CHEMICAL COMPOSITIONS OF REFRACTORY INCLUSIONS IN AXTELL, A CV3 CHONDRITE OF THE OXIDIZED SUBGROUP; S. Yoneda[1], S.B. Simon[1] and L. Grossman[1,2]. [1]Department of the Geophysical Sciences, [2]The Enrico Fermi Institute, University of Chicago, Chicago, IL 60637, USA.

Abstract: Chemical compositions of 13 CAIs from Axtell, a newly discovered oxidized subgroup CV3 chondrite, have been determined by INAA. REE patterns and contents of refractory siderophiles and nonrefractory elements in most Axtell inclusions are very similar to those in Allende, another member of the oxidized subgroup. There are, however, several exceptional features which are found more commonly in CAIs of the reduced subgroup of CV3 chondrites: three of 11 coarse-grained inclusions have Group II patterns with positive Eu anomalies; three Group I inclusions contain Ru/Re ratios differing from C1 values by much more than 20 %; and one has very low Au and Na contents. Another inclusion is exceptional in having an ultrarefractory REE pattern like those seen in Murchison hibonite. Thus, either CAIs of the oxidized subgroup have wider chemical variations than those in Allende alone, or Axtell is a unique meteorite whose inclusions have chemical characteristics of both the oxidized and reduced subgroups.

Introduction: Studies of CAIs from the reduced subgroup of CV3 chondrites such as Leoville, Vigarano and Efremovka (e.g. [1]) reveal that they have experienced different physicochemical conditions in the solar nebula than CAIs of the oxidized subgroup. Studies of CAIs of the oxidized subgroup, however, have been heavily biassed by those in Allende. In order to address properly whether CAIs in Allende are representative of those in the oxidized subgroup, we have analyzed by INAA 11 coarse-grained and 2 fine-grained CAIs from the Axtell meteorite, a newly discovered member of the oxidized subgroup [2].

Petrography: Of the 13 samples analyzed by INAA, five were described by Simon et al. [3]; AX-2, a fluffy Type A (FTA); AX-4, a compact Type A (CTA); AX-5, B1; AX-7, B1; and AX-9, B2. AX-10 is a CTA with anhedral melilite crystals 70-300 μm in size, some of which enclose spinel (20-40 μm across) and anhedral perovskite (< 20 μm across). Alteration products are abundant. AX-26 is a B1 with a relatively thin (~ 100 μm) melilite mantle ($Åk_{15-64}$) and a 20 μm-thick Wark-Lovering (W-L) rim. Coarse (up to ~ 600 μm across) fassaite crystals are isolated from each other by a finer-grained intergrowth of anorthite and Mg-rich melilite ($Åk_{47-66}$). Fine-grained spinel (~ 2-20 μm across) is abundant and evenly distributed throughout the inclusion except for the outermost 50 μm of the melilite mantle, which are relatively spinel-poor and more heavily altered than the interior. AX-27 is an elongated and irregularly-shaped nodular FTA, 7 mm long in thin section, with subhedral, equant melilite grains ~ 35 μm across, and fine perovskite, most of which is in the nodule interiors. AX-30 is a nearly unaltered CTA, 2.2 mm long in thin section, with a pronounced W-L rim sequence and subhedral, equant melilite grains ~ 100 μm across that are between $Åk_{15}$ and $Åk_{36}$ and average $Åk_{25}$. Anhedral perovskite occurs between melilite grains, intergrown with spinel in the inclusion interior, and as a rim layer near the margin. AX-32 is classified as a B2 but its texture is unique. The inclusion is dominated by fine-grained aluminous diopside (4.1-15 wt % Al_2O_3; 0.3-3 wt % TiO_2), which encloses spinel (occurring in small clumps of grains, framboids and palisade bodies), and minor anorthite and extremely Mg-rich melilite ($Åk_{\sim 85}$) occurring in rounded pockets up to ~ 200 μm across. In these pockets, melilite or anorthite enclose small (5-10 μm), rounded grains of Al-diopside in a spongy texture. Some pockets consist of spinel enclosed in anorthite. AX-17 and AX-29 are large, unzoned fine-grained inclusions with spinel+perovskite-centered, pyroxene-rimmed nodules and abundant alteration products (nepheline, sodalite, grossular, andradite). AX-28 is irregularly-shaped, nodular, and is rich in 30 μm-long hibonite laths occurring in sprays and intergrown with spinel. Many hibonite laths enclose small grains of perovskite. This assemblage is associated with an Al_2O_3-rich (~ 89 wt %) phase that also contains ~ 7 wt % SiO_2. This inclusion is reminiscent of the hibonite-spinel portion of the compound Allende inclusion TS63F1 [4].

Rare earth elements: Five coarse-grained inclusions, AX-4, AX-9, AX-10, AX-27 and AX-28, have Group I REE patterns, which are characterized by uniform enrichment (19, 23, 22, 27, and 23 × C1, respectively) of REEs except for positive Eu anomalies (Eu/Sm = 1.35, 1.35, 1.51, 1.36 and 1.30 × C1, respectively). These patterns are interpreted to arise from total condensation of REEs into proto-CAIs. AX-32 has a Group VI pattern (~ 19 × C1) with positive Eu and Yb anomalies (Eu/Sm = 1.18 × C1 and Yb/Lu = 1.24 × C1). This inclusion probably sampled two REE-bearing components from the solar nebula. One is a Group I component and the other, containing only the most volatile REE, Eu and Yb, was formed by condensation and removal of the other REEs at a relatively high temperature. Although several coarse-grained inclusions with Group II patterns have been reported from Allende (e.g. 4691 [5]), those in Axtell are more abundant: three coarse-grained inclusions out of 11 studied here, AX-2, AX-7 and AX-30, have Group II patterns in addition to two fine-grained inclusions, AX-17 and AX-29. While the fine-grained inclusions have negative Eu anomalies (Eu/Sm = 0.39 and 0.72 × C1, respectively), the coarse-grained inclusions all have positive Eu anomalies (Eu/Sm = 1.18, 1.28 and 3.33 × C1, respectively), atypical in Allende Group II inclusions. AX-30 has low light REE abundances (La: 6.4 × C1; Sm: 10.2 × C1) with Ce/La = 1.84 × C1. This is a modified Group II pattern, very similar to that of Leoville inclusion 3537-1 [6] but not common in Allende. "Normal" Group II inclusions condensed from a gas reservoir depleted in the most refractory

HREEs by prior high temperature condensation. In modified Group II inclusions, however, this early condensation stage took place at slightly lower temperatures so that not only HREEs but also the least volatile of the light REEs (LREEs) were removed. Ce is slightly more volatile than La and Sm, and the gas from which modified Group II inclusions were formed was therefore enriched in Ce relative to La and Sm. The positive Eu and Yb anomalies also imply lower equilibration temperatures during the next stage, condensation of the inclusion from the HREE-depleted gas. AX-5 has a HREE-enriched pattern (La = 18 × C1, Sm = 27 × C1, Lu = 34 × C1) with negative Eu and Yb anomalies (Eu/Sm = 0.61 × C1, Yb/Lu = 0.88 × C1). This may be due to the high abundance of fassaite in this inclusion [3], a phase which prefers HREEs relative to LREEs, compared to normal melilite-rich Type B1 inclusions. AX-26 has LREE abundances of ~ 40 × C1 and a negative Eu anomaly (Eu/Sm = 0.33 × C1). The Tb content jumps to 70 × C1 and abundances of HREEs decrease steadily with increasing Z to Yb (35 × C1) and then increase to Lu (52 × C1). Similar patterns are observed in several hibonite+spinel inclusions in the Murchison CM2 chondrite measured by ion probe (e.g. GR-1 [7]; SHIB 13-60 and 8-65 [8]), but have not been reported previously from inclusions in any CV3 chondrite. This pattern is interpreted as an ultrarefractory pattern, modified by the effect of crystallographic preference of the condensate host for REEs of larger ionic radius.

In summary, while many coarse-grained, Axtell inclusions have REE patterns common in their Allende counterparts, an unusual number, 3 out of 11, have Group II patterns with positive Eu anomalies which are more common among CAIs in the reduced subgroup, and a fourth has a REE pattern unique among CAIs in CV3 chondrites.

Refractory siderophile elements: Re, Ir and Ru enrichment factors relative to C1 chondrites in the five Group I inclusions are comparable to those of the REEs (mean of Re, Ir and Ru = 18-32 × C1). While these siderophiles in Allende coarse-grained inclusions are known to be fractionated from one another by no more than 20 % [9], several Axtell Group I inclusions show small volatility-controlled fractionations from one another in excess of 20 %, which are found occasionally in bulk inclusions of the reduced subgroup: more volatile Ru is depleted in AX-4 (Ru/Re = 0.48 × C1), and enriched in AX-9 and AX-28 (Ru/Re = 1.43 and 1.52, respectively). All five inclusions show significant depletions of Mo relative to other refractory siderophiles (Mo = 5.5-9.9 × C1) and AX-27 shows a W depletion, which are commonly seen in Allende inclusions. The mean enrichment factors of Re, Ir and Ru in the Group VI inclusion, AX-32, and two HREE-enriched inclusions, AX-5 and AX-26, are 7.3, 17 and 14 × C1, respectively, and are lower than those of REEs except for Eu. All Group II inclusions contain very low amounts of siderophile elements (< 5 × C1), as do Allende Group II inclusions.

Nonrefractory elements: Sylvester et al. [1] showed that most coarse-grained inclusions of the reduced subgroup have lower nonrefractory element contents than those of the oxidized subgroup. Au and Na contents of Axtell coarse-grained inclusions studied here are plotted in Fig. 1. They are in good agreement with those observed in the oxidized subgroup [1] except for AX-30, which has the lowest modal abundances of secondary alteration products of the inclusions studied herein. This supports the idea that alteration of coarse-grained inclusions of the reduced subgroup took place at a higher temperature or for a shorter time than those of the oxidized subgroup. Na contents of Axtell fine-grained inclusions (AX-17: 0.35 %, AX-29: 0.56 %) are lower than those typically seen in Allende fine-grained inclusions (1.1-5.1 % [10]), suggesting less intense alteration. Although additional studies of Allende inclusions may show those with very low Au and Na contents, Axtell inclusions seem to have wider composition ranges for these elements.

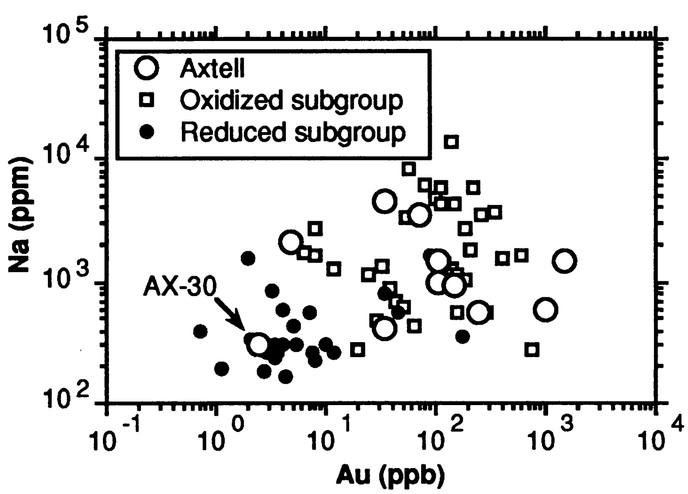

Fig.1 Au and Na abundances in CV3 chondrites

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