THE NWA 7325 UNGROUPED ACHONDRITE – POSSIBLE LINK TO UREILITES? OXYGEN AND CHROMIUM ISOTOPES AND TRACE ELEMENT ABUNDANCES.

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Introduction: Northwest Africa (NWA) 7325 is an ungrouped achondrite that consists of olivine, anorthite, and diopside with high Mg# (molar [MgO]/[MgO+FeO]%) mafic minerals (~97) and shows bulk oxygen isotope ratios similar to ureilites [1]. The bulk NWA 7325 is depleted in incompatible trace elements, such as REE and U-Th [1-2]. These characteristics do not match any known achondrite groups and [1] suggested that NWA 7325 could be from Mercury. . However, the U-Pb age of NWA 7325 is reported to be 4562.5±4.4 Ma [2]; which is probably too old to be of mercurian origin.

The only objects in the meteorite literature that match the observed chemical and mineralogical characteristics of NWA 7325 are An-rich plagioclase-bearing clasts with high Mg# mafic minerals described in the Dar al Gani (DaG) 319 polymict ureilite [3-4]. Clasts γ8 and β34A in DaG 319 show ureilitic oxygen isotope signatures, indicating they might be derived from ureilite parent body (UPB) [4]. Plagioclase in γ8 and another anorthite fragment γ18 are highly depleted in incompatible trace elements, such as K, Ba, and Ti, suggesting that their source regions experienced fractional melting processes [4], which were also proposed as a differentiation model of UPB [5].

In order to examine the relationship between NWA 7325 and the UPB, we report SIMS oxygen isotope analyses of silicate minerals and trace element (Mg, K, Sc, Ti, Cr, Mn, Fe, Sr, and Ba) analyses in plagioclase, and bulk Cr isotope analyses. The detailed petrology of the NWA 7325 is reported in [6].

Methods: The SIMS oxygen three-isotope analyses and plagioclase trace element analyses were conducted using the IMS-1280 at University of Wisconsin using the methods similar to [4, 7]. For oxygen isotope analyses, the Cs^+ primary beam was focused to 15μm spot and the reproducibility of $\delta^{18}O$, $\delta^{17}O$, and $\Delta^{17}O$ for San Carlos olivine standard were 0.3-0.5 ‰ using multi-collection Faraday Cups [7]. For Cr isotopic analysis, sample dissolution, Cr separation, and mass spectrometry procedures were identical to those described in [8] and references therein.

Results: A total of 19 oxygen isotope analyses were obtained from olivine, pyroxene, and plagioclase (Fig. 1). As described in [6], plagioclase contains μm-scale Na-rich domains that appear darker in BSE images, which might be caused by shock. We tried to avoid overlapping with dark domains as much as we could. Most data show a cluster on the three-isotope diagram and are consistent with bulk analyses [1]. The $\delta^{18}O$ values slightly increase from pyroxene, olivine, and plagioclase, but there is no systematic variation in $\Delta^{17}O$ values among the three minerals. One plagioclase datum, which overlapped with Na-rich dark domains, deviates toward the ^{16}O-poor side. Excluding this outlier, the average $\Delta^{17}O$ value is –0.90±0.13‰ (2SE, n=18).

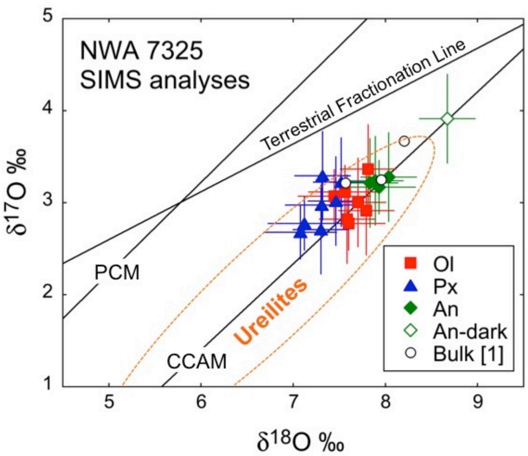

Fig. 1. SIMS oxygen isotope analyses of minerals in NWA 7325. The range of bulk ureilites is from [9]. CCAM line [10] and PCM line (defined from chondrules in Acfer 094 [11]) are shown as references.

We obtained 7 trace element analyses of plagioclase, which are shown in Fig. 2. We also analyzed dark domains of plagioclase and found elevated Mg and Cr contents, while concentration of other elements were nearly the same. Trace element abundances in NWA 7325 plagioclase are very similar to those in the An-rich plagioclase in DaG 319 [4], showing low Fe contents and a significant depletion in K, Ti, and Ba, while Mg contents are high. Sr contents (not shown) were homogeneous (320 ppm) and similar to those in An-rich plagioclase in DaG 319 (~200 ppm, [4]).

The results of Cr isotope analyses are shown in Fig. 3, in which $\varepsilon^{54}Cr$ and $\Delta^{17}O$ values of NWA 7325 are compared to other types of meteorites. The NWA 7325 data plot close to acaplucoite data, while the $\varepsilon^{54}Cr$ value of NWA 7325 is clearly resolved from the range observed from multiple ureilites [12].

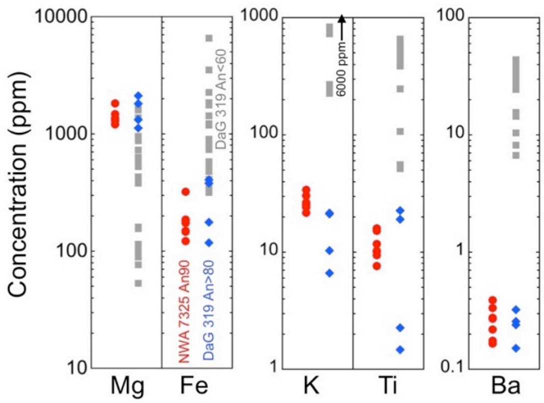

Fig. 2. Trace element concentrations in NWA 7325 plagioclase (red circles) and DaG 319 feldspathic clasts (blue diamonds for An-rich plagioclase An>80 and grey squares for Ab-rich plagioclase An<60 [4]).

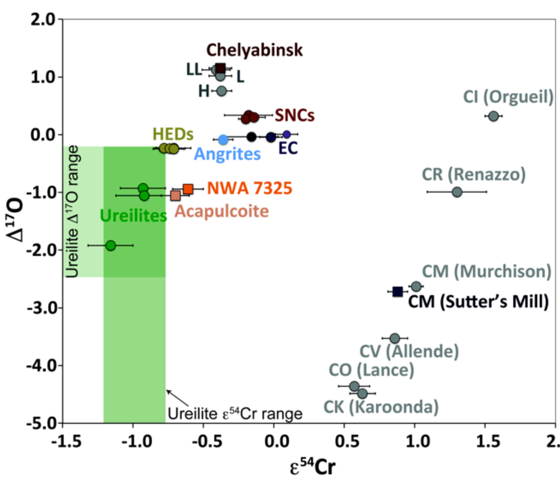

Fig. 3. Cr isotope ratios of NWA 7325 in comparison to oxygen isotopes ($\Delta^{17}O$). Literature values for $\varepsilon^{54}Cr$ and $\Delta^{17}O$ data are provided in [13] and references therein.

Discussion: Oxygen isotope ratios and trace element abundance in plagioclase from NWA 7325 are very similar to those of high-Mg# An-rich plagioclase-bearing clasts in polymict ureilites. Olivine in NWA 7325 shows subchondritic Mn/Mg ratios, similar to that of clast γ8 [6]. However, ε^{54}Cr values of NWA 7325 are different from those of ureilites, suggesting that NWA 7325 is not from the UPB. The ε^{54}Cr-Δ^{17}O diagram shows a similarity between acaplucoites and NWA 7325, though acaplucoites are very different in mineralogy and chemistry from NWA 7325 [6]. Thus, NWA 7325 represents a separate achondrite group originating from a previsouly unsampled parent body.

As discussed in [4] for An-rich clasts in DaG 319, the parental magma of NWA 7325 would be enriched in Sr, but depleted in Ti, Ba, and K. The selective depletion of highly incompatible elements (Ti, Ba, and K) requires the prior removal of low-degree partial melts [4]. Thus, the source regions of NWA 7325 experienced fractional melting processes similar to those proposed for UPB differentiation [5]. The old U-Pb age of NWA 7325 [2] is consistent with early differentiation of an asteroidal body, similar to the UPB [12, 14-15]. Fractional melting would be one of the important processes in the early stages of planetsimal differentiation that resulted in significant depletion of incompatible trace elements.

Recent oxygen isotope studies of chondrules in primitive chondrites and primitive achondrites [e.g., 11, 16] suggest that primary oxygen isotope reservoirs of solids in the protoplanetary disk are represented by a slope 1 line that locate to the left of the CCAM line (PCM; Fig. 1). They suggest that aqueous alteration on parent asteroids would modify oxygen isotope ratios towards the CCAM line. It is possible that both the UPB and the parent body of NWA 7325 experienced aqueous alteration at lower temperatures prior to igneous differentiation, which resulted in their observed oxygen isotope ratios on the CCAM line. This particular mechanism would require that the NWA 7325 parent body accreted in the outer asteroidal regions where water ice was available.

Conclusions: The ungrouped meteorite NWA 7325 might be derived from a previously unsampled asteroid, either a common or a similar source as that of the rare An-rich and high Mg# clasts in polymict ureilites. The parent body of NWA 7325 and the UPB probably derive from the outer asteroidal region and experienced similar parent body processes.

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