CHROMIUM ISOTOPIC COMPOSITION OF THE ANOMALOUS EUCRITES: AN ADDITIONAL GEOCHEMICAL PARAMETER FOR EVALUATING THEIR ORIGIN. M. E. Sanborn[1] and Q.-Z. Yin[1], [1]Department of Earth and Planetary Sciences, University of California at Davis, One Shields Avenue, Davis, CA 95616 USA. E-Mail: mesanborn@ucdavis.edu

Introduction: There has long been a proposed petrogenetic link between eucrites (and more broadly HEDs) and the asteroid 4 Vesta [e.g., 1-2]. The present DAWN mission is providing the opportunity to couple the observations with geochemical laboratory measurements of physical samples to further decipher the evolution of dwarf planets [3]. However, the use of HED data for interpreting the processes occurring on 4 Vesta may be complicated if not all eucrites originated from the same parent body. The possibility of multiple parent bodies for some of the eucrites has arisen based on recent oxygen isotopic composition measurements (i.e., Δ^{17}O) across a suite of eucrite samples [4-5]. Five eucrites in particular, Northwest Africa (NWA) 1240, Pasamonte, Pecora Escarpment (PCA) 91007, Asuka 881394, and Ibitira, deviate from the mean eucrite Δ^{17}O value by 4σ, 5σ, 5σ, 15σ, and 21σ, respectively [5]. Such variations may be caused by input of chondritic impactor material or isotopic heterogeneity of the source material for the main group eucrites, but there is no clear geochemical evidence to indicate either process, leading to the suggestion by [5] for multiple parent bodies for at least some eucrites.

In recent years, heterogeneity in ^{54}Cr has been observed across all meteorite groups (e.g., [6]) and is increasingly becoming an important parameter for elucidating petrogenetic links among planetary materials [7-8]. Combining these observed ^{54}Cr anomalies with Δ^{17}O data provide a 2-D space in which to investigate geochemical variations that is often not obviously distinct in three-oxygen isotope plots alone. To this end, we measured the Cr isotopic composition in the five eucrites with anomalous oxygen isotopic composition to investigate what additional insight into the origin of the anomalous eucrites can be gained using this additional geochemical parameter.

Analytical Methods: For each of the five eucrites analyzed, a ~35 mg fusion-crust free chip was crushed in an agate mortar and pestle. The resulting powders were placed in Teflon capsules with a 3:1 concentrated HF-HNO_3 mixture and sealed in stainless steel Parr bombs. The bombs were heated at 190°C for 96 hours to ensure complete dissolution of refractory phases. After dissolution was complete, Cr was separated from the solutions following a 3-column chemistry procedure [9].

High-precision Cr isotopic measurements were made using a Thermo *Triton-Plus* Thermal Ionization Mass Spectrometer at the University of California at Davis. The pure Cr separates obtained from the column chemistry were mixed with an activator and loaded onto degassed single W filaments (4 filaments for each sample with 3μg Cr on each filament). The four sample filaments were bracketed with two terrestrial standards before and after. Filament runs consisted of 1200 ratios (8 second integration time) with a typical intensity of the ^{52}Cr signal of ~10 V. A gain calibration was made at the start of each filament run and a baseline measured every 25 ratios. The measured ^{54}Cr/^{52}Cr ratios are expressed as ε-notation (i.e., parts per 10^4 deviations relative to a terrestrial standard).

Results and Discussion: The ε^{54}Cr values for each of the five anomalous eucrites analyzed are given in Table 1 and their position in Δ^{17}O-ε^{54}Cr space is shown in Fig. 1. The ε^{54}Cr value for four of the eucrites (Asuka 881394, Ibitira, Pasamonte, and PCA 91007) are well resolved from the ε^{54}Cr of the normal eucrites that cluster around ε^{54}Cr ~ -0.75. For these four eucrites, the ε^{54}Cr values for Asuka 881394, Ibitira, and Pasamonte are the same within error. In contrast, NWA 1240, while resolved from the normal eucrites in terms of Δ^{17}O, has a ε^{54}Cr value that overlaps the normal eucrite range within error.

Table 1. Cr isotopic results for anomalous eucrites.

Sample	Δ^{17}O [5]	ε^{54}Cr (±2SE)
Asuka 881394	-0.122±0.015	-0.37±0.10
Ibitira	-0.069±0.017	-0.40±0.08
Pasamonte	-0.204±0.008	-0.33±0.08
PCA 91007	-0.202±0.011	-0.21±0.09
NWA 1240	-0.271±0.007	-0.63±0.10

The earlier oxygen isotopic work [5] indicated the possibility of 5 Vesta-like parent bodies for the anomalous eucrites (plus Vesta for the normal eucrites) using Δ^{17}O alone. With the added parameter of ε^{54}Cr, there are several ways to infer the possible number of distinct parent bodies for the anomalous eucrites. First, if all the samples that plot in distinct regions in Δ^{17}O-ε^{54}Cr space are considered unique parent bodies, then ε^{54}Cr data indicates five distinct parent bodies with PCA 91007 and Pasamonte originating on the same parent body (as suggested by [5]). However, this scenario requires the assumption that each of the Vesta-like parent bodies of the anomalous eucrites were isotopically homogenized for both O and Cr.

However, an alternate possibility is that the Vesta-like parent bodies of the anomalous eucrites did not undergo isotopic homogenization to the same extent that Vesta experienced. If this occurred, than it is possible that the variation among the five samples in both $\Delta^{17}O$ and $\varepsilon^{54}Cr$ is recording some heterogeneity of the single source material. The question arises as to the extent of $\varepsilon^{54}Cr$ variability spatially compared with $\Delta^{17}O$ in such a scenario. However, we can look at ureilites for some insight. For example, ureilites may have originated from a single parent body that did not generate a magma ocean and isotopically homogenize [11]. However, while the variation in $\Delta^{17}O$ ranges in ureilites from -0.93 to -1.92 [12], the $\varepsilon^{54}Cr$ only encompasses a rather narrow range (-0.93±0.16 to -1.16±0.16) [13-16] with a gaussian distribution. As such, it is plausible that Ibitira, Asuka 881394, Pasamonte, and PCA 91007 are originating from one parent body (or two parent bodies if Ibitira and PCA 91007 can be considered resolved from each other in $\varepsilon^{54}Cr$), and NWA 1240 another, indicating two or three parent bodies for the anomalous eucrites.

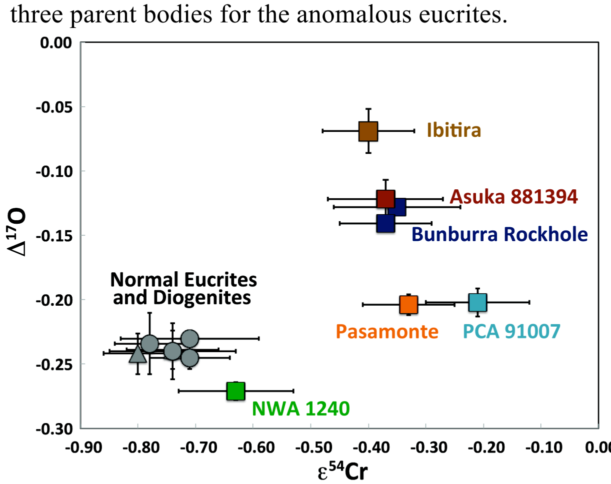

Figure 1. *$\Delta^{17}O$ versus $\varepsilon^{54}Cr$ plot of the five anomalous eucrites from this study. Also shown for comparison are the composition of normal eucrites and diogenites. $\Delta^{17}O$ values are from [4-5,10] and $\varepsilon^{54}Cr$ values for the normal eucrites and the diogenites are from [6] and Bunburra Rockhole are from [10].*

Previous work [15] investigated the observed variation in ^{54}Cr in differentiated objects noted an apparent linear correlation between the $\varepsilon^{54}Cr$ and the heliocentric distance from the Sun as defined by the Earth, Mars, 4 Vesta (from 'normal' eucrites), and the Ureilite parent body (UPB). Implicity in such a correlation is that current structure of the planetary system was largely configured since each planetary body has acquired its average $\varepsilon^{54}Cr$ composition. That they did not migrate significantly since its formation is difficult to prove, largely depending on when Jupiter formed and acquired its stable orbit. If the brief period of chondrule formation can be linked with Jupiter formation, then the Fig. 2 may have been largely stabilized early. If the late heavy bombardment is due to planetary migration, then the current solar system must have been configured after ~ 3.9 Ga. Proceeding under the assumption that this linear correlation holds independent of the timing issue, the measured $\varepsilon^{54}Cr$ in the anomalous eucrites may provide information into the regions from which they originated. Figure 2 shows the apparent location from this trend of the anomalous eucrites. From this qualitative comparison, it appears that the anomalous eucrites may have originated from between ~1.8 and ~2.3 AU (based on the $\varepsilon^{54}Cr$ composition) compared to the present location of 4 Vesta and the known V-type asteroids at between 2.2 and 2.5 AU. Interestingly, it has been recently proposed that some V-type asteroids may have formed in a region closer to the sun (i.e., 'the terrestrial planet region') and then scattered into the main asteroid belt [17].

The Cr isotopic composition of the anomalous eucrites coupled with the observed range of $\Delta^{17}O$ point toward a complex history for the meteorites currently grouped together as eucrites including the possibility of between 2 to 4 parent bodies in addition to 4 Vesta. In addition, using the measured $\varepsilon^{54}Cr$, the parent bodies may have originated from material located between ~1.8 and ~2.3 AU. The anomalous eucrites appear to further point to a wide diversity of magmatic processes and parent bodies evolving contemporaneously over a wide spatial region in the early Solar System.

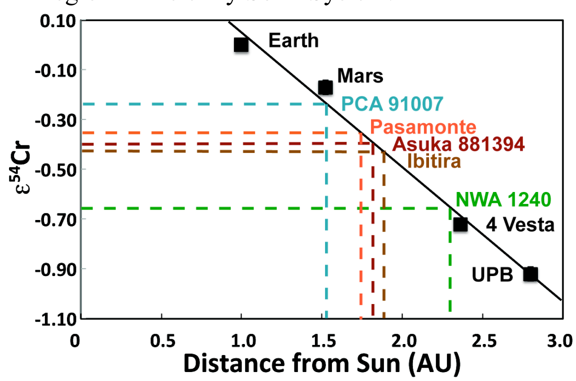

Figure 2. *$\varepsilon^{54}Cr$ versus distance from Sun. Data for Earth, Mars, 4 Vesta, and Ureilite Parent Body (UPB) are from [6,15] and references therein.*

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