Fe-Ni Sulfide Mineralogy of Tagish Lake and Other Carbonaceous Chondrites

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CM and CI carbonaceous chondrites have experienced extensive aqueous alteration resulting in significant changes to their primary mineralogy [1]. It has therefore been argued that any Fe-Ni sulfide minerals within these groups must have a secondary origin. However, more recent studies have noted widespread occurrences of primary sulfides which retain textures that can only form at high temperatures, such as in the solar nebula [2]. Here we examine the mineralogy, textures, and compositions of Fe-Ni sulfides in Tagish Lake (TL), an ungrouped C2 chondrite, and Aguas Zarcas (AZ), a CM2 chondrite, using scanning electron microscopy and electron probe microanalysis, to gain insights into the role of alteration on their asteroidal parent bodies and constrain their potential origins.

These samples contain sulfides with a variety of textures, including: 1) pyrrhotite grains exhibiting pentlandite exsolution, indicating formation at high temperatures [2], often associated with Fe-rich olivine chondrules; 2) sulfide grains which lack exsolution, including a previously described "bull's-eye" morphology interpreted to be secondary in origin [3]. Compositional analysis of pure phases plotted on Fe-Ni-S ternary diagrams at various temperatures allows for the determination of the temperature of formation of the different sulfide morphologies. Grains with coarse exsolution textures and unexsolved pentlandite grains form mainly at high temperatures of ~500-600°C, while unexsolved pyrrhotite and bull's eye sulfides form between ~25-135°C. Together, these observations suggest that it is common for highly altered carbonaceous chondrites to contain multiple generations of sulfides, with distinct formation mechanisms. Two main groups of sulfides have been identified: 1) high temperature (~500-600°C) sulfides crystallized during chondrule formation; 2) low temperature (<135°C) sulfides formed during parent body aqueous alteration.

Additionally, the Fe/S ratio of pyrrhotite can be used to place these meteorites and their lithologies into a relative order of alteration [4] such that TL11v chip1< TL4 < TL11v chip2 < TL5b ≤ TL10a < TL11h < TL1 < TL11i, and AZ [4] < AZ-PT1 < AZ-PT3 ≤ MET11791-3 ≤ MET11791-1 ≤ AZ-PT2.

[1] Brearley A. J. (2006) The action of water. In *Meteorites and the early solar system II*, 587–624. [2] Schrader D. L. et al. (2016) *Geochim. Cosmochim. Acta. 189*, 359-376. [3] Blinova A. I. (2014) *Meteorit. Planet. Sci. 49,* 473-502. [4] Schrader D. L. et al. (2021) *Geochim. Cosmochim. Acta. 303,* 66-91.

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