DISTINGUISHING BETWEEN TERRESTRIAL AND EXTRATERRESTRIAL ORGANIC COMPOUNDS IN THE CM2 AGUAS ZARCAS CARBONACEOUS CHONDRITE

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INTRODUCTION

On April 23, 2019 the fall of the Aguas Zarcas CM2 carbonaceous chondrite was reported in San Carlos county, Alajuela province, Costa Rica (Figure 1). 27 kg of material was collected, with approximately 11 kg of the total mass being recovered prior to rainfall in the area [1].

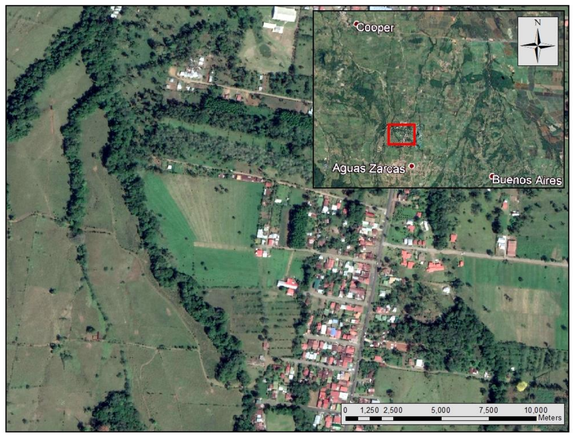

Figure 1. Collection area of the Aguas Zarcas meteorite specimens in San Carlos county, Alajuela province, Costa Rica.

OBJECTIVES

1. Discriminate between intrinsic (extraterrestrial) and contaminants (terrestrial) organic compounds within Aguas Zarcas meteorite specimens.
2. Explore environmental controls on organic contamination, more specifically, rainfall.
3. Determine proper techniques to recover, store, process, and curate carbonaceous chondrites like Aguas Zarcas based on their organic compound content.

METHODS

SAMPLE PREPARATION

One pre-rain (4.858 g) and one post-rain (3.12 g) Aguas Zarcas stone were obtained from Mendy Ouzillou (Skyfall Meteorites) with an additional post-rain (1.92 g) stone provided by The Meteorite Market. Each were subsampled within the Subzero Curation Facility at the University of Alberta [2] to obtain ~0.5 g samples then powdered and extracted in 5 mL of dichloromethane (DCM) 4 times.

PROCEDURE

Any materials used in the subsampling and extraction processes were cleaned and swabbed with DCM to monitor potential laboratory contaminants. All DCM extractions (including swabs, meteorite extractions, and blanks) were then analyzed by gas chromatography – mass spectrometry (GC-MS) to determine the detectable DCM-soluble organic compounds present following the methods outlined by [3].

RESULTS

Table 1. Organic compounds detected in the DCM extract of pre-rain Aguas Zarcas #1.

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

Footnotes:
* Indicates compounds that are likely intrinsic
Highlighted compounds are common to all 3 specimens

Table 2. Organic compounds detected in the DCM extract of pre-rain Aguas Zarcas #2.

Compound	Potential Terrestrial Source
***Cyclic octaatomic sulfur**	Pharmaceuticals
***Fluoranthene (2 peaks)**	Pesticides
Heptadecane	Fuels
***Hexathiane (7 peaks)**	Pharmaceuticals
Tetradecane, 2,6,10-trimethyl-	Fuels, pesticides, and polymers

Table 3. Organic compounds detected in the DCM extract of post-rain Aguas Zarcas.

Compound	Potential Terrestrial Source
1-Naphthalenecarboxylic acid	Pharmaceuticals
1,4-Benzenedicarboxylic acid, bis(2-methylpropyl) ester	Adhesives, plasticizers, resins, and sealants
Chloromethyl propanoate	Pharmaceuticals
***Cyclic octaatomic sulfur**	Pharmaceuticals
***Fluoranthene**	Pesticides
Hentriacontane	Food additives, fuels, personal care products, pharmaceuticals, and plants
Pyridine, 4,4'-(1,2-ethenediyl)bis-, (E)-	Olefins, polymers, and solvents
Sulfurous acid, 2-propyl tridecyl ester	Food additives, pesticides, and pharmaceuticals

DISCUSSION

EXTRATERRESTRIAL ORGANIC COMPOUNDS

Both polycyclic aromatic hydrocarbons (PAHs) and elemental sulfur are common organic materials found in carbonaceous chondrites, however it is possible for them to have terrestrial sources [4, 5]. Terrestrial PAHs are typically present in a wide variety of combinations whereas extraterrestrial PAHs consist of a simple groupings of minimal compounds [6].

TERRESTRIAL ORGANIC COMPOUNDS

The majority of the DCM-soluble organic compounds that are likely terrestrial contaminants are consistent with a fall on agricultural land, primarily in the from of pesticides (Tables 1-3).

LABORATORY MATERIALS

Materials used within the laboratory contained unique contaminants not detected in any of the Aguas Zarcas extractions. This suggests that there was no detectable contamination transferred from the materials to the meteorites themselves.

RAINFALL IMPACTS

The rain appears to have introduced a new suite of terrestrial contaminants while carrying away the common contaminants detected in both pre-rain specimens; heptadecane and tetradecane. However there is no visible effect on the intrinsic compounds, cyclic octaatomic sulfur and fluoranthene, that are detected in both pre-rain and the post-rain specimens.

IMPLICATIONS

Based on the DCM results, no extraordinary curation methods are necessary for Aguas Zarcas: there are few intrinsic organic compounds, and the ones present are not especially volatile. Therefore, typical curation conditions (i.e., at room temperature) should suffice to preserve its intrinsic properties. However, this is subject to reconsideration when amino acid data are available. Our study demonstrates the importance of being able to discriminate between intrinsic and contaminant organics in assessing whether unique handling conditions are required for future astromaterials – either recovered meteorites or returned samples from space exploration.

NEXT STEPS

Next steps for the Aguas Zarcas meteorite include water extraction and amino acid determination on both pre- and post-rain specimens.

REFERENCES

[1] Meteoritical Bulletin Database. [2] Herd C. D. K. (2016) *Meteoritics & Planet. Sci.*, 51, 499 – 519 [3] Simkus D. N. et al. (2019) *Meteoritics & Planet. Sci.*, 54, 1283 – 1302. [4] Bada J. L. et al. (1998) *Science*, 279, 362 – 365. [5] Kaplan I. R. and Hulston J. R. (1966) *Geochimica et Cosmochimica Acta*, 30, 479 – 496. [6] Becker L. et al. (1997) *Geochimica et Cosmochimica Acta*, 61, 475 – 481.

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