Investigations into the distribution of the highly volatile trace elements Bi, Pb, Cd, In, and Tl within the Allende carbonaceous chondrite

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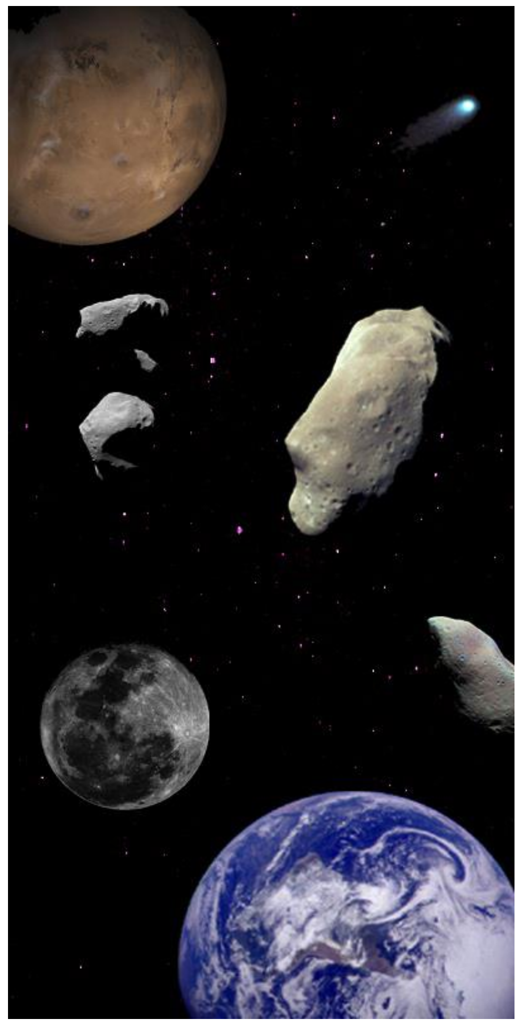
We demonstrate a new analytical procedure designed to elucidate the distribution of the highly volatile trace elements (HVTEs) Cd, In, Tl, Pb, and Bi in meteorites. We utilize non-destructive synchrotron X-ray microtomography (μCT) for the *a priori* determination of the volumetric content of three distinguishable phases (matrix, inclusions, and opaque materials) in a ~1400 mg specimen of the well-characterized chondritic meteorite Allende ($CV3_{oxA}$). We subsequently determine concentrations of 60 major, minor, and trace elements in 10 spatially correlated sections cut from this specimen. We determine the phase volume and elemental heterogeneity of this specimen and assess the extent to which there are significant correlations between modal phase volumes and elemental concentrations via multivariate correlation analysis. We readily detect heterogeneities between 10 sections sampled from a bulk specimen ranging in mass from ~60-500 mg. The overall mean volumetric contents for the three distinguishable phases are 77.7% matrix, 21.5% inclusions, and 0.75% opaque materials. We see statistically significant correlations between modal phase volume contents and elemental concentrations that are consistent with previous direct measurements for major, minor, and refractory trace elements in Allende.



Our analyses reveal a multifaceted behavior of the HVTEs on the basis of heterogeneity, phase-element correlation, and interelemental-correlations. Concentrations of all of the five HVTEs studied correlate with matrix content indicating a disposition related to matrix vol.-%. Thallium, Pb, and Bi correlate significantly with S demonstrating chalcophile affinity. The most likely scenario is that these elements were most likely incorporated with iron sulfides that formed during the sulfurization of Fe alloy grains. In contrast, Cd and In correlate positively with the most unique matrix marker element, Mg. However, they do not show a strong correlation with S. This information indicates that, at least, these element's final disposition is associated with fine-grained matrix independent of the S content. Due to the higher post-condensation mobility of these two elements a likely scenario is late thermally-induced mobilization with recondensation on the surface of abundantly available fine-grained silicate dust. Our data suggest that this occurred prior to accretion.

Dr. Stephen F. Wolf received his B.S. in Chemistry in 1987 and Ph.D. in Analytical Chemistry in 1993 from Purdue University. His graduate research, performed under the mentorship of Professor M. E. Lipschutz, focused on the use of volatile trace elements as a tool to identify meteorites derived from co-orbital meteoroid streams. After his graduate studies, Dr. Wolf accepted a staff position in the Chemical Technology Division at Argonne National Laboratory where he worked on the development of analytical techniques and testing methodologies for the study of nuclear waste forms and their long-term disposition in a nuclear repository. In 2001 Dr. Wolf joined the Department of Chemistry at Indiana State University in Terre Haute, Indiana where he has taught and performed research with undergraduates for the past 17 years.

Dr. Wolf has published over 50 peer-reviewed papers and book chapters in the fields of cosmochemistry, analytical chemistry, and nuclear waste materials science. He recently contributed the chapter "Trace Analysis of Actinides in Geological, Environmental, and Biological Matrices," and a section on analytical methods for the chapter "Uranium" to the 3rd edition of the five-volume publication "The Chemistry of the Actinide and Transactinide Elements" published by Springer. His research at Indiana State University has been funded by the Research Corporation, The Camille and Henry Dreyfus Foundation, and the National Science Foundation. His current research interests focus on the measurement of trace and ultra-trace elements for the study of cosmochemical, geochemical, and environmental processes. Currently, he is primarily working on developing chemical and physical methods in conjunction with elemental determination by inductively coupled plasma mass spectrometry (ICPMS) with chemometric data analysis techniques in order to identify volatile trace element host phases in primitive meteorites.