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The efficiency of magma heat transport in accreting planetesimals

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Compositional differences between meteorites have been interpreted as being indicative of wide variations in the degree of differentiation of their parent bodies (planetesimals). Differentiated planetesimals must have undergone (partial) melting which suggests that melting was a wide-spread phenomenon in the early solar system. The heat sources that have been suggested to be capable of providing sufficient thermal energy to the planetesimal are the decays of the short lived nuclides ^{26}Al and ^{60}Fe. Thermal models have shown that planetesimals may experience differing degrees of partial melting depending on the onset time of accretion relative to the time of formation of the Ca-Al-rich inclusions (CAIs), the accretion time, and the final size of the planetesimal [1]. Even the presence of a magma ocean for these bodies has been suggested in the case of rapid accretion. One problem with these thermal models is, however, that they assume the planetesimals to cool mainly by thermal conduction and that they neglect the influence of magma transport on their thermal evolution. We study numerically this processes using 1D thermal energy balance models of an accreting body that further include magma heat transport. We have improved the 1D thermal model of [1] by considering additionally the change of thermal conductivity, specific heat capacity and density due to porosity, porosity loss due to sintering, redistribution of heat sources etc. to study the influence of those factors on the thermal evolution. The heat transport by melt segregation is modeled assuming melt flow in porous media and by supplementing the heat conduction equation with an advection term. This expression is calculated using the Darcy flow equation and is valid for melt fractions large enough such that the melt forms an interconnected network but lower than the rheological critical melt fraction. The efficiency of the heat transport depending on the melt fraction, the permeability, the enrichment factor of ^{26}Al and ^{60}Fe in the melt over the solid phase will be discussed.

[1] Merk, R. et al. (2002) Icarus, 159, 183–191.