ESTABLISHING A PRISTINITY INDEX FOR EUCRITES USING THE HIGHLY SIDEROPHILE ELEMENTS.
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Introduction: The eucrite meteorites represent early-formed (~4.557-4.565 Ga; [1-2]) basalts and basaltic to gabbroic cumulates from the howardite-eucrite-diogenite (HED) parent body, or bodies, based on oxygen isotope and spectroscopic data [3-6]. The unbrecciated eucrites are a subset of this meteorite class that are considered to be free from post-crystallization impact contamination. They are therefore particularly promising samples for understanding metal-silicate differentiation and magmatic evolution on the HED parent body(ies), if they are truly *pristine*. Prior petrologic and geochemical studies, however, show evidence that some *unbrecciated* eucrites may not represent pristine cumulate and basaltic melts from their parent body(ies) [e.g., 7-12].

In order to resolve these problems, we have begun a campaign to analyze bulk rock samples of eucrites for Os isotopes and highly siderophile element (HSE: Os, Ir, Ru, Pt, Pd, Re) abundances. Our goals are to provide a highly sensitive measure of pristinity for eucrites using the HSE, as has been done for lunar crustal rocks [13-15], and to seek evidence for metal-silicate differentiation signatures in eucrites.

We build on previous petrology research [16-17] and present highly siderophile element (HSE: Os, Ir, Ru, Pt, Pd, Re) abundances and Os isotopic ratios for unbrecciated Antarctic eucrites (PCA 82502, QUE 97053), brecciated eucrite GRO 06059, eucrite desert-finds (NWA 1000, NWA 5232, NWA 5356, NWA 5601), eucrite falls (Bereba, Juvinas, Millbillillie, Pasamonte, Stannern), a eucrite find (Bouvante), and the howadiite, Kapoeta. Our study sought to include monomict, polymict and brecciated eucrites for development of methods to establish pristinity in eucrites.

Methods: Bulk rock samples were prepared and analyzed at the *Scripps Isotope Geochemistry Laboratory* (SIGL) for major and trace element abundances. Isotope-dilution HSE abundances and Os isotopic ratios were obtained using methods involving both Carius tube and High Pressure Asher digestion, as described previously [5]. Blank contributions ranged from 0.2-65% for Re, and 0.1-69% for Os, with a similar range of blank contributions for the other HSE (Ru, Ir, Pt, Pd).

Results: Evidence for impact contamination in some eucrites is reflected in a plot of Ni versus Co, in which brecciated Antarctic eucrite GRO 06059 has the highest Ni content (~42 ppm; Figure 1). However, additional samples (NWA 5232, NWA 5601) also have elevated Ni contents. We describe samples as having high (>10 ppm), intermediate (5-10 ppm), low (5-2 ppm) and very low (<2 ppm) Ni content.

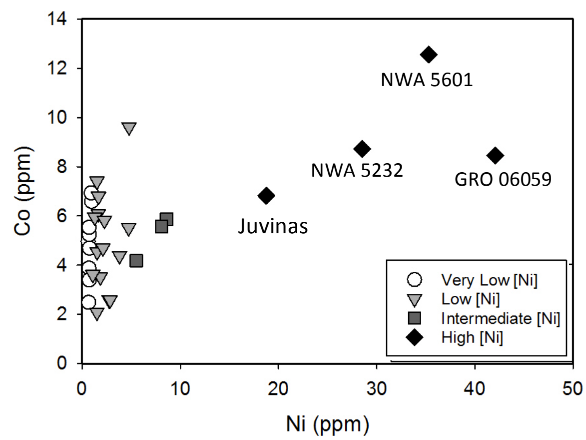

Figure 1: Nickel versus Co plot for eucrites. Here, elevated contents of nickel are interpreted to relected impact contamination.

Highly Siderophile Elements: Eucrites meteorites that we have measured have HSE abundances ~0.01 to 0.00001 × CI-chondrite (Figure 2). High HSE concentration samples, including the howardiite Kapoeta, generally have broadly flat CI-chondrite normalized HSE patterns, whereas eucrites with lower HSE concentrations can exhibit Os/Ir and Pd/Ir fractionations. Similar fractionations have also been observed in a diogenite sample with low HSE concentrations (NWA 1877, [5]). Such signatures are not a predicted feature of an impact contamination signature as the Os/Ir ratio in chondrites is typically ~1 [18]. The flat CI-chondrite-relative HSE patterns of the howardite and eucrite samples with higher HSE abundances likely reflect late accretion addition, as observed in many diogenites [5].

Osmium isotope systematics: Eucrite meteorites have a range of measured $^{187}Os/^{188}Os$, from 0.111 to 0.377. Samples with flat CI-chondrite relative HSE patterns also have $^{187}Os/^{188}Os$ values that are in the range of chondrites, including Kapoeta (0.126-0.128). Some eucrites with low Os concentrations plot along a mixing line from an initial chondritic composition to the sample QUE 97053, which represents the most radiogenic sample with the lowest Os content of our dataset (Figure 3). The samples that plot close to chondritic values are interpreted to reflect significant impact contamination because of their elevated Os contents (>50 pg) and approximately chondritic $^{187}Re/^{188}Os$. The meteorites that plot off the line either reflect evolution mechanisms distinct from the chosen QUE 97053 end-member, or unique mixing relationships of indigenous eucrite components with impactor contaminants. In the samples that we have measured to date, QUE 97053 and NWA 5356 appear to be the most pristine, having very low Ni, low HSE relative abundances and non-chondritic $^{187}Os/^{188}Os$.

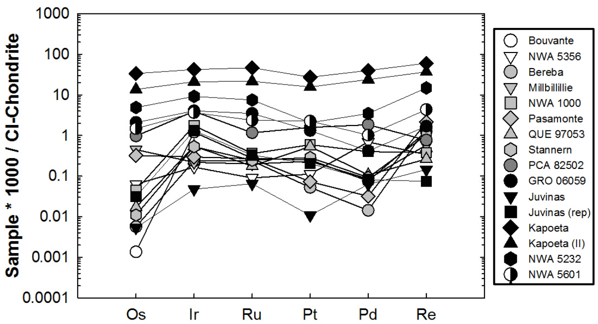

Figure 2: CI-chondrite normalized HSE abundances for eucrite and howardite samples, where all eucrites with low nickel abundances (white and light grey; see Figure 1) also exhibit low HSE abundances.

Discussion: Our preliminary dataset examining eucrites demonstrates the utility of using coupled trace-element, highly-siderophile element abundances and Os isotope systematics to determine relative pristinity for eucrites, as has been demonstrated previously for the Moon [13]. Combination of this information with petrographic information [16-17] will allow indentification of truly indigenous signatures to eucrites, both for the HSE, as well as for other elements, including volatile elements. Indeed, the data indicate that the term 'unbrecciated' is not indicative of 'pristine' rocks (e.g. PCA 82502); conversely, other eucrite types may be shown to be pristine (e.g. NWA 5356). The meteorite Juvinas is unique because it exhibits elevated nickel contents, but relatively low HSE abundances. In this instance, its chondrite-like Os-isotope ratio is potentially valuable for identifying impact contamination.

Given indications of pristinity in some eucrites, the HSE patterns that they preserve are of potential importance for assessing early mantle processes in the differentiation of the HED parent body. The lowest HSE content samples do not have flat, CI-chondrite-relative HSE patterns. Instead, they show significant fractionations of Ir from Os, Ru, Pt and Pd. Such fractionations presumably reflect fractional crystallization processes in the eucrite parent body, or are source features that reflect an early differentiated mantle signature. This is particularly important for understanding early metal-silicate differentiation on the HED parent body, including models of the Vestan magma ocean [19-21]. From the current data, the fractionations measured in the lowest HSE abundance eucrites to not directly match any known low-P, high-T partitioning experiments (e.g., [22]). Instead fractionations of the HSE observed in eucrites are more likely explained by fractional crystallization of melts from very low HSE sources during eucrite petrogenesis.

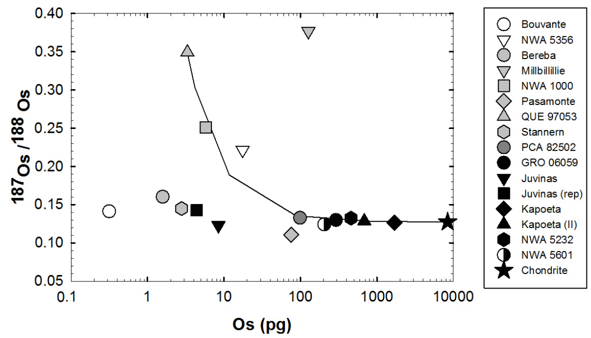

Figure 3: Osmium contentrations versus Os isotope ratios for eucrites and Kapoeta. Several eucrite samples plot along a mixing line between a CI-chondrite component and an assumed HED crustal component (represented by sample, QUE 97053). High Ni-content samples (dark grey and black) plot close to the chondrite initial and likely reflect impact conatimination. All samples with radiogenic $^{187}Os/^{188}Os$ also have low HSE and Ni contents.

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