A numerical model of mantle evolution in the Hadean and Archean

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A numerical model of mantle evolution has been presented for the first 2 billion years of the earth's history. Mantle is assumed to evolve as a result of (a) mass and energy transfer by magma-migration and solid state convection and (b) chemical differentiation by magmatism. The plate motion is self-consistently reproduced in the model of mantle convection. The influence of the 660km phase transitions, i.e. spinel-post spinel transition and garnet-perovskite transition is included, too. Magmatism is modeled as a permeable flow of magma produced upon pressure release melting beneath ridges, hot spots and other upwelling regions in convecting mantle. The numerically modeled mantle evolves in two stages. In the earlier stage, the entire mantle is chemically stratified; the shallower parts of both upper and lower mantles are occupied by depleted materials, while the deeper part of both the upper and lower mantles are occupied by undepleted or enriched materials. The chemically stratified structure develops because of vigorous but episodic mantle magmatism, which is induced by flushing events in the mantle. The entire mantle is almost stagnant except when the flushing events take place. As the internal heat source decays, however, the secondary convection begins beneath the lithosphere and the upper mantle becomes more chemically homogeneous owing to the convective stirring, though the lower mantle still remains chemically stratified. In the later stage of mantle evolution, plate motion begins as a part of thermal convection in the mantle. Subducting slabs penetrate deep into the lower mantle. In spite of the whole mantle convection induced by plate motion, however, the mantle still remains chemically stratified as a whole; the upper mantle and the shallower part of the lower mantle is occupied by depleted materials while the deeper part of the lower mantle is occupied by undepleted materials. The effect of convective stirring by the whole mantle convection is balanced by chemical differentiation due to ridge and hot spot magmatism. Heat builds up and conspicuous lateral heterogeneity develops at depth in the lower mantle. I will continue the calculation for another 2.5 billion years to simulate the entire history of the earth's mantle evolution.