Amino Acids in the Tagish Lake Meteorite

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Summary

Amino acids are crucial to metabolic processes in life on Earth, particularly in the formation of proteins. As such, amino acids in meteorites are considered of prime importance for prebiotic chemistry. The Tagish Lake (B.C.) meteorite, which fell January 18, 2000, is an ungrouped C2 chondrite rich in primitive organic matter (Grady et al., 2002). The pristine nature of the first samples collected provides an opportunity to study astromaterials that have not been significantly affected by terrestrial contamination. We demonstrate that nearly all identified amino acids in all pristine samples analyzed thus far show concentrations greater than non-pristine Tagish Lake samples (Kminek et al., 2002). It is unlikely that these amino acids are terrestrial contamination. Furthermore, differences in amino acid concentrations and ratios between samples suggest that parent body alteration plays a significant role in the production of amino acids. In this way, processes on the asteroid parent body of carbonaceous chondrites may have assisted in dictating the complement of prebiotic compounds that were delivered to the surface of the early Earth.

Introduction

This study takes advantage of the pristine nature of the Tagish Lake meteorites collected within a few days after their fall to determine the complement of amino acids present. Previous work by Kminek et al. (2002) on amino acids utilized Tagish Lake meteorite samples collected during the spring thaw that were exposed to meltwater. The complement of amino acids and their relative abundances in the meteorite sample are similar to amino acids in the lake water, and these workers conclude that the sample was contaminated.

Method

The Tagish Lake meteorite is heterogeneous, with a range of macroscopic characteristics (Herd and Herd, 2007), including differences in the proportions of matrix and chondrule-like objects, and mineralogy (e.g., Blinova et al., 2009, Blinova et al., this meeting). Remarkably, these lithological differences are borne out in differences in the organic matter: Insoluble Organic Matter (IOM) in different samples varies in terms of H/C and H isotopic composition over a range that encompasses several carbonaceous chondrite groups (Herd and Alexander, 2009); soluble organics vary from sample to sample in abundance and type (Hilts and Herd, 2008).

Samples for amino acid analysis were selected to represent the range of lithologies observed; a 1.4 g subsample of each of samples 5b and 11h were extracted using a sterile scalpel under cold conditions (in a walk in freezer at -20 °C). Sample 5b is rich in chondrule-like objects, and contains IOM that is higher in an aliphatic component (Herd and Alexander, 2009), indicative of a lesser degree of parent body alteration. Sample 11h is similar to sample 11i, a member of the so-called dark, dusty lithology; like 11i, it is matrix rich and may have undergone a greater degree of parent body processing.

Ultrapure (HPLC grade) water was added to each sample, and the resulting suspension was refluxed for six hours. The water extract was allowed to cool to room temperature and then split, with half used for amino acid concentration analysis, and the other half set aside for compound-specific isotopic analysis (forthcoming). Concentrations were determined using Gas Chromatograph Mass Spectrometry (GC-MS) after amino acids were derivitized to form *N*-substituted acid amide esters for each amino acid; these esters dissolved in 0.500 mL dichloromethane were analyzed on an Agilent 5975C/7890A GC-MSD with a HP-5 (5%-phenyl)methyl polysiloxane column. A standard solution was prepared and analyzed along with the unknowns. Blanks were also analyzed.

Results and Discussion

Concentrations determined for Tagish Lake samples 11h and 5b are shown in Figure 1, with results from Kminek et al. (2002) for comparison. Unlike Kminek et al. (2002), our analysis does not discriminate between the different enantiomers; in Figure 1, the D and L enantiomers of Kminek et al. (2002) are grouped together for ease of comparison with our results.

The concentrations of all amino acids analyzed in sample 11h are greater than those obtained by Kminek et al. (2002). In sample 5b, only aspartic (Asp) and glutamic (Glu) acid are lower. Kminek et al. (2002) found that the analyzed aspartic and glutamic acids had L-enantiomeric excesses, indicating that the meteorite has been contributed from a terrestrial source. The low concentrations of the other amino acids may reflect leaching by lake water.

Notably, our samples have significant concentrations of aminoisobutyric acid (AIB) and α-amino-n-butyric acid (α-ABA), both of which are non-biological. The presence of these amino acids, our low blanks, and the overall high concentrations of amino acids strongly suggest that we have analyzed the intrinsic complement of amino acids in the Tagish Lake meteorite.

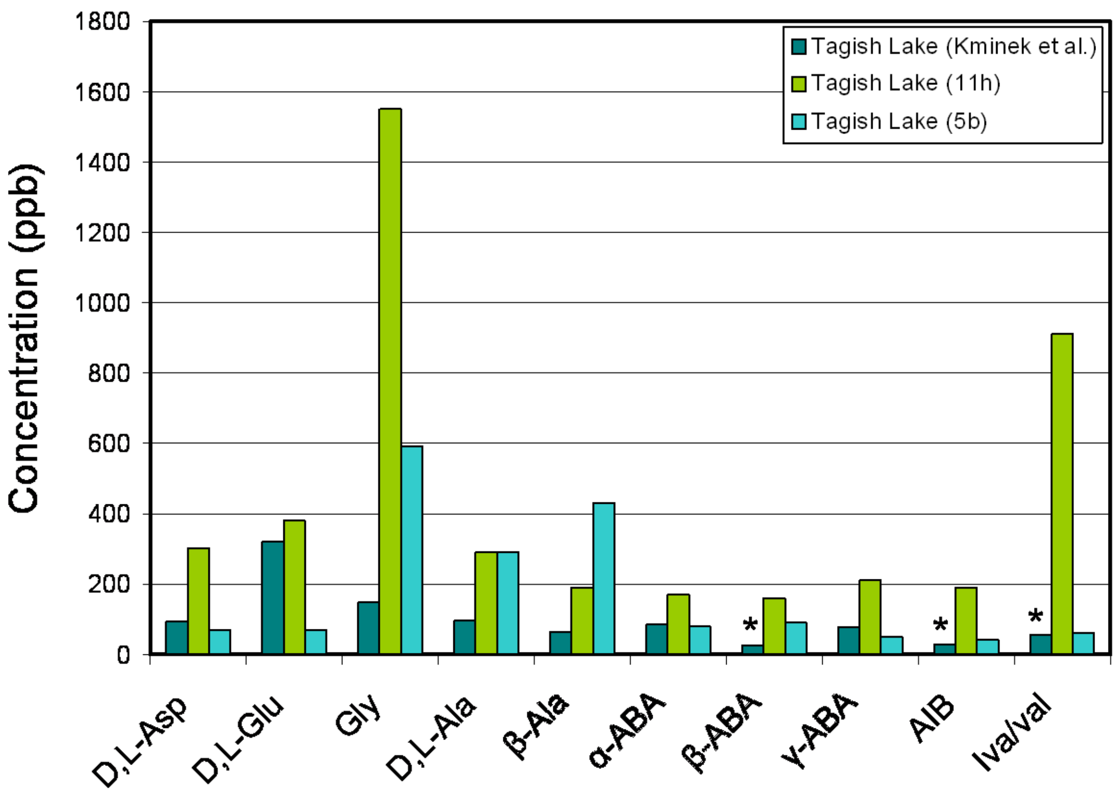

Figure 1. Amino acids abundances in the Tagish Lake meteorite. Data from Kminek et al (2002) is for meteorite material exposed to lake water. Asterisks (*) denote where concentrations are maximum values.

Another notable aspect of our results is that there are significant differences in concentration between samples 5b and 11h, with concentrations of all amino acids in sample 11h higher than in sample 5b with the exception of alanine (Ala). The concentration of glycine (Gly) in sample 11h is nearly three times larger than in sample 5b. The mineralogy and petrology of sample 11h may reflect a greater degree of parent body hydrothermal alteration; the observation of higher concentrations of amino acids in this lithology suggests that parent body processes play a role in the production of amino acids, e.g., by Strecker-cyanohydrin synthesis or other parent body processes (see Botta and Bada, 2002 for a review).

The complement of Tagish Lake amino acids show similarities to results from both CI and CM chondrite meteorites. A comparison is shown in Figure 2.

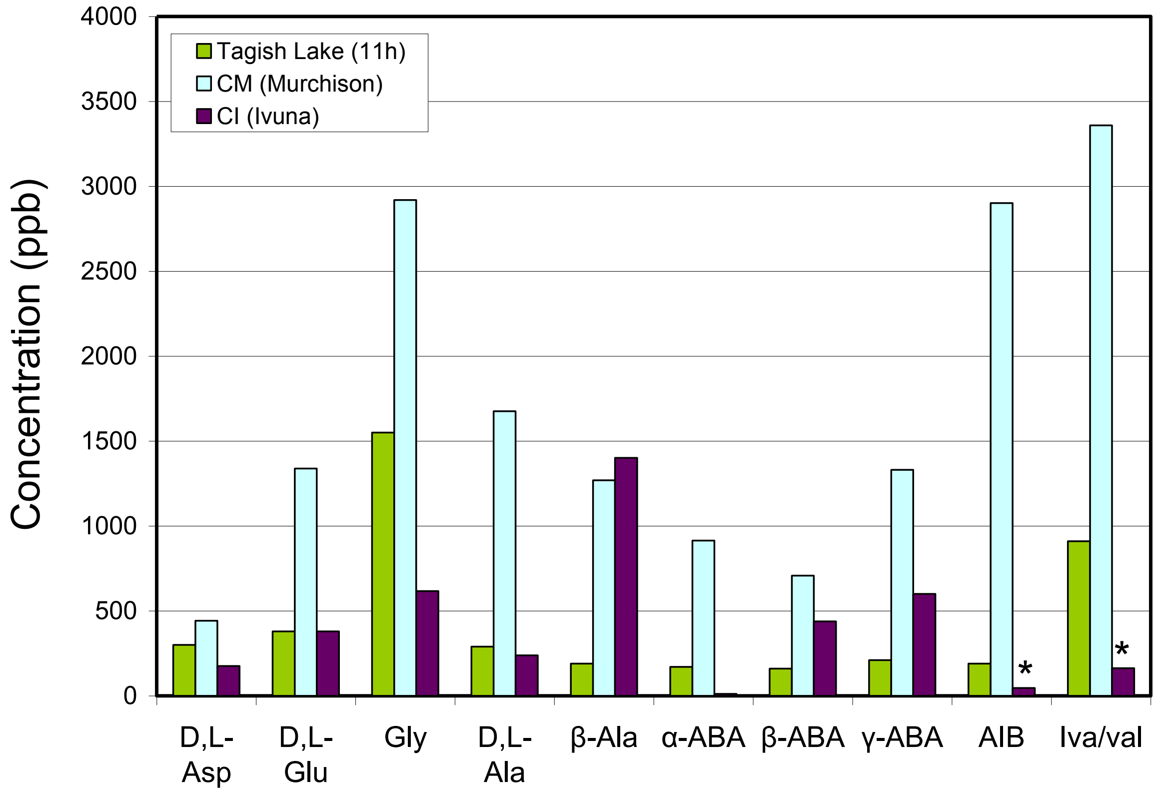

Figure 2. Results from Tagish Lake (sample 11h) with results from CM and CI meteorites for comparison (after Ehrenfreund et al., 2001). Asterisks (*) denote where concentrations are maximum values.

In CM chondrites, glycine, AIB and isovaline are most abundant, whereas in CI chondrites, β-alanine is most abundant, followed by glycine (Ehrenfreund et al., 2001). Tagish Lake appears to be similar to both – in sample 11h (Figure 2), glycine is most abundant, followed by valine; in sample 5b, glycine is most abundant, followed by α- and β-alanine. In terms of total concentration of amino acids, Tagish Lake (4400 ppb; sample 11h) is most similar to CI chondrites, in which the total concentration is ~ 4000 ppb (Ehrenfreund et al., 2001).

Conclusions

The results of our analysis of amino acid concentrations in pristine Tagish Lake meteorites strongly indicate that amino acids in these samples have not been significantly affected by terrestrial contamination through exposure to meltwater. The complement of amino acids in Tagish Lake shows similarities to both CI and CM chondrites. Variations in the relative proportions and total concentrations of amino acids between two pristine samples with different mineralogical and petrological characteristics support the role of parent body alteration in the production of amino acids. Therefore, if the delivery of pre-biotic compounds to the early Earth was in large part due to the infall of carbonaceous chondrites, then the processes occurring on the asteroid parent bodies from which these meteorites were derived may have had a significant influence on the type and concentrations of the pre-biotic compounds.

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