Paris: The slightly altered, slightly metamorphosed CM that bridges the gap between CMs and Cos

Conference or Workshop Item

PARIS: THE SLIGHTLY ALTERED, SLIGHTLY METAMORPHOSED CM THAT BRIDGES THE GAP BETWEEN CMs AND COs.
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Introduction: A fresh, fusion crusted stone weighing 1.3 kilo, purchased at an auction, was later acquired by the MNHN Paris and named "Paris". Classified as a CM chondrite, it is less aqueously altered than other members of this group and has experienced mild thermal metamorphism (~ 3.0 ± 0.1). Petrographic and oxygen isotope evidence indicates that it has affinities with the CO chondrites.

Petrography: Compared with other CMs, Paris contains more abundant, well preserved metal, chondrules (Fig. 1) and refractory inclusions. Its matrix abundance (66 vol%)*, is less than that of Murchison (71%)*, one of the least matrix-rich CM falls [1] (*both determinations by BSE image analysis).

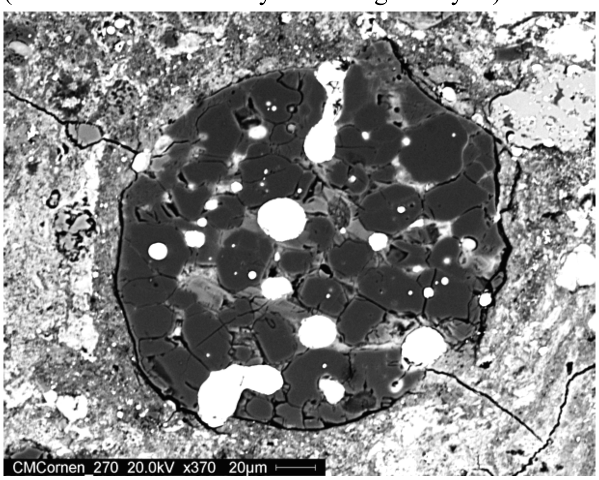

***Figure 1**: A well preserved chondrule with metal and areas of unaltered mesostasis.*

Iron sulfides are present, as well as PCPs with mean compositions 1.5 to 2 times lower in SiO_2 than those of the least altered CMs [2] (Fig. 2). Phyllosilicates are present in the matrix and replace most, but not all, of the chondrule mesostasis. Magnetite is rare; we only found it in one area of our 6 cm^2 section. Metal hosts Cr, P and a variety of inclusions: pure silica, daubreelite and a Cr-phosphide (Fig. 3). Cr_2O_3 in type II chondrule olivine ranges between 0.15 and 0.57 wt%, with an average at 0.41 wt% and σ-Cr_2O_3 = 0.11.

Oxygen isotopes: High-precision oxygen isotopic measurements performed by laser fluorination [3] yield $\delta^{17}O = -1.37‰$, $\delta^{18}O = 3.34‰$, $\Delta^{17}O = -3.11‰$ consistent with Paris being less hydrated than the least hydrated CM falls (Fig 4).

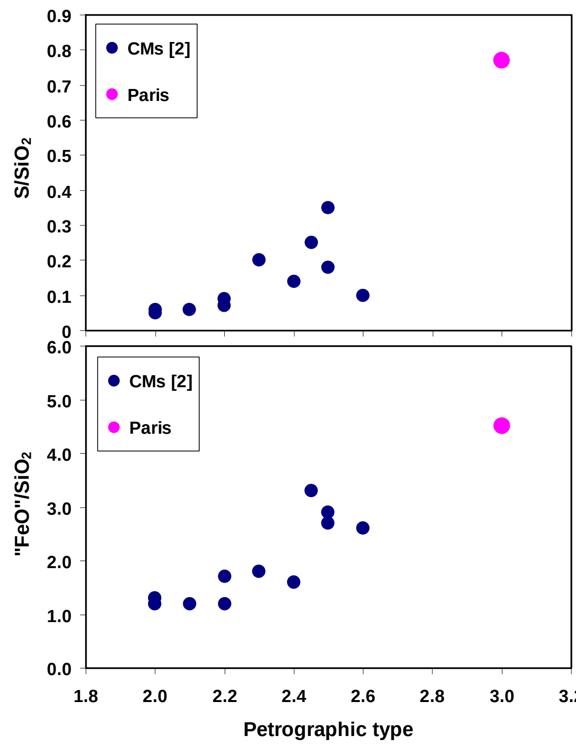

***Figure 2**: Average S and "FeO" content of Paris PCPs compared with data from [2] as a function of petrographic type. Paris was arbitrarily placed at 3.0.*

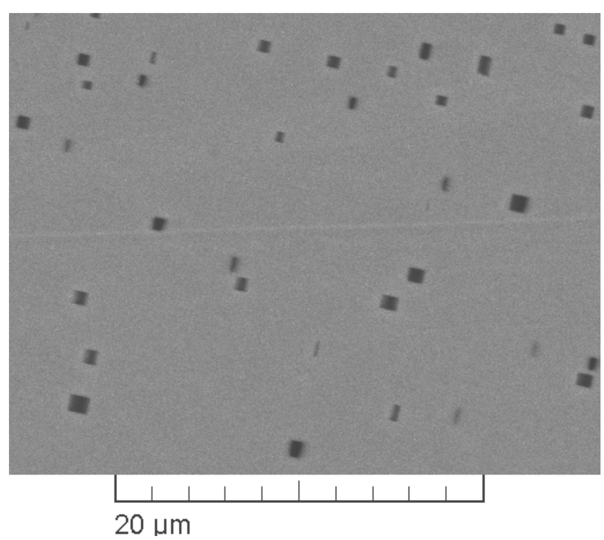

***Figure 3**: Silica (& daubreelite) inclusions in a metal grain. The exsolved crystals are oriented by the parent metallic phase.*

Rare gases: Two aliquots of Paris were heated at CRPG-Nancy by the CO_2-laser heating method and analyzed for He, Ne, and Ar by a static mass spectrometer. Cosmogenic productions rates of $^{3}He_c$, $^{21}Ne_c$ and $^{38}Ar_c$ were computed following the procedure of Eugster *et al.* [4]. Both aliquots present consistent cosmic ray exposure (CRE) ages of 0.14 m.y. ± 0.02 and 0.16 m.y. ± 0.02, respectively. Such CRE ages are in good agreement with other CMs, which have very short CRE ages of < 2 m.y., with a peak at 0.2 m.y. based on ^{26}Al and ^{10}Be measurements [5].

Paris has a high concentration of trapped neon relative to COs and most of the CMs (i.e., 1.12 10^{-6} cc/g), consistent with a meteorite that underwent only gentle thermal alteration.

Discussion: Paris is a new chondrite with unique characteristics which make it difficult to classify. Here we discuss the extent of its parent body processing and its relationship with other primitive chondrites.

Alteration. The preservation of chondrules that contain relict mesostasis, the presence of metal and Fe-sulfide all indicate Paris to be less altered than typical CMs, which is consistent with its oxygen isotopic signature and its comparatively low abundance of matrix. The most important feature indicating low levels of aqueous alteration is the high [FeS] of its PCPs compared to analyses from other CMs [2] (Fig. 2).

Metamorphism. Cr_2O_3 has been shown to exsolve out of type II chondrule olivine with metamorphism, so that its concentration and variability can be used to derive petrographic types between 3.0 and 3.2 [6]. σ-Cr_2O_3 = 0.1 in Paris makes it comparable to Acfer 094 and Semarkona. Metal in CM2 chondrites contains dissolved Si, Cr and P [7] but no inclusions [8]. In Acfer 0.94, it contains inclusions of phosphates and chromites but no silicides or silicates, even when it is enriched up to 3wt% in Si [9]. By contrast, Si exsolved out of metal grains to form silicide inclusions in Semarkona and silica at higher petrographic types [8]. The presence of silica inclusions in the metal of Paris indicates it to be more metamorphosed than Acfer 094 and perhaps even Semarkona, although clearly more altered. Further studies will better constrain the parent-body evolution of the Paris chondrite. However, the presence of preserved metal, sulfide and chondrule mesostasis, as well as the oxygen signature falling exactly on the CM regression line (Fig. 4), and the high concentration of trapped neon compared to other CMs all point to limited transformations and the absence of an extensive dehydration episode.

A transition to COs? [10] pointed out the chemical and isotopic similarity between CO and CM chondrites, suggesting that these meteorites differ mostly by

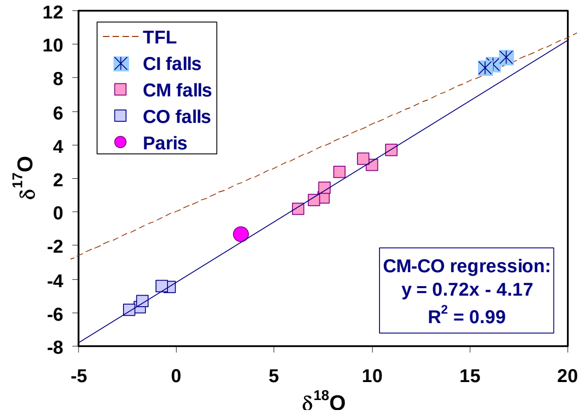

***Figure 4**: Paris plots in the gap between CO and CM falls in the oxygen 3-isotope plot. Data from [10].*

the extent of hydration undergone by CM chondrites. The two groups also differ in terms of thermal metamorphism. Most CMs have seen little or no metamorphism (setting aside the dehydrated ones), whereas COs range between petrographic grades 3.03 (for ALHA 77307) up to ≥3.7 [11]. Paris is less altered than regular CMs and has a petrographic grade comparable to that of the least metamorphosed COs. It is also intermediate between CM and CO in terms of oxygen isotopes (Fig. 4) and in terms of relative abundances of chondrules and matrix.

Conclusion: Paris has unique properties. It has undergone only limited parent-body transformations and may be comparable to the least altered/least metamorphosed chondrites ALHA 77307, Acfer 094 and Semarkona. A more thorough petrographic, chemical and isotopic study is under way to compare it with these primitive chondrites and with the few Antarctic CMs that fall in the CO oxygen field (for which no detailed description exists). This comparison should help untangle the complex relationship between alteration and metamorphism around 3.0 and decide whether separate scales are required for these two processes.

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