Cr ISOTOPIC COMPOSITION OF DIFFERENTIATED METEORITES: A SEARCH FOR ^{53}Mn.

I. D. Hutcheon[1] and E. Olsen[2] [1]The Lunatic Asylum, Division of Geological & Planetary Sciences 170-25, Caltech, Pasadena, CA 91125. [2]Field Museum of Natural History, Chicago, IL 60605

Studies of Pd-Ag isotope systematics in iron and stony-iron meteorites have provided evidence for the *in situ* decay of ^{107}Pd($\tau_{1/2}$ = 6.5 x 10^6y) and the formation of small differentiated planetary bodies within ~10^7y of ^{107}Pd production [1]. If ^{53}Mn ($\tau_{1/2}$ = 3.7 x 10^6y) was added to the nebula during late-stage nucleosynthesis in comparable amounts to ^{26}Al and ^{107}Pd, i.e. (^{53}Mn/^{55}Mn)$_o$ ~ 5 x 10^{-5}, some evidence should be preserved in meteorites containing excess ^{107}Ag*. Olivine from the Eagle Station pallasite contains small ^{53}Cr excesses [2], but until recently no evidence for large ^{53}Cr excesses correlated with Mn/Cr was reported. Davis and Olsen [3] found a large ^{53}Cr excess in the IIIA iron El Sampal and inferred an initial ^{53}Mn/^{55}Mn of ~ 5 x 10^{-7}. We have investigated the Mn-Cr isotopic systematics of four iron meteorites and one pallasite to see if evidence for ^{53}Mn is widespread among differentiated meteorites and to examine possible correlations between ^{53}Mn-^{53}Cr and ^{107}Pd-^{107}Ag timescales.

In this study we focussed on Mn-rich phosphate minerals in the Springwater pallasite and in 4 IIIAB iron meteorites -Bella Roca, Cape York, El Sampal and Grant. (Table 1) Phosphates are concentrated in troilite nodules or found at troilite-metal boundaries (Cape York). The silico-phosphate in Springwater occurs at an olivine-metal-troilite contact. Olivine adjacent to silico-phosphate was also analyzed. Mn is homogeneous in olivine but Cr is strongly depleted at crystal boundaries enabling us to obtain much higher Mn/Cr than previous studies [2]. Analyses were performed with the PANURGE IMS-3F using an $^{16}O^-$ primary beam and mass resolving powers (MRP) between 3500 and 6000. All molecular species except $^{52}CrH^+$ were fully resolved; measurements at MRP 6000 showed $^{52}CrH^+/^{53}Cr^+$ < 0.6‰. $^{50}Ti^+$ is an unresolved isobaric interference with $^{50}Cr^+$. Analyses were corrected for Ti^+ contribution based on $^{49}Ti^+$; the correction was ≤ 10‰. Isotope ratios were corrected for mass-dependent fractionation using a power law after normalizing to ^{50}Cr/^{52}Cr = 0.051859. ^{53}Cr/^{52}Cr ratios are expressed as δ^{53}Cr relative to 0.11338. ^{55}Mn/^{52}Cr ratios were calculated from $^{55}Mn^+/^{52}Cr^+$ using sensitivity factors determined in silicates and high-Cr phosphates.

All of the meteorites show evidence for excess ^{53}Cr in Mn-rich, Cr-poor phases and for normal Cr in chromite or troilite. The ^{53}Cr excesses range from δ^{53}Cr = 5.5±2.0‰ in Cape York to δ^{53}Cr = 32.2±4.1‰ in El Sampal and are linearly correlated with ^{55}Mn/^{53}Cr ratios in the respective minerals (Fig 1&2). Analyses of silica-phosphate and olivine in Springwater give well resolved ^{53}Cr excesses and with data from troilite define a linear array with slope, ^{53}Cr*/^{55}Mn = (1.4±0.4) x 10^{-5}. These data show δ^{53}Cr ~ 100 times higher than measured in olivine from Eagle Station and yield a $^{53}Cr^+/^{55}$Mn ratio ~ 6 times higher [2]. Analyses of two phosphates in Cape York show evidence for δ^{53}Cr > 0 (Fig 2). One high Mn phosphate gave precise data (δ^{53}Cr = 5.5±2.0‰) but relatively low Mn/Cr; a second phosphate contained only trace Cr, heterogeneously distributed, and gave much higher Mn/Cr and δ^{53}Cr but poorer precision (δ^{53}Cr = 23±14‰). Together with data from chromite these data yield an array with slope similar to that found for Springwater, ^{53}Cr*/^{55}Mn = (2.2±1.0) x 10^{-5}. Most phosphates from the other iron meteorites have much higher Mn/Cr ratios but comparable ^{53}Cr excesses. Phosphate in El Sampal gives δ^{53}Cr = 32‰, confirming the value reported in [3], but with a Mn/Cr ratio that is ~ 40% lower. The slope of the array, ^{53}Cr*/^{55}Mn = (8±1) x 10^{-7}, is accordingly higher. Phosphates in both Bella Roca and Grant span a large range in Mn/Cr. Phosphates in Bella Roca yield δ^{53}Cr = 0.5±2.0‰ with ^{55}Mn/^{52}Cr = 12 and δ^{53}Cr = 14.6±3.0‰ with ^{55}Mn/^{52}Cr = 950. These data yield an array with slope ~ 2x higher than the El Sampal array, ^{53}Cr*/^{5}Mn = (1.7±0.4) x 10^{-6}. Phosphates from Grant span the widest range in Mn/Cr, 12 to 2800 with corresponding δ^{53}Cr values of 5.0±1.5‰ to 25.6±5.0‰. Data for chromite and 3 phosphates with Mn/Cr ≥ 1000 define an array with slope, ^{53}Cr*/^{55}Mn = (1.0±0.4) x 10^{-6} and passing through δ^{53}Cr = 0. Data from one high-Mn, high-Cr phosphate, however, lies above the line: δ^{53}Cr = 4.0±1.5 with ^{55}Mn/^{52}Cr = 12.

These data are most plausibly interpreted as reflecting the presence of radiogenic ^{53}Cr* produced by the *in situ* decay of ^{53}Mn, subsequent to the differentiation and cooling of the parent planetesimals. The long exposure ages of IIIAB irons and pallasites require consideration of cosmic ray spallation-induced isotope effects in Cr. We assessed the magnitude of these effects based on the analysis of spallogenic Cr in Grant metal [4,5]. Assuming Fe is the only significant target and normalizing spallation yields to Fe contents of the phosphates, we find a significant correction for spallation (10‰ in δ^{53}Cr) only for one phosphate containing ~ 17ppm Cr. In all other Grant phosphates the correction is ≤ 3‰ and does not affect our conclusions. The Grant data reported are corrected for spallation.

The results suggest that ^{53}Cr excesses are widespread in phases with high Mn/Cr in two classes of differentiated meteorites. The ^{53}Cr excesses appear well correlated with Mn/Cr ratios, further suggesting the production of ^{53}Cr* by *in situ* decay of ^{53}Mn. The highest initial ^{53}Mn abundance inferred from these data, ^{53}Cr*/^{55}Mn ~ 2.2 x 10^{-5}, approaches the value found for Allende CAI [2], confirming the suggestion that comparable abundances of 4 short-lived nuclides, ^{26}Al, ^{53}Mn, ^{107}Pd and ^{129}I, were added to the solar nebula as a last-gasp addition of freshly synthesized nuclear material. The inferred initial ^{53}Mn abundances appear to vary rather widely, ^{53}Cr*/^{55}Mn ranges from ~ 8 x 10^{-7} to ~ 2 x 10^{-5}. If this variation reflects a decay interval for ^{53}Mn, the data suggest age differences of 6 x 10^{6}y between Cape York and the other IIIAB irons. A comparison between Mn-Cr and Pd-Ag chronologies provides mixed results. El Sampal, Grant and Cape York have ^{107}Ag*/^{108}Pd ~ 1.5 x 10^{-5}. The similarity in ^{53}Cr*/^{55}Mn also suggests El Sampal and Grant are contemporaneous but the higher abundance of ^{53}Cr* in Cape York does not fit the simple model of formation of IIIAB irons in a common planetismal.

Ref: [1] J.H. Chen & G.J. Wasserburg (1984) GCA 47, 1725; [2] J-L Birck & C.J. Allegre (1988) Nature 331, 579; [3] A.M. Davis & E. Olsen (1990) LPS XXI, 258; [4] M. Shima & M. Honda (1960) EPSL 1, 65; [5] T. Shimamura *et al.* (1986) LPS XVII, 795; [6] J.H. Chen & G.J. Wasserburg (1990) XXI, 184.

Table 1

Phosphate minerals in differentiated meteorites.

	1	2	3	4
Na_2O	3.42	nd	9.75	23.2
MgO	32.30	nd	nd	1.7
SiO_2	2.36	.05	nd	nd
P_2O_5	47.95	40.95	40.74	40.9
CaO	9.83	.06	0.11	26.1
Cr_2O_3	nd	nd	0.82	0.1
MnO	0.80	19.67	7.41	2.8
FeO	4.34	38.95	42.26	5.5
Sum	101.00	99.68	101.09	100.3

1. Springwater silico-phosphate; 2. Grant 2165A; 3. Grant 836 B; 4. Cape York

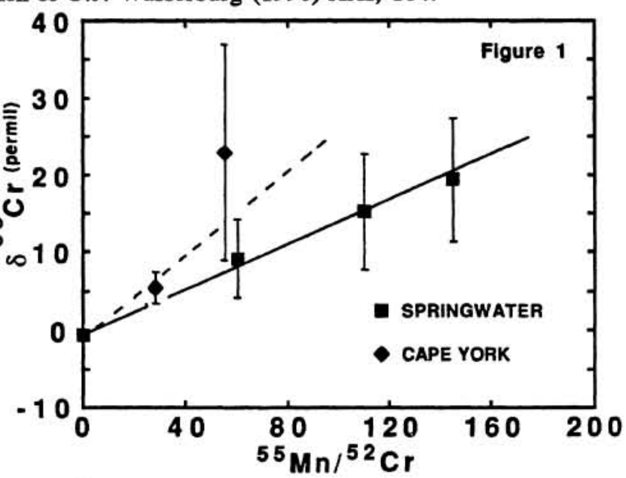

Fig 1. Mn-Cr isotope systematics of Springwater and Cape York. Solid line through Springwater data has slope ^{53}Cr*/^{55}Mn = 1.4 x 10^{-5}; dashed line through Cape York data has slope 2.2 x 10^{-5}

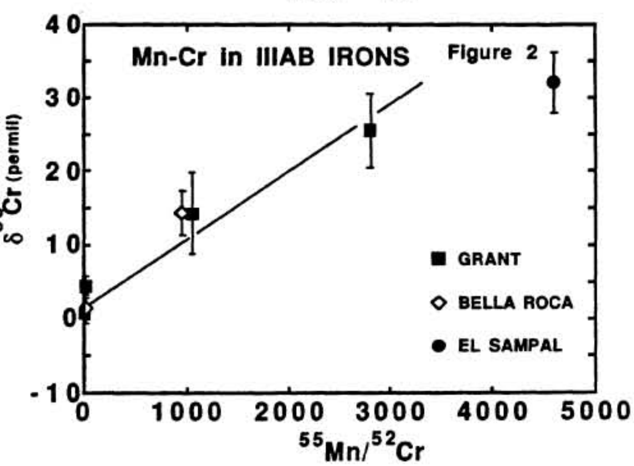

Fig 2. Mn-Cr isotope systematics of IIIAB irons. Solid line is fit to Grant data; slope is ^{53}Cr*/^{55}Mn = 1 x 10^{-6}