patroclus? Menoetius? Do we expect these worlds to be roughly spherical, and if so why? Suppose Lucy finds that these worlds are roughly spherical, what would that tell us about their history?

Question 3. True Polar Wander. The kinetic energy of rotation of a body with a principal moment of inertia I about some axis is given by $E = 0.51\omega^2$, where ω is the angular rotation rate (radians/s). The angular momentum L of a rotating body is given by $L = I\omega$. For fixed angular momentum, show that the kinetic energy of a rotating body is a minimum if it rotates about the axis with the maximum moment of inertia C of the three principal moments $C \geq B \geq A$. (from Melosh "Planetary Surface Processes," chapter 2 https://geosci.uchicago.edu/~kite/doc/ ch2_of_melosh.pdf, question 2.3)

Question 4. The transition between elastic behavior on short timescales and viscous behavior on long timescales. In class we mentioned that the lithospheric thickness is time-dependent, but we did not quantify this. Here we shall. Assume that the temperature in the upper mantle of the earth is 273K at the surface and increases to 1473K at 100 km depth at a constant slope (roughly the source depth of basaltic rocks that erupt at this temperature). Still deeper the temperature, controlled by convection, is approximately constant. Use the following wet olivine creep law

strain rate (s^{-1}) = $10^{4.0}\,\sigma^{3.4}$(σ in MPa) $\exp(-444\ \mathrm{kJ\ mol^{-1}} / RT)$

with R = 8.314 J/K, to estimate the Maxwell time as a function of depth for a typical stress $\sigma \approx 30$ MPa (produced by loads ca. 1 km thick). Upper mantle shear modulus $\mu = 65$ GPa. How thick is the "lithosphere" for loads applied for: 1 Myr, 10 Myr, 100 Myr, and 1 Gyr? How sensitive is this thickness to the assumed stress? Beware of unit conversions! (Melosh "Planetary Surface Processes," chapter 4 https://geosci.uchicago.edu/~kite/doc/ch2_of_melosh.pdf question 4.3)