Paper Number: 2962

ET at high-*T*: metamorphism of ordinary chondrites

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New thermodynamic models calibrated to very low *P* for minerals and melt in terrestrial mantle peridotite [1] permit quantitative investigation of high-*T* metamorphism in ordinary chondrites using phase equilibria modelling [2]. Isochemical *P*–*T* phase diagrams based on the average composition of H, L and LL chondrite falls (Fig. 1) and contoured for the composition and abundance of olivine, ortho- and clinopyroxene, plagioclase and chromite provide a good match with values measured in so-called equilibrated (petrologic type 4–6) samples. Some compositional variables, in particular Al in orthopyroxene and Na in clinopyroxene, exhibit a strong pressure dependence when considered over a range of several kilobars, providing a means of recognising meteorites derived from the cores of asteroids with radii of several hundred kilometres, if such bodies existed at that time. At the low pressures (<1 kbar) that typified thermal metamorphism, several compositional variables are good thermometers. Although those based on Fe–Mg exchange are likely to have been reset during slow cooling, those based on coupled substitution, in particular Ca and Al in orthopyroxene and Na in clinopyroxene, are less susceptible to retrograde diffusion and are potentially more faithful recorders of peak conditions. The intersection of isopleths of these variables may allow pressures to be quantified, even at low *P*, permitting constraints on the minimum size of parent asteroid bodies. The phase diagrams predict the onset of partial melting at 1050–1100 °C by incongruent reactions consuming plagioclase, clinopyroxene and orthopyroxene, whose compositions change abruptly as melting proceeds. These predictions match natural observations well and support the view that type 7 chondrites represent a suprasolidus continuation of the established petrologic types at the extremes of thermal metamorphism. The results suggest phase equilibria modelling has potential as a powerful quantitative tool in investigating key processes in the early evolution of the solar system, including progressive oxidation during metamorphism, the degree of melting and melt loss or accumulation required to produce the spectrum of differentiated meteorites, and whether the onion shell or rubble pile models best explain the metamorphic evolution of asteroid parent bodies.

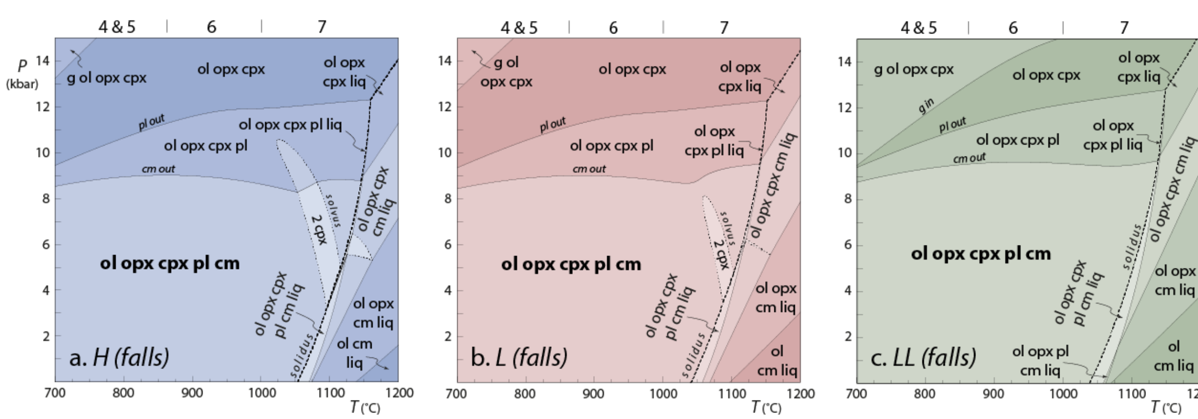

Figure 1: Calculated P–T pseudosections for the average composition of H, L and LL chondrites.

References:

[1] Jennings E and Holland T (2015). J. Petrol. 56: 869–892.
[2] Johnson T et al. (2016). Earth. Planet. Sci. Lett.. 433: 21–30.