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**CONTINUED INVESTIGATION OF THE LIGHT ELEMENT GEOCHEMISTRY OF TAGISH LAKE.**

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**Introduction:** Preliminary analysis of the light element stable isotope geochemistry of the Tagish Lake primitive carbonaceous chondrite showed that it was a carbonate-rich meteorite containing abundant presolar grains [1, 2]. Tagish Lake seemed to be more carbon-rich than CI chondrites, with over 5 wt. % carbon distributed almost equally between organic and inorganic (mostly carbonate) components. We have continued our investigation of this unusual meteorite, turning attention to (i) the abundant carbonates; (ii) the distribution of nitrogen between organic and inorganic components and (iii) pre-solar grains.

Isotope analyses were carried out at the Open University. The abundance and isotopic composition of carbonates were obtained by sequential dissolution of two 30 mg aliquots taken from a powdered 300 mg sample of pristine Tagish Lake material. The carbon and oxygen isotopic composition of the carbonates were analysed by two-stage orthophosphoric acid dissolution [3, 4]. The first extraction, performed at 25°C primarily releases calcite, whilst the second, at 75°C, attacks dolomite/siderite. After purification, the CO<sub>2</sub> liberated was analysed on a PDZ Europa Geo 20-20 mass spectrometer;  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$  were measured to precisions of  $\pm 0.5\%$ . Nitrogen and argon results were obtained simultaneously by stepped combustion (room temperature to 1400°C in steps of 25°C) of a single chip of Tagish Lake weighing 4.40 mg. Isotopic compositions were measured on the *Finesse* noble-gas type static vacuum mass spectrometer to precisions of  $\pm 1\%$ .

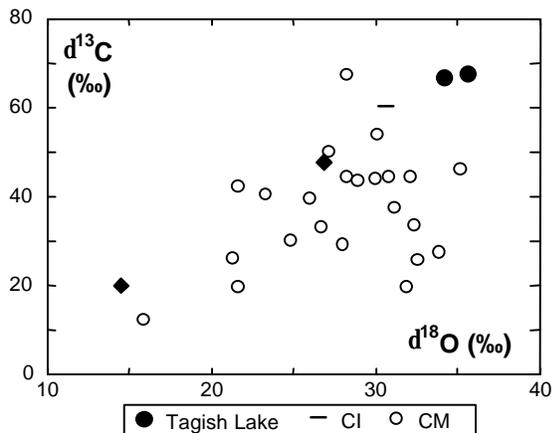
*Carbonates:* petrographic analysis of Tagish Lake has shown that areas of the chondrite are rich in fine-grained carbonates, both Ca- and Fe-rich [2]. Initial measurement of the carbonates by thermal decomposition indicated that they were enriched in <sup>13</sup>C, around 3.2 wt.% carbon as carbonate, with  $\delta^{13}\text{C}$  between +45‰ and +65‰, and Fe, Mg carbonate approximately twice as abundant as calcite [1]. Sequential acid dissolution of whole rock Tagish Lake has allowed better dis-

inction to be drawn between the different carbonates present (see table). The overall carbonate yield is lower, by a factor of three, than that determined from thermal decomposition, and carbon isotopic composition higher. Reasons for the difference between the two sets of results are probably due to sample heterogeneity and failure of the stepped combustion method to resolve adequately the organic and carbonate components. Acid dissolution results show that Fe,Mg carbonates dominate over Ca carbonates, confirming petrographic and combustion observations. However, the difference in  $\delta^{13}\text{C}$  between the two generations of carbonate, as seen from stepped combustion, is not mirrored by the dissolution experiments.

**Table: Carbonate analysis by acid dissolution**  
(mean of two analyses)

	Yield (ppm)	$\delta^{13}\text{C}$ (‰)	$\delta^{18}\text{O}$ (‰)
Ca (25°C)	2340	+67.4	+31.9
Fe,Mg (75°C)	10500	+67.6	+35.6
<b>Total</b>	<b>12840</b>	<b>+67.6</b>	<b>+35.2</b>

The total isotopic composition of Tagish Lake carbonates (Fe, Mg and Ca) is slightly heavier than any previously reported carbonaceous chondrites (Figure 1), and abundance is higher than in any other chondrite group [4]. Carbonates in CMs show no apparent co-variation of  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$  and no clear relationship to those in Tagish Lake. But curiously, this new sample falls at the extreme end of a trend of increasing  $\delta^{13}\text{C}$  with  $\delta^{18}\text{O}$  for the CIs. Zito et al. [5] noted a similar relationship between calcite, dolomite and breunnerite in Orgueil; it is possible that the results from Tagish Lake signify a higher abundance of calcite relative to the Fe- and Mg-rich carbonates compared to CIs. If this is the case, it raises the possibility that Tagish lake carbonates share some common origin or history to those in CI carbonaceous chondrites.

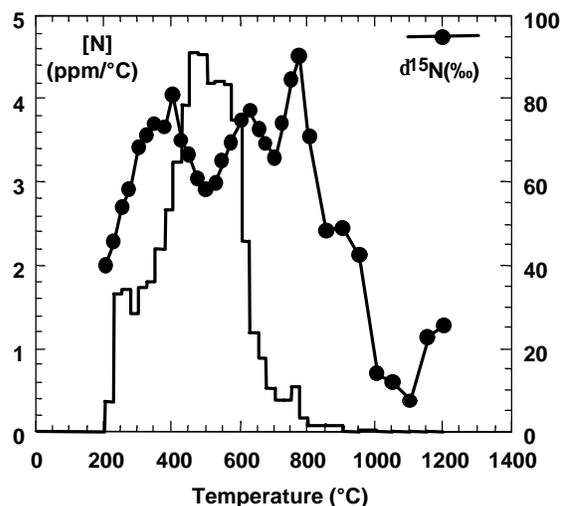
**Figure 1: Isotopic composition of carbonates from CI and CM chondrites [4]**

**Nitrogen:** Tagish Lake has a nitrogen abundance between CI and CM, with an isotopic composition more  $^{15}\text{N}$ -enriched than CI or CM chondrites:  $[\text{N}] = 1218 \text{ ppm}$ ;  $\delta^{15}\text{N} \sim +67\text{‰}$ . As shown in Figure 2, there are several nitrogen components present in Tagish Lake. Most nitrogen combusts below around  $600^\circ\text{C}$ . Up to  $400^\circ\text{C}$ , nitrogen exhibits a practically monotonic increase in  $\delta^{15}\text{N}$  with temperature. Most of this material is from organic matter – that released at the lowest temperatures (below around  $300^\circ\text{C}$ ;  $\delta^{15}\text{N} \sim +40$  to  $+60\text{‰}$ ) is from more labile components such as amino acids, whereas that combusting at slightly higher temperatures (around  $350 - 500^\circ\text{C}$ ;  $\delta^{15}\text{N}$  up to  $+70\text{‰}$ ) is from the highly-cross linked, aromatic macromolecular material that comprises most of the carbon in carbonaceous chondrites. Superimposed on the nitrogen released from organic materials is nitrogen from interstellar nanodiamonds. The presence of nanodiamonds can be inferred from the steep drop in  $\delta^{15}\text{N}$  between  $475^\circ\text{C}$  and  $525^\circ\text{C}$ , where  $^{14}\text{N}$ -enriched nitrogen is released as the nanodiamonds combust. When compared with the corresponding carbon data [1], the presence of interstellar graphite and silicon carbide grains is also shown by excursions in  $\delta^{15}\text{N}$ : up to  $\sim +90\text{‰}$  at  $800^\circ\text{C}$  (combustion of graphite) and down to  $0\text{‰}$  at  $1100^\circ\text{C}$  (SiC).

Comparison with nitrogen data acquired from Orgueil and Murchison shows that Tagish Lake is slightly depleted in nitrogen at the lowest temperatures, and  $\delta^{15}\text{N}$  of the remaining nitrogen is also lower. This is probably a result of loss of

some of the most water-soluble organics, including  $^{15}\text{N}$ -enriched amino acids, during either processing on Tagish Lake's parent body, or during the defrosting process prior to analysis.

There has been much discussion on the origin of organic nitrogen in carbonaceous chondrites, whether it is nebular (e.g., ref. 6) or remnant interstellar material [7]. Recognition that interstellar nanodiamonds account for an approximately constant percentage of carbon in carbonaceous chondrites (once parent body processing has been taken into account) has led to the suggestion that much of the organic material might also be presolar in origin [7]. Since Tagish Lake seems to be relatively enriched in nanodiamonds (with maybe up to 20% of the total carbon coming from this source), it is an ideal sample to study to pursue potential relationships between organic and inorganic nitrogen-bearing components. To this end, a suite of acid-resistant residues are being prepared, for high resolution carbon and nitrogen isotope analysis.

**Figure 2: Nitrogen in Tagish Lake**

**References:** [1] Grady et al. (2000) *MAPS* **35**, A62-A63; [2] Brown P. G. et al. (2000) *Science* **290**, 320-325; [3] McCrea J. M. (1950) *J. Chem. Phys.* **18**, 849-857; [4] Grady M. M. et al. (1988) *GCA* **52**, 2855-2866; [5] Zito K. L. et al. (1998) *MAPS* **33**, A171-A172; [6] Geiss J. and Bochsler, P. (1982) *GCA* **46**, 529-548; [7] Alexander C. M. O'D. et al. (1998) *MAPS* **33**, 603-622.