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On the potential role of serpentinization in the thermal evolution of planetesimals in the early outer Solar system

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Some meteorite samples show that in addition to heat from accretion and radioactive decay, there may have been chemical processes that, at least at some point in the history of the Solar System, could significantly alter the lithological characteristics of the objects and contributed notably to internal heat production.

We constructed a model considering the chemical process of serpentinization. Serpentine is a hydrous magnesium phyllosilicate mineral, resulting from the hydration of olivine and/or pyroxene, in an exothermic reaction that takes place in the presence of liquid water.

$2Mg_2SiO_4 + 3H_2O \rightarrow Mg_3Si_2O_5(OH)4 + Mg(OH)_2$
$Mg_2SiO_4 + MgSiO_3 + 2H_2O \rightarrow Mg_3Si_2O_5(OH)_4$

Our model is based on earlier models (Cohen et al., 2000; Góbi et al., 2017) which estimated the serpentinization time scale and examined the effect of interfacial liquid water below the melting point of ice and calculated the necessary initial temperature and the amount of heat produced. We take into account several effects that have previously been neglected.

Our results show a significant difference compared with previous outcomes, under the same initial conditions: the reaction time scale increased significantly especially in cases where the initial temperature was below the melting point of water -- in these cases, the difference in the characteristic length of the process was longer by two orders of magnitude. Another significant difference was the extent of the effect of interfacial water, as previous studies found that the process takes place at a similar rate below the freezing point of water as above. Our results show that although the process works below the freezing point it slows down significantly. We also examined whether these chemical processes could take place under the different conditions in the outer Solar System and influence significantly the evolution of the objects there.