The influences of 660 km phase transitions on mantle evolution

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A self-consistent numerical model is developed for mantle convection influenced by mantle magmatism, moving plates, and the solid-solid phase transitions at the depths around 660 km to clarify how the phase transitions influence the thermal and chemical state of the mantle as well as its dynamic behavior. When the internal heating rate in the mantle is sufficiently low and the mantle magmatism is not so active as to significantly influence mantle structure (the thermal convection regime), the influence of phase transitions on mantle convection is limited. The garnet vs. perovskite transition does not, of course, influence mantle convection at all and the post spinel transition cannot stop slab penetration by itself. The slab stagnation observed for the earth's mantle is, therefore, most likely a result of other agents like trench retreat and the high viscosity in the lower mantle. When the internal heating rate is high enough to keep the mantle hot and mantle magmatism active (the chemically stratified regime), in constrast, the influence of garnet vs. perovskite transition becomes significant. A layer enriched in the basaltic component develops above the 660 km discontinuity, while a layer enriched in the harzburgite component develops beneath the discontinuity even under the influence of the slabs that penetrate deep into the lower mantle. The basaltic materials and harzburgite are both produced by ridge volcanism and after having subducted into deep mantle as parts of subducting slabs, separate from each other and a part of the materials uprise to the depths around the 660 km discontinuity by their chemical and/or thermal buoyancy. When, besides the barrier effect of the garnet vs. perovskite transition, the barrier effect of the post spinel transition is also strong, plates stop moving and the lithosphere becomes a stagnant lid. This occurs because the post spinel transition stops hot upwelling plumes from deep lower mantle, which maintains plate motion by breaking the lithosphere to form new plate boundaries. Recent high pressure experiments suggest that the barrier effect of the post spinel transition is not so strong as to stop hot upwelling plumes. The earth's mantle is probably on the transitional stage from the chemically stratified regime to the thermal convection regime at present and it is likely that a chemical discontinuity develops along the 660 km phase boundary owing to the garnet vs. perovskite transition.