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Modelling of thermal mode for siberian craton by inversion of seismic profiles "Rift" and "Meteorite"

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Temperature of the bowels of the earth is one of the most indefinite physical parameters. As seismic velocities are more sensitive to the temperature then to the composition, so the inversion of seismic profiles into thermal models is one of the most perspective way for estimation of the thermal field.

On constructing the seismic models all researchers have a problem with quality control of their results, because nobody knows the exact meaning of seismic velocities that can more accurately describe the features of the Earth structure. Seismic data obtained from the raw material by superlong seismic profiles survey within Siberian Craton was processed by different science groups [*Oreshin, et al.*, 2002; *Pavlenkova and Pavlenkova*, 2006; *Egorkin*, 1999]. All velocity models differ from each other by structure and absolute values of seismic velocities. According to geodynamics, variation 0.2 km/sec in longitudinal velocity leads to temperature alteration about 500^{o}C. Thermal profiles obtained by velocity inversion is the way to estimate the quality of each seismic model.

The main target of this research is to reconstruct the composition and thermal mode for archean mantle of Siberian Craton. Our initial data is compositions of garnet peridotite and fertile primitive mantle, also we use seismic velocities [*Pavlenkova and Pavlenkova*, 2006], thermobarometry [*Griffin, et al.*, 1996] and heat-flow research [*Aremieva* and *Mooney*, 2001].

We must estimate the influence of chemical composition to seismic velocity and density and compare processed data with P–T valuations and thermal models. Calculation executes by minimization of Gibbs-energy in system Na_2O–TiO_2–CaO–FeO–MgO–Al_2O_3–SiO_2. P-velocities depend on P–T–X conditions, effects of phase-transformations, anharmonicity and inelasticity. To make an adjustment for inelasticity we estimate Q-factors: Q_S and Q_P.

For the composition of Siberian Craton we set a model of garnet peridotite (GP) for the depth less than 180 km and primitive mantle (PM) for more than 180 km [*Kuskov, et al.*, 2011]. Deviations in velocities for GP and PM are small – 0.3% for V_P and 1% for V_S, so geotherms received from seismic models vary within 50^{o}C [*Kuskov, et al.*, 2011]. Difference in composition has a little small influence to seismic velocities and can't be registered by seismic methods [*Kuskov, et al.*, 2006; *Kuskov, et al.*, 2011], but it leads to increasing of density (fig. 1). The density of fertile primitive mantle is more than density of garnet peridotite at about 2–3%, that is equal to temperature deviance at 500^{o}C.

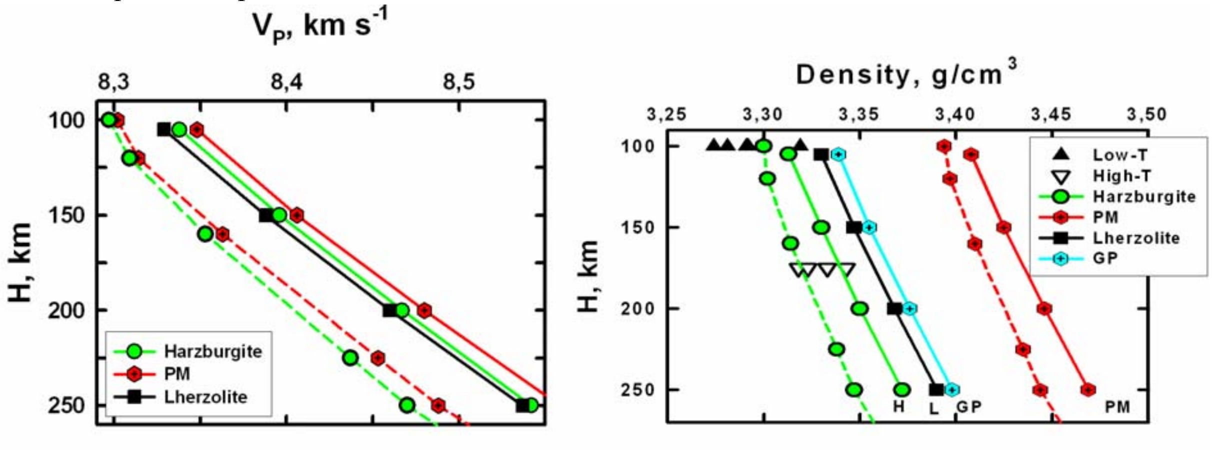

Fig. 1. P-velocities and densities along geotherms 35 (solid lines) and 40 mW/m^2 (dashed lines). Velocities of depleted matter are very close to primitive mantle, but density of primitive mantle is 2–3% more than density of garnet peridotite that equals ΔT about 500–700^{o}C.

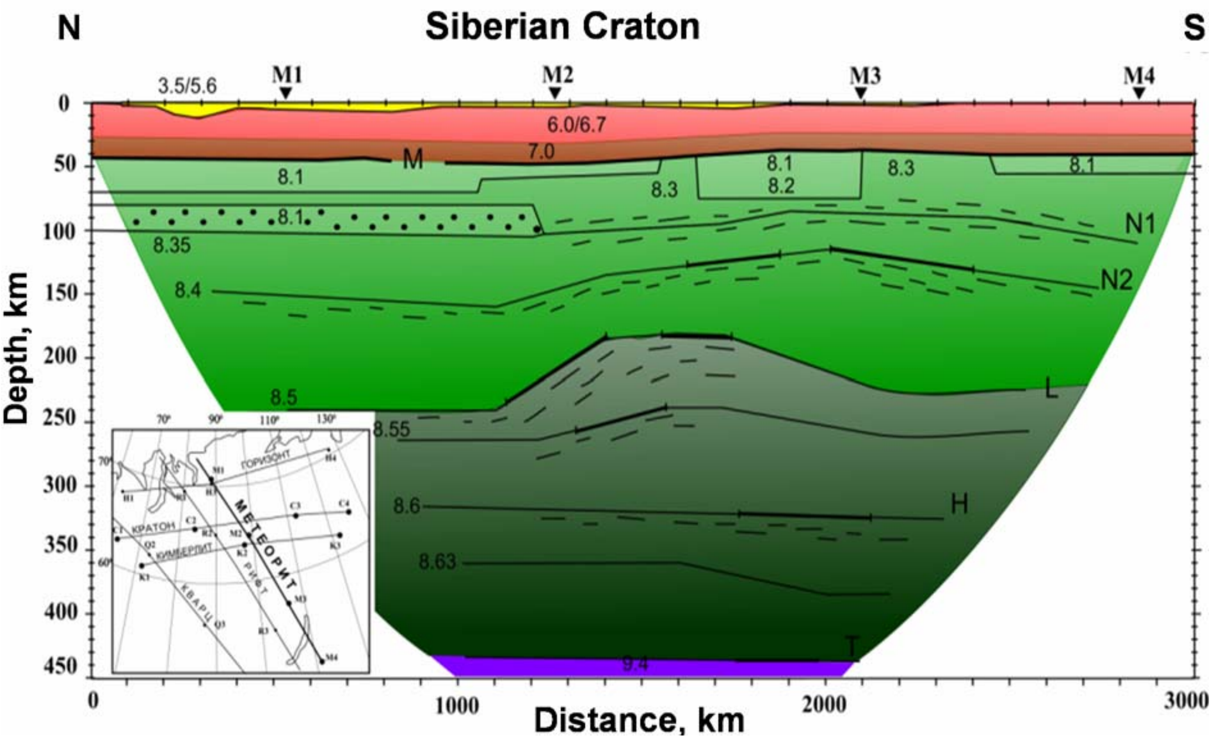

Fig. 2. Seismic velocities for profile “Meteorite” [*Pavlenkova* and *Pavlenkova*, 2006].

We process two profiles – “Meteorite” (fig. 2) and ”Rift” from the seismic model of N.I. Pavlenkova [*Pavlenkova and Pavlenkova*, 2006].

On figs 3 and 4 appears the distinction of temperatures and densities for different composition models. Comparing the permanent (GP) and variable (less than 180 km – GP, more than 180 km – PM) composition it appears, that difference in temperatures is small, but density of variable composition is more correct. On depth 210–300 km density of GP-PM model (3.42–3.49 g/cm^3) is closer to mantle density (3.426–3.486 g/cm^3) according to reference-model AK135 [*Kennett, et al*., 1995]. Density of GP on the same depth (3.40–3.42 g/cm^3) is obviously less than surrounding rock.

Also we determine the depth of the thermal lithosphere bound. Thermal lithosphere bound, where heat transfer accomplishes in conductive way, may be identified by finding intersections between adiabat 1200-1300^{o}C with gradient 0.3–0.5^{o}C/km and calculated temperature profile.

We use adiabat 1300^{o}C and gradient 0.465^{o}C/km. Obtained intersections describes the depth of the thermal lithosphere bound on every section of our profiles. Calculated depths was marked on 2D thermal distribution (figs. 5, 6)

Thereby the depth of the thermal lithosphere of Siberian Craton for researched profiles is very close to 1450^{o}C isotherm and is estimated as 310–330 km that conforms with estimation by heat-flow[*Aremieva and Mooney*, 2001] and tomographic models [*Bijwaard, et al.*, 1998].

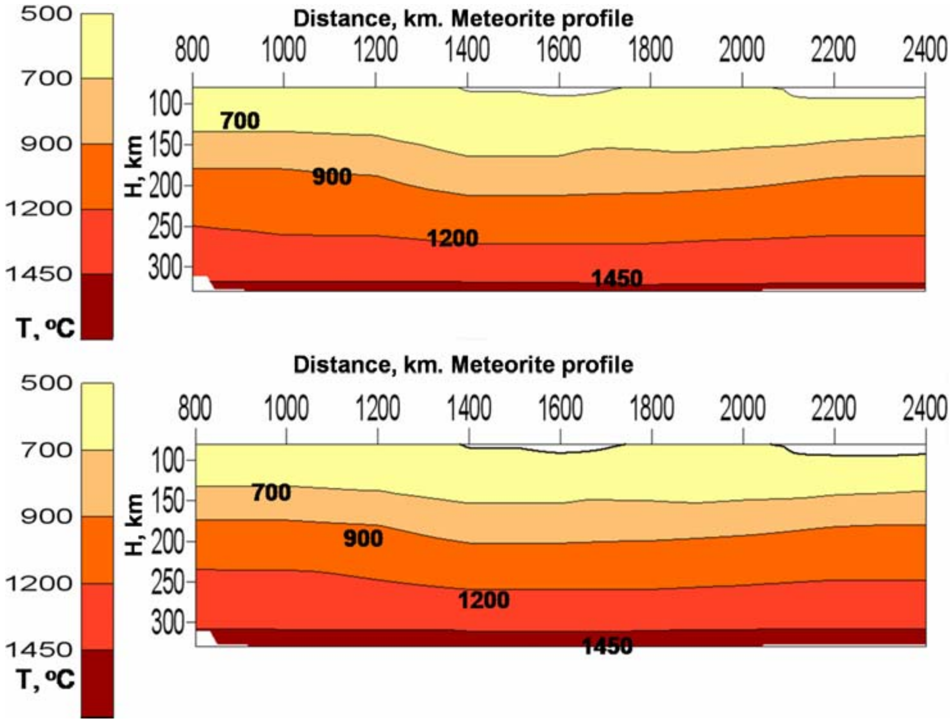

Fig. 3. Recovered temperature as a function of composition model. The upper pattern – permanent composition of garnet peridotite (GP), the lower one – variable composition (less than 180 km – GP, more than 180 km – primitive mantle (PM))

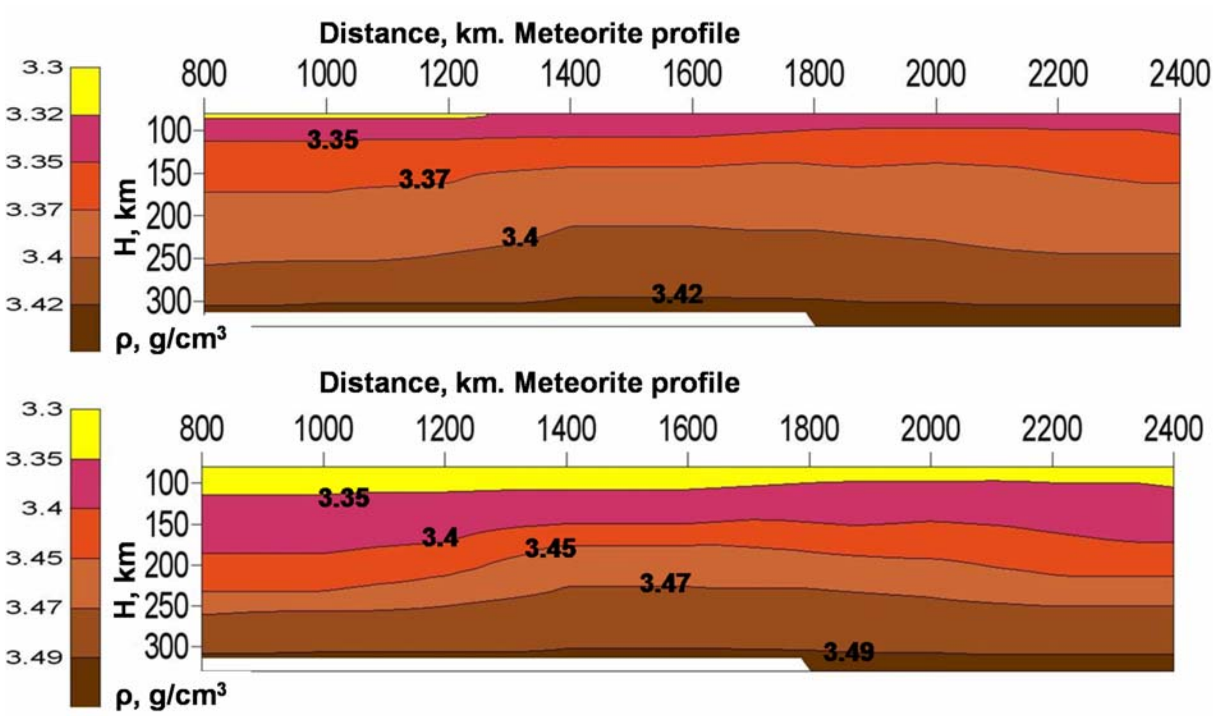

Fig. 4. Recovered density as a function of composition model. The upper pattern – permanent composition of garnet peridotite (GP), the lower one – variable composition (less than 180 km – GP, more than 180 km – primitive mantle (PM))

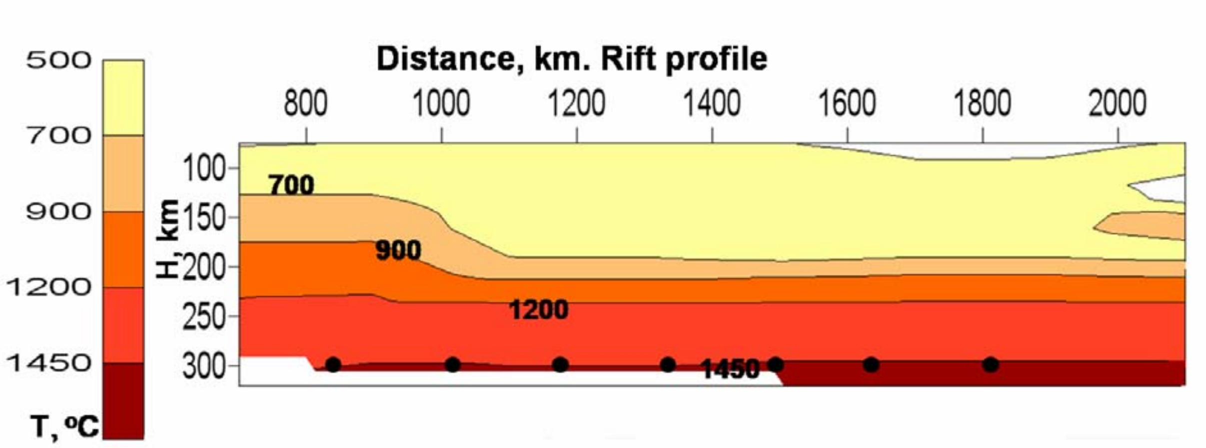

Fig. 5. Temperature distribution beneath Siberian Craton along Rift profile. Variable composition GP-PM. Black dots mark the depth of thermal lithosphere, that is close to 1450°C isotherm and is estimated as 300-320 km

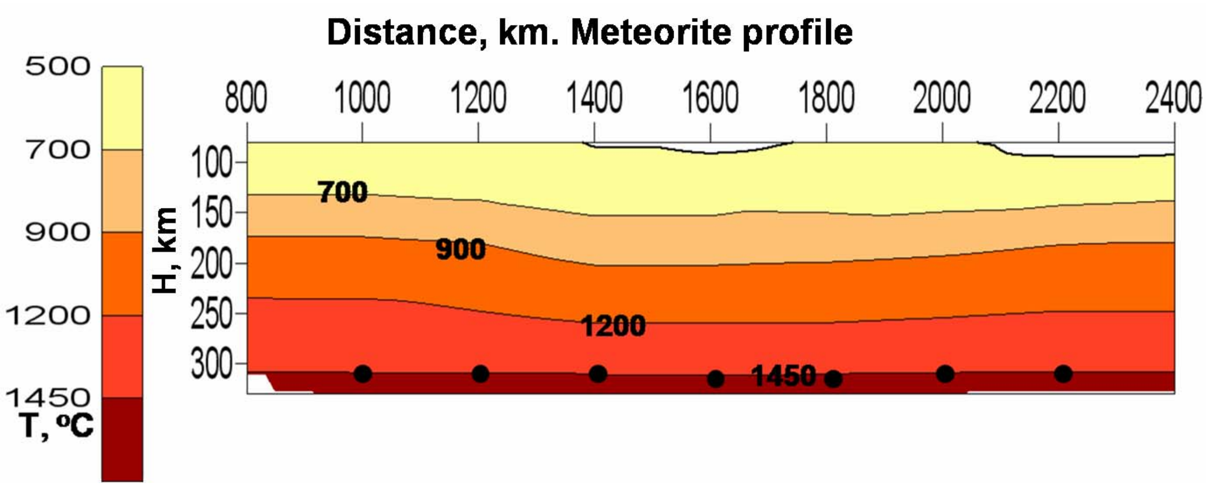

Fig. 6. Temperature distribution beneath Siberian Craton along Meteorite profile. Variable composition GP-PM. Black dots mark the depth of thermal lithosphere, that is close to 1450°C isotherm and is estimated as 310-330 km

References

Oreshin S., L. Vinnik, L. Makeyeva, G. Kosarev, R. Kind and F. Wentzel (2002), Combined analysis of SKS splitting and regional P traveltimes in Siberia, *Geophys. J. Int., vol. 151*, pp. 393–402.

Pavlenkova G.A., N.I. Pavlenkova (2006), Upper mantle structure of the Northern Eurasia from peaceful nuclear explosion data, *Tectonophysics, vol. 416*, pp. 33–52.

Egorkin, A.V. (1999), Study of the Mantle on Super Long Geotraverses, *Izv.Phys. Earth (Engl. Transl.), vol. 35*, nos. 7–8, pp. 630–645.

Griffin, W.L., F.V. Kaminsky, C.G. Ryan, et al. (1996), Thermal State and Composition of the Lithospheric Mantle beneath the Daldyn Kimberlite Field, Yakutia, *Tectonophys., vol. 262*, pp. 19–33.

Artemieva, I.M. and W.D. Mooney (2001), Thermal Thicknessand Evolution of Precambrian Lithosphere: A Global Study, *J. Geophys. Res., vol. 106*, pp. 16387–16414.

Kuskov O.L., V.A. Kronrod, A.A. Prokof'ev (2011), Thermal Structure and Thickness of the Lithospheric Mantle Underlying the Siberian Craton from the Kraton and Kimberlit Superlong Seismic Profiles, *Izv.Phys. Earth (Engl. Transl.), vol. 147*, no. 3, pp. 155–175.

Kuskov, O.L., V.A. Kronrod (2006), Determining the Temperature of the Earth's Continental Upper Mantle from Geochemical and Seismic Data, *Geochem. Int. (Engl. Transl.)*, no. 3, pp. 232–248.

Kennett B.L.N., E.R. Engdahl, R. Buland (1995), Constraints on seismic velocities in the earth from travel times, *Geophys. J. Int, vol. 122*, pp. 108–124

Bijwaard H., W. Spakman, E.R. Engdahl (1998), Closing Gap between Regional and Global Travel Time Tomography, *Geophys. Res., vol. 103*, pp. 30055–30078.