MN-CR SYSTEMATICS IN SULFIDES OF UNEQUILIBRATED ENSTATITE CHONDRITES: PARENT BODY VS. NEBULAR PROCESSING AND IMPLICATIONS FOR ACCRETION TIMES. M. Wadhwa[1], E. K. Zinner[2,3], and G. Crozaz[2,4]. [1]Department of Geology, The Field Museum, Roosevelt Rd. at Lake Shore Dr., Chicago, IL 60605; [2]McDonnell Center for the Space Sciences, [3]Dept. of Physics, and [4]Dept. of Earth and Planetary Sciences, Washington University, St. Louis, MO 63130.

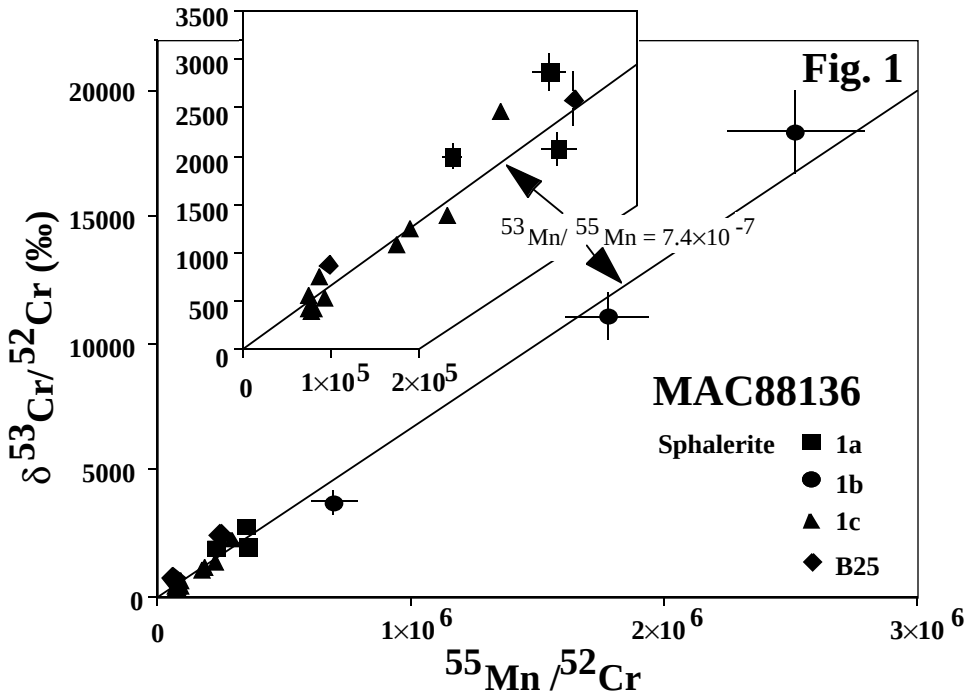
We recently reported the results of an ion microprobe study of Mn-Cr systematics in individual sulfide grains of unequilibrated enstatite chondrites (UECs) [1]. In that study, we measured Mn/Cr ratios and Cr isotopes in sphalerite (ZnS) and alabandite (MnS) grains of four EL3 chondrites (MAC88136, MAC88180, MAC88184, and EET90299) and sphalerite and niningerite (MgS) grains of five EH3-4 chondrites (Indarch, Qingzhen, Kota Kota, Y-69001, and Y-74370). The main findings from this investigation are summarized as follows: (1) Sulfide grains analysed in four of the nine UECs (MAC88136, MAC88180, MAC88184, and Indarch) have clear ^{53}Cr excesses. (2) These excesses can be extremely large, with δ^{53}Cr/^{52}Cr ranging up to ~18,400 ‰, the largest ^{53}Cr excess measured so far. Additionally, in some grains, these excesses in ^{53}Cr correlate well with the Mn/Cr ratios (see Figs. 1 and 2 for sphalerites in MAC88136 and Indarch) and are, thus, most likely produced by *in situ* decay of live ^{53}Mn. (3) In the four meteorites with ^{53}Cr excesses, there are variations in the inferred ^{53}Mn/^{55}Mn ratios *between* different sulfide grains within the same meteorite. Furthermore, *within* some individual grains data points scatter and do not lie on a single isochron. These variations are explained by diffusional re-distribution of Mn and/or Cr after partial or complete decay of ^{53}Mn. (4) Although no strict chronological significance can be ascribed to the differences in inferred ^{53}Mn/^{55}Mn ratios in sulfides of the four meteorites that have ^{53}Cr excesses, limited time constraints may be obtained. Specifically, our data indicate that the ^{53}Mn/^{55}Mn ratio in sulfides in the EL3 chondrites was $(7.4 \pm 0.3) \times 10^{-7}$ at the time of isotopic closure, while the *minimum* inferred value for sulfides in the Indarch meteorite at the time of isotopic closure was $(1.7 \pm 0.3) \times 10^{-6}$. This further implies that the time of last isotopic equilibration of sulfides in the EH meteorite Indarch preceded that of sulfides in the EL chondrites by *at least* ~3 Ma.

Although it is clear that diffusive re-equilibration has indeed affected the Mn-Cr systematics of the sulfide grains in both EH and EL, we did not ascribe a parent body or nebular environment for this subsequent processing. However, if the disturbance in the Mn-Cr systematics can be attributed to a specific environment (nebular or parent body), it would have important implications for the time of condensation of the sulfides and/or accretion of the EH and EL chondrite parent bodies. Therefore, we consider here some plausible scenarios for the environments that may have affected the Mn-Cr systematics in sulfides in these EH and EL chondrites, and their possible implication for the relative accretion times of the EH and EL parent bodies.

In the case of the Indarch EH4 chondrite, it has been previously suggested that the sulfides equilibrated at temperatures in excess of 1000 °C, and may even have undergone partial melting [2,3,4]. This event is generally believed to have occurred "post-accretion" on the EH parent body. It most likely marked the time of last isotopic equilibration for this meteorite. Therefore, it is at this time that the ^{53}Mn/^{55}Mn ratio in the sulfides in this meteorite was at least $(1.7 \pm 0.3) \times 10^{-6}$. This value may, thus, be regarded as the *lower limit* on the ^{53}Mn/^{55}Mn ratio in Indarch sulfides at the time of accretion. Regarding the isotopic closure of sulfides in the EL chondrites, when the ^{53}Mn/^{55}Mn ratio was $(7.4 \pm 0.3) \times 10^{-7}$, there are three possibilities, i.e., that it occurred at the time of (1) condensation of the sulfides in the nebula, (2) accretion of the EL parent body, or (3) "post-accretion" metamorphism at a later (unknown) stage. In either of the first two cases, the accretion time for the EH parent body would have to precede that for the EL parent body by *at least* ~3 Ma. However, in case (3), it is not possible to make any inferences regarding the accretion times of the EH and EL parent bodies. It should be noted that of the three possibilities, the first one is most likely since major and minor element zonation patterns preserved in the sulfides in these EL3 chondrites suggest equilibration during cooling in a nebular environment [5,6]. Therefore, it seems most likely that the time of accretion of the EH parent body preceded that of the EL parent body by at least ~3 Ma.

Finally, it should be noted that the above comparisons between EH and EL chondrites are only valid if ^{53}Mn was homogeneously distributed in the region where the enstatite chondrites formed. Recent work [7] suggests that this may indeed be the case.

References. [1] Wadhwa M. et al. (1997) Meteorit. Planet. Sci. 32, 281. [2] Mason B. (1966) GCA 30, 23. [3] Hohenberg C.M. et al. (1967) Science 156, 233. [4] Birck J.-L. and Allègre C.J. (1988) Nature 331, 579. [5] Lin Y.T. et al. (1991) LPSC XXII, 811. [6] El Goresy A. et al. (1992) LPSC XXIII, 331. [7] Lugmair G.W. and Shukolyukov A. (1997) LPSC XXVIII, 851.



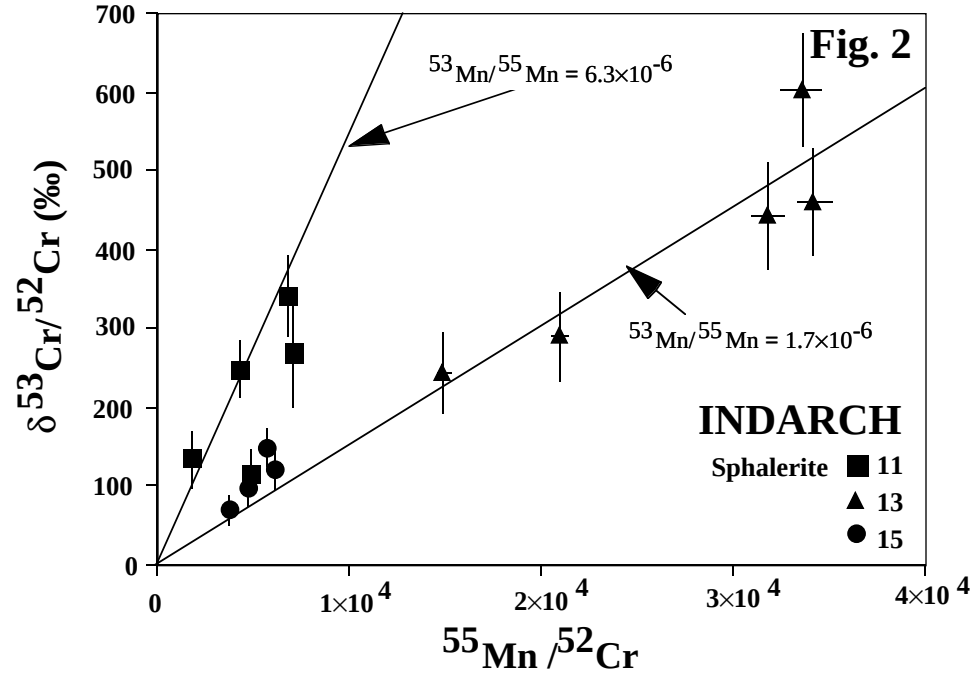


FIGURE CAPTIONS. Fig. 1: Mn-Cr evolution diagram for isolated sphalerite grains, sphalerite #1 (spots a, b, and c) and #B25, in MAC88136 (EL3). The data are consistent with an inferred $^{53}Mn/^{55}Mn$ ratio of (7.4±0.3) x 10^{-7}. Fig. 2: Data for sphalerite #13 and #15 in Indarch (EH4) are consistent with an inferred $^{53}Mn/^{55}Mn$ ratio of (1.7±0.3) x 10^{-6}, while that for sphalerite #11 appear to be disturbed, with five of the six data points plotting along a line (within 2σ) corresponding to a $^{53}Mn/^{55}Mn$ ratio of 6.3 x 10^{-6}. NOTE: Errors plotted in both figures are ± 1σ.