PRESOLAR SILICATE AND OXIDE GRAINS IN THE UNGROUPED CARBONACEOUS CHONDRITE ADELAIDE: EFFECTS OF THERMAL ANNEALING. C. Floss and F. J. Stadermann. Laboratory for Space Sciences and Physics Dept., Washington University, St. Louis, MO 63130, USA; (Email: floss@wustl.edu)

Introduction: Apart from nano-diamonds, presolar silicates appear to be the most abundant type of stardust and have by now been found in most types of extraterrestrial materials. However, there are large variations in their reported abundances [1-6]. Although limited statistics certainly play a role in some of this variation, much of it is also due to the fragile nature of presolar silicate grains, which can lead to their easy destruction. These grains, therefore, provide an opportunity to investigate the effects of secondary processing.

Adelaide is an ungrouped carbonaceous chondrite with affinities to the CO3 chondrite ALHA77307. Although this meteorite has been characterized as containing pristine matrix material [7, 8], our preliminary examination [9] showed that abundances of O-anomalous grains are lower than in Acfer 094, ALHA77307, and the CR3 chondrites QUE 99177 and MET 00426 [1-4]. Here we report on the compositions of the presolar grains found in Adelaide and discuss evidence for a higher degree of processing than that observed in other primitive meteorites with higher presolar grain abundances.

Experimental and Results: We used the NanoSIMS to carry out ion imaging searches ($^{12}C^-$, $^{13}C^-$, $^{16}O^-$, $^{17}O^-$, $^{18}O^-$) in 20,200 μm^2 of matrix material from Adelaide, and found ~60 ppm of O-anomalous grains. All but one of the grains belong to O isotope group 1 and likely have origins in low mass red giant or asymptotic giant branch stars [10]. The remaining grain belongs to group 3 and may have a supernova origin [11]. Subsequent Auger elemental analyses [e.g., 12] of 25 of the 27 grains found show that 20 are ferromagnesian silicates, three are Al-rich oxides and two are complex grains with multiple components.

Complex Presolar Grains: One of the two complex presolar grains in Adelaide, 5a-1o2, consists of adjacent oxide and silicate portions. The oxide is Ca- and Al-rich, and contains no Mg, while the silicate is Mg-rich. Auger spectra of both grains contain significant amounts of Fe. However, elemental mapping shows that the Fe forms a rim around both grains (Fig. 1), suggesting that it is infiltrating the grains from the surrounding matrix and, therefore, is not primary to the grains. On an Fe-free basis the Ca-Al oxide has a composition consistent with hibonite, while the silicate has a forsterite-like composition.

The other complex grain, 3a-1o2, consists of a central portion dominated by Al, one portion of which also contains Ca. This core is partially surrounded by several distinct Mg- and Fe-bearing oxide grains. As in the other complex grain, the Auger elemental maps suggest that Fe has infiltrated from the matrix into the Al-rich core. However, it is unclear whether the Fe present in the Mg-Fe oxides is of primary or secondary origin. The Al-rich core has a stoichiometry consistent with Al_2O_3, but the Ca-bearing portion is too Ca-rich to be hibonite. The Fe-Mg oxides have variable compositions; one also contains considerable Al.

Both complex grains belong to group 1, with enrichments in ^{17}O and modest depletions in ^{18}O. However, the O isotopic composition of grain 5a-1o2 is homogeneous over the two portions comprising this grain, whereas complex grain 3a-1o2 shows internal heterogeneity in the O isotopes. Isotopic heterogeneity among the sub-grains of 3a-1o2 may be understood in terms of condensation under varying conditions or variable secondary processing, but the homogeneity observed in complex grain 5a-1o2 is more enigmatic.

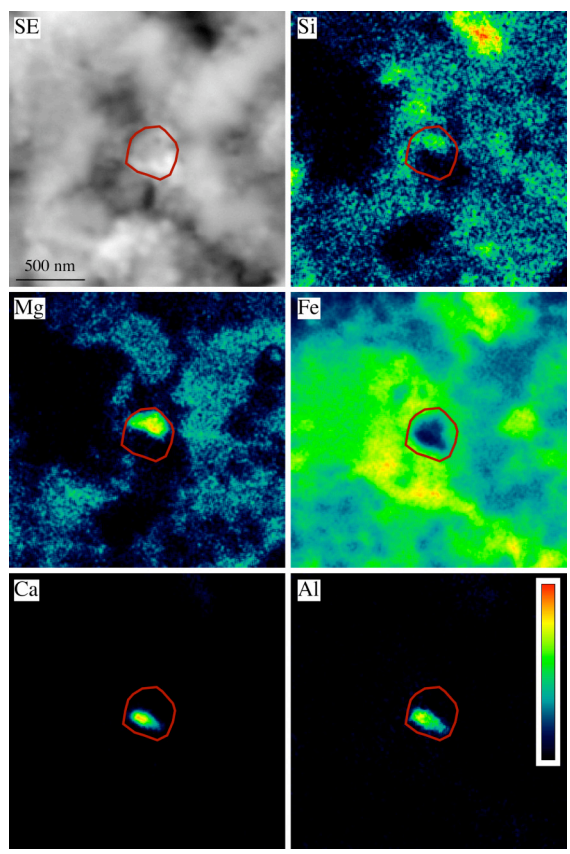

Figure 1. FE-SE and Auger elemental images of complex grain 5a-1o2 from Adelaide. The region of the isotopic anomaly is outlined in red.

Fe-rich Ferromagnesian Silicates: Previous Auger Nanoprobe work on presolar silicate grains in Acfer 094 and the CR3 chondrites QUE 99177 and MET 00426 showed that most grains had elemental compositions consistent with olivine or pyroxene (atomic [Mg+Fe±Ca]/Si = 2 or 1, respectively) or had non-stoichiometric compositions intermediate between these two phases [2-4]. In distinct contrast, all but one of the 20 presolar ferromagnesian silicates in Adelaide have [Mg+Fe]/Si ratios significantly higher than those expected for these minerals (2.4–5.3), as well as elevated cation/O ratios. Only one presolar silicate in Adelaide, the group 3 grain, 3c-3o1, has a [Mg+Fe±Ca]/Si ratio consistent with pyroxene; this grain also has the highest mg# (83) of all the Adelaide presolar silicates. The elevated [Mg+Fe±Ca]/Si ratios in Adelaide are largely the result of higher Fe concentrations in these grains compared to presolar silicates from QUE 99177 and MET 00426 (Fig. 2); median mg#s (atomic Mg/[Mg+Fe]) are also distinctly lower in Adelaide than in the CR3 chondrites (21 vs. 49). Presolar silicates in Acfer 094 also have somewhat elevated Fe abundances compared to the CR3 chondrites, but do not exhibit the high [Mg+Fe±Ca]/Si ratios seen in Adelaide [3, 4].

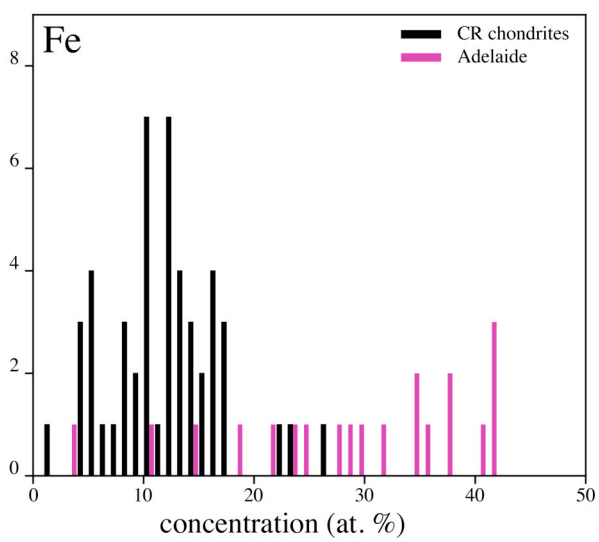

Figure 2. Histogram of Fe abundances in presolar silicates from Adelaide and the CR3 chondrites QUE 99177 and MET 00426. Data for the CR chondrites from [2].

Discussion: Mg-rich presolar silicates are predicted from equilibrium condensation theory and astronomical observations, and the high Fe contents seen in many presolar silicates have been unexpected [1-4]. The paucity of Fe isotopic data for many of these grains has made it difficult to evaluate whether the high Fe abundances are of primary origin, perhaps as the result of kinetic condensation in circumstellar environments, or whether secondary alteration processes are responsible [e.g., 2-4].

The matrix of Adelaide is dominated by olivine grains that are significantly more fayalitic than the Mg-rich ones typically seen in ALHA77307, and bulk analyses of the matrix show that it is more Fe-rich than chondrite matrices in general [13]. Auger elemental maps of some of the larger and more magnesian presolar silicates show rims of Fe around Mg-rich cores, similar to the Fe-rich rim around complex grain 5a-1o2, (Fig. 1). These observations suggest that diffusion of Fe into the grains is responsible for the particularly high Fe contents observed in the presolar grains from this meteorite.

Adelaide is unequilibrated, but the presence of a dominantly crystalline matrix, compared to ALHA77307, suggests that it has experienced thermal annealing [13]. Diffusion of Fe during thermal metamorphism results in increased Fe contents of originally Mg-rich grains [14]. Thus, the Fe-rich rims on some of the larger Mg-rich presolar grains and around complex grain 5a-1o2 are probably due to the thermal annealing experienced by Adelaide. In smaller grains, Fe infiltration was more extensive, resulting in Fe-rich grains with elevated [Mg+Fe]/Si ratios. This process probably also results in the destruction of some presolar grains, or in re-equilibration of their oxygen isotopes, accounting for the lower abundances of presolar silicates and oxides in Adelaide compared to other primitive meteorites.

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