Heat conduction and production
Lecture 7.6 - Influence of topography

Lecturer: David Whipp
david.whipp@helsinki.fi
Goals of this lecture

- Look at some examples of the 2D variations in temperature in the Earth as a result of surface topography
Geodynamic implications

- We’ve now see that radiogenic heat production can significantly influence the subsurface thermal field, particularly in the crust.

- This may influence geodynamic behavior of the deforming crust by affecting the depth of the transition from brittle to ductile deformation, or the potential for partial melting of the crust.

- Another important influence on the crustal thermal field is topography at the Earth’s surface.

- Why might topography matter?
Thermal field beneath periodic topography

- In our calculations of temperatures in the Earth thus far, we’ve assumed a known surface temperature $T_0$ at $y = 0$.
- Atmospheric temperatures decrease with elevation following an atmospheric lapse rate $\beta$ (typical value: $\beta = 6.5^\circ$C km$^{-1}$).
- Combined, this suggests surface temperatures should vary with elevation in mountainous regions, an effect we can simulate.
- Importantly, this is clearly a 2D problem.
Thermal field beneath periodic topography

To do this, we compensate for the temperature variations with elevation by scaling the temperature by $\Delta T$ at $y = 0$, yielding

$$T(x, y) = T_0 + \frac{qm y}{k} + \frac{\rho H_0 h_r^2}{k} \left(1 - e^{-y/h_r}\right) + \Delta T \cos \frac{2\pi x}{\lambda} e^{-2\pi y/\lambda}$$

with

$$\Delta T = \left(\beta - \frac{qm}{k} - \frac{\rho H_0 h_r}{k}\right) h_0$$

where $T_0$ is the surface temperature a sea level in nature, $qm$ is the mantle heat flux, $k$ is thermal conductivity, $\rho$ is density, $H_0$ is the surface heat production value, $h_r$ is the e-folding depth for heat production, $\lambda$ is the wavelength of the topography and $h_0$ is the amplitude.
Thermal field beneath periodic topography

$A = 2.5 \, \mu W \, m^{-3}$

$h_r = 10 \, km$

$k = 2.75 \, W \, m^{-1} \, K^{-1}$

$q_m = 20 \, mW \, m^{-2}$

$h_0 = 4 \, km$

$\lambda = ??? \, km$

$\beta = 6.5^\circ C \, km^{-1}$
Thermal field beneath periodic topography

$A = 2.5 \, \mu W m^{-3}$
$h_r = 10 \, km$
$k = 2.75 \, W m^{-1} K^{-1}$
$q_m = 20 \, mW m^{-2}$
$h_0 = 4 \, km$
$\lambda = ??? \, km$
$\beta = 6.5^\circ C \, km^{-1}$
Thermal field beneath topography

- Topography can influence the geometry of the thermal field beneath it, particularly as the relief and wavelength grow.
- The depth of the perturbation is related to the wavelength, with longer wavelengths affecting deeper crustal levels.
- This has important implications for data that depend on the thermal structure of mountainous regions, such as low-temperature thermochronology data.
Let’s see what you’ve learned…

- If you’re watching this lecture in Moodle, you will now be automatically directed to the quiz!