

SCALING OF MIXING RATE IN MANTLE CONVECTION MODELS WITH SELF-CONSISTENT PLATE TECTONICS, MELTING AND CRUSTAL PRODUCTION

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It is generally thought that the early Earth's mantle was hotter than today, which using conventional convective scalings should have led to vigorous convection and mixing. Geochemical observations, however, suggest that mixing was not as rapid as would be expected, leading to the suggestion that early Earth had stagnant lid convection [1]. Additionally, the mantle's thermal evolution is difficult to explain using conventional scalings because early heat loss would have been too rapid, which has led to the hypothesis that plate tectonics convection does not follow the conventional convective scalings [2]. One physical process that could be important in this context is partial melting leading to crustal production, which has been shown to have the major effects of buffering mantle temperature and carrying a significant fraction of the heat from hot mantle [3], making plate tectonics easier [4], and causing compositional differentiation of the mantle that can buffer core heat loss [5]. Here, the influence of this process on mantle mixing is examined, using secular thermo-chemical models that simulate Earth's evolution over 4.5 billion years. Mixing is quantified both in terms of how rapidly stretching occurs, and in terms of dispersion: how rapidly initially close heterogeneities are dispersed horizontally and vertically through the mantle. These measures are quantified as a function of time through Earth's evolution. The results will then be related to geochemically-inferred mixing rates for different stages of Earth evolution.

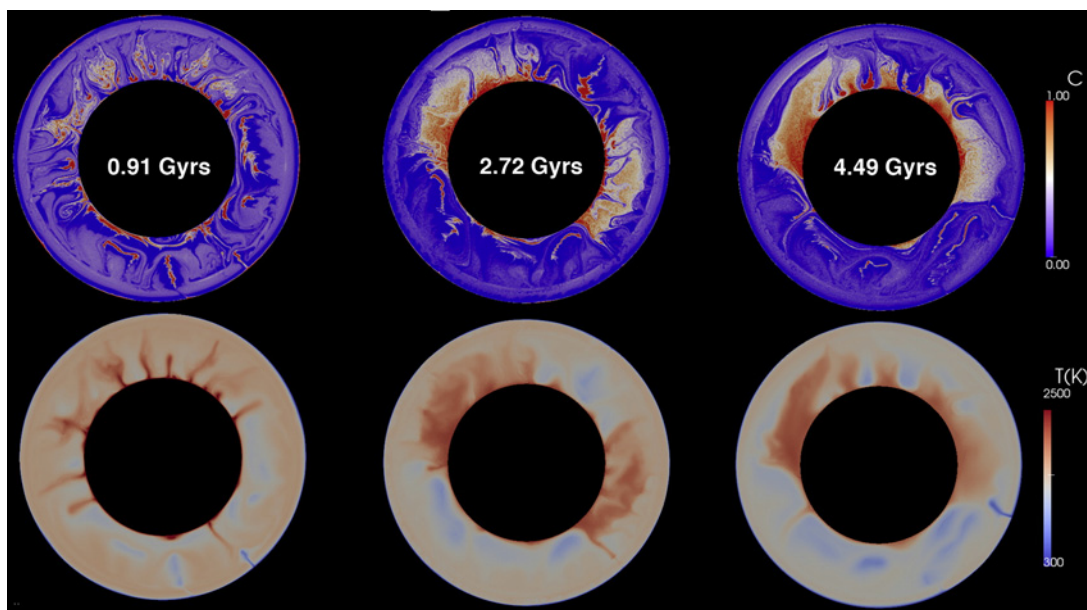


Figure 1. Time evolution of mantle composition and temperature in a simulation in [3].

References

- [1] V. Debaille, C. O'Neill, A. D. Brandon, P. Haenecour, Q.-Z. Yin, N. Mattielli, & A. H. Treiman, *Stagnant-lid tectonics in early Earth revealed by ^{142}Nd variations in late Archean rocks*, Earth Planet. Sci. Lett. **373**, 83-92 (2013).
- [2] J. Korenaga, *Energetics of mantle convection and the fate of fossil heat*, Geophys. Res. Lett. **30**, 1437 (2003).
- [3] T. Nakagawa, and P. J. Tackley, *Influence of magmatism on mantle cooling, surface heat flow and Urey ratio*, Earth Planet. Sci. Lett. **329-330**, 1-10 (2012).
- [4] D. Lourenco, A. Rozel and P. J. Tackley, *Melting and crustal production helps plate tectonics on terrestrial planets*, Earth Planet. Sci. Lett., in press. (2016)
- [5] T. Nakagawa, and P. J. Tackley, *Influence of initial CMB temperature and other parameters on the thermal evolution of Earth's core resulting from thermo-chemical spherical mantle convection*, Geophys. Geochem. Geosyst. **11** (Q06001) (2010).