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二段階進化する地球のマントルの熱史
The thermal history of the Earth's mantle that evolves in two stages

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The thermal history of the mantle calculated from numerical models of a coupled magmatism-mantle convection system is compared with that of the Earth. Both magmatism and mantle convection with tectonic plates are self-consistently reproduced in a two-dimensional rectangular box. The mantle evolves in two stages in these models. On the earlier stage that continues for 1-2 Gyr, heat producing elements (HPEs) and heat flux from the core (HFC) strongly heat the deep mantle, and frequently let hot materials there ascend to the surface as bursts. The mantle-bursts cause vigorous magmatism, stir the mantle efficiently, and make plates move chaotically. As HPEs and HFC decay, however, mantle-bursts stop. On the later stage, subducted basaltic crusts accumulate on the core mantle boundary to form compositionally dense basaltic piles, and plate motion becomes more stable. The average temperature in the entire mantle Tw steadily decreases with time owing to heat extraction by magmatism and mantle convection. The cooling rate is 80-130 K/Gyr on average depending on the internal heating rate. The thermal history of the upper mantle is, however, quite different from this: The average temperature in the upper mantle Tu drops to about 1800 K within the first 100 Myr, and remains almost constant at 1700-1800 K for the subsequent 3 Gyr or even longer regardless of the internal and basal heating rate as well as the initial temperature; Tu gradually decreases to around 1600 K only after that. The thermostat effect of magmatism keeps Tu below 1800 K on the earlier stage no matter how strongly the mantle is heated or how high the initial temperature is. Tu does not decrease on the later stage till 3 Gyr because subducted slabs stagnate on the CMB and do not return back to cool the upper mantle till that time; the steady decrease in Tw during this period is due to the cooling of the lower mantle. The delayed cooling of the upper mantle makes the heat flux at the surface remain almost constant throughout the 4.5 Gyr history of the mantle. At 4.5 Gyr, the Urey ratio is as low as 0.4-0.5 depending on the internal heating rate, and the lower mantle is significantly colder than expected from adiabatic extrapolation from the upper mantle.

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