OXYGEN ISOTOPE STUDY OF NORTHWEST AFRICA (NWA) SHERGOTTITES

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45th Lunar and Planetary Science Conference, March 17-21, 2014, The Woodlands, Texas, USA

INTRODUCTION

Shergottites represent over three quarters of the known Martian meteorites (SNC) after nakhlites and chassignites. Shergottites are broadly divided into basaltic, ol-phyric and lherzolitic groups based on their mineralogy. SNC meteorites from Northwest Africa (NWA) make up the largest source of samples from Mars and their study has added to our understanding of the Red Planet. In particular, NWA 7034 [1], NWA 5298 [2] and NWA 7533 [3] have provided unique insights about upper and lower mantle conditions and the long-debated mysteries of the origin and age of the shergottites. Recent study of crystal-melt partitions of Ni and S in SNC meteorites and soils [4] suggests that Mars' surface might have oxidized early in its history from which NWA 7034 might have originated at around 2 Ga [1]. The oxygen isotope values of NWA 7034 [1] are heavier and further offset (see Figure 6 of [1] & Figure 9 of this poster) from the terrestrial fractionation line (TFL) than the main SNC cluster [5-10]. The characteristic petrological and geochemical similarities and oxygen isotope compositions and age variances between NWA 7034 and the SNC group motivated us to study the oxygen isotopes of NWA shergottites.

METHODOLOGY

We prepared 4 NWA shergottites and a representative Shergotty sample for bulk and separated components for oxygen isotope analyses. New oxygen isotope data from these shergottites (ol-phyric & basaltic) were obtained using a novel laser fluorination method [11]. Our CO_2 laser fluorination mass spectrometry protocols [11] provide enhanced precision and accuracy. The calibration method for reporting triple oxygen isotope data provides precision and accuracy better than ± 0.1‰. All the bulk powders and mineral separates were acid-leached to remove any terrestrial weathering products.

DISCUSSION

Acid-leached bulk powders, maskelynite fractions and pyroxene separates of NWA shergottites have been analyzed for oxygen isotope compositions. All isotopic values are averages of 3 individual runs of each bulk sample or separated phase of a particular meteorite. The $\delta^{18}O$ vs. $\delta^{17}O$ plots of bulk powders, maskelynite, pyroxene and all-fractions constructed on the basis of all data and averaged values of individual meteorites are shown in Figures 1-8.

The relevant slopes obtained from the triple oxygen isotope plots and $\Delta^{17}O$ of bulk powders, maskelynite fraction, pyroxenes separates and all-fractions are given in Table 1. The slope (0.5289) obtained from all-fractions of NWA shergottites in this study is broadly consistent with the previous MFL slope of 0.526 achieved by analyzing SNC bulk samples [6]. Given the slopes of our MFL (0.5289) and TFL (0.5223), it is evident that both planets (Mars and Earth) display broadly homogenized oxygen isotopes.

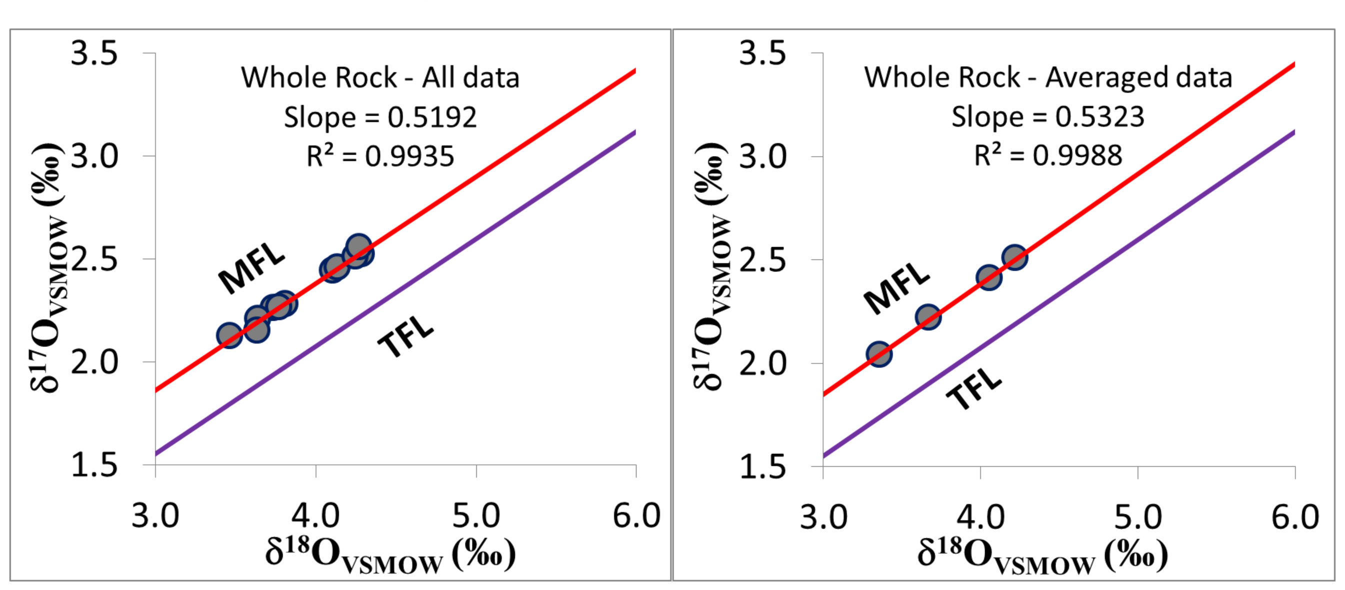

Figure 1: Triple oxygen isotope plots of whole rock powders of NWA shergottites (NWA 1068, NWA 1110, NWA 1195, NWA 3171).

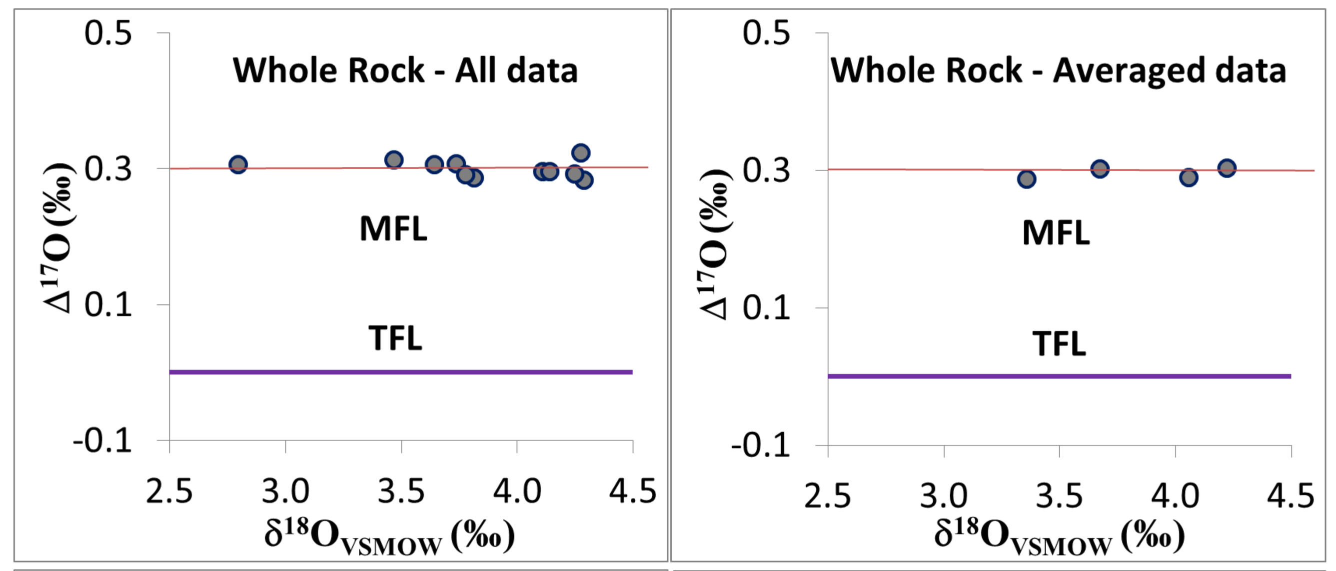

Figure 2: $\delta^{18}O$ vs. $\Delta^{17}O$ plot of whole rock powders of NWA shergottites (NWA 1068, NWA 1110, NWA 1195, NWA 3171). The average $\Delta^{17}O$ = 0.300±0.008 (2σ). TFL and MFL stand for terrestrial and martian fractionation lines respectively.

However, the oxygen isotope data of NWA 7034 [1] bulk solids (acid washed, non-acid washed and decarbonated to 1000ºC) are heavier and further offset from the TFL (Figure 9) than the NWA shergottites in this study, which overlaps the combined SNC [5-10] data array (not shown in Figure 9 for simplicity).

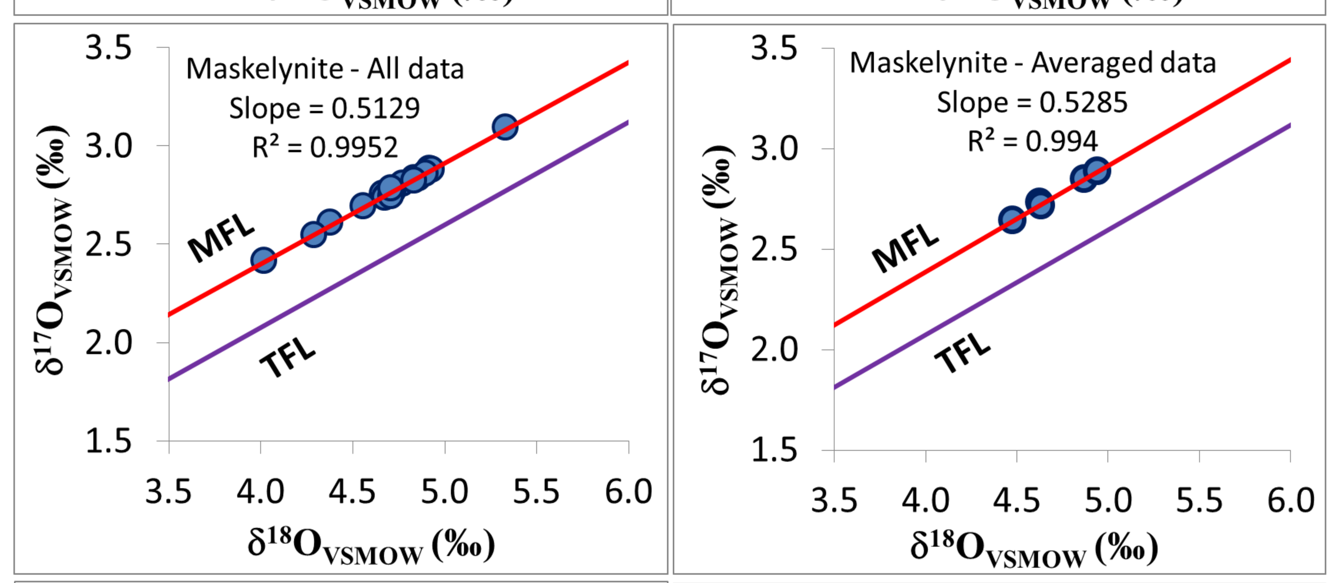

Figure 3: Triple oxygen isotope plots of maskelynite fractions of NWA shergottites (NWA 1110, NWA 1195, NWA 3171, NWA 4468) & Shergotty.

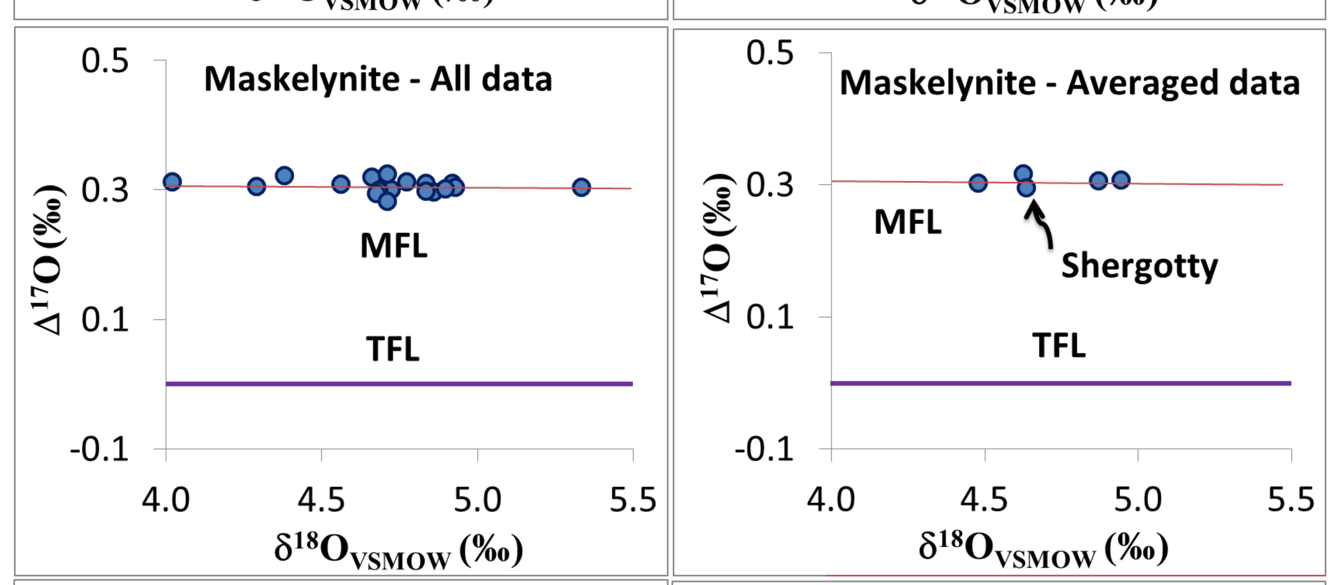

Figure 4: $\delta^{18}O$ vs. $\Delta^{17}O$ plot of maskelynite fractions of NWA shergottites (NWA 1110, NWA 1195, NWA 3171, NWA 4468) & Shergotty. The average $\Delta^{17}O$ = 0.306±0.005 (2σ).

The disagreement in oxygen isotope compositions of SNC's and NWA 7034 is possibly due to the presence of multiple oxygen reservoirs on Mars [1] and increased oxygen fugacity at Mars' surface during early history [4]. Our oxygen isotope data for NWA shergottites and SNC's [5-10] in general compared to NWA 7034 suggest that early oxidation effects on Mars had not yet reached the deeper upper mantle levels sourced by the SNC's possibly due to the disputed dearth of subduction zones on Mars. Therefore, the shallower upper mantle, represented by NWA 7034, shows heavier oxygen isotope compositions than the SNC's. Recently, it is observed in chondrules that high oxygen fugacity causes to increase the oxygen isotope compositions [12].

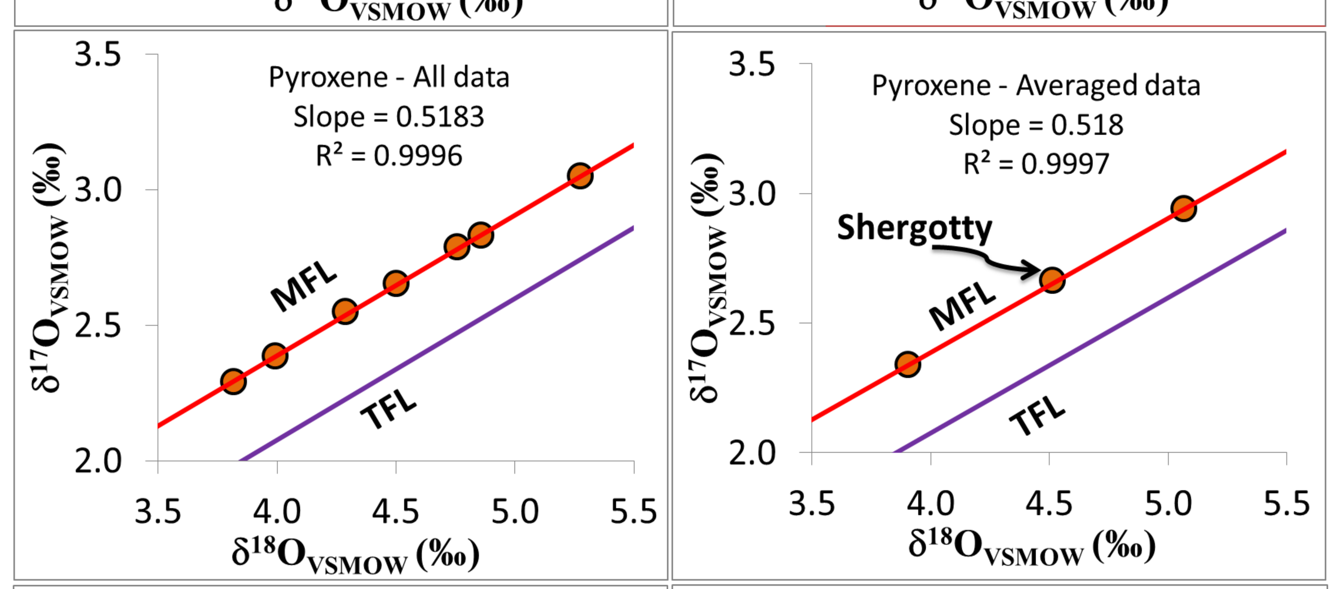

Figure 5: Triple oxygen isotope plots of pyroxene separates of NWA shergottites (NWA 1195, NWA 3171) & Shergotty.

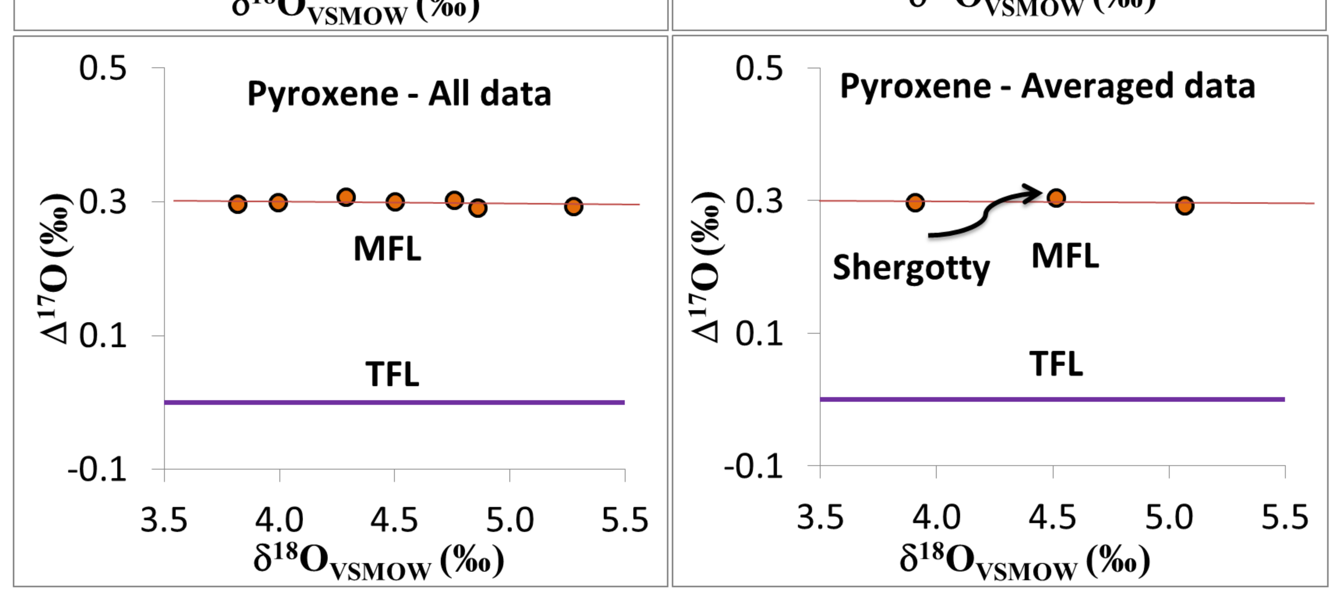

Figure 6: $\delta^{18}O$ vs. $\Delta^{17}O$ plot of pyroxene separates of NWA shergottites (NWA 1195, NWA 3171) & Shergotty. The average $\Delta^{17}O$ = 0.298±0.004 (2σ).

Fraction	Slopes: All data	Slopes: Averaged data	$\Delta^{17}O$	Ranges (‰): $\delta^{18}O_{VSMOW}$	Ranges (‰): $\delta^{17}O_{VSMOW}$
WR	0.5192	0.5323	0.300±0.008 (2σ)	3.40 – 4.20	2.00 – 2.50
Mask	0.5129	0.5285	0.306±0.005 (2σ)	4.50 – 4.95	2.65 – 2.90
Px	0.5183	0.5180	0.298±0.004 (2σ)	3.90 – 5.05	2.30 – 2.95
ALL	0.5257	0.5289	0.303±0.004 (2σ)	3.35 – 5.05	2.00 – 2.95

Table 1: New triple oxygen isotope data ranges, $\Delta^{17}O$ and slopes of different fractions in NWA shergottites (NWA 1068, NWA 1110, NWA 1195, NWA 3171, NWA 4468) & Shergotty. Abbreviations: WR = whole rock; Mask = maskelynite; Px = pyroxene.

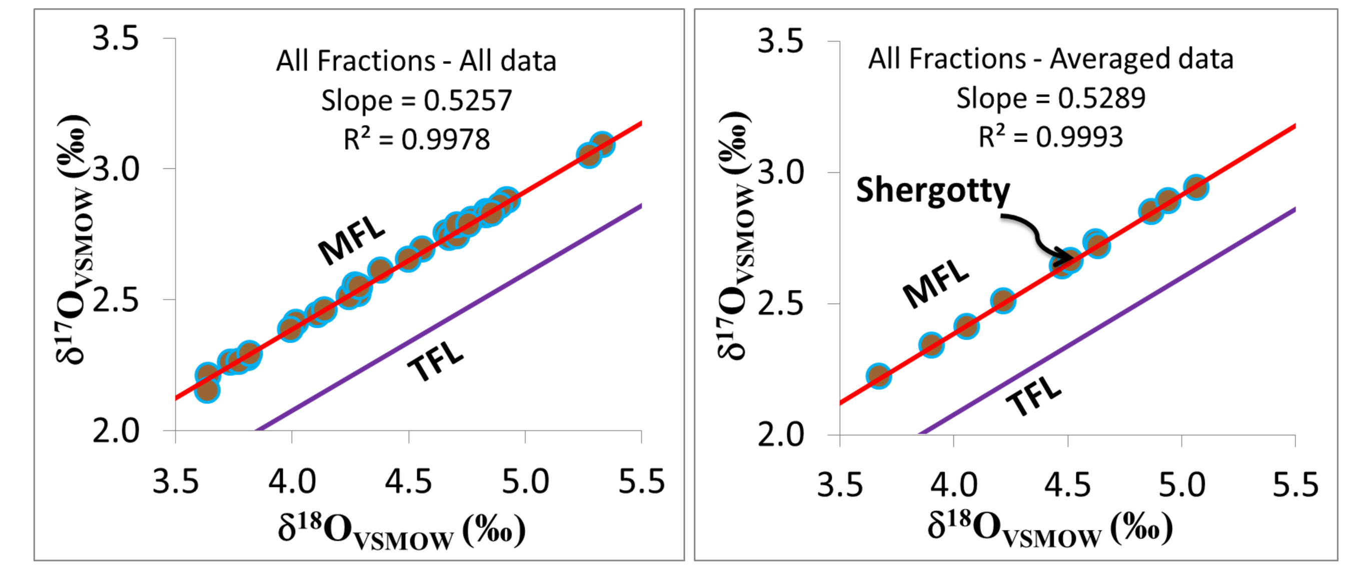

Figure 7: Triple oxygen isotope plots of all fractions of NWA shergottites (NWA 1068, NWA 1110, NWA 1195, NWA 3171, NWA 4468) & Shergotty.

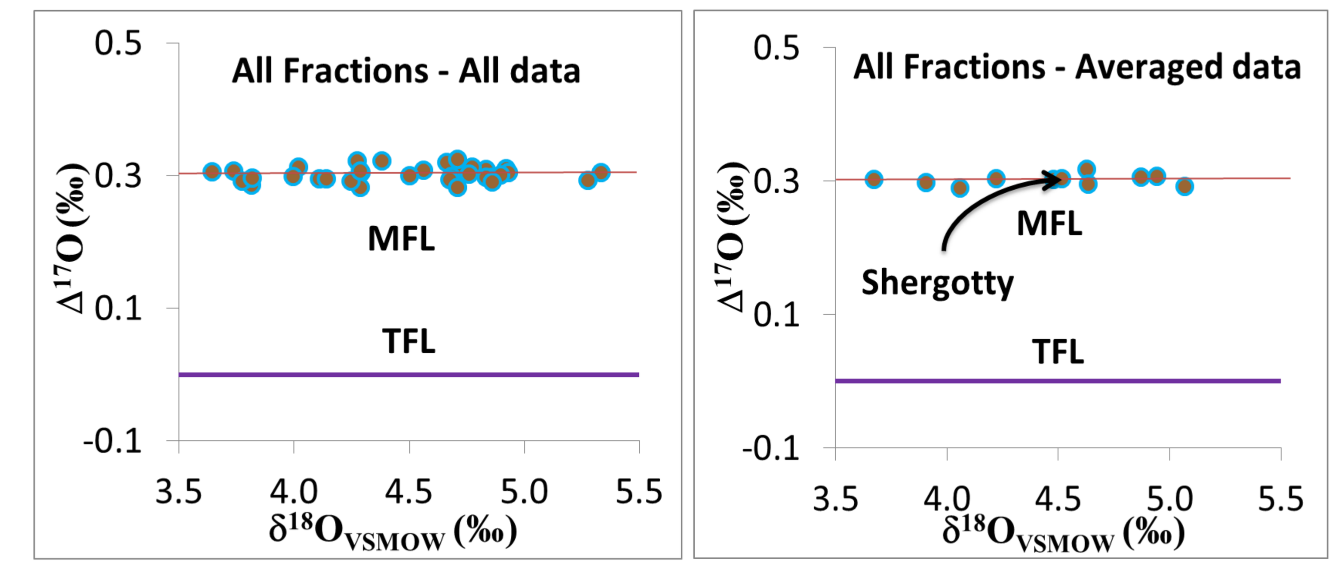

Figure 4: $\delta^{18}O$ vs. $\Delta^{17}O$ plot of all fractions of NWA shergottites (NWA 1068, NWA 1110, NWA 1195, NWA 3171, NWA 4468) & Shergotty. The average $\Delta^{17}O$ = 0.303±0.004 (2σ).

The slopes obtained from triple oxygen isotope plots (Figures 1,3,5,7) of bulk materials and separated components of NWA shergottites are variable and range from 0.52 to 0.53. It is noticeable that the slopes of averaged data of WRs and maskelynite fractions are marginally steeper than the slopes based on all data (Table 1). Conversely, pyroxene show indistinguishable slopes for both all- and averaged data so is the case in all-fractions slopes within uncertainty.

CONCLUSIONS

Our new shergottite data fall on the MFLs previously reported for SNC's [6, 10] and differ from the NWA 7034 data [1]. The triple O-isotope compositions of bulk NWA shergottites are essentially in agreement with the earlier SNC's data [6, 10]. However, minor slope variations in all- and averaged data are observed for whole rocks and maskelynite unlike pyroxene separates, which probably linked to isotope variations in maskelynite, a glassy phase, due to potential impact-related isotope fractionation. More data on SNC separates are needed to better determine if the possible impact-related oxygen isotope fractionations in maskelynite are widespread.

REFERENCES

[1] Agee C. B. et al. (2013) *Science, 339,* 780-785. [2] Moser D. E. et al. (2013) *Nature, 499,* 454-458. [3] Humayun M. et al. (2013) *Nature, 503,* 513-516. [4] Tuff J. et al. (2013*) Nature, 498,* 342-345. [5] Clayton R. N. and Mayeda T. K. (1983) *EPSL, 62*, 1-6. [6] Franchi I. A. et al. (1999) *Meteoritics & Planet. Sci., 34*, 657-661. [7] Mittlefehldt D. W. et al. (2008) *Rev. Mineral. Geochem., 68*, 399-428 [8] Rumble D. et al. (2009) *LPS XXXX*, 2293-2294. [9] Karlsson H. R. et al. (1992) *Science, 255*, 1409-1411. [10] Banerjee N. R. et al. (2013) *MetSoc 76th,* Abstract #5248. [11] Ali et al. (2013) *LPS XLIV,* Abstract #2873 [12] Schrader D. L. et al. (2013) *Geochim. Cosmochim. Acta, 101,* 302-327.

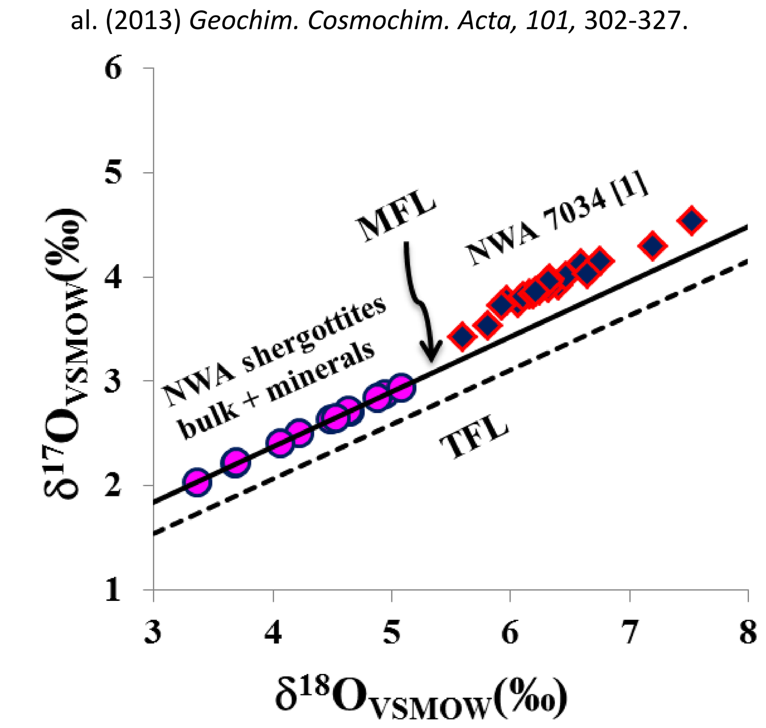

Figure 9. Triple oxygen isotope plot of NWA shergottites (circles; this study) and NWA 7034 (diamonds; [1]).

Acknowledgements

F. Longstaffe
Liz Webb
Kim Law
Li Huang

CSA-ASTRO

INSTITUTE FOR STUDY OF THE EARTH'S INTERIOR OKAYAMA UNIVERSITY

Ali Al-Kathiri
Claire Mortera
Grace Yau
Jon Jacobs