

IS THERE ANY EVIDENCE TO LINK OXYGEN ISOTOPIC ABUNDANCES TO THE PROCESS THAT CONTROLLED THE REDOX STATE OF CHONDRULES: A STUDY OF NWA 7731? H. C. Connolly Jr.^{1,2,3,4}, K. Domanik⁴, C. B. Agee⁵, K. Ziegler⁵, K. Nagashima⁶, G. R. Huss⁶, H. Barcena^{1,2,3} and M. K. Weisberg^{1,2,3}.

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Introduction: We have been investigating the redox conditions experienced by ferromagnesian chondrules with a specific interest on constraining what process or processes controlled chondrule redox. To solve this problem, we are testing the following hypotheses [1,2]: (1) Chondrule redox was controlled by reaction of molten chondrules with ambient gases, (2) Chondrule redox was controlled by their precursors materials, or (3) Chondrule redox was controlled by a combination of both (1) and (2). Furthermore, we have been collecting data to find out if the oxygen isotopic composition of chondrules is linked with their redox state and, if so, what processes may have controlled both chondrule redox states and their oxygen isotopic abundances.

The L3.0 Unequilibrated Ordinary Chondrites (UOC), NWA 7731, was officially recognized in 2012 [3]. Because there are only a handful of L 3.00-3.05 chondrites known, and we have studied two already [1,2], a detailed petrographic and petrologic characterization of NWA 7731 is required to better understand this chondrite and its relationship to others UOCs. Thus, adding an investigation of NWA 7731 to our research goals is warranted. In addition to the main focus of our study, we have expanded it to simultaneously investigate the overall petrographic and petrologic nature of NWA 7731. However, in this work we focus on our initial oxygen isotope data.

Analytical methods: A *pristine* thin section of NWA 7731 from the collection of the Institute of Meteoritics was investigated. BSE-images along with major and minor element abundances in silicates, oxides, opaques, and glasses were obtained with the SX-100 at the Lunar and Planetary Laboratory. X-ray maps were created at high resolution, *following* analyses. Oxygen isotope abundances in olivine and pyroxene (Ca-poor) were analyzed with the Cameca ims 1280 ion microprobe at the University of Hawai'i at Mānoa [4].

Results: General Petrography: Petrographically, we divided the thin section into chondrules and then regions of interest (ROI) within the matrix. To date we have investigated 21 chondrules or chondrule

fragments in considerable detail. Texturally, a total of 17 chondrules or fragments are porphyritic, one is barred olivine-pyroxene, one is transition barred to porphyritic, one transitional barred pyroxene to radial pyroxene and . They span a range of chemical types: IA, IAB, IB, IIA, IIAB and IIB. Abundance of different textural and chemical types of chondrules found in NWA 7731 is very similar to 3.00-3.05 UOCs as are their olivine compositions. We have also investigated 7 areas of interest in the matrix and will report these results elsewhere.

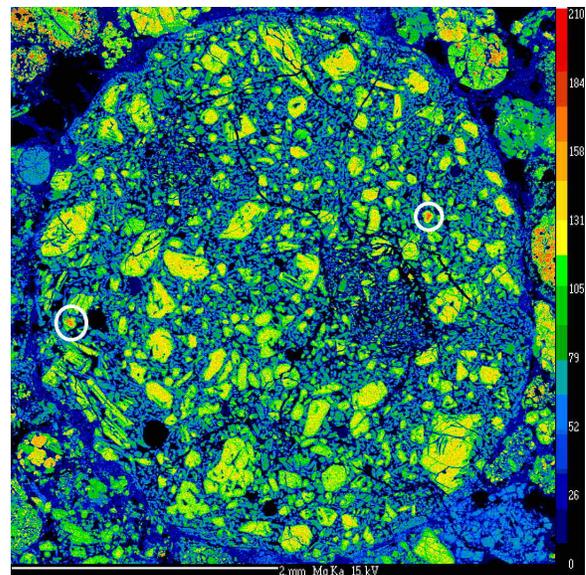


Figure 1. MgK α map of Chondrule 1. Circles highlight relict grains. Note scale bar is 2 mm in length.

Of the 21 chondrules analyzed, 9 were chosen for *in situ* oxygen isotope analysis with SIMS. These chondrules were chosen because they contained something of petrographic interest (e.g., size, relict grains, crystal form, etc.). The investigated chondrules (or fragments) that we have oxygen isotope data are chemical types: IA (Ch 2), IAB (Ch 4, 7 & 8), IB (Ch 9), type IIA (Ch 1 & 5), -IIB (Ch 6) and one agglomeratic olivine chondrule (Ch 3). Chondrule 1, which is ~ 4 mm in apparent diameter,

contains several petrographically identifiable relict grains (Fig 1). Although this chondrule is large, it is not unusual to find such chondrules in UOCs. It is also noteworthy to mention the mesostasis contains up to ~ 6 wt% Na_2O and ~ 1.3 wt% K_2O and that these are not the highest values analyzed (Ch 5 contains up to 11 wt% Na_2O , but curiously K_2O below detection).

Oxygen Isotopes: We analyzed 18 olivine and 17 orthopyroxene grains from 9 chondrules in NWA

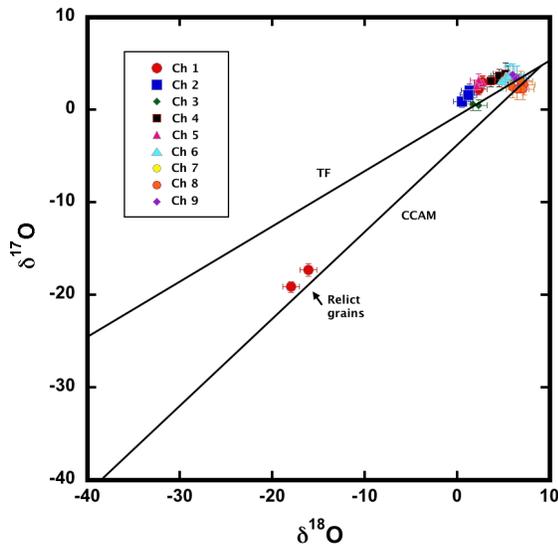


Figure 2. Three-isotope oxygen diagram of data from this investigation.

7731 (Fig. 2). The bulk of the *in situ* data cluster around the TF and CCAM lines, with some grains plotting on CCAM line, not unlike the data of [1,2] from UOCs (Fig. 3), but slight different than reported by [5]. Relict grains from Ch 1 are more ^{16}O -rich than phenocrysts, consistent with other data [1,2,5]. Olivine and pyroxene grains from the same chondrules are plotted with the same symbols to lessen confusion on these small images because no discernable difference exists in their isotopic values.

Discussion: Our data shows that the *in situ* oxygen isotopic compositions of olivine and pyroxene within chondrules of NWA 7731 are within the range previously observed for other UOCs [1,2,5]. Although we have limited data for type II chondrules, we predict that the oxygen isotopic values for other type II chondrules from NWA 7731 will cluster in a tight grouping on to slightly above the TF line as shown by [1,2] for MET 00526,9 and QUE 97008,14 (both L3.05) and as shown by [5] for Semarkona (LL3.00), Bishunpur and Krymka

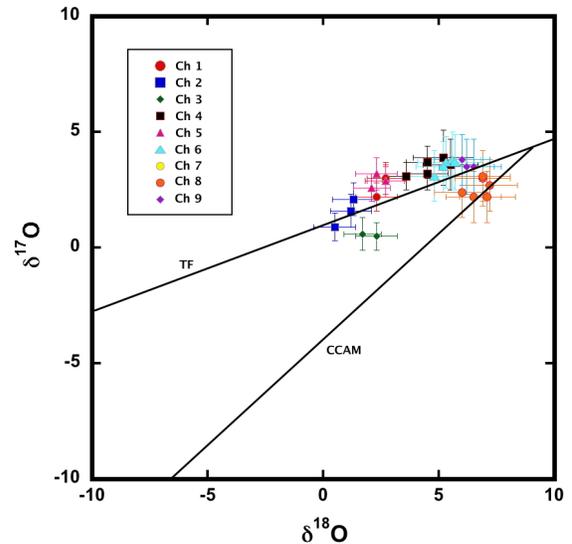


Figure 3. Magnified plot of Figure 1 showing the data that clusters around the TF-CCAM join.

(LL3.1). To explain the narrow range in oxygen isotope composition of type II chondrules compared with type I, a hypothesis was posed by [2] that, as chondrules were increasingly recycled, the final product was type II chondrules. Thus, we predict type II chondrules will always have a more homogenous oxygen isotopic composition than type I.

Type I chondrules show a wide range in oxygen isotope abundance compared with type II. Thus, a gross link between the redox state of chondrules and oxygen isotopic compositions exists. Incorporation of carbon-phases or ices (e.g. H_2O) as chondrule precursors could have controlled their redox state and brought their unique oxygen isotopic signatures. This is especially true for H_2O ice, which would have a lighter composition than silicates and also potentially explain the redox state of type II chondrules [8]. We find no evidence for mass-dependent fractionation in oxygen isotopes, which might be expected if carbon was a reducing agent in type I chondrules [7]. However, lack of such evidence cannot be interpreted as refuting the hypothesis that carbon may have been a precursor of type I chondrules.

References: [1] Connolly et al. (2012) *LPSC* abst#2204. [2] Connolly et al., (2012) *MaPS* abst#5236. [3] Agee C. B. et al., (2013) *MaPS*, # 5130. [4] Makida et al. (2009) *GCA*. [5] Kita et al. (2010) *GCA* **74**, 6610. [6] Connolly et al. (1994) *Nature* **371**, 136. [7] Barcena and Connolly (2012) *LPSC* #2506. [8] Connolly and Huss (2010) *GCA* **74**, 2473. This research funded by NASA grants NNX09AB86G to HCCJr.