Geodynamics 5690/6690: Exercises I Due 8 March
Show all work; your writeup should include answers to all questions and any relevant figures you create.

(1) Roy et al. (2009)'s "preferred" geotherm model assumed steady-state initial conditions (i.e., for $t \leq 0$) including a surface temperature of 0°C and a basal temperature (at 200 km depth) of T_a = 400°C. They don't mention thermal conductivity, but their thermal diffusivity $\kappa = 10^{-6}$ implies a constant thermal conductivity ~ 3 W/m°K.
a. Given these parameters, what would be the surface heat flow at time $t \leq 0$?
b. Roy et al. also assumes heat production of 3×10^{-6} W/m^3 in a layer from 0 to 15 km depth. What would the heating contribute to surface heat flow? What temperature change would be expected across this layer just due to radioactive heating?
c. The total geotherm is the sum of the effects from conduction plus those from radioactive heating in the 15-km thick layer. With the radioactive heating present, the conduction part occurs across a 200-km thick layer with temperature change of 400°C minus the temperature change calculated in part b. What is the total surface heat flow for this geotherm?

(2) At time t = 0, the base of the tectosphere (200 km deep under the Colorado Plateau; 100 km deep elsewhere) is assumed to be replaced by asthenospheric mantle with a temperature of T_b = 1300°C. Using their coefficient of thermal expansion ($\alpha = 2.5 \times 10^{-5}$) and a reference mantle density of ρ_0 = 3350 kg/m^3 for T_0 = 0°C, what instantaneous elevation change would be expected off the Plateau? (Assume Airy isostasy: i.e., uniform stress in a fluid asthenosphere and no flexural rigidity, so $\rho_0 g \Delta h = \int_{200}^{0} \Delta\rho g \, \mathrm{d}z$, where Δh is change in elevation and $\Delta\rho$ is change in density. Assume also that the geotherm calculated in question 1c is the same both on and off the Plateau!)

(3) Assume the Laramide slab is 60 km thick and its temperature varies linearly from 400°C at the top to 1300°C at the bottom. If the slab is isostatically coupled to the base of the lithosphere for $t < 0$ and completely decoupled after, what would be the instantaneous elevation change everywhere at t = 0 due to delamination of the Laramide flat slab?

(4) Do these calculations suggest testable predictions for the hypothesis of Roy et al.? If so, what are the predictions, and what observations might you compare them with?

(5) There are several parameters in a conductive geotherm model that can affect both heat flow and temperature. You can explore the effects of these using the Matlab script Geotherm.m in Matlab, which is included as a download as part of this assignment. USU has a site-license for Matlab, so you should be able to either find it on Oldham-room computers or download it from the campus software site. You will need to place the Matlab script, Geotherm.m, in a directory where you want to work and then change your location

to that directory using the file box within the software or from the Matlab command line using, e.g.,
>> cd /Users/~myusername/Desktop/
if that is where you put the script. Then you can run the code from the Matlab command line by typing:
>> Geotherm

Using the outputs from running the Geotherm script, discuss the effects on surface heat flow and Moho temperature for the following cases (with the remaining parameters held fixed to "Suggested values" [given in brackets]). As you discuss your results, be sure to specify what numbers you used!

(a) What are the surface heat flow and Moho temperature using thermal conductivity parameters expected for a mafic rock versus those for a quartz-rich rock?

(b) What are the effects of higher versus lower crustal heat production (H_0 or l_{rad})?

(c) What are the effects of higher versus lower conductive lengthscale l_{con}?

(d) The Basin and Range in the Bonneville region has surface heat flow ~90 mW/m^2, A_0 ~1.3 μW/m^3, crustal thickness 31 km, and Moho temperature ~700°C. The Wyoming craton nearby has surface heat flow ~60 mW/m^2, A_0 ~1.5 μW/m^3, crustal thickness 48 km, and Moho temperature ~500°C. First, given these, find a geotherm parameterization that matches these observations. (Describe the parameters you used, and include the plot of the two geotherms together that is created as a .png file by the Matlab script). Do the parameters and geotherms seem reasonable? Note that l_{con} has a physical meaning! It reflects either advective heat transfer or transient cooling/heating, and it can be related to steady-state extensional strain rate using Lowry et al. (J. Geophys. Res., 2000) eqn 6, or with half-space cooling (compare Lowry et al. (2000) eqn 5 with T&S eqn 4-113). Are these results consistent with what you might expect for these regions?

Grads only (but undergrads can do for extra credit!)
(6) The temperature differences in your two geotherms in part 5 should result in an isostatic elevation difference for the two locations. Modify the Matlab script Geotherm.m to calculate the Airy isostatic difference in elevation expected for these two cases. How does that compare with observed elevations?