MINERALOGICAL AND CHEMICAL STUDIES OF MATRIX IN THE ADELAIDE METEORITE, A UNIQUE CARBONACEOUS CHONDRITE WITH AFFINITIES TO ALH A77307 (CO3). Adrian J. Brearley, Institute of Meteoritics, Department of Geology, University of New Mexico, Albuquerque, NM87131

The Adelaide chondrite is an unequilibrated carbonaceous chondrite, whose chemical and petrographic properties, whilst having affinities to the CO and CV carbonaceous chondrites, are not entirely consistent with either group. Adelaide was originally classified as a C2 with C3 like affinites by [1], although its low Ca/Al ratio is unusual. Because of their similar Ca/Al ratios [2] concluded that Adelaide formed a distinct chemical subgroup with Bench Crater and Kakangari. More extensive chemical studies by Kallemeyn and Wasson [3] have failed to support this conclusion, and have shown that of the carbonaceous chondrites with unusual chemical characteristics, Adelaide most closely resembles the carbonaceous chondrite ALH A77307. ALH 77307 has been classified as a CO3 [4], based on petrographic characteristics, but because of its high Cd content (similar to Adelaide) Kallemeyn and Wasson [3] were unable to justify a CO classification. However for most purposes a CO3 classification appears to be reasonable. Adelaide shares some petrographic similarities with ALH A77307 and other CO3 meteorites, e.g. matrix abundance, chondrule size, etc. despite arguments to the contrary [1,3]. Adelaide and ALH A77307 are highly unequilibrated and consequently are extremely important meteorites, because they are likely to retain evidence of processes and conditions which prevailed during the early history of the solar nebula. In this study matrix in Adelaide has been studied in detail using electron microprobe, SEM and TEM techniques to determine the matrix mineralogy and facilitate further comparisons with ALH A77307.

Matrix textures: Matrix constitutes around 35 vol% of Adelaide and is extremely fine-grained. Individual grains of magnetite and sulfides with a grain size of 1 -2 μm can be resolved using BSE imaging. Rare angular grains of olivine and pyroxene with a grain size of ~2 -15 μm also occur set in the ultrafine-grained silicate matrix. Unlike ALH A77307 well-defined accretionary rims on chondrules and other objects in Adelaide are extremely rare and for the most part are absent.

Bulk chemistry of Adelaide matrix: The bulk composition of Adelaide matrix has been determined by broad beam WDS electron microprobe techniques using a 10 micron diameter electron beam. Adelaide matrix has a relatively wide range of compositions, but the majority of analyses are very similar, especially for the minor elements TiO_2, Cr_2O_3, CaO, Na_2O, K_2O, and P_2O_5. The broadest compositional ranges are for SiO_2 (16-38 wt%), FeO (23-61wt%) and MgO (4-29wt%) clearly reflecting extreme mineralogical diversity on a fine scale. The average matrix composition of Adelaide along with data for ALH A77307 (3.0) [5] and Kainsaz (3.1) [6] are plotted in Fig.1 normalized to Si and to CI chondrite values. The overall shape of Adelaide data is very similar to that of ALH A77307: there are marked depletions in Ca, Na and S, and an enrichment in Ni. Elemental ratios for Ti, Mg, Cr and Mn in ALH A77307, Kainsaz and Adelaide are also remarkably similar. However, Adelaide matrix does show some significant departures from CO3 chondrite matrix compositions. Al has a ratio close to CI value, K is depleted and Fe is extremely enriched with an enrichment factor of 1.9 (c.f ALH A77307 = 1.035), significantly higher than any other CO3 matrix or chondrite matrices in general. One possible explanation for these differences is that the matrix composition, particularly K and Na have been significantly affected by terrestrial weathering. However, it does not seem probable that the very high Fe ratios could be the result of mobilization of Fe. Despite its unusual compositional characteristics, Adelaide matrix clearly has much closer affinities to CO3 chondrite matrix than matrix in any of the other carbonaceous chondrite groups.

Matrix mineralogy: Preliminary TEM studies have not revealed any evidence for asteroidal aqueous alteration in the matrix, but show that Adelaide matrix is extremely complex in nature. The matrix is dominated by fine-grained olivine which has a variety of morphologies. The most common occurrence of olivine is as aggregates of anhedral interlocking crystals with a grain size of 0.1-0.2 μm. Such regions may extend over areas of tens of μm^2. Olivines are also present with a highly irregular morphology which are set in an amorphous or microcrystalline matrix which has a highly variable composition. These olivines have a corroded appearance and are sometimes associated with a microcrystalline Fe-rich phase which preliminary diffraction data suggests may be goethite. The final occurrence of olivine is as euhedral crystals with well-formed crystal faces. They typically have a platy morphology elongate parallel to the c-direction. These different types of matrix olivines all have extremely iron-rich compositions, with few exceptions. The total compositional range observed is 31-84 mol% Fa with a mean of 61 mol% Fa. Analyses of olivines at different locations in the matrix show that they usually have relatively constant compositions on a scale of a few microns, but can vary by up to 20 mole % Fa from region to region on a scale of a 100 microns or more. This variation in olivine composition clearly accounts for the variable bulk Fe/(Fe+Mg) ratio of the matrix as determined by electron microprobe. In comparison with ALH A77307 matrix, fayalitic olivines are much more abundant in Adelaide. Relatively Mg-rich olivines which comprise the bulk of olivines in ALH A77307 are essentially absent in Adelaide. The abundance of very fayalitic olivine is consistent with the very iron-rich bulk composition of Adelaide matrix and is likely to be a primary nebula characteristic. Very fine-grained pyroxenes are rare in the matrix, but clusters (1-1.5 μm in size) of pyroxene grains occur set within the matrix of fine-grained olivines. The clusters consist of anhedral crystals 0.1-0.5 μm in size with highly curved mutual grain boundaries. Electron diffraction and high resolution electron microscopy show that the pyroxene is the ortho polymorph with rare narrow intergrowths of clinopyroxene. These pyroxenes are close to pure enstatite (En), but have high Cr and Mn contents (0.93-1.32 wt% and 0.39-3.5wt % respectively). This component of Adelaide matrix is identical to that found in the matrix of ALH A77307 [5]. Unlike ALH A77307 no Fe,Ni metal has been identified in the matrix, probably as a result of the extensive terrestrial alteration. However, magnetite which is common in ALH A77307 is also an abundant phase in Adelaide and is found as very small grains (30 nm) associated with fine-grained fayalitic olivine and as 400-600 nm clusters or aggregates of 100 nm grains. Pentlandite has been found in Adelaide matrix as spherical aggregates of 10-30 nm grains and as individual nanometer-sized grains. However these occurrences are rare and most sulfur in the matrix appears to be present in the amorphous component.

Conclusions: Adelaide matrix clearly shares some similarities with matrix in ALH A77307, but differs in a number of important respects, principally its high abundance of very fayalitic olivine and very high bulk Fe/(Fe+Mg) ratio. Most components, such as clusters of LIME pyroxenes, amorphous material and Fe-rich olivine are common to both meteorites, but differ markedly in their modal abundance. This suggests that during accretion mixing of matrix components on a large scale in the nebula was poor, or that the two meteorites accreted in significantly different environments, locations or times and consequently sampled material mixed to different degrees. The matrix of Adelaide is largely crystalline compared with ALH A77307 matrix which contains abundant amorphous material. This suggests that the matrix components in Adelaide have been more extensively annealed that in ALH A77307 according to the model of [5].

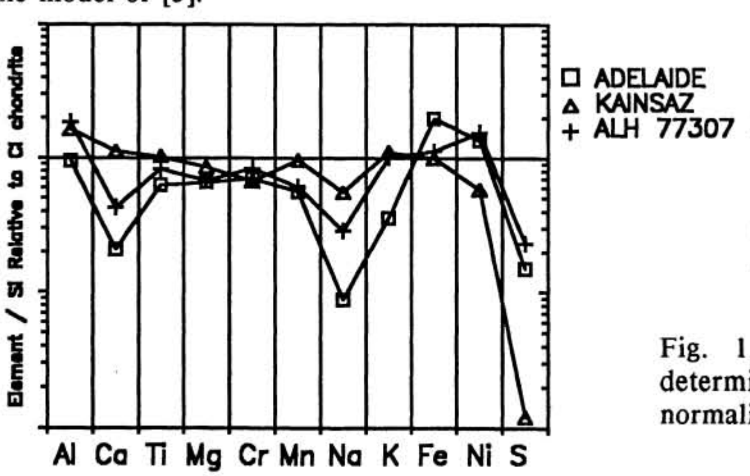

Fig. 1. Adelaide matrix composition as determined by electron microprobe plotted normalized to Si and CI chondrite values.

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