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Thermal and chemical budgets of Earth and their implications for plume dynamics

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I will review some fundamental constraints we have on the thermal and chemical budgets of Earth, and discuss the possible role of mantle plumes throughout geologic history as deduced from this global perspective. There have been a number of speculations about what mantle plumes could achieve in various geological problems, but there is a rather tight upper bound on the strength of plumes if one realizes that plumes can exist because of core cooling, which is a small fraction of the secular cooling of the entire Earth. The rate of secular cooling depends on the thermal evolution of Earth, which in turn depends primarily on the heat budget and the style of mantle convection. This subject has been very controversial for obvious reasons and also sometimes (unnecessarily) confusing. I revisit this issue on the basis of the energetics of plate-tectonic convection and the recently-revised chemical composition of primitive mantle, and show that a surprisingly simple (albeit somewhat counterintuitive) view of Earth's evolution could simultaneously satisfy various kinds of geophysical, geochemical, and geological observations. The style of mantle convection is most likely whole-mantle convection with no hidden large-scale geochemical reservoir, and plate tectonics with slower plate motion and large plates may have prevailed at least back to about 3 Ga. With increasing internal heat production in the past, this new evolution model predicts diminishing core heat flux in the past, which implies much less reduced plume activities. This evolution of plate tectonics and mantle plumes can considerably retard mantle mixing, thereby preserving chemical heterogeneities at various spatial and temporal scales.