Theoretical and experimental arguments for Earth's heat flux being 31±2 TW

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Global power (heat flux averaged over Earth's surface) links to radiogenic content, geodynamic state and thermal evolution. Recent computations involve replacing measured flux over substantial parts of the ocean floors with calculations from 1-D cooling models. Cooling models muster support through their alleged prediction of seafloor depths. But, a factor of 3 error exists in equations used to predict depth as a function of seafloor age. Specifically, 1-D models presume that temperature varies in the Z-direction only, so contraction is only in Z and is governed by linear thermal expansivity, not volumetric as mistakenly imple-mented. Values predicted for depth are 1/3 those measured if reasonable physical parameters are used. To reproduce depth data requires using ~3000 K as the basal temperature, which is incompatible with petrology, and provides global power of ~132 TW, not 44 TW. Other problems exist with cooling models and the database. Recent assesment of heat flow data, corrected for duplications and errors in location, limits global power to between 28.6 and 34.1 TW, with uncertainties largely stemming from the need to estimate flux in certain geographic regions. Hydrothermal circulation has been rationalized as causing the discrepancy of model with measurements, but practically speaking, measurements are made mostly in strongly sedimented areas where the confining lid prevents effects of hydrothermal circulation, local or extensive. In hydrothermal systems, temperature gradients in the rocks are reduced below ideal conductive values where the water enters the system in recharge regions far from the ridges and robs heat from the rocks, not near the ridges where ascending hot water warms rocks and enhances conductive gradients. The rationalization thus implicity assumes that measurement sites are preferentially located over recharge zones, which is unlikely. Harmonic expansions, up to degree 36, reveal that previous low-degree hybrid spherical harmonic analysis (wherein high fluxes near the ridges from 1-D cooling models are used in place of data) causes heat flux in the mathematical representation to be overestimated, even in continental regions, due to the importance of lowest order spherical harmonic coefficients. Enstatite chondrite models provide ~30 TW, suggesting that additional heat sources, such as K in the core or secular delay, are not necessary to explain Earth's thermal state.

References

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Timescale for metal-silicate separation by metal rainfall in a magma ocean

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The largest sequestering event in Earth's evolution, which ultimately lead to the differentiation of Earth's mantle and core, was the separation of metal from silicate in a magma ocean. The only separation mechanism that can explain geochemical observations is metal rainfall. Essential to the metal rainfall mechanism is that metal disperses into small droplets which chemically equilibrate with the surrounding silicate while they sink by means of turbulent density currents. Höink *et al*. (2006) have studied the metal rainfall mechanism under the assumption of constant silicate viscosity and found that the time scale of metal silicate separation under these conditions are on the order of the Stokes' settling time, which for centimeter-sized metal droplets in Earth's magma ocean corresponds to a time scale of weeks.

However, it is well known that magma dynamics are fundamentally influenced by variations in viscosity. A non-constant viscosity, i.e. a temperature dependent viscosity, or even more realistically, a temperature- and pressure dependent viscosity may alter the mechanism of metal rainfall significantly. In the present work we analyse the influence of temperature dependent viscosity and temperature- and pressure dependent viscosity on the rainfall mechanism by employing a numerical convection model combined with a sedimentation method.

We find that the metal-silicate separation time depends on the thermal viscosity contrast and also on the viscosity contrast due to pressure. For values suitable to Earth's magma ocean, the time scale of metal-silicate separation by metal rainfall increases to the order of tens to hundreds of years. Accordingly, metal rainfall is a very rapid mechanism for metal-silicate separation in a magma ocean. This short timescale has profound implications for the timing of Earth's evolution.

References

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