COSMOGENIC STABLE ISOTOPE EFFECTS ON TUNGSTEN, OSMIUM AND CHROMIUM IN THE CARBO IRON METEORITE.
L. Qin[1], N. Dauphas[2], M. F. Horan[1], R. W. Carlson[1], C. M. O'D. Alexander[1], I. Leya[3], and J. Masarik[4]. [1]Department of Terrestrial Magnetism, Carnegie Institution of Washington, 5241 Broad Branch Road, NW, Washington, DC 20015, USA. [2]Origins Laboratory, Department of the Geophysical Sciences and Enrico Fermi Institute, The University of Chicago, Chicago IL 60637, USA. [3]Institute of Physics, University of Berne, Sidlerstrasse 5, 3012 Berne, Switzerland. [4]Department of Nuclear Physics, Komensky University, SK-842 48 Bratislava, Slovakia (E-mail: lqin@ciw.edu)

Introduction: Several studies have shown that interaction of meteorites with cosmic rays can affect the isotopic composition of a wide range of elements. These cosmogenic effects can superimpose on isotopic variations arising from decay of short-lived chronometers and can hamper geochronological interpretations. The ^{182}Hf-^{182}W decay system ($t_{1/2}$= 9 My) is very important to constrain the time scales of metal-silicate differentiation processes [e.g., 1,2]. Model calculations have shown that W isotopic compositions of iron meteorites can be affected by neutron capture reactions on W isotopes during their exposure to cosmic rays, and thus yield inaccurate ages [3,4]. A modulation in ^{182}W/^{184}W values with distance from the preatmospheric surface has been documented for the magmatic iron meteorite Carbo (IID) [5,6]. Thus, one major challenge in establishing the ^{182}Hf-^{182}W system in iron meteorites as a reliable chronometer is to find a way to accurately correct for these cosmogenic effects. Iron meteorites are deficient in most elements that are commonly used to monitor neutron capture effects. A recent study found Os isotopic anomalies in IVB meteorites [7]. The correlation between ε^{190}Os and ε^{189}Os anomalies was consistent with model predictions for capture of thermal neutrons (slope ~-0.7). Osmium, a highly siderophile element, is present at a relatively high abundance in iron meteorites, which ensures a precise determination of its isotopic composition. Here, we show how Os isotopic variations can be used as a neutron dose monitor in iron meteorites to correct cosmogenic effects on W isotopes.

Unlike Os and W, which can be affected by neutron capture reactions, light elements such as Cr can be affected by spallation reactions. In iron meteorites, the major target elements are Fe and Ni. Because the atomic number of Cr is slightly lower than that of Fe, the production rates of Cr isotopes are high [8]. In our recent study, we found coupled excesses in ε^{53}Cr and ε^{54}Cr in three Carbo samples [9].

With an exposure age of ~850 Ma, Carbo is ideal for studying correlated cosmogenic effects in these isotope systems. In addition, the samples we studied came from a slab with a well documented exposure profile, which provides a good reference point against which model predictions can be compared.

Methods: Sample digestion was achieved using Carius tube. Osmium was purified by CCl_4 extraction and micro-distillation (e.g. [10]). Chemical separation of Cr weas achieved through several steps of ion-exchange chromatography [9]. Both elements were analyzed on a Triton thermal ionization mass spectrometer at DTM. The analytical blanks were always negligible compared to analyte concentrations. Each sample and terrestrial isotopic standard were analyzed multiple times for both Os and Cr isotope compositions to achieve better precision. Because the Os isotopic compositions were measured as a negatively charged trioxide, the Os isotope compositions were corrected for contributions by ^{16}O and ^{17}O, and the isotope ratios were normalized to the ^{192}Os/^{188}Os ratio.

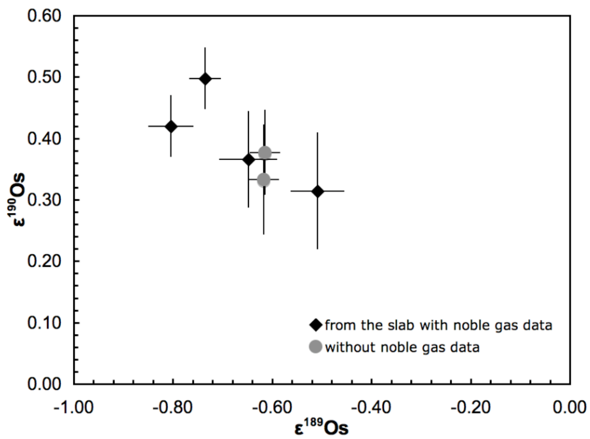

Fig. 1. Os isotopic compositions of Carbo samples.

Results and discussions: *Os isotopic composition* Six samples were analyzed for Os, including 4 samples from the slab where noble gas data were available, and two samples from a bar with unknown noble gas information. Because ^{186}Os and ^{187}Os are radiogenic, only the other two isotope ratios ^{189}Os/^{188}Os and ^{190}Os/^{188}Os were examined. As shown in Fig. 1, relative to the Os standard, all Carbo samples show defičts from -0.8 to -0.5 in ε^{189}Os and excesses in ε^{190}Os of 0.3-0.5. The slope in Fig. 1 is similar (~ -0.65) to that observed for group IVB irons [7], consistent with model calculations on neutron capture effects on Os isotopes based on thermal neutron-capture cross sections. Fig. 2 shows a plot of ε^{182}W against ε^{189}Os. A positive correlation can be observed. At ε^{189}Os=0, ε^{182}W=-3.3 ±0.8, which represents the pre-exposure value of this sample. We note that this value is less unradiogenic than the previously estimated value (-3.9) [5, 6]. Although both values agree within uncertainty, the new pre-exposure ε^{182}W for Carbo is more in line with iron meteorites from other magmatic groups [11, 12]. Additional pieces will be studied to further constrain this correlation and model calculations will be carried out to compare those effects with predictions.

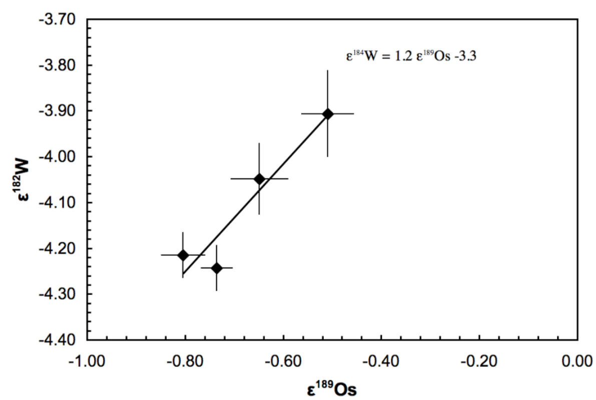

Fig. 2. Correlation between ε^{182}W and ε^{189}Os in Carbo.

Cr isotopic composition Similar to what has been observed previously for three pieces of Carbo [9], the 10 pieces of Carbo that came from a slab with well documented noble gas concentrations show coupled excesses in ε^{54}Cr and ε^{53}Cr with a slope of 3.89±0.02, consistent with calculations on cosmogenic production rates of Cr isotopes. Compared to [9], larger variations in Cr isotopic compositons were found for these samples, with ε^{54}Cr values ranging from 15 to 735. These variations are not correlated with depth from the pre-atmospheric center. Because only 0.1 g of sample was dissolved, this may result from sample heterogeneity. in the Fe/Cr ratio. Taenite usually has a higher Ni content and an order of magnitude higher Cr concentration than kamacite, thus the cosmogenic contribution to Cr isotopic composition in taenite is much smaller than that in kamacite. However, we did not find a correlation between Cr isotopic composition and Fe/Ni ratio. This suggests that Cr abundance is very heterogeneous in Carbo. This is evidenced by the sample with the highest amount of Cr showing the lowest Cr isotopic anomalies. Precise determinations of Fe/Cr in these samples are needed to correct for sample heterogeneity and to examine the depth-dependent effect on Cr isotopes.

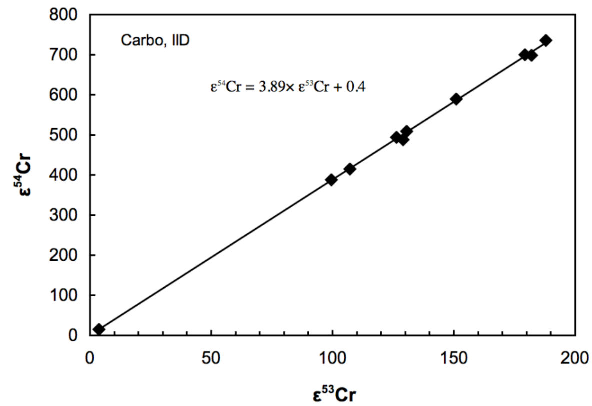

Fig. 3. Cr isotopic compositions of Carbo samples.

Conclusions: Osmium isotopic anomalies were found for Carbo samples, consistent with neutron capture effects previously reported in IVB irons [7]. A potential correlation was found between W and Os isotopes suggesting that Os can be used as neutron dose monitor in iron meteorites. The new corrected pre-exposure ε^{182}W value for Carbo is higher than previous estimates for this meteorite, but is consistent with estimated pre-exposure values for other groups of magmatic iron meteorites. Correlated excesses in ε^{54}Cr and ε^{53}Cr were found in Carbo. Some of these variations likely reflect heterogeneity in the Fe/Cr ratio rather than depth of shielding from cosmic rays.

Acknowledgment: We thank Rainer Wieler, Carl A. Francis, and Stein B. Jacobsen for their help in making the Carbo samples available for this study; and to Richard J. Walker for providing an aliquot of the Os standard used at University of Maryland.

References: [1] Harper C. L. and Jacobsen S. B. (1996) *GCA, 60,* 1131–1153. [2] Lee D. C. and Halliday A. N. (1997) *Nature, 388,* 854–857. [3] Masarik J. (1997) *EPSL, 152,* 181–185. [4] Leya I. et al. (2003) *GCA, 67,* 529–541. [5] Markowski A. et al. (2006) *EPSL, 250*, 104-115. [6] Qin L. et al. (2009) *LPS* XXXX, abstract #2278. [7] Huang S. and Humayun M. (2008) *LPS XXXIX*, abstract #1168. [8] Birck J.-L. and Allègre C. J. (1985) In *Isotopic Ratios in the Solar System, pp*, 21-25. [9] Qin L. et al. (2009*) GCA, in press.* [10] Puchtel I. S. et al. (2005) *EPSL, 237*, 118-134. [11] Markowski A. et al. (2006a) *EPSL, 242*, 1-15. [12] Qin L. et al. (2008) *EPSL, 273*, 94-104.