

**DISTINGUISHING BETWEEN TERRESTRIAL AND EXTRATERRESTRIAL ORGANIC COMPOUNDS IN THE CM2 AGUAS ZARCAS CARBONACEOUS CHONDRITE.** L. D. Tunney<sup>1</sup>, P. J. A. Hill<sup>1</sup>, C. D. K. Herd<sup>1</sup>, and R. W. Hiltz<sup>2</sup>, <sup>1</sup>Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton, Alberta T6G 2E3, Canada, Email: [ltunney@ualberta.ca](mailto:ltunney@ualberta.ca), <sup>2</sup>Department of Physical Sciences, MacEwan University, Edmonton, Alberta T5J 4S2, Canada.

**Introduction:** Analysis of organic compounds intrinsic to meteorites can provide important information regarding the origin and modification of organic matter, volatiles, and carbon chemistry in the interstellar medium, solar nebula, and asteroid parent bodies, and potentially the origin of life [1]. However, the conditions under which meteorites are formed are extraordinarily different than the conditions meteorites are subject to at the surface of the Earth [2]. Upon entering the Earth's atmosphere and landing on the surface, meteorites are subject to significant sources of terrestrial organic contamination due to the presence of life. Organic compound analysis in meteorites allows for the discrimination between intrinsic (extraterrestrial) and contaminant (terrestrial) compounds.

On April 23, 2019 the fall of the Aguas Zarcas CM2 carbonaceous chondrite was reported in San Carlos county, Alajuela province, Costa Rica. A total of 27 kg of material was collected, with approximately 11 kg of the total mass being recovered prior to rainfall in the area [3].

The fall of the Aguas Zarcas meteorite allows for the opportunity to test advancements in the field of astromaterials curation, especially in cold curation as applied to organic-rich samples. Recent advantages in harnessing cold temperatures and processing within an inert atmosphere to maintain astromaterials in their pristine states have been identified and include: reduced reaction rates, preservation of intrinsic organic compounds, restriction of potential bacterial growth, and limitation of organic contamination, especially in the volatile phase [4]. The sensitivity of astromaterials to contamination demonstrates the importance of proper techniques when recovering, storing, and processing astromaterials in order to manage the inevitable terrestrial contamination and preserve its indigenous state for scientific research [5,6]. However, a better understanding of sources of contamination are needed to reduce potential for contamination – which is critical in maintaining the pristine nature of astromaterials [7]. Aguas Zarcas also permits the identification of how environmental factors, rainfall in this case, impact the organic compounds detected on the sample by comparing results of pre- and post-rain specimens.

**Materials and Methods:** An individual pre-rain Aguas Zarcas specimen weighing 4.858 g was acquired

from Mendy Ouzillou (Skyfall Meteorites). The specimen was subsampled to obtain a ~0.5 g sample within the Subzero Curation Facility at the University of Alberta using a guillotine cutter inside an argon atmosphere glove box and was subsequently powdered using a ceramic mortar and pestle. The powdered sample was extracted in 5 mL of DCM 4 times at room temperature in the Class 1000 clean room inside the facility. The extract was then evaporated to 0.2 mL in a fume hood to concentrate the solution, and analyzed by gas chromatography – mass spectrometry (GC-MS) to determine the detectable DCM-soluble organic compounds present following methods presented by [8]. The GC-MS analysis was performed on an Agilent 5975C using a HP-5MS column (30 m length, 0.25 µm film thickness, 250 µm internal diameter). Detection was executed with an Agilent 5975C mass selective detector (MSD). Alongside the specimen, a blank was processed with identical steps to monitor potential contamination introduced during the extraction. Prior to use all materials used in the subsampling and extraction processes that could come into contact with the Aguas Zarcas sample were cleaned with ultrapure water and HPLC grade DCM, and if possible, were combusted at 450°C for >6 hours. DCM extractions of swabs from a multitude of surfaces within the facility were also analyzed to elucidate baseline contamination that could influence the Aguas Zarcas results; comprising of processing tools, laboratory surfaces, and storage materials.

**Results:** The GC-MS organic compound results for Aguas Zarcas are reported in Table 1, including their potential terrestrial sources. These results were then compared to the organic compounds detected on the laboratory materials.

Table 1. Detectable organic compounds in the pre-rain Aguas Zarcas in the GC-MS analysis, including possible terrestrial sources for each compound.

Compound	Potential Terrestrial Source
1-Dodecanol	Agricultural products
3-Trifluoromethylbenzoic acid, 4-tetradecyl ester	Fuels, pesticides, and polymers
*9H-Fluorene, 9-methylene-	Pharmaceuticals
*Acenaphthene	Fuels, pesticides, pharmaceuticals, and plastics
*Azulene	Fragrances
Butylated hydroxytoluene	Agricultural products, fuels, and plasticizers

Carbonic acid, dodecyl phenyl ester	Salt
*Cyclic octaatomic sulfur	Pharmaceuticals
Diethyltoluamide	Pesticides (DEET)
Dodecanol	Pesticides
Eicosane, 2-methyl-	Fuels and plasticizers
*Fluoranthene	Pesticides
Heptadecane	Fuels
Nonyl pentafluoropropionate	Pharmaceuticals
Phenol, 4-(1,1-dimethylpropyl)-	Pesticides
*Pyrene	Pesticides
Tetradecane, 2-methyl-	Fuels, pesticides, and polymers
Undecane, 4,7-dimethyl-	Fuels

\*indicates compounds that are likely intrinsic; see text for details.

**Extraterrestrial Organic Compounds.** There are a total of 6 detectable, DCM-soluble organic compounds that were deemed to be intrinsic to Aguas Zarcas; 1 elemental sulfur and 5 polycyclic aromatic hydrocarbons (PAH's). These included: 9-methylene-9H-fluorene, acenaphthene, azulene, cyclic octaatomic sulfur, fluoranthene, and pyrene. PAH's are commonly found in carbonaceous chondrites, although they can be derived terrestrially from combustion of fossil fuels [9]. These compounds are likely intrinsic to the meteorite as the PAH's detected in Aguas Zarcas are the common grouping found intrinsic to other CM2 chondrites, and their distribution is inconsistent with a terrestrial source - terrestrial PAH's are present in more complex combinations whereas extraterrestrial PAH's consist of a simple groupings of minimal compounds [10]. Elemental sulfur, such as cyclic octaatomic sulfur found on Aguas Zarcas, is also commonly found in carbonaceous chondrites [11], again, it is possible to find such compounds on Earth. In spite of the fact that these proposed extraterrestrial compounds can originate from a terrestrial source, namely in pesticides and pharmaceuticals, these 6 compounds are typically not commonly used in such applications. Since terrestrial PAH's would appear in a larger abundance with a wider variety of compounds, it can be deduced that they are more likely intrinsic to the meteorite due to their simple and limited distribution.

**Terrestrial Organic Compounds.** The remaining 12 detectable, DCM-soluble organic compounds were determined to be likely caused by the interaction of the meteorite with the terrestrial surface. In particular, they suggest landing on agricultural land; 7 of the detected compounds are directly related to agricultural land in the form of pesticides or agricultural products. The carbonic acid (salt) could also be sourced from an additive in fertilizers, again linking these compounds to agriculture. Undecane and heptadecane are commonly found in fuels, which could be sourced from agricultural equipment, or could be attributed to proximity of the fall to roads and cars; both of which are terrestrial sources.

Possible sources of polymers and plasticizers could be from the terrestrial surface or handling prior to arrival at the University of Alberta.

**Laboratory Materials.** Materials used within the laboratory appeared contaminated with compounds not found on Aguas Zarcas. This suggests that there was no contamination transferred from the materials to the meteorite itself. However, the more likely explanation for this would be that the transferred contamination may not be high enough in concentration to detect by the GC-MS method. In any case, any potential laboratory sourced contamination is negligible suggesting all the contamination is sourced from the terrestrial surface.

**Conclusions and Next Steps:** By understanding the sources of terrestrial contamination, astromaterials can be kept in pristine condition for future research. This knowledge enables the design of the best procedures for mitigating contamination in order to improve analyses on samples. Being able to discriminate between intrinsic and contaminant organic compounds becomes increasingly important in carbonaceous chondrites due to the higher intrinsic organic compound content of these meteorites. In turn, better insights into the origin and modification of intrinsic organic compounds in the solar system can be obtained.

Next steps for the Aguas Zarcas meteorite include amino acid determination on both pre- and post-rain specimens, and carrying out the DCM extractions on post-rain specimens. A comparison between the results of the pre- and post-rain samples will help to constrain the amplitude of environmental impacts on detectable organic compounds of Aguas Zarcas, and by extension, other carbonaceous chondrites.

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**References:** [1] Huss G. R. and Draine B. T. (2006) *Proceedings of the International Astronomical Union*, 2, 353–356. [2] Allen C. C. et al. (2011) *Chemie der Erde - Geochemistry*, 71, 1–20. [3] Meteoritical Bulletin Database. [4] Herd C. D. K. et al. (2016) *Meteoritics & Planet. Sci.*, 51, 499–519. [5] Fries M. et al. (2014) *Meteoritics & Planet. Sci.*, 49, 1989–1996. [6] McCubbin F. M. (2019) *Space Sci. Rev.*, 215, 1–81. [7] Hilts R. W. et al. (2014) *Meteoritics & Planet. Sci.*, 49, 526–549. [8] Simkus D. N. et al. (2019) *Meteoritics & Planet. Sci.*, 54, 1283–1302. [9] Becker L. et al. (1997) *Geochimica et Cosmochimica Acta*, 61, 475–481. [10] McKay D. S. et al. (1996) *Science*, 273, 924–930. [11] Kaplan I. R. and Hulston J. R. (1966) *Geochimica et Cosmochimica Acta*, 30, 479–496.