THE MN-CR ISOTOPE SYSTEMATICS IN THE UREILITES KENNA AND LEW85440. A. Shukolykov and G.W. Lugmair, Scripps Institution of Oceanography, University of California, San Diego, La Jolla CA 92093-0212, USA

Ureilites are coarse-grained olivine-pigeonite ultramafic rocks with equilibrated textures, and homogeneous mineral compositions (e.g. [1]). The high depletion in REE indicates that the ureilite parent body (UPB) underwent extensive igneous processing. Some properties of ureilites (e.g. their unusual Ca/Al ratios, the diversity of REE abundances in the plagioclase) are difficult to reconcile with single-stage melting models [2]. Ureilites have several properties that are typical for primitive materials. Specifically, olivine-pigeonite ureilites contain carbon-metal veins with a trapped noble gas component that is among the most primitive observed in meteorites [1]. These features are difficult to explain if the ureilite parent body experienced planetary scale differentiation. For these reasons it was suggested that the ureilites formed as partial melt residues of a chondritic precursor and that the UPB has not experienced igneous processing on a large scale [1]. Oxygen isotopes in the ureilites plot along a mixing line between CAIs, dark inclusions and matrix in carbonaceous chondrites [3]. The recent petrologic and the oxygen isotope study suggests that carbonaceous chondrite type materials may be the probable UPB precursors [2]. It was shown earlier that, in contrast to most meteorite classes, the bulk samples of carbonaceous chondrites are characterized by excesses of the isotope ^{54}Cr [4,5]. This ^{54}Cr excess provides a potential possibility to establish a genetic link between the ureilites and the carbonaceous chondrites by measuring the Cr isotopic composition in bulk ureilite samples. The other important aspect of investigating ureilites is the UPB chronology that is poorly known. The recent Mn-Cr study of the polymict ureilite DaG 165 [6] indicates that at least some of the ureilites formed (or last equilibrated) early in the history of the solar system (~4562 Ma ago) and that the ^{53}Mn-^{53}Cr isotope chronometer can be used to date processes within the UPB. Thus, the goal of this work was to test if the ureilites are indeed genetically linked to carbonaceous chondrites and to obtain chronological information on magmatic processes within the UPB.

We started our study with the ureilites Kenna and LEW 85440. To obtain phases with different Mn/Cr ratios we applied a differential dissolution procedure. A 0.98 g sample of Kenna was ground to a grain-size smaller than 200 μm and two size fractions were generated: <45 μm and 45-200 μm. These fractions were treated with 0.5 N acetic acid. Surprisingly, even such a weak acid dissolved a relatively large portion of the material: 8.5% in Leach 1(<45 μm) and 1.8% in Leach 2 (45-200 μm). The high Fe and Mg concentrations in the leaches suggest that olivine was partly dissolved. The residue was dissolved in an HF/HNO_3 mixture at room temperature. The remaining residue was further dissolved in an HF/HNO_3 mixture at ~180°C. For LEW 85440 the first step (0.5 N acetic acid) was omitted. In addition, we analyzed total rock (TR) samples of these meteorites.

We have measured the Mn/Cr ratios and the Cr isotopic composition in all these samples. In order to achieve higher precision we applied the second order fractionation correction based on the ^{54}Cr/^{52}Cr ratio [7]. This procedure assumes no excesses or deficits of ^{54}Cr, which is the case for many meteorite classes. However, for example, the bulk samples of carbonaceous chondrites have variable excesses of ^{54}Cr [4,5]. There are recent additional data [5,8] indicating deficits of ^{54}Cr in several meteorite classes. Here we present both the normalized (the second order fractionation correction is applied) and the raw ratios. The results are presented in Figures 1-3. The ^{53}Cr/^{52}Cr and ^{54}Cr/^{52}Cr ratios (or ε(53) and ε(54)) are given as the relative deviation from the terrestrial standard value and are expressed in ε - units (1 ε is one part in 10^4).

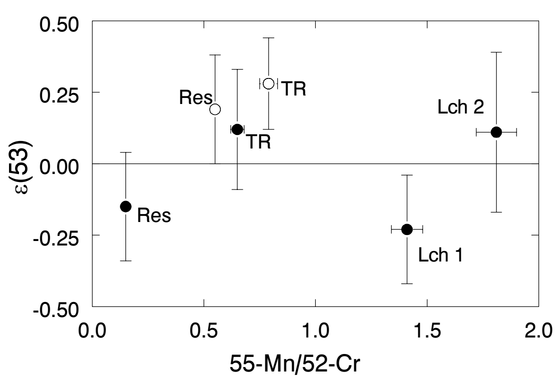

Fig.1 RAW ^{53}Cr/^{52}Cr ratios in various phases in ureilites. Here and in the other figures Kenna samples are indicated by filled symbols, LEW 85440 samples by open symbols.

When the raw ^{53}Cr/^{52}Cr ratios are plotted versus their respective ^{55}Mn/^{52}Cr ratios (Fig. 1) no correlation of the ^{53}Cr excesses with the ^{55}Mn/^{52}Cr values is observed in Kenna and LEW 85440 (only two data points are presently available). At first glance the scatter of the data points may imply that the Mn-Cr isotope system in Kenna is disturbed. We note, however, that there is a clear correlation between the $^{53}Cr/^{52}Cr$ and $^{54}Cr/^{52}Cr$ ratios for all samples (Fig.2). This correlation is due to the residual mass fractionation effect as is also observed for the terrestrial standards. The slope of the line in Fig. 2 is the same as for the standards. The second order fractionation correction can be applied to remove this effect.

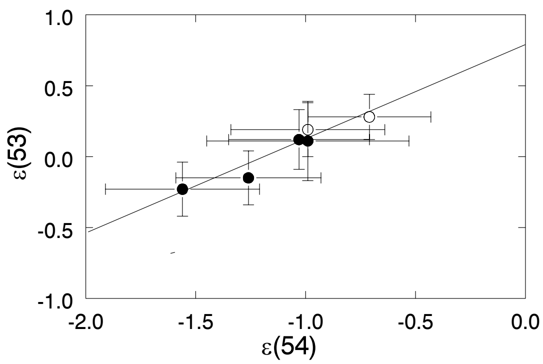

Fig.2 Correlation between raw $^{53}Cr/^{52}Cr$ and $^{54}Cr/^{52}Cr$ ratios caused by the residual mass fractionation effect.

After correction for this effect it becomes apparent from Fig. 3 that all data points from both meteorites fall within a few ppm on the same horizontal line at ~0.7 ε(53). This indicates that the Cr isotopes equilibrated in these meteorite after all ^{53}Mn had decayed. The ^{53}Cr excesses in the Kenna and LEW 85440 total rock samples are the same. This implies that the sources of these meteorites also formed late and/or that they were the same.

One important finding is that the $^{54}Cr/^{52}Cr$ ratios for both ureilites indicate a clear deficit in ^{54}Cr (see Fig. 2).

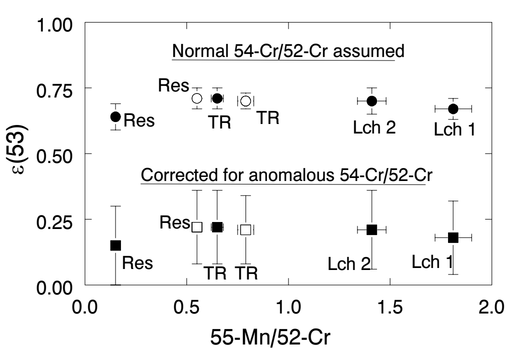

Fig.3 Normalized $^{53}Cr/^{52}Cr$ ratios, “apparent” (top) and “true” (bottom). For the true ratios the uncertainties in the $^{54}Cr/^{52}Cr$ ratios were taken into account.

As mentioned above, the variation of the $^{54}Cr/^{52}Cr$. ratios (from -1.6 ε up to -0.7 ε, Fig. 2) is due to a residual mass fractionation effect. However, ε(54) is clearly negative. Our current best estimate for the $^{54}Cr/^{52}Cr$ ratio in these ureilites is –0.92±0.20 ε. This value agrees well with the recently published preliminary value of –0.97±0.16 ε for the ureilite Y791538 [8].

As is obvious, the application of the second order fractionation correction provides a much better resolution for $^{53}Cr/^{52}Cr$ ratios. This is demonstrated by the comparison of the uncertainties in Fig. 1 and Fig. 3. Thus, even for samples with anomalous ^{54}Cr this procedure is applicable for precise calculations of the slopes of isochrons. However, in such cases, deficits or excesses of ^{54}Cr would translate into apparent excesses or deficits of ^{53}Cr - the data points would be shifted along the y-axis (without any change of the slopes of the isochrons). Although, as shown here, the data points can be returned to their correct positions.

To determine the actual $^{53}Cr/^{52}Cr$ values for the analyzed samples we used our best estimate of ε(54) = -0.92±0.20 ε. This value allows to compensate for the systematic shift due to application of the second order correction that is made with the assumption of normal ^{54}Cr (Fig. 3). The uncertainties in the $^{53}Cr/^{52}Cr$ ratios became larger because the uncertainty in $^{54}Cr/^{52}Cr$ ratio (±0.20 ε) is propagated. However, it is still smaller than that of the raw ratios. Thus, the actual ε(53) in the total rock samples of Kenna and LEW 85440 are 0.22±0.14 ε and 0.22±0.13 ε, respectively.

In summary, we found that in contrast to the ureilite DaG 165, Kenna and LEW 85440 are young: the Cr isotopes equilibrated after ^{53}Mn had decayed. The UPB is characterized by an anomalous $^{54}Cr/^{52}Cr$ ratio that is deficient in ^{54}Cr. This indicates that the precursor material of the UPB was different from the known carbonaceous chondrite classes. Finally, the second order fractionation correction procedure is a useful tool, even for samples with an anomalous abundance of ^{54}Cr.

References. [1] Goodrich et al. (2001) *GCA*, *65*, 621-652. [2] Kita et al. (2004) *GCA*, *68*, 4213-4235. [3] Clayton and Mayeda (1988) *GCA*, *54*, 1313-1318. [4] Shukolyukov and Lugmair (2000) *MAPS*, *35*, A146. [5] Trinquier et al. (2005), *LPS*, Abstract #1259. [6] Goodrich et al. (2002) *MAPS*, *37*, A54. [7] Lugmair and Shukolyukov (1998), *GCA*, *62*, 2863-2886. [8] Yamashita et al. (2005) *Antarctic Meteorites XXIX*, 100-101.