Rocks with elasticity in mantle convection

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All modern mantle convection equations are based on pure viscous media model, which has compressibility only in frames of thermoelastic problem solution (impact of temperature on volume change and absence of such impact from pressure — positive and negative elastic dilatation and from deviator stresses — inelastic dilatation) [Trubitsyn, 2008]. Analyzing the results obtained in these studies one may ask: how much we can trust these results? This question follows from our knowledge that mantle is a rigid crystalline rock and not a fluid; and also from understanding the difference in mechanisms of viscous fluid flow and ductile behavior of solid body.

It is well-known that Poisson coefficient of crystalline rocks varies in wide range from 0.15 to 0.40, most often observed values are 0.25, which essentially differs from values for fluids — 0.5. Seismic data in the crust and mantle are compatible with coefficient close to 0.25, except some local anomalous areas, which are mostly concentrated in the crust. This let us assume that mantle rocks have elastic properties and their ability to flow is conditioned by rather low yield strength magnitude; (elasticity) in the lithosphere and high rates of diffusion and re-crystallization processes in the low mantle. Taking into account the knowledge of real rock state it is interesting to understand what we are missing, when in mantle convection problem we replace ductile flow of solid rocks having elasticity by viscous fluid flow without elasticity.

In the recent publications [Rebetsky, 2008] it has been shown that in the problem of gravitational forces acting on rock massive, triaxial pressure with depth goes closer to lithostatic (weight of the rock column) due to inelastic deformation taking place in confined conditions (neighbor rocks, which are in the same conditions, limits horizontal spreading. Such deformation under gravitational forces leads to the increment of confining stresses in horizontal direction and to the vertical compaction in the same time [Jager, 1962]. This mechanism could be called as *gravitational elasto-plastic compaction*. If the rocks react on gravitational loading only in elastic manner, then for Poisson coefficient 0.25 horizontal pressure would be only 1/3 of vertical one [Dinnik, 1926]. Inelastic strains developing under lateral confining stresses brings *additional horizontal confining stresses* and elastic compaction of rocks [Rebetsky, 2008]. If the rocks as fluids would have Poisson coefficient 0.5 (ideal rubber) then gravitational stresses will not cause deviatory stresses and normal stresses in any direction will be equal to rock column weight.

Inelastic deformation at different tectonoshpere levels is conditioned by different mechanisms: in the crust — due to fracture flow (upper and middle crust) or quasi plastic midgrain flow (lower crust) when Coulomb stresses reach threshold value; in under crust lithosphere — due to the ductility flow [Nikolaevsky, 1996] when deviatory stresses reach yield strength; in lower mantle — due to the diffusion and re-crystallization mechanisms of viscous flow. If the rock specimen which underwent such elasto-plastic compaction under gravitational forces will be drilled out from rock massive (maintaining horizontal confining condition) then only additional horizontal confining stresses occurred at gravitational compaction stage will be left. In the rock specimen not healed at post-deformation stage by later mineralization these stresses will disappear practically immediately after canceling lateral confinement. For the rock specimen having such new formation, sudden destruction may occur after extracting the specimen from drilling holder. In this case, above mentioned additional confining pressure should be treated as residual stress forming in the specimen specific type of mutually compensating stress state.

What happened when we drill out the rock specimen from certain depth? In such case, first of all the weight of upper layers are canceled, relaxation occurs, but stress relaxation is not complete. In such relaxation conditions, when lateral confinement still acts, vertical stresses completely dropped; and horizontal ones — according to Poisson coefficient ν — *elastic relaxation law*. For rocks having $\nu = 0.25$ only 1/3 of overlaying column weight (lithostatic pressure) is relaxed. Elastic relaxation law together with lateral confinement and erosion processes at surface conditions occurrence in rocks residual stresses when vertical uplift, what was marked at first time in [Goodman, 1989]. It has to be noted, if rocks would have Poisson elastic coefficient 0.5 (rubber), then elastic relaxation of gravitational stress state leads to equal decrement of both vertical and horizontal stresses, what actually happened in all modern computation of mantle convection.

Evaluations of the gravitational stress state energy are known $2.5\cdot10^{32}$ J. It is by three orders larger than kinetic energy of the planet and by four orders larger than energy of thermal convection. Our evaluations show that residual horizontal stresses of gravitational stress state (2/3 of lithostatic pressure and $\nu=0.25$) compose circa half of total energy of elastic strains. This energy will relax through vertical convection movements causing additional (relative to ideal viscous fluid) plastic deformations, which *finally will be transitioned into heating*. Comparing the residual stress energy of unit volume released when uplifting from the core up to upper mantle boundary with the work spent on vertical transferring of this volume in thermal convection we will get $8\cdot10^9$ J и $3\cdot10^9$ J respectively. *Thus, energy confined in residual stress state is more than the energy spent on vertical uplift of unit volume*.

Therefore, our analysis has demonstrated that in all modern computations of thermal convection in the mantle in solutions is missing one of the most important components in energy balance — residual stress state conditioned by gravitational elastic-plastic compaction. In the presentation in the frames of traditional viscous model the problem will be posed and the solving equations followed from it, which take into account existence of the residual stresses in mantle and its impact on mantle convection will be given.

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Seasonal variation of induction vectors

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In the geoelectromagnetic studies of electrical conductivity of the Earth's interior, the response function (RF) is supposed to be any function (impedance, apparent resistivity, induction arrow, horizontal MV tensor…) derived from the Earth's electromagnetic (EM) data which provides us with possibility to determine the conductivity structure in the Earth. Ideally RF depends only on the Earth's conductivity and does not depend on the properties of external EM field used.

Widely used RF for EM monitoring is induction vector $\mathbf{C}$:

$$\mathbf{C} = Ae_x + Be_y\ , \qquad (1)$$

where e_x and e_y are unit vectors, x — is pointed to