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**Advanced School on Scaling Laws in Geophysics: Mechanical and
Thermal Processes in Geodynamics**

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Exercises in basic isostasy

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Exercise: Isostasy and Elevation

- 1a. Use the principle of Airy isostasy to determine the elevation of a mountain range, where the crustal thickness is 65 km, relative to a reference region where the crust is 35 km thick. Assume a simple 2-layer model with constant density crust, $\rho_c = 2.8 \times 10^3 \text{ kg m}^{-3}$ overlying constant density mantle, $\rho_m = 3.3 \times 10^3 \text{ kg m}^{-3}$.
- 1b. If the upper surface of the above mountain chain is eroding at a rate of 2 mm/yr, what will be the surface elevation of this mountain range after 10 Myr ?
2. The mid-ocean ridge is at a depth of 2.5 km, and the deep ocean basin is at a depth of 6 km. Assuming that oceanic lithosphere everywhere has the same vertical structure, use a Pratt-type model of isostasy to estimate the average density difference between lithospheric mantle at the ridge and lithospheric mantle below the basin. Assume a compensation depth of 130 km below sea-level, average mantle density beneath the basin of $3.3 \times 10^3 \text{ kg m}^{-3}$, water layer density of $\rho_w = 1.0 \times 10^3 \text{ kg m}^{-3}$ and crust (6 km thick) of density $\rho_c = 2.8 \times 10^3 \text{ kg m}^{-3}$.
- 2b. If you assume that the temperature of mantle beneath the ridge is 1350°C , equal to the temperature at the base of the lithosphere (of thickness $L = 130 \text{ km}$) beneath the deep ocean basin, and assume a linear geotherm through the old ocean basin, what coefficient of thermal expansion, α , do you deduce for a density law of the following form?

$$\rho = \rho_0 (1 - \alpha \Delta T)$$

- 1c. (returning to the problem in Q1a): a cold mantle root beneath the thick continental crust extending from depth 65 km to 250 km with the same average density as the mantle lithosphere of old ocean ($3.3 \times 10^3 \text{ kg m}^{-3}$), is replaced by mantle with the same average density as mantle beneath the ocean ridge: what change in elevation of the surface is expected ?
3. Assume that continental lithosphere consisting of crust with thickness 36 km, density $\rho_c = 2.8 \times 10^3 \text{ kg m}^{-3}$ is thinned rapidly by horizontal extension to 18 km. Assuming mantle density is $\rho_m = 3.3 \times 10^3 \text{ kg m}^{-3}$, and local isostasy is maintained during and after the extension, what is the new level of the basement surface (relative to the pre-extension level), assuming
- (a) subsidence is sub-aerial throughout,
- (b) subsidence is sub-marine throughout,
- (c) the basin is filled with sediment of density $\rho_s = 2.2 \times 10^3 \text{ kg m}^{-3}$ as it is formed.