

GENESIS SiC CONCENTRATOR SAMPLE TRAVERSE: CONFIRMATION OF ^{16}O -DEPLETION OF TERRESTRIAL OXYGEN. K.D. McKeegan¹, A.P.A. Kallio¹, V.S. Heber^{1,7}, G. Jarzabinski¹, P.H. Mao², C.D. Coath³, T. Kunihiro⁴, R. Wiens⁵, J. Allton⁶, and D.S. Burnett² ¹Dept. of Earth & Space Sciences, UCLA, Los Angeles, CA. 90095-1567 USA, ²Div. Geol. & Planetary Sci., Caltech, Pasadena, CA 91125, USA. ³Dept. of Earth Sciences, Univ. of Bristol, Bristol, BS8 1RJ, UK, ⁴SEI, Okayama Univ., Misasa, Tottori 682-0193 Japan, ⁵Los Alamos National Laboratory, Los Alamos, NM 87545 USA, ⁶Johnson Space Center, Houston, TX 77058 USA, ⁷Earth Sciences, ETH, Zurich, Switzerland.

Introduction: An accurate and precise determination of the oxygen isotopic composition of the Sun is the highest priority scientific goal of the Genesis Mission [1] as such data would provide a baseline from which one could interpret the oxygen isotopic anomalies found at all spatial scales in inner solar system materials [2]. We have previously reported preliminary data on solar wind oxygen isotope compositions obtained from the Genesis SiC target sample 60001 by depth profiling with the UCLA MegaSIMS [3,4]. The initial results, obtained on two separate areas of the target, identified the Sun as being enriched in ^{16}O by $\sim 6\%$ relative to terrestrial values [4]. The majority of the data, obtained on one area of the target (9.9 mm from the center, now labeled area “B”; see figure 1), plotted within error of the CAI mixing line [4]. However, because the target was located at the focal plane of an electrostatic mirror (“the concentrator” [5]), this agreement was considered somewhat fortuitous [4] since large mass-dependent fractionation effects would be induced by the ion optics of the concentrator. Limited data obtained on a second area (“D”, ~ 10 mm further removed from the center) show significantly lower concentration, as expected, and also a composition consistent with mass dependent fractionation of that from area “B” by approximately -20% /amu, albeit with significantly large uncertainties. Such radially-dependent mass fractionation was already known from measurements of neon isotopes on the Au-cross retaining bar [5], in qualitative agreement with expectations based on ion optical simulations [6].

In order to resolve ambiguities associated with mass dependent fractionation induced by the concentrator optics and to account for solar wind (SW) back-scattering losses, we were authorized to conduct a radial traverse comprising 6 separate areas of the SiC concentrator target. This has been accomplished with 40 depth profiles, each corresponding to a sputtered area of $\sim 150 \times 150 \mu\text{m}^2$. A parallel radial traverse will be undertaken in January at the ETH to analyze neon isotope abundances [7] so that the mass dependent fractionation can be quantified by comparison of the concentrator $^{22}\text{Ne}/^{20}\text{Ne}$ with that measured in a bulk SW target (diamond-like carbon on Si). The result can then be employed to model the oxygen isotope fractionation, thereby permitting a correction to obtain the SW composition that was sampled by Genesis at L1.

Here we discuss the oxygen SW data corrected only for instrumental mass fractionation in the MegaSIMS and some general implications.

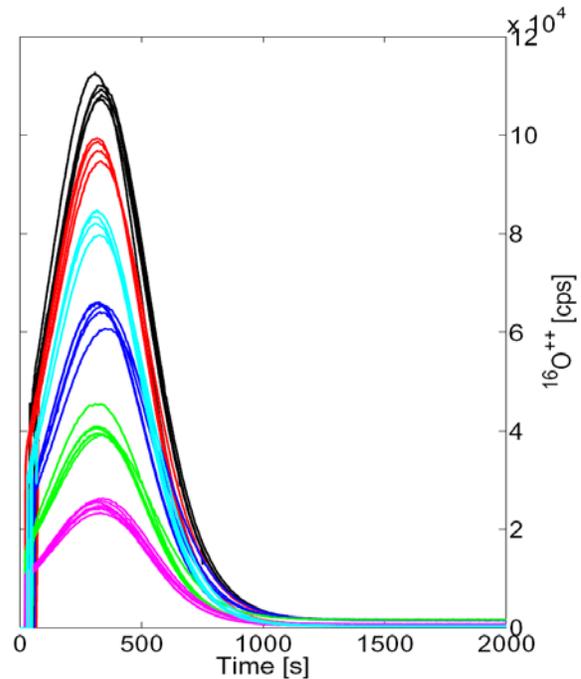


Fig. 1. Depth profiles from areas A (top curve) through F (bottom) from Genesis sample GCS60001. Count rate is proportional to concentration and time is proportional to depth via sputter rate. The peak of the profiles occur at ~ 78 nm.

Genesis Concentrator sample #60001: Forty analyses were performed in six separate areas of the Genesis sample #60001 with methods similar to those reported in [4]. As before, the area to be analyzed was first selected optically to be free from defects and particles larger than a few microns and then was cleaned by low-energy Cs sputtering (5 keV impact) to remove the top ~ 20 nm which is typically contaminated with adsorbed terrestrial oxygen. The ion extraction voltage and primary beam focusing were then rapidly switched to the analytical mode and the ion microscope imaging capability of the MegaSIMS was used to inspect the analytical area for contaminant dust particles larger than $\sim 0.5 \mu\text{m}$. If any were identified (the usual case), the sample was shifted such that the of-

fending dust was outside the analytical area of the depth profile (defined by an optical gate or “field aperture” inserted in an image plane of the secondary ion beam path). Frequent instrument baking and careful vacuum maintenance enabled operating pressures $< 2 \times 10^{-11}$ Torr during analysis. Intense (~ 100 nA) Cs-sputtering of blank SiC was used for “cleaning” the immersion lens extraction plate (to minimize back-scattered oxygen onto the sample surface), ultimately resulting in levels of instrumental background a factor of ~ 2 better than those achieved last year.

Results: A summary of the O^{++} profiles is shown in Figure 1. Profiles from within the same vicinity on the sample are highly reproducible with differences in peak position and intensity due primarily to slight changes in sputter rates (crater depths will be determined by interferometry once the sample is extracted from vacuum). From the interior (area “A”) to the exterior of the sample (area “F”), the implanted SW oxygen concentration falls by a factor ~ 5 . In all cases, the integrated background is $< 2\%$ of the SW signal.

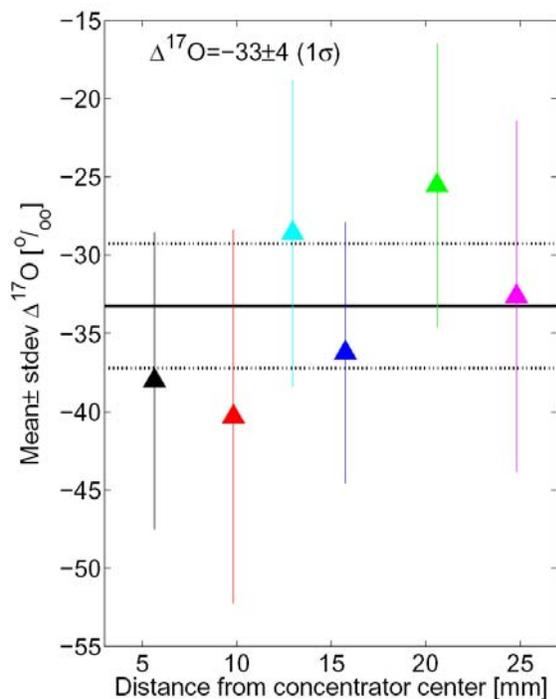


Fig. 2. Mean $\Delta^{17}O$ values measured over 5 or more depth profiles in each area of Genesis SiC sample 60001 as a function of radial distance from the center of the concentrator target. Colors correspond to the profiles shown in Fig. 1.

All analyses are consistent with an ^{16}O -rich composition for the captured solar wind with a mean $\Delta^{17}O = -33 \pm 4\%$ (Fig. 2); the uncertainty estimate on $\Delta^{17}O$

represents the standard error of repeated measurements over the 6 target areas investigated. That the analyses from different radial positions agree in $\Delta^{17}O$ within error demonstrates that it is only mass dependent fractionation that is induced by the concentrator and that background corrections, which vary in significance due to the radially-dependent concentration factor, are properly accounted for. Tests on olivine grains from the Eagle Station pallasite demonstrate that MegaSIMS is accurate at a level commensurate with the stated precision. For multiple electron multiplier analyses, the MegaSIMS data yield $\Delta^{17}O = -3.4 \pm 4.1\%$ compared to the accepted value for Eagle Station of -4.8% [8]. Most of the uncertainty in this parameter is due to the low count rates; a repeat of the measurement utilizing a more intense beam and a Faraday cup detector for $^{16}O^{++}$ yielded $\Delta^{17}O = -5.7 \pm 0.8\%$ for the Eagle Station olivine.

Implications: The first-order conclusion remains that the Earth and other planetary materials from the inner solar system are highly depleted in ^{16}O relative to the Sun and the bulk starting composition of the solar system. The data agree with expectations based on isotope-selective photochemical self-shielding of CO in the solar nebula or its precursor molecular cloud [9-11]. The Earth is also depleted in the major isotope of nitrogen, ^{14}N [12,13], which may further be indicative of a major role for photochemistry [9,14]. Calcium-aluminum-rich inclusions of carbonaceous chondrites have oxygen isotope compositions approaching the solar value but, with very rare exceptions, they do not agree quantitatively most having $\Delta^{17}O$ in the range -20 to -25% . A notable exception is the unusual chondrule found by Kobayashi et al. [15], which contains solar oxygen.

References: [1] D. Burnett et al. (2003) Space Sci. Rev. 105, 509. [2] R. Clayton (1993) Ann. Rev. Earth Planet. Sci. 21, 115. [3] K. McKeegan et al. (2008) LPSC XXIX, #2020. [4] K. McKeegan et al. (2009) LPSC XL, #2494. [5] V. Heber et al. Space Sci. Rev. 130, 309. [6] R. Wiens et al. (2003) Space Sci. Rev. 105, 601. [7] V. Heber et al. (2010) LPSC XLI, #1067. [8] R. Clayton and T. Mayeda (1978) EPSL 40, 168. [9] R. Clayton (2002) Nature 415, 860. [10] H. Yurimoto and K. Kuramoto (2004) Science 305, 1763. [11] J. Lyons and E. Young (2005) Nature 434, 317. [12] B. Marty et al. (2010) GCA 74, 340. [13] A. Kallio et al. (2010) LPSC XLI. [14] J. Lyons et al. (2009) GCA 73, 4998. [15] K. Kobayashi et al. (2003) Geochem. J. 37, 663.