The provenance of volatiles in asteroidal and planetary meteorites

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Background: Meteorites contain volatiles including water and CO₂ that have been used with great effect to explore Solar System processes including aqueous alteration of the interiors of asteroids¹¹, the delivery of water to the early Earth², and the composition of the Martian hydrosphere and atmosphere³. These extraterrestrial compounds are hosted by phyllosilicate and carbonate minerals, and organic matter. All meteorites have acquired an additional set of volatiles from the terrestrial environment (i.e., our atmosphere, hydrosphere, biosphere). This ‘contamination’ is most pronounced in meteorite finds, especially those that have been recovered after an extended duration of terrestrial residence, although it is also of concern for even the most recent falls. The aims of this project are to understand the mechanisms and rates of acquisition of terrestrial volatiles by extraterrestrial rocks.

Project outline: Most previous studies of the terrestrial contamination of meteorites has focused on oxidation of iron and sulphur in ordinary chondrite finds⁴. This project will target meteorites that are mineralogically and genetically closer those that contain extraterrestrial volatiles, namely carbonaceous chondrites, and Martian meteorites. One focus of the project will be to determine the quantity, carriers and isotopic fingerprints of water. An emphasis will be on phyllosilicates because they are the main hosts of extraterrestrial water in meteorites from primitive asteroids and Mars, yet can also form on Earth⁵,⁶. The content of water and its deuterium/hydrogen (D/H) ratio will be determined by stepped heating. D/H is a very powerful tracer of the provenance of water throughout the Solar System, yet the extraterrestrial signal can be rapidly obscured by terrestrial contamination⁷. Carbonate minerals are also powerful tracers of the former presence and movement of liquid water and CO₂ in both asteroidal and planetary contexts¹¹. The petrographic, microstructural and chemical characteristics of these carbonates will be determined by electron microscopy including electron backscatter diffraction (EBSD). The volume of carbonate-hosted CO₂ in each sample and its ¹²C/¹³C and ¹⁸O/¹⁶O values will be determined by conventional acid dissolution/mass spectrometry. The project will also utilise the novel clumped isotope technique to determine the temperatures at which the carbonates crystallized and the O isotope compositions of solutions from which they precipitated. The clumped isotope data will provide a wealth of new insights into environmental conditions within meteorites exposed at the Earth’s surface.

Outcomes: This project will yield a new understanding of the rates and mechanisms of volatile exchange between extraterrestrial rocks and the Earth. Results will be of interest to planetary scientists who use meteorites to explore the Solar System, but also to those who are devising strategies to minimise the contamination of samples that will be returned to Earth from the moon, asteroids, and Mars. The student will gain comprehensive training in the latest analytical techniques, together with communication skills by publication, attendance at international conferences, and outreach.

Application procedure: This project is eligible for funding by several schemes within the University of Glasgow. For entry in 2017 apply via the website of the College of Science and Engineering*. The application deadline is 31 January 2017. Please contact the principal supervisor with any questions (Martin.Lee@Glasgow.ac.uk).