INVESTIGATING THE ALCOHOL CONTENT OF THE MURCHISON METEORITE. D. N. Simkus[1,2], J. C. Aponte[2,3], J. E. Elsila[2], J. P. Dworkin[2]. [1]NASA Postdoctoral Program, Universities Space Research Association, NASA Goddard Space Flight Center, Greenbelt, MD 20771 (danielle.n.simkus@nasa.gov), [2]NASA Goddard Space Flight Center, Greenbelt, MD 20771, [3]Dept. of Chemistry, Catholic Univ. of America, Washington, DC 20064

Introduction: Aliphatic monoalcohols with no other functionalization (hereafter "alcohols") are among the key potential precursors to several biologically-relevant organic compounds detected in carbonaceous chondrite meteorites (Figure 1), including amino acids and carboxylic acids, which are subunits of proteins and simple membranes, respectively. As such, compound-specific stable isotopic measurements, enantiomeric measurements, and quantifications of meteoritic alcohols should provide important insights into both the cosmochemical and prebiotic history of asteroid parent bodies.

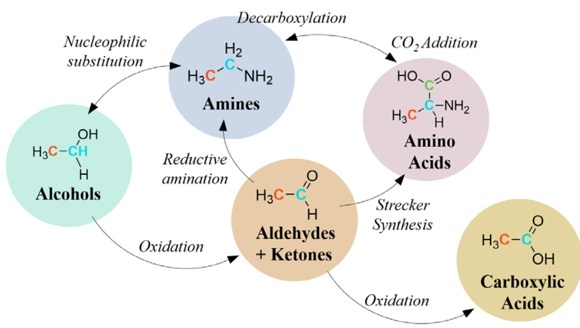

Fig. 1. Schematic of potential synthetic relationships between alcohols and other soluble organic compounds in carbonaceous chondrites.

Stable isotopic ratios ($\delta^{13}C$, δD) can provide insights into potential origins of the molecules (for example, to distinguish between primordial organics from early solar system formation vs. asteroidal aqueous alteration products vs. terrestrial organic contaminants). The enantiomeric compositions (relative abundances of mirror-image *R*- and *S*- stereoisomers for chiral molecules) can be measured to investigate the origins of enantiomeric excesses in meteoritic amino acids and homochirality on Earth.

Previous Studies: The alcohol content of meteorite samples currently represents a significant gap in the literature. One of the early investigations of volatile organics in meteorites reported mass spectrometric evidence of alcohols in the Murray carbonaceous chondrite, but no individual compound identifications [1]. A later study reported compound-specific identifications and abundances for a suite of C_1-C_4 alcohols in the Murchison carbonaceous chondrite (Table 1; [2]) and revealed a general trend of decreasing abundance with increasing molecular weight. No stable isotopic or enantiomeric measurements were included and no further investigations of meteoritic alcohols have been reported to date. The methods employed by previous studies are inadequate for compound-specific stable isotopic analyses due to insufficient separation of isomers (e.g., co-elution of the butanols) and the lack of enantioseparation for chiral alcohols. Thus, investigating the isotopic and enantiomeric compositions of meteoritic alcohols required a new methodology.

Table 1. Alcohols in the Murchison meteorite previously identified by Jungclaus et al., 1976 [2].

Compound	Abundance (μg/g)
Methanol	5
Ethanol	3
Isopropanol	2
n-Propanol	n.d.
Butanols[a]	1

n.d. – not determined
[a]Butanols include four isomers: *tert*-butanol, *n*-butanol, isobutanol, and *R*,*S*-*sec*-butanol

Method Development: We have developed a novel method to characterize, quantify, and measure the stable isotopic ($\delta^{13}C$) and enantiomeric compositions of meteoritic alcohols using gas chromatography coupled with mass spectrometry and isotope ratio mass spectrometry (GC-MS/IRMS). All glassware and tools are wrapped in aluminum foil and heated at 500°C in air for a minimum of 6 hours before use in order to remove potential organic contaminants. Meteorite samples are powdered using porcelain mortars and pestles and extracted in ~500 mg portions in dichloromethane (DCM). The DCM extracts are purified using functionalized silica gels and the alcohols are derivatized using an enantiopure derivatizing agent in order to allow chromatographic separation of individual enantiomers of chiral alcohols via GC-MS (Figure 2).

Alcohols in the Murchison Meteorite: Recently, we analyzed a 200 mg sample of the Murchison CM2 meteorite as an initial test of our newly developed methodology [3]. We identified a suite of alcohols, including a relatively high abundance (~ 8 μg/g) of methanol and trace quantities of C_2-C_7 alcohols. Although the distribution of alcohols closely resembled those observed by Jungclaus et al. (1976), a highly ^{13}C-depleted isotopic value (−67‰) measured for methanol in the Murchison sample and the presence of trace quantities of alcohols in the corresponding procedural blanks suggested that a portion of the alcohols detected may have been terrestrial in origin. Further work has now been carried out to eliminate potential sources of alcohol contamination in the method and to optimize the procedure to permit analyses of larger meteorite sample masses in order to quantify trace alcohols in the measurements.

Here, we present the results from a repeat analysis of the Murchison meteorite, this time from an analysis of a 5 g chip of the meteorite. Potential origins of the meteoritic alcohols identified will be discussed based on their distributions, isotopic compositions, and comparisons with previous analyses of potentially related compounds.

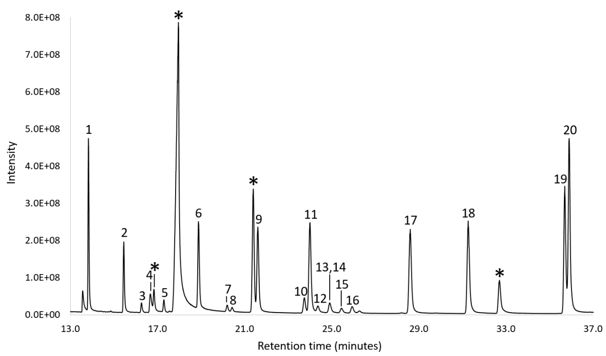

Fig. 2. GC-MS chromatogram of 20 derivatized alcohols standards: 1) Methanol, 2) Ethanol, (3) 2-Propanol, (4) 2-Methyl-2-butanol, (5) *tert*-butanol, (6) 1-Propanol, (7) (*R*)-(-)-2-Butanol, (8) (*S*)-(+)-2-Butanol, (9) 2-Methyl-1-propanol, (10) 2,2-Dimethyl-1-propanol, (11) *n*-Butanol, (12) (*R*)-(-)-3-Methyl-2-butanol, (13) (*S*)-(+)-3-Methyl-2-butanol, (14) (*R*)-(-)-2-Pentanol, (15) (*S*)-(+)-2-Pentanol, (16) 3-Pentanol, (17) (*R*)-(-)-2-Methyl-1-butanol (18) *n*-Pentanol, (19) 4-Methyl-1-pentanol, (20) 3-Methyl-1-pentanol. Reaction by-products are labelled with asterisks.

References: [1] Studier, M. H. et al. (1965) *Science* 149, 1455-1459. [2] Jungclaus, G. A. et al. (1976) *Meteoritics* 11, 231-237. [3] Simkus, D. N. et al. (2019) *AbSciCon*, Abstract #210-4.