MN – CR ISOTOPE SYSTEMATICS AND EXCESS OF 54-CR IN METACHONDRITE NORTHWEST AFRICA 3133. A. Shukolyukov[1], G.W. Lugmair[1], and A.J. Irving[2], [1]Scripps Institution of Oceanography, University of California, San Diego, La Jolla CA 92093-0212, USA, [2]Dept. of Earth & Space Sciences, University of Washington, Seattle, WA 98195, USA

Introduction: Irving et al. [1] recently recognized groups of stony meteorites that have no chondrules, but have elemental and oxygen isotopic compositions and textures suggesting that they were altered by metamorphism and/or partial melting from precursor carbonaceous chondrites. These metachondrites include examples related to CR, CV and CO [2] and possibly to yet unknown types of carbonaceous chondrites. The re-crystallization has completely erased textural evidence of chondrules and CAI, although chemical and modal mineralogical inhomogeneities remain in the resulting metachondrites.

Northwest Africa 3133 is currently the most extensively studied carbonaceous metachondrite. This rock has a metamorphic texture and is completely lacking chondrules [2]. It is composed mainly of olivine (46 vol.%) and orthopyroxene (28 vol.%), plagioclase, Cr-diopside, chromite, Na-Mg-bearing merrillite, troilite, and Fe-Ni metal. Clinopyroxene, chromite and merrillite are inhomogeneously distributed as relatively large grains [2]. The oxygen isotopic compositions for whole subsamples and clean olivine plot right on the best-fit line for bulk CV chondrites. The preliminary Hf-W data indicate metamorphism of NWA 3133 within the first ~10 Ma of solar system history [2].

This work is a continuation of our effort to improve our understanding of the early evolutionary period of the solar system by applying ^{53}Mn-^{53}Cr systematics to NWA 3133. The other important goal of this work was to determine a characteristic ^{54}Cr/^{52}Cr ratio for this unusual meteorite in order to test the proposed genetic link between this meteorite and carbonaceous chondrites.

Experimental: To obtain phases with different Mn/Cr ratios we applied our usual differential dissolution procedure that allows separating chromites from silicates and other easily soluble phases ("Sil"). We have measured ^{53}Cr/^{52}Cr and ^{54}Cr/^{52}Cr ratios and Mn and Cr abundances in chromite (Chr), silicates (Sil), and total rock (TR). As in the past, in order to achieve higher precision, we also have applied the second order fractionation correction to the "raw" ^{53}Cr/^{52}Cr data where a "normal" ^{54}Cr/^{52}Cr ratio is assumed [3]. However, it was shown earlier, that bulk samples of carbonaceous chondrites are characterized by variable relative excesses of ^{54}Cr [4], while bulk samples of some other meteorite classes posess relative deficits of ^{54}Cr [5]. Nevertheless, if Cr isotopes totally equilibrated between mineral phases the application of the second order correction is legitimate. We demonstrated that first order corrected data and second order corrected data (primarily used for precise age determination) agree well, e.g. [6]. We have to stress here that the application of the second order fractionation correction, even for samples with anomalous ^{54}Cr abundances, *does not* affect chronological conclusions: the slopes of isochrons remain the same.

Here we present both the 'raw' data and the second order corrected data.

Results and discussion: The results are presented in Figure 1 and 2. The data points in the figures represent the average of repeat ^{53}Cr/^{52}Cr measurements (30-40 runs, 300 ratios each) versus ^{55}Mn/^{52}Cr ratios. The relative abundances of ^{54}Cr in TR, Chr, and Sil are +1.24±0.18 ε, +1.28±0.18 ε, +1.31±0.18 ε, respectively, and are essentially the same. The average from all three fractions is +1.28±0.11 ε.

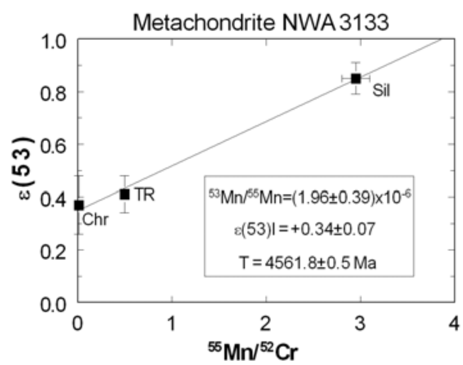

Figure 1. *^{53}Mn-^{53}Cr systematics in the metachondrite NWA 3133. "Raw" data (no second order correction applied to the ^{53}Cr/^{52}Cr ratios, see text).*

From the slope of the isochron we calculate a ^{53}Mn/^{55}Mn ratio of (1.96±0.39) x 10^{-6} at the time of isotope closure. Using our new absolute time marker [6], the angrite NWA 4801, we calculate an absolute age. The Pb-Pb age of NWA 4801 is 4558.0±0.13 Ma [7] and the corresponding ^{53}Mn/^{55}Mn ratio is (0.96±0.04) x 10^{-6} [6]. We obtain a metamorphic age of NWA 3133 of 4561.8±0.5 Ma. The initial ^{53}Cr/^{54}Cr ratio at the time of isotope closure is +0.34±0.07 ε. Because we found that the excesses of ^{54}Cr are the same in all fractions of NWA 3133 (well equilibrated), we also used the second order corrected data. The results are given in Fig.2.

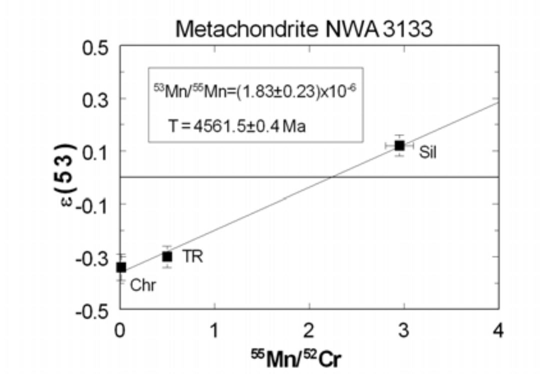

Figure 2. *^{53}Mn-^{53}Cr systematics in the metachondrite NWA 3133. The data are second order corrected (see text).*

We calculate from the slope a ^{53}Mn/^{55}Mn ratio of (1.83±0.23) x 10^{-6} at the time of isotope closure. Within the uncertainties this value is the same as obtained from the "raw" data but the uncertainty is smaller. Again using the angrite NWA 4801 as an absolute time marker, we calculate an absolute age of 4561.5±0.4 Ma. This again demonstrates that the application of the second order fractionation correction is a useful tool for obtaining well-resolved ages even for samples with anomalous ^{54}Cr. Obviously, initial ^{53}Cr/^{52}Cr ratios can only be determined from the "raw" data. However, the age calculations are based merely on the isochron slopes.

The age of NWA 3133 is relatively ancient. It postdates the formation of the first condensates in the early solar system only by ~6 Ma. However, it is younger that the group of old eucrites (such as Juvinas and Chervony Kut) and angrites (such as D'Orbigny and Sahara 99555): 4563-4565 Ma [3,7]

The excess of ^{54}Cr (+1.28±0.11 ε) in NWA 3133 clearly indicates that the precursor of this meteorite was a carbonaceous chondrite material since only this class of meteorites is characterized by elevated relative abundances of ^{54}Cr. The exception is the pallasite Eagle Station. We have shown [4] that this meteorite has an excess in ^{54}Cr of +0.71±0.20 ε. This value is indistinguishable from that found in the CV chondrite Allende: +0.85±0.17 ε [4]. This strengthens the conclusions of earlier studies [8,9] (based on the investigations of chemical compositions and oxygen isotopes) and that the precursor of Eagle Station may have been part of a CV-type parent body.

The excess of ^{54}Cr in NWA 3133 (+1.28±0.11 ε), however, is clearly larger than in CV chondrites. It is similar to to the relative ^{54}Cr abundance in the CM chondrite Murray: +1.13±0.0.21 ε. We also note that the excess of ^{53}Cr in the bulk sample (TR) of NWA 3133 (+0.41±0.07 ε) is considerably larger than in the bulk Allende: +0.10±0.09 ε and is similar to that in the bulk samples of the CI chondrites Orgueil and Ivuna: 0.40±0.10 ε [4].

Thus, the Cr isotope systematic may imply that the precursor of the metachondrite NWA 3133 was a complex conglomerate of different carbonaceous chondrite lithologies or represents a yet unknown type of carbonaceous chondrite.

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References: [1] Irving A.J. et al. (2005) *Meteoritics & Planet. Sci., 40*, Abstract #5218. [2] Schoenbeck T.W. et al. (2006) *LPS XXXVII*, Abstract #1550. [3] Lugmair G.W. and Shukolyukov A. (1998) *GCA, 62*, 2863-2886. [4] Shukolyukov A. and Lugmair G.W. (2006) *Earth Planet. Sc. Lett., 250,* 200-213. [5] Trinquier A. et al. (2007) *ApJ, 655*,1179-1185. [6] Shukolyukov A. et al. (2009) *LPS XL,* Abstract #1381. [7] Amelin Y. and Irving A. J. (2007) *Workshop on Chronology of Meteorites*, Abstract #4061. [8] Scott E.R.D. (1977) *GCA, 41*, 349-360. [9] Clayton R.N. and Mayeda T.K. (1996) *GCA, 60*, 1999-2017.