CORRELATED NUCLEOSYNTHETIC ANOMALIES IN Mo, Ru AND Pd FROM IRON METEORITES.

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Introduction: A correlation between the Mo and Ru nucleosynthetic isotope compostions has been identified in a number of meteorites [1-5]. These nucleosynthetic isotope anomalies are generally considered to reflect variability in an *s*-process component. Recently, small Pd nucleosynthetic isotope anomalies (related to s-process variability) have been identified in IVB iron meteorites [6]. These nucleosynthetic isotope anomalies may represent spatial and/or temporal heterogeneity in the early solar nebula, or may be due to chemical processing within the solar nebula [e.g. 1, 7]. Investigating the interrelationships between the different isotope systems which possess nucleosynthetic anomalies may provide important constraints on the origin of these anomalies. Given that Mo, Ru, and Pd are all siderophile and but have different condensation temperatures [8] and abilities to from carbides [9-10], determining if the isotope correlations persist between these systems may shed light on the topic. The initial work establishing the first correlation between Mo and Ru isotope anomalies was done using meteorite group averages [1], and to this day there are few measurements available for multiple elements on the same aliquot of meteorite.To examine the finer details of the nucleosynthetic puzzle, a collaborative effort has been initiated to measure the Mo, Ru, Pd, Os, and Pt isotope compositions of a range of meteorites from the same solutions. Mo, Ru, and Os measurements were performed at UMd and Pd and Pt isotope measurements were performed at FSU. Os and Pt data are collected to correct for cosmic ray exposure (CRE) effects (following [12] for Pt and [12, 13] for Os). Here we present the first Mo-Ru-Pd data from North Chile (IIA), Casas Grandes (IIIA), Maria Elena (IVA), Charlotte (IVA), Hoba (IVB), and Skookum (IVB). Importantly, all isotope compositions have been obtained from the same dissolution solutions and these data have been corrected for CRE effects. This is the first study presenting Mo, Ru, and Pd isotopic compositions measured on the same sample specimen.

Analytical Methodology: Samples were digested in HCl, and after dissolution, the samples were divided into aliquots for Mo, Ru, Pd, Os and Pt isotope measurements. For Mo [4], Pd, and Pt [6] column excahnge chromatography was used to extract and purify the elements while Ru was purified via microdistillation [3,14]. Os was isolated using solvent extraction and microdistillation [13]. The Mo, Ru, and Os isotope compositions were measured using a *Thermo Triton Plus* TIMS operated in negative mode at UMd (details in [15-16]). Pd and Pt isotopic compositions were analyzed on the *Thermo Neptune*™ MC-ICP-MS (at the NHMFL, FSU Tallahassee, see [17] for more details). All data are given in epsilon notation as deviation from a terrestrial reference material.

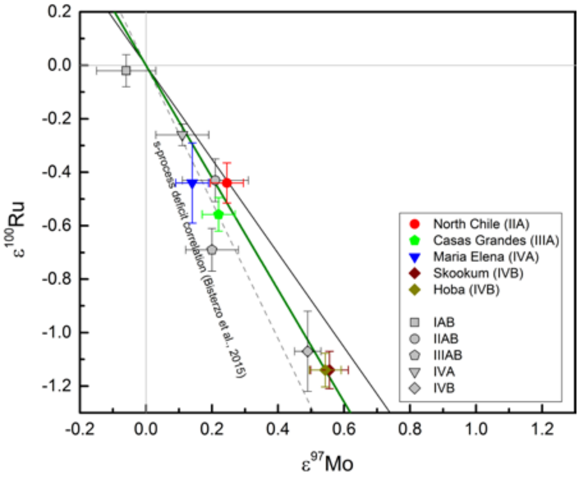

Fig. 1: Mo and Ru isotopic composition of iron meteorites with 2σ errors. Note that ε^{100}Ru are CRE corrected. Gray symbols relate to literature Ru and Mo data [3,4]. Dashed gray line corresponds to a model of s-process deficit obtained by subtracting s-process yields [11] from solar abundances. Solid black line corresponds to the Cosmic Ru-Mo correlation of [1].

Results: Isotopic anomalies in ε^{97}Mo, ε^{100}Ru and ε^{104}Pd have been resolved from the *Alfa Aesar* standards in all iron meteorites studied here (Fig. 1,2, and 3). CRE causes neutron capture in iron meteorites leading especially to the burning of ^{103}Rh [6] resulting in an excess in ^{104}Pd. Isotopic anomalies in Os and Pt indicate CRE effects in Maria Elena, North Chile, Skookum and Hoba. CRE corrections were not applied to ε^{97}Mo, because it does not show resolvable CRE effects. The pre-exposure Ru isotope compositions for meteorite groups were calculated by taking the intercept at the origin of the ε^{189}Os vs. ε^{100}Ru correlations [16]. The ε^{104}Pd has been corrected with the measured ε^{192}Pt [6,17]. Molybdenum and Ru isotopic anomalies are similar to previous reported data [1-5]. The IVB iron meteorites Hoba and Skookum are identical within analytical error with literature data on different specimens [6].

Discussion: The CRE corrected ε^{97}Mo, ε^{100}Ru, and ε^{104}Pd anomalies in the iron meteorites can be attributed to a variable s-process deficit (Fig. 1, 2, 3). As observed before [1], Mo and Ru show a uniform cosmic correlation, meaning the observed anomalies in the different iron meteorites correlate to each other and seem to follow observed s-process model calculations [11] and the s-process line defined by SiC measurements [9,10]. The Mo-Ru correlation was based previously on measurements on separate specimens for Ru and Mo, and group averages that were not CRE corrected [1]. The inferred slope between ε^{97}Mo and ε^{100}Ru (Fig. 1) has been -1.76 [1]. The slope observed in this study for the Mo-Ru correlation is -2.10 ± 0.17, while predicted slopes are at -2.56 (using [11]).

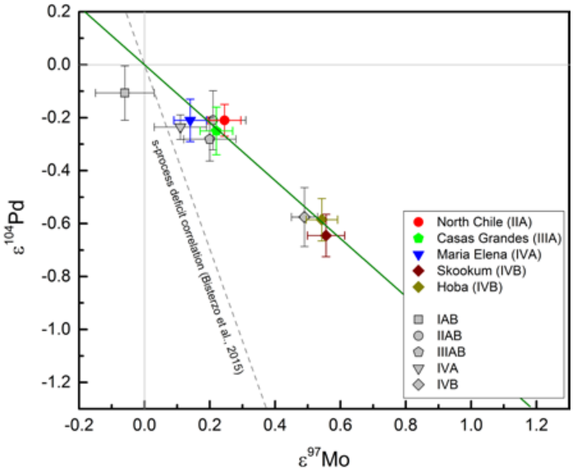

Fig. 2: Pd and Mo isotopic compositions of iron meteorites. Note that ε^{104}Pd is CRE corrected. Dashed grey line and grey symbols similar to Fig. 1.

All meteorites show a correlation in their Pd with their Mo and Ru isotopic composition. Additionally, the correlation between Pd and Mo as well as Pd and Ru does not follow the s-process model predictions. This observation is not an artifact of sample heterogeneity or digestion differences since this study used the same sample digestion for all analyzed isotopic compositions. This discrepancy of the modeled and observed correlation between the Pd isotopic composition and Ru and Mo persists with any known s-process yield model (e.g. main or single low-mass AGB component, implementing different MACS or a galactic chemical evolution model [6]). Previously, several hypotheses have been proposed to explain the cosmic correlation between Ru and Mo. Due to the huge observed Mo and Ru anomalies in SiC reflecting s-process excess, one possibility of the different anomalies in the iron parent bodies has been postulated to be inhomogeneous distribution of these presolar grains in the solar nebula [1]. However, SiC and other carbides are unlikely carriers of Pd [6]. Therefore, other presolar carriers might be more suitable for such inhomogeneous distribution of nucleosynthetic sources of Mo, Ru, and Pd [3]. Other possible scenarios are thermal and physical processing of presolar carriers (oxides, metal nuggets, silicates, organic material) resulting in heterogeneity of the nucleosynthetic sources carried by the different presolar grains [e.g. 7]. One conclusion made by the combined Mo, Ru and Pd isotopic compositions may be that a common presolar carrier must have been thermaly processed on which the more volatile Pd was lost and homogenized in the solar nebula, resulting in the deviation from the s-process deficit line. Since these anomalies are persistent throughout the iron meteorites, the thermal processing must have occurred prior to the formation of the iron meteorite parent bodies, i.e. <1 Ma after CAIs. Our results confirm a Mo-Ru-Pd isotopic correlation related to nucleosynthetic anomalies. The nature of the processes which led to the observed correlations must be further investigated.

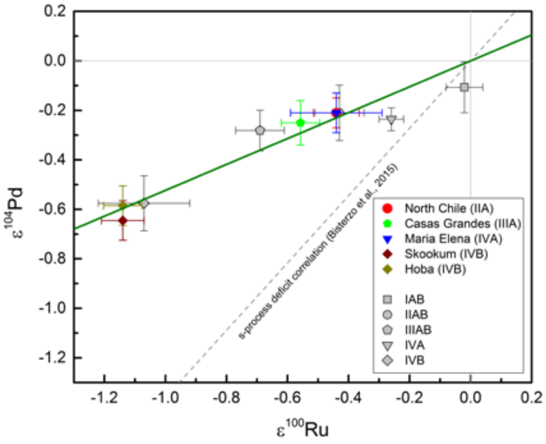

Fig. 3: Pd and Ru isotopic compositions of iron meteorites. Dashed gray line and gray symbols similar to Fig. 1.

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