Heavy metal insights into the formation of Planet Earth

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Overview: Our planet is unique. The Earth is the only planet with stable liquid water at the surface, and the only known planet to host life. How did this happen? How do you build a habitable planet? It is vital to answer these key questions if we ever want to figure out how life got started on Earth and if we are alone in the Universe.

The Earth initially formed as a dry desert planet – very different to the planet we inhabit today. Current theories suggest that most of Earth’s water, in addition to large quantities of organic material, could have been delivered in the final stages of Earth’s formation from water-rich asteroids, providing the vital components required for life to emerge. Several types of meteorites derived from water-rich asteroids are a close match to Earth’s ocean’s isotope composition, supporting such theories. However, these same asteroids are also very different to the Earth both chemically and isotopically in other key components, particularly in the metal loving highly siderophile elements (HSEs). This presents a challenge and an opportunity.

While highly siderophile elements are heavily utilised in green technologies, and thus vital for meeting NetZero targets, HSEs are also key recorders of planetary processes. For example, the unexpected enrichment of HSEs in Earth’s mantle suggests a final veneer of primitive asteroids fell on the Earth during the last stages of planet formation, and famously the global “Iridium layer” at 66 Ma is evidence for the catastrophic impact that wiped out the dinosaurs. Highly siderophile elements can therefore be utilised to trace meteoritic addition to our Earth system. However, our ability to answer questions regarding planetary-scale processes is limited due to our limited understanding of the mineralogical and textural context of HSEs within extraterrestrial materials.

In this project the student will use correlative microscopy to explore the structure, petrology and isotopic composition of HSE bearing minerals in a variety of meteorites and returned asteroid samples to answer the following questions:

1) How does HSE mineralogy, geochemistry and isotope geochemistry vary between meteorites?
2) What do these results tell us about the formation and evolution of asteroids?

3) Which asteroid types could really have delivered water to the early Earth to form our habitable world?

**Methodology:** The key to understanding HSEs and their importance in cosmochemistry is by locating the minerals that they are found within, in the rocks themselves. However, HSEs are low in abundance, and so detailed microanalysis is needed.

The research will use a series of correlated complementary microanalytical techniques to locate HSE minerals and characterise them in exquisite detail from the cm scale down to the atomic scale.

1) X-ray computed tomography will be used to characterise the meteorites in 3D

2) Scanning electron microscopy and laser ablation inductively coupled plasma mass spectrometry will be used to automate the location of HSE-rich minerals, and determine their chemistry and crystallography.

3) Focused ion beam microscopy will be used to extract very small samples for thermal ionisation mass spectrometry as well as transmission electron microscopy and atom probe tomography.

4) Thermal ionisation mass spectrometry will be used to constrain the Os isotopic composition of HSE minerals, and potentially date phases using the Re-Os isotope system – this will be undertaken at the University of Bristol.

5) Atom probe tomography to get atomic structure, composition, and isotopes – this will be undertaken at the University of Oxford.

By combining all these datasets together, we will get the first clear picture of the diversity and context of HSE minerals and use this data to inform interpretations on the formation of habitable worlds.

The meteorites and asteroid samples to be studied are already in hand at Glasgow and further samples can be requested if required. The student will get a unique transferrable skillset of advanced correlative microanalysis as well establishing the material properties or resources that are vital for the green economy.

**Training & skills:** The student will be trained in a series of desirable transferrable skills:

1) Planetary science and materials science. The student will gain a deep understanding of how planets and asteroids form and evolve as well as strong understand of minerals and their material properties.

2) Laboratory skills associated with advanced correlative microscopy.

3) Science writing, communication and presentation skills for publications, conferences and to the general public.

Candidates must be willing to learn to use several advanced microanalytical tools. The candidate will also gain expertise in meteoritics, Planet formation, working with asteroid sample return materials, the structure and evolution of the Earth, and Astrobiology.

**Application details:** The project would suit a geologist, (geo-)physicist, or STEM graduate with an interest in Space and Planetary Science, and the entry requirement is a 2.1 Honours degree or equivalent in geology, Earth science, planetary science, materials science or a cognate discipline. The application deadline is Wednesday 31 January 2024. Interviews will be held in mid-late February 2023, and the studentship will start in October 2024. Information on how to apply is [here](#):
References