Final Exam Tectonophysics, January 24 2019, 13:30-16:00 (Jesse: 13:30-16:30)

1. *Switch off your smartphone and put it out of sight*
2. *Not allowed: Head- or earphones, notes, books*
3. *Allowed: graphical calculator, pencils, pens, ruler, compass*
4. *Answer every question (and just the question) as precisely and concise as possible*
5. *You are allowed to leave the room one hour after the test has started (late comers will be allowed in during the first hour).*

Assignment 1 Dynamic surface topography.

Title: Dynamic surface topography: a new interpretation based upon mantle flow models derived from seismic tomography (Forte et al., 1993).

Abstract. The very long wavelength (i.e. in the degree range $\ell = 1$–8) dynamic topography at the Earth's surface, estimated by isostatic reduction of the observed topography, is shown to be in good agreement with the topography predicted by a model of viscous flow in the mantle. This flow model was previously derived by independent consideration of the observed nonhydrostatic geoid and is based upon a recent model of large-scale seismic shear velocity heterogeneity in the mantle. Our estimate (and prediction) of the long wavelength dynamic surface topography reveals significant depressions (≈ 2-3 km) of the continental shields relative to their hydrostatic reference positions.

Here to the left is the title and abstract of the paper by Forte and colleagues (1993) that we discussed in class.

a) what is the research question?

b) how do they answer the research question? In your answer, explain terms that you take from the title and abstract.

c) what is the answer to the research question?

Assignment 2 Stress around an infinite fault.

A fault in the $x_2 - x_3$ plane has a uniform slip s on it (see Figure 1). The fault is embedded in an infinite space with uniform and isotropic elastic properties. The fault itself also has an infinite surface area. The figure shows a cylindric cut-out of the continuum and the fault.

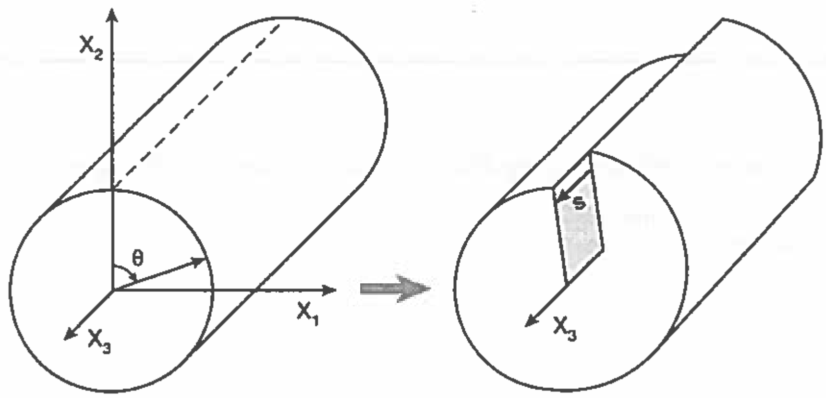

Figure 1. Geometry for assignment 2.

The slip on the fault is described by

$$u_1 = u_2 = 0 \qquad u_3(\theta = 2\pi) - u_3(\theta = 0) = s$$

where the displacement vector is $\vec{u} = (u_1, u_2, u_3)$.

a) Use Hooke's law:

$$\sigma_{ij} = 2\mu\varepsilon_{ij} + \lambda\varepsilon_{kk}\delta_{ij}$$

(summation convention) with Lamé parameters μ and λ to demonstrate that the only non-zero components of the stress tensor are equal to

$$\sigma_{13} = \mu\frac{\partial u_3}{\partial x_1} \qquad \sigma_{23} = \mu\frac{\partial u_3}{\partial x_2}$$

b) The stresses must satisfy the mechanical equilibrium equations:

$$\nabla\cdot\sigma + \rho\vec{g} = \vec{0}$$

Motivate that we can ignore the gravity term, and show that u_3 therefore satisfies the Laplace equation:

$$\frac{\partial^2 u_3}{\partial x_1^2} + \frac{\partial^2 u_3}{\partial x_2^2} = 0$$

c) Assume that the displacement in the elastic medium around the fault varies linearly with θ, as follows:

$$u_3 = \frac{s\theta}{2\pi}$$

Derive from the Laplace equation that this results in the following expressions for the non-zero stress components:

$$\sigma_{13} = \mu\frac{s\cos\theta}{2\pi r} \qquad \sigma_{23} = -\mu\frac{s\sin\theta}{2\pi r} \qquad r = \sqrt{x_1^2 + x_2^2}$$

Assignment 3. Gravitational potential energy in oceanic lithosphere

a) Why do lateral density variations result in horizontal forces within the lithosphere?

b) We consider two columns of oceanic lithosphere (Figure 2). Due to age differences, the columns have different average densities ρ_0 and ρ_1. The columns are in local isostatic balance (Pratt isostasy) at compensation depth L (depth of the base of the lithosphere from sea level).

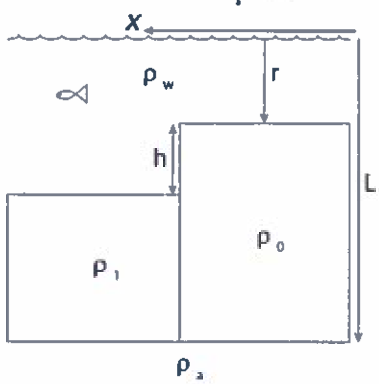

Figure 2, vertical cross section through oceanic lithosphere

Find an expression for h as function of the densities.

c) Compute the total horizontal force on the oldest column due to lateral density variations from

$$F_x = -g\int_0^L \Delta\rho(z')z'dz'$$

where g is the gravity acceleration, $\Delta\rho(z) = \rho_{left} - \rho_{right}$ is the lateral density contrast at depth z. Do not substitute your result for h (from b)) in this expression.

d) Compute F_x from your expression in c) and assume that the young column is located at the ridge, i.e., choose realistic numbers for r, L, h, ρ_0, and ρ_1 (you may also compute h from your result in **b**). Physically explain the sign of the horizontal force.