IRON ISOTOPE COMPOSITIONS OF LARGE METAL NODULES FROM THE NORTON COUNTY AUBRITE. S. Ray[1], M. Wadhwa[1], V. K. Rai[1], [1]Center for Meteorite Studies, School of Earth and Space Exploration, Arizona State University, 781 East Terrace Rd., Tempe, AZ 85287-6004 (Soumya.Ray@asu.edu).

Introduction: Aubrites or enstatite achondrites are differentiated, igneous meteorites which are essentially monomineralic enstatite pyroxenites [1]. Their highly reduced condition of formation is revealed by their mineralogy that comprises enstatite (75-98 vol.%), almost FeO-free diopside and forsterite, Si-bearing Fe-Ni metal, variable amounts of plagioclase, troilite and, a variety of accessory minerals [1]. Metal in aubrites occurs in a variety of textural settings including as 1) small inclusions (with a maximum size of a few microns) within enstatite, 2) submicron-sized blebs dispersed in the matrix, 3) irregularly shaped grains of up to hundreds of microns and, 4) large (~0.2 to ~1.5 cm) nodules [2].

We recently determined that the iron isotope compositions of six metal grains (ranging in size from 100 to 600 microns) from Norton County aubrite were correlated with their Si contents and structure [3,4]. Based on these preliminary results, we suggested that the origin of Si-poor metal nodules from aubrites is different from the Si-bearing nodules (which appear to have a "residual" origin and likely formed during igneous processes operating on the aubrite parent body) [5]. We also analyzed the Horse Creek iron meteorite (which is suggested to be analogous to the core of the differentiated aubrite parent body [6] as well as the silicate fraction from Norton County and posited that core formation on the aubrite parent body did not fractionate iron isotopes [5]. As a follow-up to our preliminary investigations, we report here the iron isotope compositions of six metal nodules from Norton County aubrite. These six metal nodules (ranging in size from 6 mm to 20 mm) are larger in size than all metal grains analyzed in our previous studies [3,5].

Methods: All sample preparation and chemical procedures were carried out under clean laboratory conditions in the Isotope Cosmochemistry and Geo-chronology Laboratory (ICGL) at Arizona State University (ASU). The six metal nodules from the Norton County aubrite (designated as NC7-12) were cut in half; one half of each nodule was mounted in epoxy, polished, and etched briefly in nital. Abundances of selected elements (Si, P, Fe, Co and, Ni) were measured via WDS with a JEOL JXA-8530F electron microprobe in the Eyring Materials Center at ASU using methods similar to [7]. A small piece was cut from the other half of each aubrite metal nodule, ultrasonicated in methanol, and then dissolved in concentrated HCl. A small fraction of each sample solution (typically a ~5% aliquot) was reserved for bulk chemical analyses. Iron was purified from the remainder of each solution using anion exchange column chemistry procedures similar to those described by [8]. Iron isotope compositions were measured on a Thermo Neptune multicollector inductively coupled plasma mass spectrometer (MC-ICPMS) in medium-resolution mode. Instrumental mass bias was corrected using both Cu-doping and sample-standard bracketing (using IRMM-014 as the standard). The accuracy and precision of our analyses were assessed using repeated analyses of the terrestrial rock standards BCR-2 and BIR as well as a powdered and homogenized bulk sample of the Allende CV3 chondrite during each analytical session.

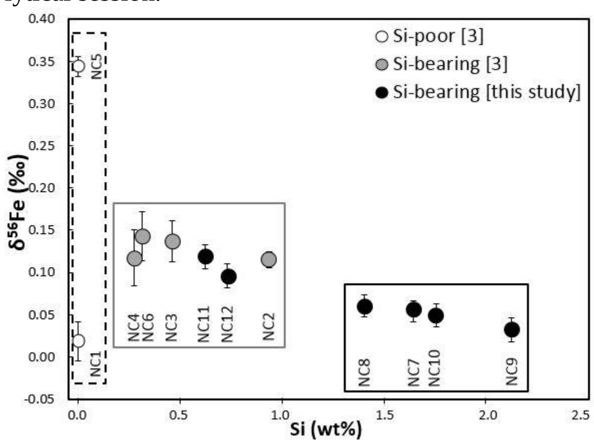

Figure 1: δ^{56}Fe values versus Si content (in wt.%) in Norton County metal nodules. Data for Si-poor metal [3] are shown as the open circles; data for Si-bearing metals is shown as the gray [3] and black circles (this study). The data define three different populations of metal in this aubrite, i.e., Si-poor metal (outlined with a dashed box), Si-bearing metal with Si ~0.2-1 wt.% (outlined with a gray box), and Si-bearing metal with Si >1.4 wt. % (outlined with a black box).

Results and Discussion: Fig. 1 shows a plot of ^{56}Fe/^{54}Fe ratios (expressed as δ^{56}Fe values, which are deviations in the ^{56}Fe/^{54}Fe ratio relative to the IRMM-014 standard in parts per mil) versus the Si content (in wt.%) in previously studied Norton County metal grains NC1-6 [3] and in the Norton County metal nodules (NC7-12) analyzed here. The twelve Norton County metal can be categorized into three populations: 1) Si-poor metal grains with widely varying δ^{56}Fe values (NC1 and NC5); 2) Si-bearing metal with Si ~0.2-1 wt.% with an average δ^{56}Fe value of 0.121 ± 0.034 (2SD) (NC2, NC3, NC4, NC6, NC11 and NC12) and, 3) Si-bearing metal (Si >1.4 wt.%) with an average δ^{56}Fe value of 0.049 ± 0.025 (2SD) (NC7, NC8, NC9 and NC10).

Silicon is generally a lithophile element but it becomes siderophile and readily partitions into metal under low oxygen fugacity conditions. Therefore, the Si-bearing aubrite metal is consistent with a residual origin, i.e., it equilibrated (partially or completely) with silicates during differentiation on the aubrite parent body under highly reducing conditions, but was incompletely extracted into the core. This is in contrast to the Si-poor metal grains in the aubrites that are likely to be of exogenous origin [5].

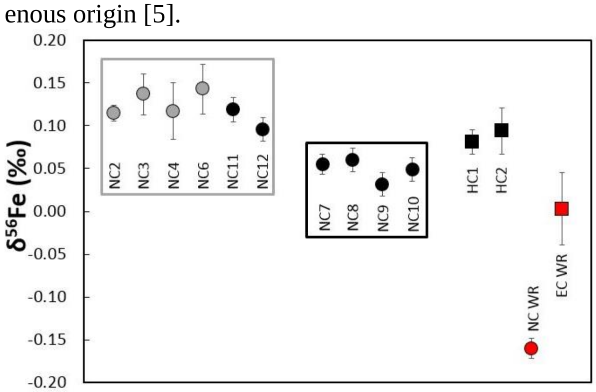

Figure 2: Iron isotope compositions (δ^{56}Fe values) of Si-bearing metal from Norton County; gray circles are from [3] and black circles are from this study. The gray outlined box includes the data for Si-bearing metal with Si ~0.2-1 wt.%, while the black outlined box includes the data for Si-bearing metal with Si >1.4 wt.% . Also shown for comparison are the data for two samples of the Horse Creek iron meteorite HC1 and HC2 (black squares) from [5] and bulk samples of Norton County (NC WR) and enstatite chondrites (EC WR) from [15] (red circle and red square, respectively).

Previous studies have documented variation in the iron isotope compositions of a variety of planetary materials, although the cause of this variation remains uncertain. Some recent experimental investigations suggest that the silicate mantles of differentiated bodies could be characterized by lighter iron isotope compositions relative to their metallic cores [9,10]. In particular, it was suggested by [10] that the near-chondritic or somewhat heavier iron isotope compositions of basaltic crustal samples from bodies such as Earth Mars, Moon, Vesta and the angrite parent body [11-14] could be the result of iron isotope fractionation during partial melting (producing heavy isotope enrichment) of their respective (relatively lighter) mantle sources. The bulk sample of the Norton County aubrite, like all main group aubrites, is enriched in the light isotopes of iron relative to chondrites (δ^{56}Fe = –0.160 ± 0.012; 2SD) [15] (Fig. 2). Based on these data, [15] suggested that the parent body of the main group aubrites (including Norton County) formed a metallic core that was relatively enriched in heavy isotopes of iron.

Our data for Si-bearing metal grains and nodules from the Norton County aubrite (likely to be of residual origin) generally supports this hypothesis. Specifically, Fig. 2 shows our data for Si-bearing metal from Norton County (from [3] and this study), along with the data for the Horse Creek iron meteorite [5] as well as bulk Norton County and enstatite chondrites [15]. As can be seen in Fig. 2, the Si-bearing metal grains and nodules in Norton County have iron isotope compositions that are similar to the Horse Creek iron meteorite (suggested to be analogous to the core of the aubrite parent body) but are relatively heavy compared to bulk enstatite chondrites (which may be representative of the iron isotope composition of the aubrite parent body) as well as bulk Norton County. This suggests that the Si-bearing metal was partially or completely equilibrated with the silicates and acquired its heavier iron isotope composition during differentiation on the aubrite parent body.

As noted previously, however, there are two populations of Si-bearing metal with somewhat different δ^{56}Fe values in the Norton County aubrite (Figs. 1-2). A possible clue that may explain this is that the δ^{56}Fe values in these metal grains and nodules are somewhat anticorrelated with their Si contents (Fig. 1). This suggests that these aubrite metals (with widely varying Si contents) may not have achieved complete equilibrium with the silicates.

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