

**Mn-Cr ISOTOPIC SYSTEMATICS IN THE EAGLE STATION PALLASITE METAL.** D. A.

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**Introduction.** We reported last year [1] on the Mn-Cr systematic of Eagle Station (ES), which is of interest, because it belongs to a chemically anomalous group of pallasites (based on high Ni, Ge, and Ir and siderophile elements in the metal and high fayalite content of olivine [2]) and has an oxygen isotopic composition which falls in the range found in whole-rock samples of CO3 and CV3 chondrites [3]. We also addressed the comparison (and differences) of our chromite and olivine Mn-Cr systematics with the reports of earlier Mn-Cr measurements on chromite and olivine grains from Eagle Station by Birk and Allègre [4] and Shukolyukov and Lugmair [5]. Based on the discrepancies between the initial <sup>53</sup>Mn/<sup>55</sup>Mn ratios and the  $\epsilon^{54}\text{Cr}$  values [1, 4, 5] and the importance of the proposed genetic link with CO3 and CV3 chondrites, we have re-examined the Mn-Cr system in ES. In particular, because we observed differences in <sup>54</sup>Cr/<sup>52</sup>Cr ratios between chromite and olivine we have determined the isotope composition of Cr in the metal of ES. The purpose is to identify the isotopic composition of cosmic ray spallation Cr in the metal, and determine whether this spallation Cr can be the cause of the observed heterogeneity in <sup>54</sup>Cr/<sup>52</sup>Cr between olivine and chromite. In the current study we report the Cr isotopic composition in the metal from Eagle Station as well as extensive trace element concentrations in ES.

**Analytical techniques.** A single piece of metal (~1 g) was prepared from Eagle Station using a dental drill to remove olivine and other impurities from the surface. After leaching with hot HCl for ~5 minutes, the metal was dissolved in aqua regia. The residue consisted of olivine and chromite (~10 wt %) and was removed by centrifuging. The abundances of 34 elements were determined on small aliquots of the metal solution (0.001 – 1 mg, equivalent metal) of ES, using an ICP-MS (Thermo X-Series, with a collision cell) and calibrated with four commercial multi-element standards. In addition, an aliquot (~0.1 g metal) was taken for Mn-Cr work while the remainder was saved for future isotopic analyses (e. g., of Ni, Ru, Os, Mo).

**Results.** The bulk analysis of metal from pallasites is difficult because of the presence of coarse taenite, kamacite, and chromite. For our technique (in which we removed the insoluble chromite) chromite does not affect the results on the metal. We compare our data with those reported for siderophiles by Wasson and Choi (2003)[7]. Most of the siderophile element abundances in Eagle Station show good agreement, except

for W, Mo and Ge (Fig. 1a, normalized to CI-chondrites and Ni). Our new results also agree with the results by laser ablation ICP-MS, except for W, Os, Ge and Sn (Humayun and Weiss, 2011 [6]). In addition, we report, for the first time, abundances of non-siderophile elements in the same metal sample. They show a large degree of depletion and a general increase in abundances from Al to Pb. We notice that the abundance of Cr in our sample is ~2000 times lower than that reported by Wasson and Choi (2003) [7] due to their smaller sample size and potential inclusion of chromite. We note that [6] reported that V and Cr were below their detection limits (<2 ppm) in the Vienna "metal". This is essentially compatible with our results on metal, which were obtained on the sample of ES from the Vienna collection.

**Mn-Cr systematics.** The results on Mn-Cr are shown in the Table 1 and in Figure 3 and 4. We note very high excesses of <sup>53</sup>Cr and <sup>54</sup>Cr in the metal reflecting spallation Cr. In Fig. 3 we show that the ES metal plot far above both <sup>53</sup>Mn/<sup>55</sup>Mn correlation lines. We have compared our data with the results on Carbo published recently by Qin et al. [8]. Our data for the ES metal fall on the same line for spallation Cr in Carbo, with a slope of ~-4, as expected ([8], and Birk and

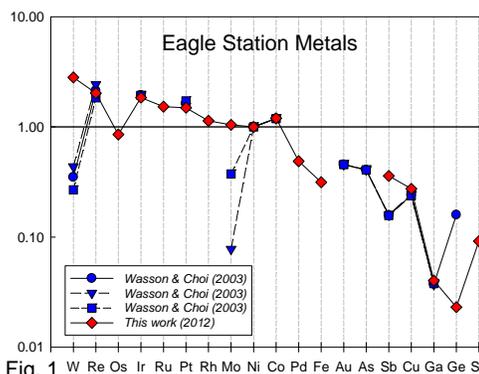


Fig. 1

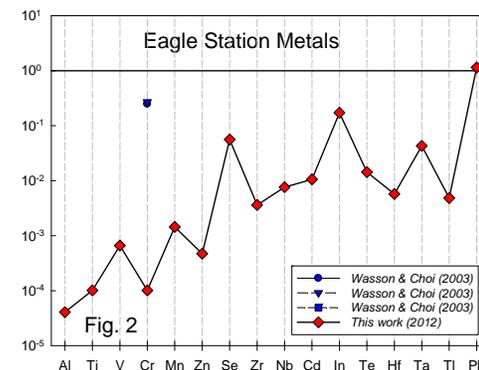


Fig. 2

Allègre 1985 [9]). The spallation effects in ES metal are larger than the range of effects observed for Carbo, based on different extent of shielding within Carbo. Based on the Fe/Cr ratios in the metal and in the olivine and by assuming the olivine composition is 20% fayalite [10], we obtain  $\text{Fe}/\text{Cr}_{\text{oliv}} = 415$  as compared to  $218 \times 10^3$  for the metal (15% Ni). The corrections for spallation are 0.08  $\epsilon$ u for  $\epsilon^{53}\text{Cr}$  and 0.33  $\epsilon$ u for  $\epsilon^{54}\text{Cr}$ . For the sample we have labeled chromite, we obtain a very low Cr concentration. Hence, our assumption that the residue was chromite is in doubt. If the insoluble phase is Fe-rich (e. g., schreibersite, which would be insoluble in the HF used to dissolve the olivine) then the data labeled as *chromite* could have significant corrections for spallation Cr, at the 0.5 to 1.5  $\epsilon$ u levels for  $\epsilon^{53}\text{Cr}$  and  $\epsilon^{54}\text{Cr}$  (which could result in deficits in  $\epsilon^{53}\text{Cr}$  and  $\epsilon^{54}\text{Cr}$ , reminiscent of initial  $^{53}\text{Cr}/^{52}\text{Cr}$  in CAI). We will measure the Fe concentration in the original solution of *chromite* and report the results. The current results indicate that Cr in pallasites may be significantly affected by spallation (cf exposure ages by [11] and [12]). The large spallation effects for Cr in ES metal relative to Grant and Carbo [8, 9, 13] indicate a significant exposure age for ES. At this stage the possible correlation of ES parent materials with CO and CV carbonaceous materials remains open.

**References.** [1] Papanastassiou D. A. and Chen J. H. LPS 42, abstr. 2195. [2] Scott E. R. D. (1977) *GCA* 41, 349. [3] Clayton R. N. and Mayeda T. (1996) *GCA* 60, 1999. [4] Birck J.-L. and Allègre C. J. (1988) *Nature* 331, 579. [5] Shukolyukov A. and Lugmair G. W. (2006) *EPSL* 250, 200. [6] Humayun M. and Weiss B. P. LPS 42, abstr. 1507. [7] Wasson J. T. and Choi 2003 *GCA* 67, 3079. [8] Qin *et al.* (2010) *GCA* 74, 1122. [9] Birck J.-L. and Allègre C. J. (1985) In *Isotopic Ratios in the Solar System*, pp. 21–25. [10] Buseck P. R. (1977) *GCA* 41, 711. [11] Megrue G. H. (1968). *J. Geophys. Res.* 73, 2027-2033. [12] Huber L. *et al.* (2010) *73<sup>rd</sup> Met. Soc. Meeting*, Abstract #5208. [13] Shima M. and Honda M. (1966), *EPSL* 1, 65.

**Acknowledgements.** This work was carried out at the Jet Propulsion Laboratory, California Institute of

Technology and was supported by NASA Cosmochemistry. The ICP-MS was obtained with JPL Technical Equipment and Facilities funds (TEFIM) in support of extraterrestrial, return sample, isotope cosmochemistry. We thank Dr. Franz Brandstätter, Naturhistorisches Museum, Vienna, for providing the Eagle Station sample.

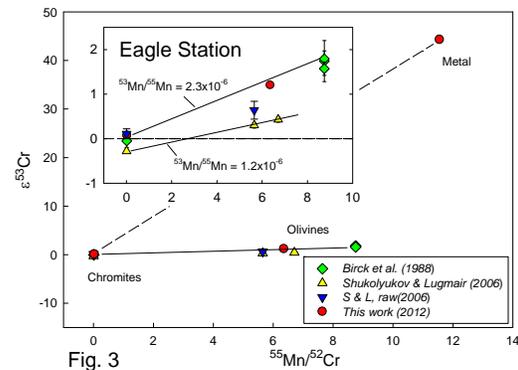


Fig. 3

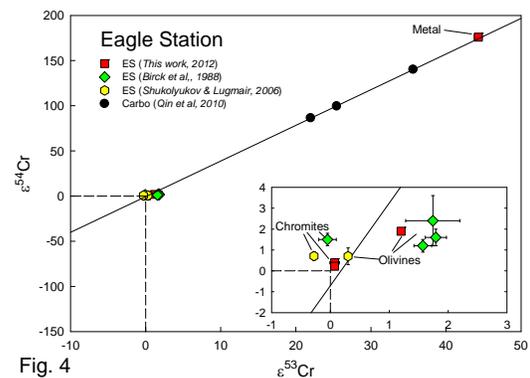


Fig. 4

Table 1. Mn and Cr data in the pallasite Eagle Station

Sample	Mn(ppm)	Cr(ppm)	$^{55}\text{Mn}/^{52}\text{Cr}$	$\epsilon^{53}\text{Cr}$	$\epsilon^{54}\text{Cr}$
Olivine	1222	217	6.36	1.2 ± 0.05	1.9 ± 0.15
Chromite a	8.65	358	0.027	0.07 ± 0.08	0.39 ± 0.19
Chromite b			0.027	0.07 ± 0.06	0.22 ± 0.16
Metal	39.9	3.9	11.56	44.3 ± 0.5	176 ± 2