CHONDRULES FROM CHONDRULES ? AN ION PROBE TRACE ELEMENT STUDY. C. M. O'D. Alexander. McDonnell Center for Space Sciences, Washington University, St Louis, MO 63130, U.S.A.

Inter-element correlations, particularly between the refractory elements, observed in INAA bulk chondrule data have led to the now generally accepted conclusion that the chondrule precursors were nebular condensates [e.g.1] rather than pre-existing crystalline rocks. Here the trace element abundances of the major UOC chondrule silicate phases, measured by ion microprobe, are used to re-examine the issue of chondrule precursors. It is shown that random sampling of a previous generation of chondrules could produce the observed range of bulk composition [2,3].

Ion probe measurements of porphyritic chondrule olivines tend to fall into two groups, 'normal' and incompatible-rich. The incompatible-rich olivines (Fo>97, low Cr and Mn) appear to have formed under highly reducing conditions. All porphyritic chondrule olivines and low-Ca pyroxenes have surprisingly unfractionated REEs compared to the patterns expected from equilibrium distribution coefficients [4]. The distribution coefficients of many trace elements in olivine and low-Ca pyroxene are strongly dependent on the cooling rate [5]. In particular, the LREEs become less fractionated, with respect to the HREEs, as the cooling rate increases. The ion probe results for chondrule minerals are consistent with porphyritic chondrules having cooled at about 1000°C/hr or even faster [2,3], in agreement with previous estimates based on zoning profiles [6].

As might be expected, ion probe measurements show that the refractory lithophiles, with the exception of Mg, are all highly incompatible in silicate melts and are, as a result, concentrated in the chondrule glasses [2,3]. The refractory lithophiles in the glass have, in most cases, essentially chondritic relative abundances suggesting that neither vapor phase nor crystal-liquid fractionation played a major role in the formation of chondrules or their precursors.

Based largely on the observation that the refractory lithophiles are concentrated in the chondrule glasses it is suggested that previously reported correlations between these elements in bulk chondrule analyses are due to chondrules themselves, as opposed to refractory condensates, having been their own immediate precursors. In this model, it is envisioned that chondrules formed by randomly sampling fragments of a previous generation of chondrules. If correct, the correlations between the incompatible elements in the bulk analyses result from chondules incorporating variable amounts of glass when they formed.

Other correlations amongst the lithophile elements in the bulk chondrule data have been reported. It is possible that some of these correlations are artifacts produced by the variable dilution of the lithophiles, whose abundances would otherwise be relatively constant but uncorrelated, by reduced and oxidized Fe. For this reason the bulk chondrule data have been recalculated on an Fe-free basis and are shown in Fig. 1. Also, in Fig. 1 are the results of a simple Monte Carlo model, which sampled at random the ion probe measurements, to simulate chondrules. The similar distribution of compositions between the natural and simulated chondrules supports the hypothesis that chondrules formed by the random sampling of a previous generation of chondrules (Fig. 1).

As can be seen in Fig. 1, the previously described inverse correlation between the refractory lithophile element abundances, such as Sm, and the Fa/Fs content of the chondrule minerals all but disappears from the Fe-free data and the correlation Mg-Al correlation becomes rather weak. The inverse correlation of the Sc/Cr ratio with the Fa/Fs content of chondrule minerals remains but, in the context of this model, could be explained by the mixing of incompatible-rich olivines (Fo>97, high Sc, low Cr) with the 'normal' olivines (Fo<97, low Sc, high Cr which correlates with Fa content) and by Cr being lost in chondrule metal from the more reduced chondrules. Finally, it has been argued that the upper limit of about one observed in the atomic Na/Al ratios of chondrule glasses is due to an albitic precursor. However, it is possible that this upper limit simply reflects that for Na to be incorporated into the structure of the melt it must take part in the coupled substitution $NaAlO_2 \rightarrow SiO_2$ [7].

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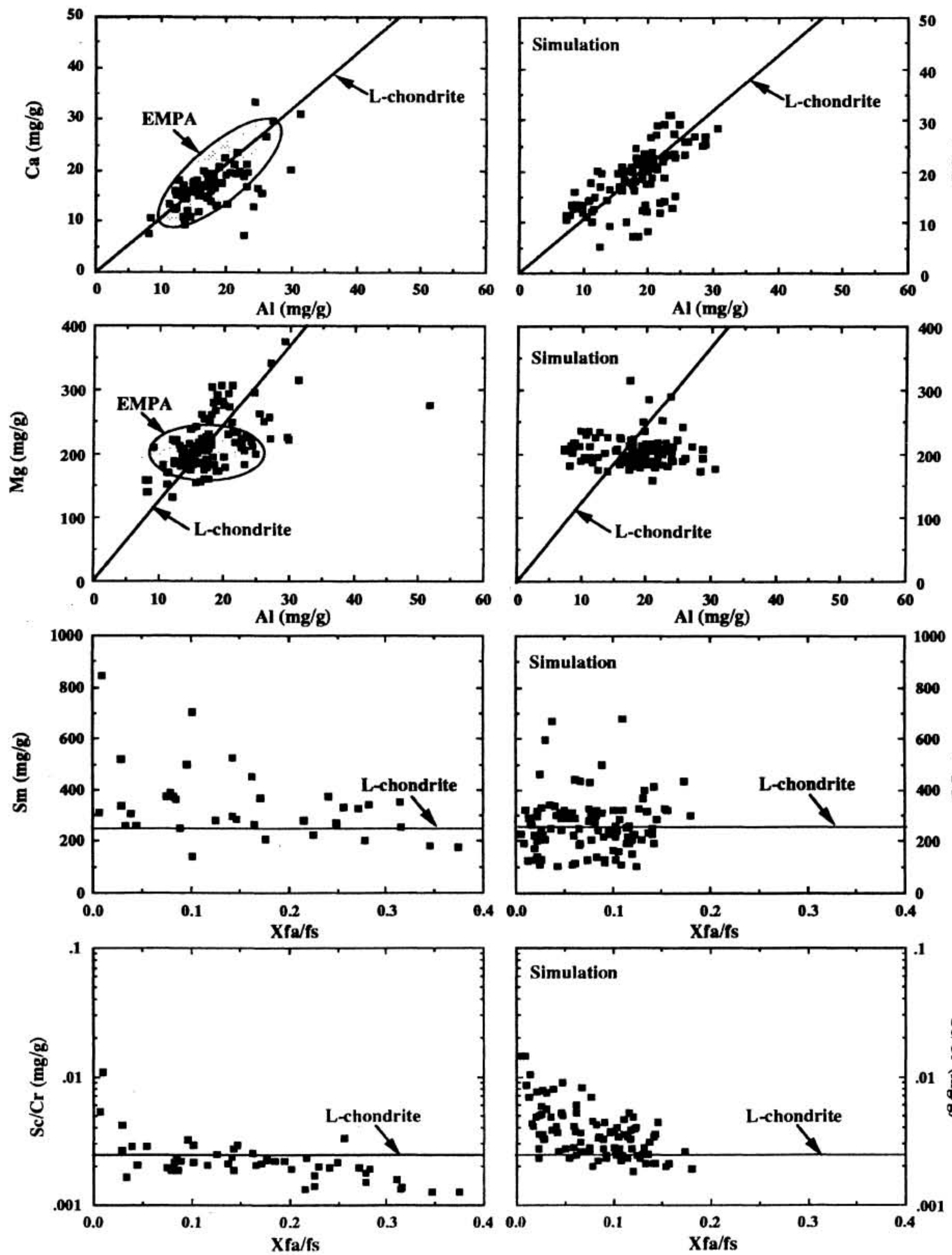

Fig. 1 Comparison of bulk chondrule INAA data taken from the literature with the compositions simulated chondrules formed by randomly sampling the ion probe data.