

三次元球殻モデルを用いた超大陸サイクルを伴うマントル対流の数値シミュレーション Numerical simulations of mantle convection with the supercontinent cycle using a 3D spherical-shell model

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The thermal heterogeneity of the Earth's mantle under the drifting continents during a supercontinent cycle is a controversial issue in earth science. Here, a series of numerical simulations of mantle convection are performed in 3D spherical-shell geometry, incorporating drifting deformable continents and self-consistent plate tectonics, to evaluate the subcontinental mantle temperature during a supercontinent cycle. Results show that the laterally averaged temperature anomaly of the subcontinental mantle remains within several tens of degrees (plus or minus 50 degrees) throughout the simulation time. Even after the formation of the supercontinent and the development of subcontinental plumes due to the subduction of the oceanic plates, the laterally averaged temperature anomaly of the deep mantle under the continent is within +10 degrees. This implies that there is no substantial temperature difference between the subcontinental and suboceanic mantles during a supercontinent cycle. The temperature anomaly immediately beneath the supercontinent is generally positive owing to the thermal insulation effect and the active upwelling plumes from the core-mantle boundary. In the present simulation, the formation of a supercontinent causes the laterally averaged subcontinental temperature to increase by a maximum of 50 degrees, which would produce sufficient tensional force to break up the supercontinent.

The supercontinent cycle bears close relation to the evolution of mantle convection and plate tectonics. Supercontinent formation involves complex processes of "introversion" (closure of interior oceans), "extroversion" (closure of exterior oceans), or a combination of these processes in uniting dispersed continental fragments, as against the simple opening and closing of individual oceans envisaged in the Wilson cycle. Results show that supercontinents are assembled by a combination of introversion and extroversion processes. Regular periodic supercontinent cycles assembled by extroversion, observed in previous 2D and 3D simulations with rigid, nondeformable continental lids, are not confirmed. Small-scale thermal heterogeneity dominates deep mantle convection during the supercontinent cycle, although large-scale upwelling plumes intermittently originate under the drifting continents and/or the supercontinent. Results suggest that subducting cold plates along continental margins generate thermal heterogeneity with short-wavelength structures, which is consistent with the thermal heterogeneity in present-day mantle convection inferred from seismic tomography models.

References:

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