REFRACTORY INCLUSIONS in PRISTINE CO3 CHONDRITES: POPULATION COMPARISONS and EQUILIBRIUM CONDENSATES

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Introduction: A fairly large suite of very low-grade (3.0-3.1) CO3 chondrites has been recovered in Antarctica, providing an opportunity for study of refractory inclusions that have not been modified by planetary metamorphism. Objectives of the present study include searches for new and unusual inclusion types; characterization and comparison of refractory inclusion populations; and determination of whether grossite-rich and grossite-poor subtypes of CO3s can be defined. The first step of this study was reported by [1].

Samples and Methods: New results are reported here for DOM 08006 (which is paired with DOM 08004) and MIL 090019 (a member of a large pairing group), which have been classified as a CO3.00 and a CO3.1, respectively, by [2]. One polished thin section of DOM and one of MIL were mapped with a scanning electron microscope (secondary electrons and Al X-rays), and the mineralogy of each Al-rich object determined.

Results: A total of 96 refractory inclusions were found in the section of DOM, supplementing the 30 found in the (small area) section available to [1]. Of these 126 inclusions, 18 (14.3%) contain grossite, 17 (13.5%) contain hibonite, and 6 (4.8%) have both phases. In MIL, 290 inclusions were found, 34 (11.7%) of which contain grossite, 28 (9.6%) contain hibonite, but just 6 (2.1%) contain both phases. In the MIL and DOM CO3s studied thus far, small inclusions consisting of melilite+spinel±perovskite are the most common, at ~35-40% of the populations, higher than the proportions found in ungrouped C3.0 Acfer 094 (22%) or the CO3.0 ALHA 77307 (27%) [1,3].

Two remarkable hibonite-, grossite-bearing inclusions were found in DOM 08006. One, inclusion 56-1, is a fragment ~60 µm across with rounded corundum grains <5 µm across enclosed in hibonite, which is enclosed in grossite, gehlenite and diopside. The hibonite/grossite contacts are irregular and corroded. Inclusion 31-2 is unfragmented, much larger (~200 µm across), and concentrically zoned from inside outward as follows: a hibonite core (40 µm across) with void space visible between laths; a wider zone of grossite + perovskite; and a thin (<10 µm) layer of melilite enclosing the grossite + pv, with anhedral spinel occurring intermittently along the grossite-melilite contact. The melilite layer is enclosed in a thicker (15-20 µm) layer of diopside, which is enclosed in an outermost accretionary rim of forsterite and enstatite. In both inclusions, hibonite has ~1.5 wt% TiO_2.

Discussion: Like typical CO3 chondrites, the CAI populations of MIL 090019 and DOM 08006 are dominated by small inclusions consisting of melilite+spinel±perovskite [1,4]. Unlike typical CO3s, in which grossite-bearing inclusions are very rare [4], >10% of the populations in the present samples are grossite-bearing. Most of those studied by [4] are of higher petrologic types than the present samples, a possible indication that grossite is destroyed by planetary metamorphism. The high abundances of grossite-bearing inclusions in some pristine CO3s and their rarity in other CO3.0s suggest that there are grossite-rich and grossite-poor CO3s.

Inclusions 31-2 and 56-1 contain phases that are predicted to be among the first condensates from a gas of solar composition [5] in textures consistent with formation in the predicted sequence. Corundum, the first major oxide to condense, should do so at 1730 K and, with falling temperature, react with the gas at ~1700 K to form hibonite, which will also react with residual gas, and form grossite. The rounded corundum remnants and corroded hibonite/grossite contacts indicate that 56-1 recorded those processes. Inclusion 31-2 also preserves an extensive record of equilibrium condensation: the core-to-rim sequence of hibonite; grossite + perovskite; melilite + spinel; and diopside is predicted for equilibrium condensation from a gas of solar composition at a total pressure of 10^{-3} atm from 1700 to ~1400 K [5]. The only equilibrium condensate predicted by [5] for this temperature range and not found in 31-2 is krotite ($CaAl_2O_4$), which should form from grossite + gas at ~1595 K and react to form grossite + gehlenite by ~1560 K. This narrow temperature range of stability can explain the rarity of this phase.

Some inclusions from Murchison and ALHA 77307 show strong evidence for direct formation of spinel from hibonite [6,7,8], a departure from the equilibrium condensation path. In contrast, both 31-2 and 56-1 and previously described inclusions from DOM 08004 [1] and Acfer 094 [3] show that, in other cases, grossite formed from hibonite, as predicted by condensation calculations. The DOM samples and Acfer 094 may be relatively rich in grossite-bearing inclusions because they are richer in equilibrium condensates than ALHA 77307 or the CM chondrites. The grossite-rich and grossite-poor meteorite groups may have sampled inclusions from different nebular regions that had different thermal histories from each other.

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