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Thermomechanical model of the North American lithosphere

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An integrated thermomechanical model of the lithosphere has been constructed based on various data sets and method. A consistent 3D model of the North American crust is based on the most recent seismic data from the USGS database. To this aim, we (1) defined the geometry of the main geological provinces of North America, (2) selected and evaluated the reliability of seismic crustal models in the database, (3) estimated the P-wave seismic velocity and thickness of the upper, middle and lower crust for each geological province. Temperature variations in the upper mantle have been estimated, taking into account compositional changes in cratonic regions, by applying a new inversion technique, which jointly interpret seismic velocities and gravity data. First, we inverted two tomography models into temperatures, using a uniform composition representative of a 'Primitive' mantle, which was affected by a small amount of melt extraction. In the next step, the thermal component of the density was estimated according to these initial thermal fields and was subtracted from the total density, to obtain the compositional component. These preliminary results might be affected by compositional changes of the cratonic upper mantle, usually depleted in heavy constituents. Then, the gravity effect of temperature variations is estimated and removed from the mantle gravity anomalies. The residual (temperature free) mantle anomalies are used to evaluate compositional changes in the cratonic mantle. We re-estimated the temperatures, using this new composition, and repeat calculations of the thermal and compositional density variations. These steps are reiterated until the convergence is reached. The results show that the upper mantle of the Archean North American cratons is characterized by temperatures higher than $\sim$150°C compared to the initial thermal model, and by strong negative compositional density anomalies (-0.03 g/cm3), corresponding to Mg # (100xMg/(Mg+Fe)) >92. In turn, in the upper mantle of the off-cratons regions high density bodies are found, probably related to fragments of subducted slabs, as close to the suture of the Appalachians and Grenville province. The use of the new crustal, thermal and compositional models gives us the opportunity to estimate lateral variation of strength and effective elastic thickness (Te). In the North American Cordillera the strength is mainly localized in the crust, which is decoupled from the mantle lithosphere. In the cratons the strength is primarily controlled by the mantle lithosphere and all the layers are generally coupled. Intraplate earthquakes (USGS database) occur mainly in the weak regions, such as the Appalachians, and in the transition zones from low to high strength surrounding the craton. Te, derived from the thermo-rheological model using new equations that take into account variations of the Young's Modulus in the lithosphere, shows large spatial variability within the cratons, ranging from 70 km to >100km, while it drops to <30 km in the young Phanerozoic regions.