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Mineralogical and Oxygen Isotope Study of a Refractory Chondrule Fragment from Comet Wild2

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1. Introduction

An unexpected result from the *Stardust* mission to retrieve samples from the coma of the Jupiter Family Comet Wild2 has been the identification of a large proportion of high temperature, crystalline material e.g. 0.5 – 0.65 [1]. An extreme example of this is the identification of refractory material similar to calcium aluminium rich inclusions (CAIs) from carbonaceous chondrites [2, 3]. Study of this material has the potential to inform us about early Solar System thermal processing, whether it originated in the inner or outer Solar System, and the relationship between asteroidal and cometary materials.

To fully understand the affinities with other planetary materials, a variety of techniques need to be used. In particular for this purpose, the combination of electron microscopy and oxygen isotope analyses is particularly useful. Transmission Electron Microscopy (TEM) of *Stardust* samples and Focused Ion Beam preparation of mineral and isotope standards have been performed at the University of Leicester (UoL). NanoSIMS 50L oxygen isotope analyses on the same section have been made at the PSSRI, Open University. We use this combination of techniques to study a terminal grain from Track#154.

2. Methods and Samples

Terminal particle #2 from C2063,1,154,0,0 (Track #154) was prepared by microtome cutting at NASA-JSC. This track is 922 µm length and bulbous (Type B) with 6 terminal particles. TEM analyses have previously been made on 3 grids at the UoL (C2063,1,154,1,14; C2063,1,154,1,15; C2063,1,154,1,17). The sample is mostly composed of Al-rich, Ti-poor diopside (average composition $En_{50}Wo_{50}$, ≤11 wt% Al_2O_3) with lesser pigeonite, minor enstatite and forsterite [4, 5].

Oxygen isotope analyses have been performed on C2063,1,154,1,15. NanoSIMS 50L isotope imaging mode was used, allowing the material available for analysis from these very thin sections (~70 nm) to be maximized. The back of the TEM grid was reinforced with a 200 nm gold coat and a further 20 nm gold coat was deposited on the top of the sections to facilitate charge dissipation. A 2 pA probe was rastered over an 8 x 8 μm^2 area for analysis. The mass resolution was >10,000 with $^{16,17,18}O$, ^{28}Si and $^{24}Mg^{16}O$ measured on electron multipliers. $\delta^{17}O$ and $\delta^{18}O$ were normalised to SMOW from San Carlos olivine measurements. Results were processed using *L'image* software and corrected for position drift, QSA effects and detector ageing. Matrix effects are thought to be negligible, compared to precision, between low FeO pyroxene and the olivine standard, a correction is therefore not applied. Reproducibility determined from analyses on comparable areas of polished San Carlos olivine was 0.9‰ for $\delta^{18}O$ and 4‰ for $\delta^{17}O$ while analyses of Eagle Station gave correct values within error. The Track #154 grain analysis was corrected for instrumental mass fractionation using the San Carlos olivine results.

3.1. Oxygen Isotopic Composition

The particle is surrounded by aerogel and so firstly we had to distinguish the cometary grain from this collection material: the sample area was defined on the basis of $^{24}Mg^{16}O$ and ^{16}O counts. The isotopic composition of the particle was determined as: $\delta^{18}O = -8.2 \pm 2.3‰$ and $\delta^{17}O = -5.0 \pm 5.4‰$ (1σ errors).

On a three-isotope diagram (Fig.1) the sample plots just above (but within 2σ) of the CCAM line.

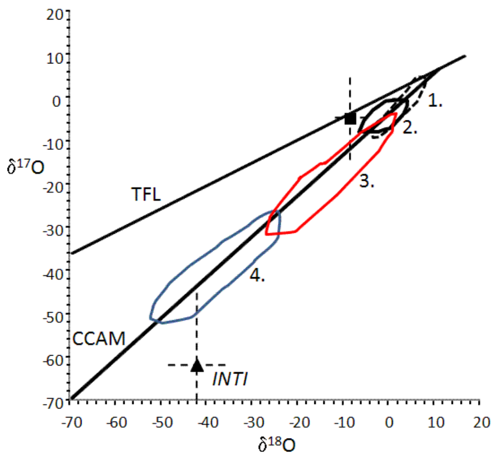

Figure 1: Three isotope plot of the oxygen isotopic compositions of the Track #154 terminal grain #2, the INTI refractory fragment from Track 25 [2] and comparison fields [6] for 1. Mg-Fe chondrules from CM, CR, CV, CK carbonaceous chondrites, 2. Al-rich chondrules without CAI fragments from CR chondrites, 3. Type C CAIs, 4. Type A, B, non-igneous CAIs. Two sigma error bars. Terrestrial fractionation Line TFL and Carbonaceous Chondrite Anhydrous Minerals Line CCAM shown for reference. Two sigma error bars are shown on INTI and the Track #154 sample.

4. Discussion: Oxygen Isotope Affinities

The oxygen isotopic composition of the Track #154 terminal grain #2 is clearly distinct from the majority of (Type A,B) CAIs and from the INTI Comet Wild2 CAI fragment [6]. Its composition does overlap Type C CAIs. However, these are characterized by olivine enrichment which this particle has a notably small amount of [4]. The Track #154 grain analysis is closer to Al-rich chondrules e.g. the field for Al-rich chondrules in CR chondrites is plotted in Fig. 1.

5. Summary and Conclusions

The mineralogy of a Comet Wild2 terminal grain from Track #154 is consistent with being a fragment of an Al-rich chondrule of carbonaceous chondrite (i.e. asteroidal) affinities. It is composed of Al-rich diopside, Al-rich pigeonite, with minor enstatite and forsterite. The oxygen isotopic analysis of the pyroxene by NanoSIMS is consistent with this interpretation. This is the first identification of an Al-rich chondrule fragment within the Comet Wild2 samples. It highlights the importance of understanding whether high temperature processing occurred in the outer Solar System region of cometary formation or whether high temperature phases drifted from the inner to outer Solar System [7].

References

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