

COMPOUND-SPECIFIC CARBON ISOTOPE COMPOSITIONS OF ALDEHYDES AND KETONES IN THE TAGISH LAKE METEORITE

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Introduction: Investigating the aldehyde and ketone content of astromaterials provides insight into the abiotic formation of prebiotic compounds on asteroid parent bodies, as aldehydes and ketones are the chemical precursors to α -amino acids in Strecker synthesis reactions. Elucidating amino acid synthesis reactions is important for understanding the origin of prebiotic compounds on Earth and the potential for life beyond our planet. Aldehydes and ketones have been previously detected via gas chromatography mass spectrometry (GC-MS) in a few carbonaceous chondrite meteorites, including Murchison [1,2], Bells [3] and Ivuna [3]. However, carbon isotope compositions of aldehydes and ketones in meteorites have not yet been measured. As such, their relationship to amino acids and other compound classes in meteorites have not been fully investigated. Here, we present the first report of compound-specific carbon isotope measurements of aldehydes and ketones in meteorite samples.

Materials: The Tagish Lake meteorite (TL) is an ungrouped type 2 carbonaceous chondrite. It is exceptionally pristine, due to careful collection and curation [4] and it is heterogeneous, both petrologically and geochemically, resulting from varying degrees of aqueous alteration across the parent body asteroid [5]. Three subsamples of TL were analyzed in this study: TL1 (2.49 g), TL10a (2.39 g) and TL4 (2.46g). Macroscopically, TL1 and TL10a are similar to the previously investigated sample TL5b [6] and are, therefore, priority samples for targeting relatively high abundances of organic compounds. TL4 is unique in terms of its bulk porosity (36% vs. 30% for the rest of the sample suite) [7].

Methods: All glassware and tools were combusted at 450°C for > 6 hours before use. Samples were powdered and then extracted in Millipore water for 24 hours at 100°C in sealed glass ampules. The samples were derivatized using a modified 2,3,4,5,6-pentafluorobenzyl hydroxylamine (PFBHA) derivatization method [8]. The derivatized samples were evaporated to 200 μ L under a stream of N₂ and analyzed by GC-MS coupled with isotope ratio MS. Concentrations were determined by comparison to a suite of standards and the carbon isotopic values ($\delta^{13}\text{C}$) of aldehydes and ketones were corrected for the addition of the PFBHA derivatization reagent. A combusted serpentine powder and a solvent blank were also processed and analyzed in the same manner.

Results & Discussion: All three Tagish Lake samples contained a suite of aldehydes and ketones, dominated by the low-molecular weight compounds: acetaldehyde, formaldehyde and acetone. The relative abundances of the individual aldehydes and ketones were similar in the three samples, but the total yields of carbonyl compounds varied widely (TL1 ~90 nmol/g, TL10a ~50 nmol/g, TL4 ~10 nmol/g). Assuming that a relatively higher organic content indicates greater preservation and a less altered lithology, this variation in total yields suggests the following sequence of increasing aqueous alteration: TL1 < TL10a < TL4. $\delta^{13}\text{C}$ values were measured for formaldehyde, acetaldehyde and acetone in each sample. Overall, the compounds were largely depleted in ¹³C (formaldehyde: -51.5‰ to -34.6‰; acetaldehyde: -23.3‰ to -0.3‰; acetone: -19.1‰ to -12.8‰). $\delta^{13}\text{C}$ values for individual compounds varied across the suite of samples, shifting towards more depleted values across the sequence: TL1 > TL10a > TL4.

A small amount of formaldehyde was detected in the procedural blanks, indicating that a terrestrial source may have contributed to the $\delta^{13}\text{C}_{\text{formaldehyde}}$ measured in the Tagish Lake samples. Nevertheless, the measured $\delta^{13}\text{C}$ values for acetaldehyde and acetone, which appear to be indigenous, are much more negative than would be expected for relic Strecker synthesis precursors [9]. This indicates that the carbonyl compounds observed in Tagish Lake may be products of secondary alteration reactions on the parent body asteroid. The lack of relic precursors also suggests that Strecker synthesis reactions involving primordial aldehydes and ketones in the parent body asteroid have gone to completion. Comparing the $\delta^{13}\text{C}$ values of aldehydes and ketones with $\delta^{13}\text{C}$ values of other carbon sources in the Tagish Lake meteorite, including amino acids, will help to constrain the structural relationship between these compound classes.

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