Nature's Starships: Amino Acid Abundances and Relative Frequencies in Meteorites

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Overview

This work is based on Cobb & Pudritz (2013, submitted). We collate available data on amino acid abundances in a class of meteorites called the carbonaceous chondrites. We identify patterns in individual amino acid concentrations, total concentrations per carbonaceous chondrite group, and relative frequencies within various meteorite subclasses. We identify an optimal temperature range for amino acid synthesis of $200°$C to $400°$C. This result is in preparation for computational modeling of amino acid synthesis based on thermodynamic principles.

Background

- Carbonaceous chondrites known for high water and organic content
  - Separated into subclasses, classified according primarily to mineralogical composition and secondarily to degrees of aqueous alteration/thermal metamorphism

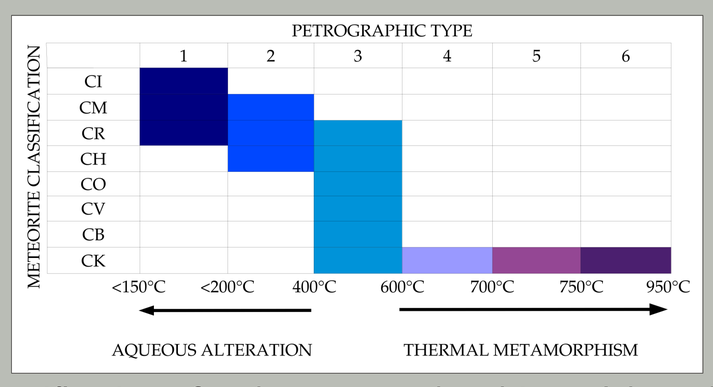

Figure: Classification of carbonaceous chondrites. Adapted from Sephton (2002); Taylor (2011).

- α-amino acids in meteoritic parent bodies synthesized via Strecker-type chemistry
  - E.g. Mass balance reaction of formaldehyde, hydrogen cyanide, water, and ammonia reacting to create glycine and ammonia

$$\mathbf{CH_2O + HCN + H_2O + NH_3 \longleftrightarrow C_2H_5NO_2 + NH_3}$$

Amino Acid Abundances Within CM Meteorites

- Wide variety of α-amino acids in CM meteorites. Data collated from wide variety of sources (see below)
- Similar figures for CI, CR, CV, and CO chondrite groups

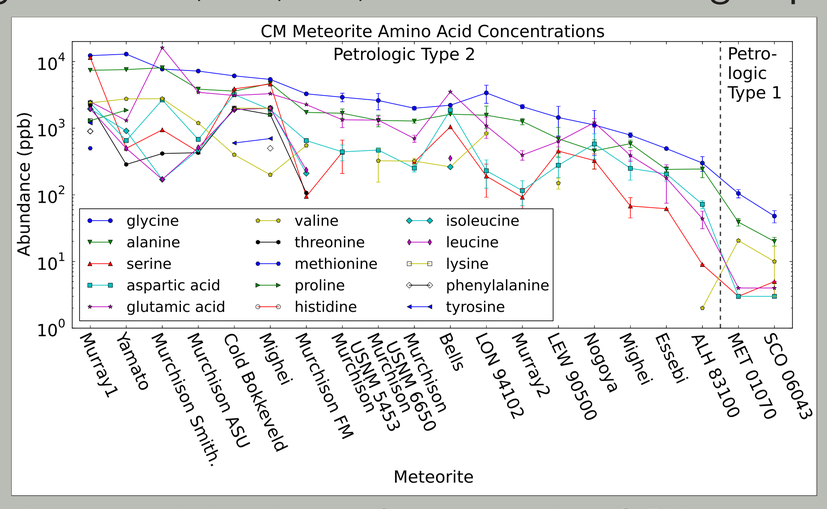

Figure: Amino acid abundances for 20 samples of CM meteorite. Abundances shown in parts-per-billion (ppb).

Total Amino Acid Abundances

- Total amino acid abundances across five subgroups
- Summed amino acids include glycine, alanine, serine, aspartic acid, glutamic acid, and valine (data completeness considerations)

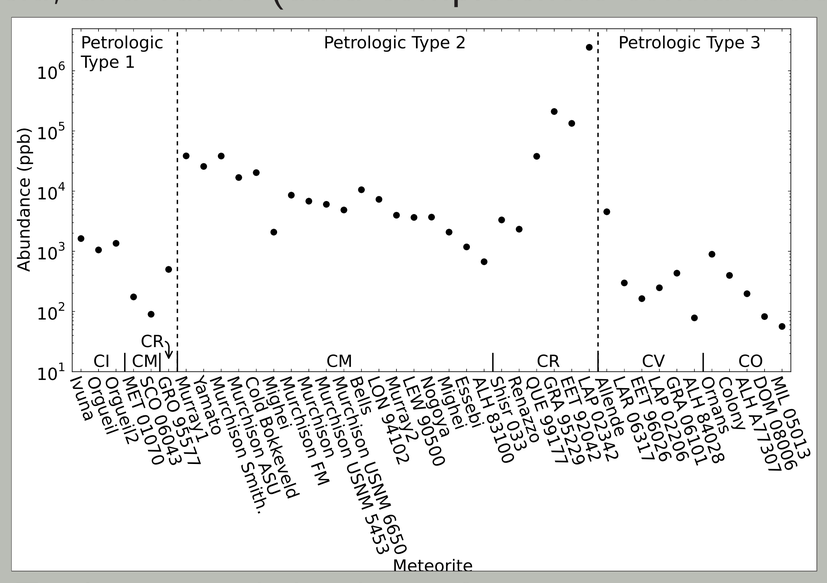

Figure: Total amino acid abundances for various meteorites. Abundances shown in ppb.

Average Amino Acid Abundances

- Average abundances across carbonaceous chondrite subclasses
- CI1, CM1/CR1, CV3, and CO3 have a complete set of data for six amino acids. CM2 and CR2 have complete data sets available for 13 amino acids

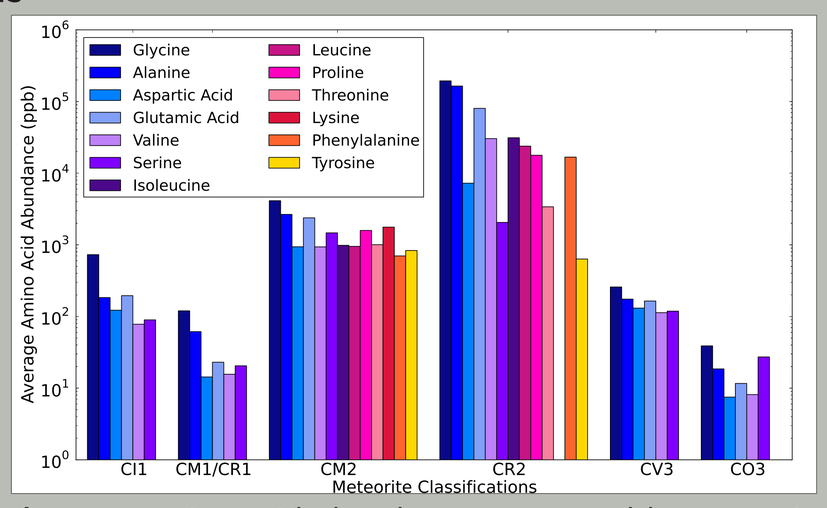

Figure: Average amino acid abundances separated by meteorite class. Abundances shown in ppb.

Relative Amino Acid Frequencies

- Amino acids most abundant amongst CM2 and CR2
- Frequencies of 13 amino acids, relative to glycine

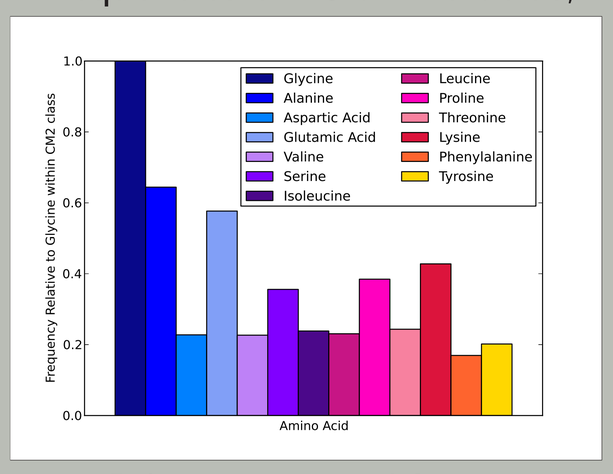

Figure: Relative amino acid frequencies within the CM2 subclass. Frequencies reported in ppb (AA) per ppb (glycine).

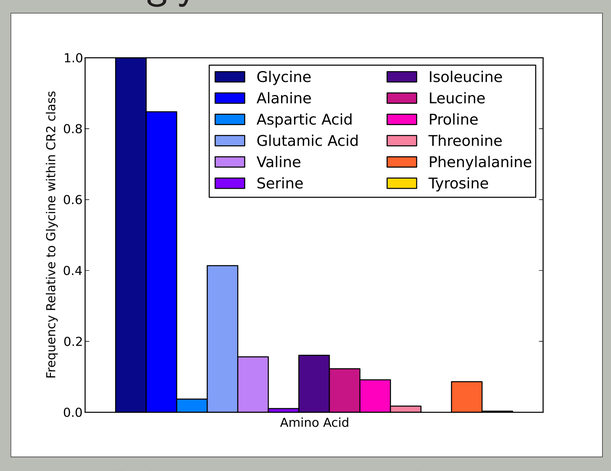

Figure: Relative amino acid frequencies within the CR2 subclass. Frequencies reported in ppb (AA) per ppb (glycine).

Conclusions

- Predominance in abundance and variety of amino acids in the subclasses of carbonaceous chondrite called CM2 and CR2. These meteorites contain concentrations of amino acids greater by several orders of magnitude than other subclasses
- Increased organic abundances in these classes correspond to an optimal temperature range from $200°$C to $400°$C for amino acid synthesis in parent bodies. This range in temperature also corresponds to a high degree of aqueous alteration, indicating that aqueous synthesis of amino acids took place
- Within the CM2 and CR2 meteorites, we additionally identify trends in the frequencies of amino acids relative to glycine in preparation for computational modeling
- In Higgs & Pudritz (2009), relative frequencies are shown to occur according to thermodynamic principles. The more extensive data shown here reinforces the conclusion that an underlying thermodynamic argument may be responsible. In Cobb & Pudritz (2013b, in prep.), we investigate computationally if temperature and aqueous conditions account for overall abundance patterns and relative frequencies of amino acids in meteorites

References & Acknowledgments

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