

FURTHER COMPLEXITIES IN SULFIDES IN THE TIL 91722 CM2 CHONDRITE: MICROSTRUCTURES OF PENTLANDITE COEXISTING WITH PYRRHOTITE

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Introduction: Pentlandite and pyrrhotite are the main sulfide phases in CM chondrites [1-3], occurring as coarse-grained crystals in chondrules and isolated within the matrix. The origins of these phases still remain poorly understood, however. Here we present new observations of complex microstructures in pentlandite grains that have not been recognized previously. These data provide additional constraints on the origin of sulfides in this meteorite and other CM2 chondrites.

Observations: Most coarse-grained sulfides in TIL 91722 are composite pyrrhotite/pentlandite (*po/pn*) grains. Pentlandite occurs on the periphery of these grains or as oriented blebs within pyrrhotite. BSE imaging of *pn* grains shows that they are not homogeneous, but exhibit a complex microstructure at the micron to submicron scale. The grains contain abundant lobate-like features with lower BSE contrast than the pentlandite. The pentlandite shows well developed fractures and cleavage along the (110) planes and secondary alteration phases are clearly present along fractures. We have used FIB/TEM techniques (STEM, electron diffraction, EDS analysis) to examine the pentlandite microstructures. TEM observations show that the pentlandite has a complex structure consisting of numerous 0.5-1 μ m-sized domains that are bounded by (110) planes. AEM data for the bleb-like phase show that it is Ni-bearing Fe-sulfide, with ~5 at% Ni. Electron diffraction for this phase are consistent with pyrrhotite with the crystallographic orientation relationship between the host pentlandite of $[100]_{po} // [1\ 1\ 2]_{pn}$ and $110]_{po} // [0\ 1\ 1]_{pn}$.

Discussion. The orientation relationship between *pn* and *po* is exactly the same orientation as observed for *pn* exsolved from Ni-bearing *po* [4]. However, to our knowledge this is the first occurrence of the reverse relationship, where the Ni-poor phase has exsolved from *pn*. This suggests that the conditions of formation of this assemblage were unusual. We have previously argued that the microstructures in coexisting *po* formed in a two stage cooling history. The first stage involved *pn* exsolution from monosulfide solid solution (*ms*) during primary nebular cooling, with a second stage of exsolution occurring at much lower temperatures [5]. The observed microstructures in *pn* may also be compatible with such a model. Rapid cooling following high temperature *po/pn* exsolution may have quenched a metastable high T S-rich *pn* composition. If the miscibility gap between *pn* and *po* widens at lower temperature, subsequent lower T annealing would drive equilibration of the composition to more Ni-rich and S-poor compositions by exsolving a Ni-bearing *po* phase. However, there are no experimental data to constrain the low temperature (<100°C) phase relations in this system, so this interpretation remains speculative and needs further investigation. Nevertheless, these microstructures clearly show that the sulfides are primary and not secondary alteration products.

References: [1] Fuchs, L.H. et al. 1973. *Smithson. Contrib. to Earth Sci.*, **10**: 1–39. [2] Zolensky, M.E. and Lie, L. 2003. *LPS XXXIV*: 1235. [3] Bullock, E.S. et al. (2007) *LPS XXXVIII*, 2057. [4] Francis, C.A. et al. 1976. *Am. Mineral.* **61**: 913–920. [5] Brearley, A.J. and Martinez, C. 2010. *LPS XL*: #1689.