

Fine-grained rims surrounding chondrules in the carbonate-poor lithology of the Tagish Lake carbonaceous chondrite

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Introduction:

Chondrules and coarse-grained components in carbonaceous chondrites are commonly surrounded by fine-grained rims. The origin of fine-grained rims has been controversial. The origin has mainly been attributed to either pre-accretionary formation [e.g. 1, 2] or parent-body formation [e.g. 3–5].

Tagish Lake is an ungrouped type 2 carbonaceous chondrite that consists of two major lithologies: carbonate-rich and carbonate-poor [6]. One of the remarkable characteristics of this meteorite is that most chondrules and coarse-grained components are surrounded by thick, fine-grained rims. By studying the carbonate-rich lithology, Nakamura et al. [7] suggested that the rims were formed during brecciation on the parent body (or bodies). In contrast, by studying the carbonate-poor lithology, Greshake et al. [8] concluded that formation of the rims by accretion in the solar nebula most convincingly accounts for their observations.

We present the results of petrographic and mineralogical study of the carbonate-poor lithology of the Tagish Lake meteorite. We studied two polished thin sections (total area of 114 mm²) of the meteorite using SEM-EDS and EPMA. Our goal is to find any evidence indicating the processes and conditions of rim formation, to determine which of the above or other models of rim formation most consistently explains the mineralogical and petrographic characteristics of the rims and other components, and to elucidate the formation history of the Tagish Lake carbonate-poor lithology.

Results:

The thin sections of Tagish Lake consist of a dominant matrix (84.1 vol.%) and 87 chondrules (11.1 vol.%), 2 Ca-Al-rich inclusions (CAIs) (0.4 vol.%), and 14 forsterite aggregates (2.1 vol.%). The matrix contains abundant pores and exhibits an uneven surface. The matrix mainly consists of fine-grained phyllosilicates with minor amounts of Fe-Mg carbonate, magnetite, forsteritic olivine, Ca carbonate, and Fe-(Ni) sulfides.

The chondrules consist mainly of forsterite and

enstatite phenocrysts. Most forsterite phenocrysts show little evidence of alteration, whereas most enstatite phenocrysts were partially replaced by Mg-rich phyllosilicates. Mesostases were completely replaced by Mg-rich phyllosilicates. Opaque nodules, which are common in chondrules in other chondrites, are absent. Most chondrules consist of irregularly shaped cores composed of forsterite and enstatite and 5–100 μm thick phyllosilicate-rich outer zones (POZs). The cores and the POZs contain characteristic round pseudomorphs that consist largely of phyllosilicates. The pseudomorphs commonly contain magnetite grains (<1–10 μm in diameter) and very small Fe sulfide grains (<1 μm in diameter). Rarely, the pseudomorphs consist largely of framboidal magnetite, with minor amounts of phyllosilicates. From these observations, we conclude that these pseudomorphs were formed by replacing opaque nodules, which had formerly consisted largely of Fe-(Ni) metal and/or Fe-(Ni) sulfides. The pseudomorphs contain significant amounts of Cr₂O₃ (up to 4.58 wt%); the chromium was probably inherited from metal in the opaque nodules.

Most chondrules are entirely or partly surrounded by fine-grained rims (5–160 μm), which exhibit much smoother surfaces compared with the matrix. The rims mainly consist of fine-grained phyllosilicates with minor amounts of Fe-Mg carbonate, Fe-(Ni) sulfides, forsteritic olivine, and magnetite. Ca carbonate, which is commonly present in the matrix, is absent. Most rims contain characteristic fractures that run radially from the core/POZ boundaries, penetrate both POZs and rims, and terminate at the rim/matrix boundaries.

Both of the CAIs studied contain large amounts of secondary minerals such as Ca carbonate, Mg-Ca carbonate, and phyllosilicates. Primary spinel occurs in both CAIs in very minor amounts. These two CAIs are also surrounded entirely by fine-grained rims, which have texture, mineralogy and chemical composition identical to those surrounding chondrules. Radial fractures, which start from the core/rim boundaries and terminate at the rim/matrix boundaries, are also common in the rims.

Forsterite aggregates are irregularly shaped compact aggregates (50–660 μm) consisting mainly of small forsterite grains, with minor amounts of small grains of magnetite and spinel. All of the forsterite aggregates studied are surrounded by fine-grained rims, which are identical in texture, mineralogy, and chemical composition to the rims surrounding the chondrules and CAIs. Radial fractures are also common in the rims.

We found 55 clasts (100–250 μm) that consist entirely of a fine-grained matrix material. They consist of materials texturally and mineralogically identical to the fine-grained rims surrounding the chondrules, CAIs, and forsterite aggregates. The matrix clasts are commonly round in shape and mostly smaller than those coarse components. We also found a large clast (450 μm) that contains three chondrules and three forsterite aggregates. The matrix of this clast is identical to the matrix clasts. The chondrules in this clast also have POZs. However, they have no rims. The forsterite aggregates in this clast also have no rims. The matrix of the clast exhibits fractures that run radially from the surfaces of the chondrules and forsterite aggregates and interconnect them.

Discussion:

The common occurrence of the pseudomorphs of opaque nodules in both chondrule cores and POZs suggests that the POZs are altered zones that were formed by replacing opaque nodules, mesostasis, and enstatite in the peripheries of chondrules. The altered zones and the rims are compositionally and texturally similar, although they exhibit some differences in secondary minerals. In comparison, the rims and the host matrix show more significant differences in bulk chemical composition, texture, and mineralogy. The observations suggest that the chondrules and the rims experienced aqueous alteration simultaneously, whereas the rims and the matrix experienced aqueous alteration under distinct conditions. We also found that the chondrules and forsterite aggregates in the clast have no rims, and the matrix of the clast and the 55 matrix clasts are mineralogically identical to the rims.

The results suggest that the chondrules, CAIs, forsterite aggregates, and their rims (generically referred to as chondrules/rims) and the clasts originated from a common precursor region in the meteorite parent body that was different from the location where the host meteorite was finally lithified.

That is, the chondrules/rims are actually clasts produced by brecciation and later transported and incorporated into the present host matrix. The rims are, therefore, remnants of matrix material that formerly filled interspaces between the chondrules and other coarse-grained components. This model is essentially consistent with those previously proposed for the carbonate-rich lithology of Tagish Lake [7] and the hydrated chondrules/rims in the Vigarano and Mokoia CV3 chondrites [4, 9].

References:

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