MN – CR ISOTOPE SYSTEMATICS OF ANGRITE NORTHWEST AFRICA 4801. 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: Chronometers based on the decay of short-lived radionuclides give the opportunity to resolve time differences of less than a million years for early events in the solar system. However, with short-lived radionuclides only relative ages can be obtained. These relative ages have to be mapped onto an absolute time scale. The absolute age is provided by the Pb-Pb chronometer which is capable of producing ages with the precision comparable to that of short-lived chronometers.

For more than a decade for the Mn-Cr relative chronometer we used the angrite LEW 86010 as an absolute time marker. The Pb-Pb age of this meteorite is 4557.8±0.4 Ma [1] and the corresponding $^{53}Mn/^{55}Mn$ ratio is (1.25±0.07) x 10^{-6} [2]. The angrites are especially suitable as time markers because they are early equilibrated planetary differentiates that mostly are undisturbed by later events. Since then a series of new angrites was discovered and high-resolution Pb-Pb ages have been obtained [3]. However, small but systematic differences between the “absolute” Mn-Cr ages and the Pb-Pb ages can be observed: the latter are slightly older, if LEW 86010 is used as a time marker (e.g. [4]). Moreover, a recently re-determined Pb-Pb age of LEW 86010 is 4558.55±0.15 Ma that is ~0.8 Ma older than the age we previously used [3]. Therefore, the goal of this work is an attempt to conduct a thorough investigation of the Mn-Cr isotope system in another angrite, NWA 4801, that is abundant in a high Mn/Cr phase (olivine) and for which a precise Pb-Pb age is now available: 4557.99±0.12 Ma [3]. For the purpose of simplicity we adopt here a value of 4558.0±0.13 Ma.

Northwest Africa 4801: The recently discovered (May 2007) meteorite NWA 4801 was classified by Irving and Kuehner [5] as a plutonic igneous cumulate angrite. This angrite has a metamorphosed texture and is coarse-grained (grain size 0.1-1.2 mm). Although it has an overall cumulus texture, there is evidence for subsequent annealing. The meteorite consists mostly of Al-Ti clinopyroxene and anorthite (some as polycrystalline aggregates), calcic olivine, pleonaste, merrillite and minor troilite and altered metal. Anorthite includes infrequent Cr-pleonaste grains (Cr_2O_3 = 6.3 wt.%). Some clinopyroxene and olivine are poikilitically enclosed in Cr-poor pleonaste mantles around large Cr-pleonaste grains. Merrillite is more abundant than in most other known angrites [5].

Experimental, Results, and Discussion: To obtain phases with different Mn/Cr ratios we first applied our usual differential dissolution procedure that allows separating chromites from silicates. Silicates (Sil) were dissolved in an HF/HNO_3 mixture at room temperature, the residue (Res 1) (mostly chromite with some remaining silicates) was dissolved in the same mixture at ~180º C, and the remaining tiny grains (Res 2) (chromite) were dissolved at ~180º C in $HClO_4$. From a separate piece of the meteorite the olivine phase (Olv 1 and Olv 2) was separated by handpicking at the University of Washington. We have measured $^{53}Cr/^{52}Cr$ ratios and Mn and Cr abundances in all these fractions and in a total rock fraction (TR). Because of the high Fe/Cr ratios in olivine (~860) and the high cosmic ray exposure age (31.6 My [6]) the Cr isotopic compositions in Olv 1 and Olv 2 were corrected for a spallation contribution (~ 7 ppm).

As in the past, in order to achieve higher precision on the $^{53}Mn/^{55}Mn$ ratio, we have applied the second order fractionation correction to the $^{53}Cr/^{52}Cr$ data based on the $^{54}Cr/^{52}Cr$ ratios [2]. This procedure assumes no excesses or deficits of ^{54}Cr. However, it was shown recently [7], that bulk samples of some meteorite classes, including the angrite Angra dos Reis, possess relative deficits of ^{54}Cr. Our data for NWA 4801 also show a deficit of ^{54}Cr: -0.35±0.06 ε. This is essentially the same value that was obtained for Angra dos Reis: -0.36±0.07 ε [7]. Here we present both the second order corrected data and the ‘raw’ data (*i.e.* with no second order fractionation correction applied).

The results are presented in Figures 1 and 2.

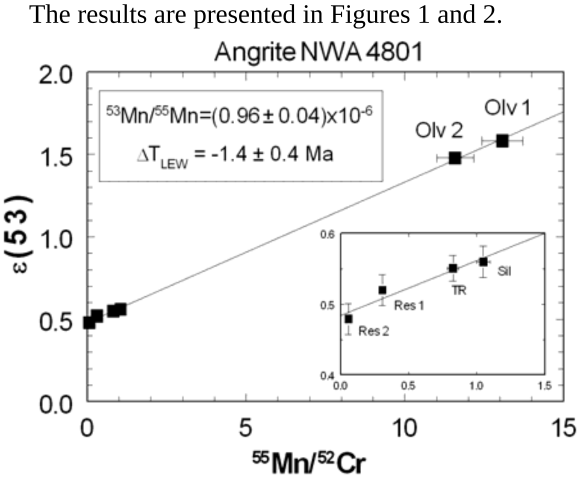

Figure 1. ^{53}Mn-^{53}Cr systematics in the angrite NWA 4801. The data are second order corrected (see text).

From the slope of the isochron (Figure 1, second order corrected data) we calculate a $^{53}Mn/^{55}Mn$ ratio of (0.96±0.04) x 10^{-6} at the time of isotope closure. This yields a time difference between NWA 4801 and LEW 86010 of -1.4±0.4 Ma, i.e. NWA 4801 is ~1.4 Ma younger. Figure 2 shows less precise "raw" data. Although the uncertainty in the "raw" data is larger, the calculated $^{53}Mn/^{55}Mn$ ratios obtained from both isochrons agree well.

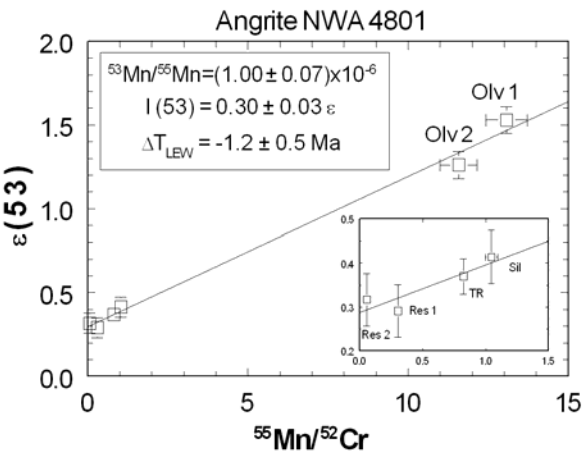

Figure 2. ^{53}Mn-^{53}Cr systematics in the angrite NWA 4801. "Raw" data (no second order correction applied to the $^{53}Cr/^{52}Cr$ ratios, see text).

The $^{53}Mn/^{55}Mn$ ratio is (1.00±0.07) x 10^{-6}. This translates into a time difference between NWA 4801 and LEW 86010 of -1.2±0.5 Ma. As in our recent publications [8,9] 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. We note again that the age calculations are based merely on the isochron slopes. The true initial $^{53}Cr/^{52}Cr$ ratio calculated from the "raw" data is 0.30±0.03 ε.

There is a some disagreement between $\Delta T_{NWA\text{-}LEW}$ calculated using the Mn-Cr and Pb-Pb isotope systems. $\Delta T_{NWA\text{-}LEW}$ is ~0.8 Ma and ~1.2-1.4 Ma using the Pb-Pb and the Mn-Cr chronometers, respectively. The reason for this difference is not yet understood. However, if we use NWA 4801 as a time marker with a Pb-Pb age of 4558.0±0.13 Ma [after 3] and a $^{53}Mn/^{55}Mn$ ratio of (0.96±0.04) x 10^{-6} - this work) the overall agreement between Pb-Pb ages and "absolute" Mn-Cr ages for the angrites is much improved. For example, the Pb-Pb age of the angrite D'Orbigny is 4564.42±0.12 Ma [3]. The Mn-Cr age calculated using 4557.8±0.4 Ma for LEW 86010 [1] is ~1.6 Ma younger [10]. However, using NWA 4801 as a time marker yields a Mn-Cr age of 4564.3±0.5 Ma – essentially the same as the Pb-Pb age. Similarly, the agreement between the Pb-Pb and Mn-Cr ages for the angrite Sahara 99555 becomes considerably better. Further, our recent calculation of the timing of the last mantle fractionation within the angrite parent body, based upon ^{53}Mn-^{53}Cr systematics anchored to LEW 86010, yielded 4563.2±0.6 Ma [8]. A comparison with the Pb-Pb ages of the "old" angrites such as D'Orbigny and Sahara 99555 (~4564.5 Ma) would imply that the formation of these individual angrites predates mantle fractionation, which does not appear plausible. Using NWA 4801 as a time marker yields the time of mantle fractionation at 4564.6±0.5 Ma ago. This time is coeval with formation time of the oldest angrites and, thus, the contradiction is removed.

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