The Oxygen Isotope Systematics of the L3.00 Ordinary Chondrite NWA 7731 and a Comparison to LL3.00 Semarkona

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1 INTRODUCTION:

- NWA 7731 is an 81 gram, single stone, with black, lightly weathered, fusion crust, and densely packed chondrules of variable size (mean 500 µm; consistent with L-group) set in a brown and a fine-grained opaque matrix. Many chondrules contain igneous-zoned porphyritic olivines and mesostasis [1] (*Fig. 1*).

Figure 1. Slice of NWA 7731 showing dense packing of chondrules of varying sizes.

- It was recognized as an L3.00 Unequilibrated Ordinary Chondrites (UOC) in 2012 [1], and, thus, was the first and only approved L3.00 until NWA 8276 was approved as L3.00 on March 6, 2014.
- Classification was based on several parameters:

  (1) electron microprobe analyses of individual coarse ferroan chondrule olivines from NWA 7731 gave mean values $Fa_{15.0\pm5.7}$, Fe/Mn=42±13, Cr_2O_3=0.43±0.11 wt.% [1]. Such high mean Cr_2O_3 contents with relatively low standard deviation are consistent with petrologic type 3.00 [2]. These results are strikingly similar to the LL3.00 Semarkona (*Fig. 2*); and

  (2) sulfur-rich opaque matrix and igneous zoning of Cr in olivine correlating with Fe in NWA 7731 [1] are further features of the most primitive petrologic grade in type 3 chondrites, and the latter is also observed in Semarkona.

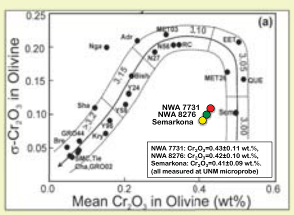

Figure 2. Plot of standard deviation vs. mean of Cr_2O_3 content of ferroan olivine in ordinary chondrites [2], with L/LL 3.00 data (this study) added.

- Due to the highly unequilibrated nature, oxygen isotope analyses of bulk rock analyses are less unequivocal in classifying UOCs than for other meteorite groups. Here, we present bulk oxygen isotope analyses of NWA 7731, and compare it with other UOCs.
- See H. Connolly's complementing *in-situ* oxygen isotope analyses of individual chondrule minerals: tomorrow @ 8:45 am - Ballroom 5.

2 ANALYTICAL METHODS:

- All samples were acid-washed prior to isotope analysis.
- Oxygen isotope analyses ($\delta^{18}O$, $\delta^{17}O$) were performed on 1-2 mg bulk rock ample aliquots using laser fluorination [3] at UNM. $\Delta^{17}O$ values were calculated from $\Delta^{17}O = \delta^{17}O - 0.528 \times \delta^{18}O$.
- Molecular O_2 was extracted in a BrF_5-atmosphere, cryogenically and gas-chromato-graphically purified, and the isotope ratios measured on a gas source mass spectrometer (Delta PlusXL).
- Analytical precision for $\Delta^{17}O$ is 0.02 ‰. Isotope values presented here are all linearized.

REFERENCES: [1] Agee C. B. et al., (2013) *MaPS, # 5130.* [2] Grossman J. N. and Brearley A. J., (2005) *MaPS,* 87–122. [3] Sharp Z.D., (1990) *GCA 54*, 1353. [4] Connolly H.C. Jr. et al., (2014) *This Conference, abstract #1889.* [5] Clayton R. N. et al., (1991) *GCA* 55, 2317. [6] Kita N.T. et al. (2010) *GCA* 74, 6610. [7] Connolly H.C. Jr. et al. (2012) *LPSC, #* 2204. [8] Choi B.-G et al., (1998) *Nature* 892, 577. [9] Hutchison R. et al., (1987) *GCA* 51, 1857.

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3 RESULTS:

- Bulk oxygen isotope analyses of a variety of NWA 7731 components are shown in *Figure 3*.
- The data show a large spread in both $\delta^{18}O$ and $\delta^{17}O$ values that cover all three groups of the Ordinary Chondrites (OC), and also fall outside these ranges, including some samples plotting close to the terrestrial fractionation line (TFL).

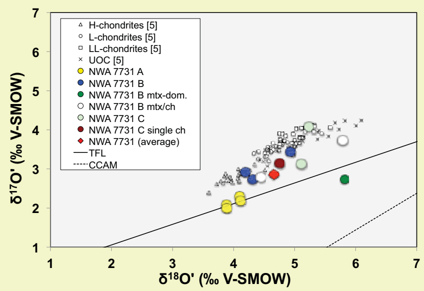

Figure 3. 3-oxygen isotope plot of NWA 7731 different types of bulk samples, in comparison with OC Data [5] (black small symbols).

5 DISCUSSION AND CONCLUSIONS:

- UOCs have undergone only minor thermal processing on their parent bodies, and, therefore, provide unaltered isotopic records from early Solar System processes, as most of their minerals retain nebular composition.
- Isotopic heterogeneity of early Solar System components is preserved in UOCs even when analyzing bulk material.
- UOC oxygen isotope distributions are commonly modeled incorporating two reservoirs: solid and gas [*e.g.*, 4-8].
- Fluid movement along grain boundaries may produce secondary low-temperature minerals, such as phyllosilicates and/or magnetite [8, and references therein]. NWA 7731 matrix contains phyllosilicates in a visually recognizable abundance (*Fig. 6*), and as does Semarkona [9].

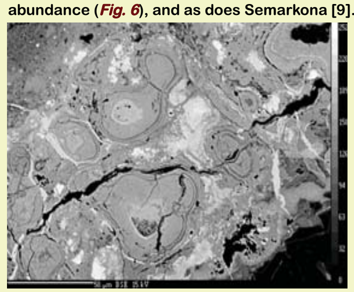

Figure 6: BSE image of NWA 7731 showing alteration with localized abundant phyllosilicate and other hydrated phases.

- Matrix oxygen isotope data of NWA 7731 might represent the composition of H_2O ice at the time of accretion; bulk matrix $\delta^{18}O$ values of this study and of [5] (*Figs. 4, 5*) are the most positive values from each dataset.
- More oxygen isotopic work on the matrix *vs.* chondrule difference, and the characteristics of the phyllosilicates (*Fig. 5*) and other hydrated phases in the matrix in NWA 7731 is being carried out, and will provide more insights into the nature of processes operating on the UOC parent body.

4 COMPARISON TO LL3.00 SEMARKONA AND OTHER UOCs:

- Electron microprobe analyses on ferroan chondrule olivines in Semarkona were compared with our results for NWA 7731. Results for Semarkona are $Fa_{14.5\pm4.9}$, Fe/Mn=45±14, Cr_2O_3=0.41±0.09 wt.%, illustrating a striking similarity between the LL3.00 Semarkona and L3.00 NWA 7731 ferroan olivines. L3.00 NWA 8276 ferroan olivines are very similar: $Fa_{17.8\pm5.9}$, Fe/Mn=47±11, Cr_2O_3=0.42±0.10 wt.%.
- When comparing NWA 7731 bulk oxygen isotope data to the LL3.00 Semarkona bulk data [5, and refs. therein] and to the newest L3.00 NWA 8276, the spread of NWA 7731 appears not that unusual (*Fig. 4*).

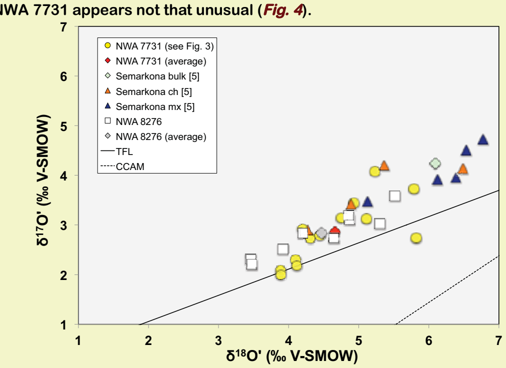

Figure 4. 3-oxygen isotope plot of NWA 7731 (L3.00) bulk samples compared to NWA 8276 (L3.00) and to different types of Semarkona (LL3.00) bulk samples [5].

- The large spread of the oxygen isotope compositions of chondrules and matrix attest to the unequilibrated, very primitive nature of these components assembled within one rock.
- Compared to *in-situ* data of individual Semarkona, Bishunpur (LL3.15), and Krymka (LL3.2) [6], and MET00526 and QUE97008 [7] chondrule minerals, bulk NWA 7731 falls in the center of a very large data array, spanning ~30‰ on the $\delta^{18}O$ axis, and ~25‰ on the $\delta^{17}O$ axis (*Fig. 5*).

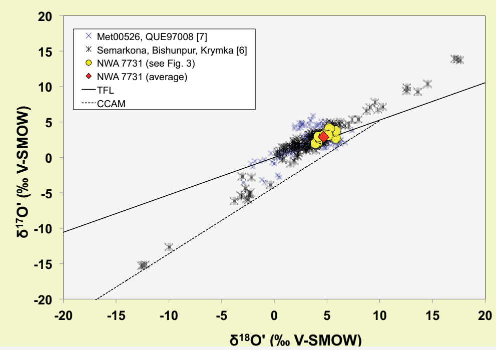

Figure 5. 3-oxygen isotope plot of NWA 7731 (L3.00) bulk samples in comparison with in-situ Semarkona (LL3.00), Bishunpur (LL3.15), Krymka (LL3.2), MET00526 (L3.05), and QUE97008 (L3.05) chondrule mineral analyses [6, 7].

- This spread of Semarkona and other UOC data is due to the variable proportions and variable oxygen isotope signatures of type I and type II chondrules, and those of relict grains. The oxygen isotope variability due to the relative proportions of these phases is larger than that observed by the bulk analyses (cf. *Figs. 3, 4, 5*).
- A similar large distribution in *in-situ* data, although not as data-dense, has also been observed for NWA 7731 [4], and was previously also observed for MET 00526,9 and QUE 97008,14 (both L3.05) [7].