## *Benchmarking major element isotopic compositions of chondritic meteorites*

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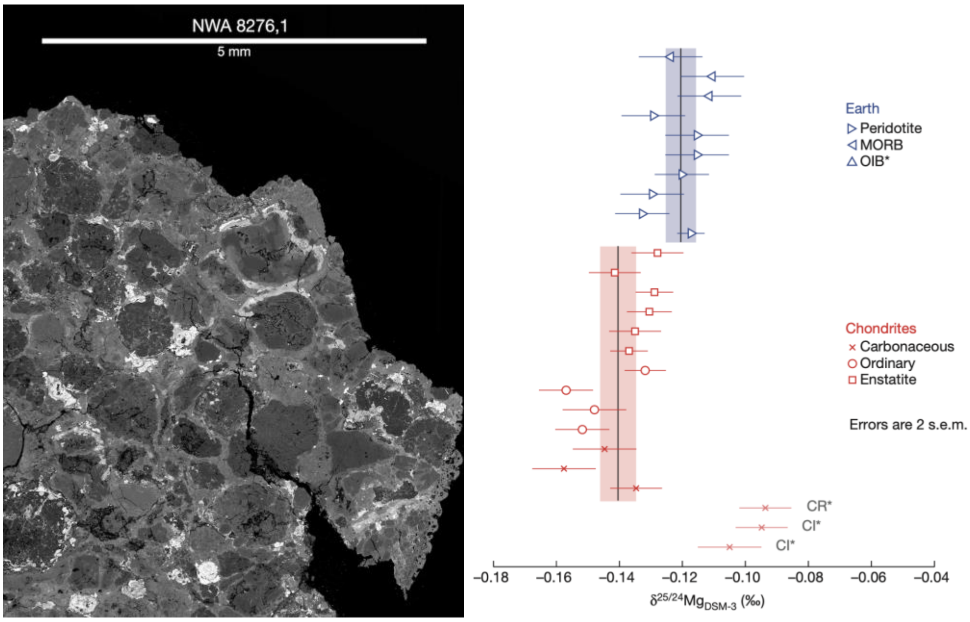


*Left*. Backscattered electron image of ordinary chondrite (NWA8276), showing the complex petrology of a primitive meteorite.
*Right*. Subtle difference in average Mg isotopic composition of chondrites (red band) and Earth (blue band), although note anomalous compositions of some meteorites (CI &CR) influenced by fluid flow on meteorite parent body. From [1].

**Project Background**

Primitive, so-called chondritic, meteorites provide a key, compositional estimate of the proto solar nebula. Planets, that grew from this nebular disk, are expected to inherit its bulk composition and so any observed differences might be attributed to processes involved during their growth (e.g. volatile loss during the energetic process of collisional accretion). This approach has long been applied to the elemental budgets of planets but with the ability of multi-collector inductively coupled plasma mass-spectrometers (MC-ICPMS) to make high-precision, mass-dependent isotopic analyses of a large portion of the periodic table, the comparison between chondritic and planetary compositions has been extended to an isotopic dimension. This has revealed some significant discrepancies e.g. [1, 2, 3] (see figure above). While small isotopic differences of major, planet forming elements and chondrites can have significant potential implications for the process of planet formation e.g. [1, 2, 3], their accurate interpretation requires other possible controls on isotopic fractionation to be understood and controlled.

**Project Aims and Methods**

This project sets out to construct a robust, new reference dataset for the chondritic isotopic composition of four, major planetary forming elements (Si, Mg, Ca and Ni), applying novel measurement methodologies we have pioneered at Bristol in combination with careful, petrographic work before analysis. This work will allow the significance of key isotopic differences between planetary bodies and chondrites for these elements to be interpreted with new clarity and precision.

The studentship has two main aspects. The first is to apply some innovative methods in isotope ratio mass-spectrometry. Mass-dependent isotope fractionation is most accurately determined by a double spiking technique e.g. [4], which is thus the method of choice for this work. Unfortunately, two of the most abundant, planet forming elements (Si and Mg) have only three stable isotopes, whilst conventional double spiking requires four. The Bristol Isotope Group have pioneered a critical mixture double spiking method for such three isotope systems [5] and applied it successfully to both Mg [1] and Si [6]. This approach will be at the heart of this comprehensive new study. However, the project will initially start by measuring Ni isotope ratios, for which more conventional double spiking works well and in which we also have considerable experience [3]. The final element we will analyse is Ca, which is challenging given several isobaric interferences, not least $^{40}Ar^{+}$ generated in the plasma source of the mass-spectrometer itself. This problem is addressed using a new generation of collision cell, MC-ICPMS. We have already developed this approach using a prototype instrument [7] and this studentship can develop the work on our new collision cell MC-ICPMS, Neoma.

The second component of the project will be careful sample characterisation and preparation. Chondrites are complex, heterogeneous objects (see figure above). The ability of MC-ICPMS to make high precision analyses on small samples can lead to measurements being made on fragments that are too small to be representative of the bulk meteorite see [8]. Moreover, the lower grade carbonaceous chondrites are known to have experienced fluid flow and this has likely perturbed the isotopic compositions of elements like Mg and Ni which are mobile in aqueous fluids[1, 4] (see also figure above). The studentship will tackle both problems. Samples will be prepared from slabs of meteorite, in which one slice is powdered and the adjacent cut surface is carefully analysed by SEM. This allows for clear documentation of the specific sample petrology and allows potential micro-sampling and analysis of unusual petrographic features. The powder prepared will also be analysed for its bulk, elemental composition which enables careful comparison with reference compositions obtained from large meteorite samples e.g. [9]. For fluid-influenced carbonaceous chondrites we will undertake a sequence of analyses on meteorites that reflecting different amounts of fluid alteration as already determined from oxygen isotope measurements {e.g. Young, 1999 #11}. This will enable us to put Mg and Ni isotopic variations in much better context.

**Candidate**

The successful candidate should have a strong background in Earth or Planetary Sciences or related physical science, preferably at MSci or MSc level. A strong interest in this field is essential, as too is an enthusiasm and aptitude for practical, laboratory work and painstaking, analytical study. This will require excellent communication and written skills.

**Training**

We will provide training in cutting-edge laboratory techniques and mass spectrometry, which are core to the activities of the Bristol Isotope Group, of which the student will become a member. Additional training will be given in microbeam techniques, which is well supported in the School. Familiarity with meteorite petrology will be gained with help from cosmochemists in the group. The student will be expected to present results at national and international conferences and to publish findings in international journals. These skills will be developed during the studentship as part of supervision and peer learning. The University of Bristol offers a wider range of less specific training opportunities.

**References:**

[1] Hin et al, *Nature*, 2017, **549**, 511-515. [2] Armytage et al, *Geochim. Cosmochim. Acta*, 2011, **75**, 3662-3676. [3] Klaver et al, *Geochim. Cosmochim. Acta*, 2020, **268**, 405-421. [4] Klaver & Coath, *Geostandards & Geoanalytical Research*, 2019, **43**, 5-22. [5] Coath et al, *Chem. Geol.*, 2017, **451**, 78-89. [6] Liu et al, *J. Anal. Atom. Spectrom.*, 2024, **39**, 2799-2808. [7] Lewis et al, *Chem. Geol.*, 2022, **614**, 121185. [8] Stracke et al, *Geochim. Cosmochim. Acta*, 2012, **85**, 114-141. [9] Jarosewich, *Meteoritics*, 1990, **25**, 323-337.

**Application deadline: 14.00 GMT, 12th Feb 2025**

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