Science Advances
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Supplementary Materials for

Oxygen isotopic evidence for accretion of Earth's water before a high-energy Moon-forming giant impact

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Published 28 March 2018, *Sci. Adv.* **4**, eaao5928 (2018)
DOI: 10.1126/sciadv.aao5928

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Other Supplementary Material for this manuscript includes the following:
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- table S5. Oxygen isotope analyses and water content values used to construct Fig. 5 and fig. S4 (Excel file).
- table S6. Late veneer end member calculations used to construct Fig. 5 and fig. S4 [Excel files (×6)].
- table S7. Water in Earth: Calculations used to construct Fig. 5 and fig. S4 (Excel file).
- model S1. A spreadsheet that calculates the oxygen isotopic composition of the Moon using a mix defined by our analyses of terrestrial basalts and aubrites (*20*) (Excel file).
- model S2. A spreadsheet that calculates the oxygen isotopic composition of the Moon using a mix defined by our analyses of olivines and aubrites (*20*) (Excel file).
- Compilation of all replicate analyses run in this study (Excel file).
- Compilation of obsidian standards data 2012–2014 (Excel file).

Supplementary Text

Further statistical analysis

The difference between the mean $\Delta^{17}O$ value of our terrestrial and lunar samples is small, being approximately 3 to 4 ppm. To further interrogate the data, we have adopted a two-pronged approach. Firstly, we have looked in more detail at the data as presented in this paper (averages) using the bootstrap technique. Secondly, we have taken the complete dataset of 260 replicate analysis and applied the same statistical treatment to those data.

Approach 1 Analysis of average values using bootstrap techniques:

For the purposes of this test we assume here that all the values have the same precision (ignoring then the standard deviation). The number of averages used in each of the Moon and Earth statistical samples is as follows:

	Earth	Moon
Number of observations	37	31

Figure S7 shows the densities we obtained through Kernel density estimation (49). It is noticeable that the density of Moon $\Delta^{17}O$ statistics are shifted towards the right-hand side with respect to the density of Earth statistics. This suggests that Moon and Earth $\Delta^{17}O$ statistics do not have the same means and that the mean for the Moon is higher.

We have two estimates of the (real) means of the Moon-Earth $\Delta^{17}O$ statistics, written $\mu^{☾}$ (Moon) and $\mu^{\bigcirc}$ (Earth). Numerical values (estimates) give, for the whole set of average data

$$\left| \begin{array}{l} \mu^{☾} = 10.21 \\ \mu^{\bigcirc} = 6.81 \end{array} \right.$$

And we need to conduct a bilateral test

$$\left| \begin{array}{l} H0 : \mu^{☾} = \mu^{\bigcirc} \\ H1 : \mu^{☾} > \mu^{\bigcirc} \end{array} \right.$$

To do this, we build the empirical density (bootstrap) of the random variable $X=\mu^{☾} - \mu^{\bigcirc}$. Therefore, we end finally with the following unilateral test

$$\left| \begin{array}{l} H0: X=0 \\ H1: X > 0 \end{array} \right.$$

Under the hypothesis H0, the set of the whole observations (37+31=68 averages) is the bootstrap sample. It is then used to compute the bootstrap distribution of X (50). Then in a fully non-parametric framework, we can replicate (bootstrap) the sample of observations in order to estimate the distribution of X under H0 and then compute the p-value (50)

$$\text{p-value} = \Pr(X>Xobs \mid H0)$$

where $Xobs=\mu^{☾} - \mu^{\bigcirc} = 10.21 – 6.81 = 3.40$.

Finally, we ran 10^6 bootstrap replicates and got the following estimated p_value

p_value(Bootstrap) = 1.3%

In other words, at the 95% level of confidence, the difference in mean observed between the Moon and the Earth samples is significant (H0 is rejected).

It is also clear that the data span is quite large (fig. S7). In this case it is useful to check the robustness of the conclusion that can be drawn from the two sets of data. In other words, the goal of this kind of analysis, is to check if the conclusion still holds when we reduce the dependency of numerical estimates to extreme observations. A usual way is to Winsorize (51) the means value estimate. This can be done by removing a small percentage of the extreme observations. In this case, we may remove the highest and the smallest value of each data set. This corresponds to removing 3.2% percent of higher and lower tails observations in the case of the Moon, and 2.7% in the case of Earth.

We then replay the previous scheme. Xobs is now equal to 3.48. And the 10^6 bootstrap replications lead to the following estimated p_value

p_value(Bootstrap, Winsorized) = 0.3%

This confirms previous conclusions and reinforce them in terms of confidence level.

Approach 2 Analysis of all replicates using bootstrap techniques:

The number of observations associated with each of the datasets in terms of individual replicate analyses is as follows:

	Number of observations
Moon	65
Earth	195
Among which: Earth- olivines	*133*
And : Earth No-olivines	*62*

Figure S8 shows the Kernel density estimates for these samples, with superimposed the curves for the subsamples of olivine Earth and No-olivine Earth.

The No-olivine and olivine statistical samples for the Earth do not look very different from each other (Fig. 2), except in one aspect: the higher tail distribution for the olivine sample is larger and this may have a tendency to reduce the difference in means between Earth and Moon data.

As was done previously, we then compute for the whole set of data, the means

$$\mu^{☾} = 10.59$$
$$\mu^{\bigcirc} = 7.71$$

which gives a value for the difference: Xobs=$\mu^{☾}$ - $\mu^{\bigcirc}$ = 10.59– 7.71 = 2.88. This value is slightly smaller than that obtained with average values (approach 1).

Again, we ran 10^6 bootstrap replicates and got the following estimated p_value

p_value (Bootstrap) = 1.9%

This shows that again, the H0 hypothesis (equality of the two means) should be rejected at the 95% level of confidence.

As a robustness check, we remove in both samples, 5% of the observations. Precisely, 10 observations (5 on both sides) for the Earth data set and 4 (2 on both sides) concerning Moon. The new value for the difference is: Xobs=$\mu^{☾}$ - $\mu^{\bigcirc}$ = 10.29– 7.61 = 2.68. This value is even slightly smaller than that obtained for the not-Winsorized samples.

Again, we ran 10^6 bootstrap replicates and got the following estimated p_value

p_value(Bootstrap, Winsorized) = 1.3%

This confirms that the mean for Moon is significantly higher than the means for Earth.

The additional statistical analysis we have undertaken is in conformity with our t-test results and indicates that, while the difference between the means for the Earth and Moon are undeniably very small, that difference is statistically significant. The scientific problem is to try and understand what this result means. In the first half of the paper we looked at the implications of our data for the evolution of the Earth-Moon system and show that such a small difference can be taken as supporting a high energy impact scenario for the Earth-Moon system, or alternatively requires a level of similarity between Theia and the proto-Earth that surpasses the similarity in oxygen isotopic composition between the Earth and aubrites. In the immediate aftermath of a very high energy giant impact event, such as that invoked by the "synestia" model (13, 14), complete oxygen isotopic equilibration is likely to have taken place. In such a high energy scenario, even the small Earth-Moon difference detected in this study is unlikely to be preserved. So, if this difference is not a residual artefact of the giant impact event, what does it represent? As discussed in the paper, we would favour a late-veneer model to explain this difference. However, in examining the implications of such a scenario it is important not to ignore the possibility that residual differences between the Earth and Moon are also permissible in the models of (2) and (3).

Defining proxies for the Δ^{17}O composition of the Earth and Moon.

In this study, we were attempting to assess whether the Earth and Moon show any significant differences in Δ^{17}O. However, as previous studies have demonstrated *(4-8),* the differences involved are small and so the choice of which materials to use for this comparison is important. Recent studies have used olivine as a proxy for the Earth *(4, 5)*. However, it has been suggested that Δ^{17}O values might be influenced by differences in crystal structure between phases such as olivine, quartz and feldspar *(22, 23).* If correct, this would pose significant problems with using pure mineral phases, such as San Carlos olivine, as a proxy for the bulk Earth. Directly comparing whole-rocks with similar δ^{18}O values, rather than using pure minerals, might seem to be a better methodology and in this study, we compare lunar whole-rocks to terrestrial basalts. But this approach also has its problems. The composition of terrestrial basalts is known to be controlled by a complex history of crust-mantle interaction e.g. *(52)*, in a way that lunar basalts are not. This may be reflected in terms of the best fit line through the lunar data, which has a slope of 0.5301 ± 0.0024 and consequently very close to the theoretical upper limit of 0.5305 *(18,43)* (fig. S2). In contrast, the terrestrial basalts measured in this study define a shallower slope of 0.5270 ± 0.0037 (fig. S3). These two groups of samples would seem to have had distinct formational histories.

In view of these potential problems, we have used a combined approach in this study and compare both terrestrial basalts and olivines, including high $^3He/^4He$ olivines *(19),* to lunar samples. Our findings show that terrestrial olivines are statistically indistinguishable in terms of their $\Delta^{17}O$ values to lunar samples. High $^3He/^4He$ olivines are potentially more pristine materials *(19)* than terrestrial basalts and hence might be taken as better proxies for the bulk Earth. However, the possible compositional control on $\Delta^{17}O$ discussed above *(22,23)* means that caution is required in adopting this approach. Terrestrial basalts show a 3 to 4 ppm $\Delta^{17}O$ difference when compared to lunar rocks, which we have interpreted in terms of post-giant impact additions to the Earth's mantle. However, it is important to stress that we can also use these terrestrial basalts as proxies for the post-giant impact composition of the Earth, as is done in Fig. 4, and still arrive at the conclusion that the Earth-Moon system formed during an impact that involved significantly more mixing than those predicted by lower-energy simulations *(1, 27).*

Oxygen isotope modeling based on a canonical giant impact

To assess how much impactor material is permissible in the Moon, based on our data, we have undertaken calculations using the parameters set by the canonical impact model *(1).* In this scenario, the proto-Earth was hit at a glancing angle by a Mars-sized body. This sets the impactor contribution to the overall Earth-Moon system at 10.6% and the proto-Earth contribution at 89.4%. We have taken the oxygen isotopic composition of the impactor to be that of the aubrites, i.e. $\Delta^{17}O$ = 28 ppm (table S1). Our observed Earth-Moon $\Delta^{17}O$ difference was 4 ppm, between terrestrial basalts ($\Delta^{17}O$ = 6 ppm) and lunar whole-rocks and mineral separates ($\Delta^{17}O$ = 10 ppm), both unfiltered (table S1). To assess the amount of aubritic impactor material that is required to be present in the Moon to produce a 4 ppm shift relative to Earth we first need to derive a composition for the proto-Earth. Since we are only interested in oxygen isotopic compositional differences, we have assumed linear mixing and so derive the composition of the proto-Earth by subtracting 10.6% impactor material from our measured present-day composition. Because of the large mass difference between the Earth (5.97×10^{24} kg) and Moon (7.35×10^{22} kg), the isotopic composition of the Earth is relatively insensitive to changes in the amount of impactor material sequestrated into the Moon (model S1). To model the 4 ppm Earth-Moon difference we have used the isotopic composition of terrestrial basalts as a proxy for the present Bulk Earth value (N = 18, filtered at $\Delta^{17}O \leq 6$ ppm). Using the unfiltered terrestrial basalt data (N = 20), as in Test 1 (table S2), would not have made a significant difference to the outcome of these calculations. The calculated proto-Earth has a $\Delta^{17}O$ composition of 3 ppm (model S1, Fig. 4).

As can be seen from Fig. 4, the 4 ppm Earth-Moon difference can be reproduced by a lunar impactor component of 25 to 28% compared to the terrestrial impactor component of 10.6%. The 70% impactor component in the Moon, predicted by the canonical model *(1)* would result in an Earth-Moon difference of 15 ppm, which is well outside the range of values found in this study. An alternative low velocity giant impact model *(27),* predicts a higher percentage of target material in the Moon compared to the canonical model *(1).* In terms of impactor mass and impact energy, run cA07 of *(27)* was closest to the parameters used by Canup and Asphaug (2001) *(1),* but compared to those earlier results predicted a somewhat lower impactor component in the Moon of 54%. Using our model, this would result in an Earth-Moon $\Delta^{17}O$ difference of 11 ppm, again outside the range of values detected in this study. However, it is important to note that the standard error (SE) of the 4 ppm terrestrial basalt – lunar whole rock difference is ± 3 ppm (2 SE), which would indicate that the range of permissible impactor contributions to the Moon is between 13 and 39 %. So, while there is still no overlap with the predictions of low velocity impact models *(1, 27)*, our data do permit a significant differential impactor contribution to the Moon.

When the average $\Delta^{17}O$ value of high $^{3}He/^{4}He$ terrestrial olivines (8 ppm) is compared to filtered lunar whole rocks (9 ppm), the observed 1 ppm difference can be accounted for by an impactor component of 13 to 16% in the Moon, compared to 10.6% in the Earth (model S2). However, this difference is not statistically significant (table S2, Test 6) and the results suggest that the Moon and Earth are isotopically homogeneous with respect to $\Delta^{17}O$. As discussed in the main article, the 4 ppm difference between the terrestrial basalts and lunar rocks is best explained by post-giant impact additions to the former, most likely as part of the late veneer *(29)*.

Constraints on the composition of the late veneer and its contribution to the whole Earth water budget

Highly siderophile element (HSE) abundance data indicate that the mantles of the Earth and Moon received an input of chondritic material after the giant impact event *(29)*. However, the amounts received by the Earth and Moon were very different, being ~ 0.5 % of the terrestrial mass and only ~ 0.02 % of the lunar mass, respectively *(29)*. Significant uncertainty exists concerning the exact composition of this late veneer. Ru isotopes point towards an enstatite chondrite-like source *(31)*, whereas sulphur, selenium and tellurium abundances in mantle peridotites suggest it may have been largely CM carbonaceous chondrite-like in composition *(53)*. In contrast, osmium isotopes and Pd/Ir ratios suggest an affinity with enstatite chondrites *(29)*, a possibility which appears to be excluded by lunar nitrogen isotopic evidence, which instead points to an important role for CO chondrite-like material *(54)*. The contradictory isotopic evidence concerning the composition of the late veneer may indicate that it comprised a complex mix of materials dominated by an enstatite chondrite component, as suggested by the osmium isotopic evidence *(29)*, but with a subordinate carbonaceous chondrite fraction *(53,54)*. A high fraction of CI material within the late veneer appears to be excluded on the basis of the suprachondritic Ru/Ir and Pd/Ir ratios of the Bulk Silicate Earth *(29, 55)*. Alternatively, it has been pointed out that the ungrouped carbonaceous chondrite Tagish Lake meets the osmium isotopic constraints *(53)*.

The oxygen isotope data presented here provides significant constraints on the composition of the late veneer and its likely contribution to the Earth's water budget (Fig. 5, fig. S4). As discussed in the main text, the $\Delta^{17}O$ composition of the Earth post-giant impact, but before the addition of the late veneer, can be taken as essentially that defined by lunar basalts. Compared to lunar basalts, terrestrial basalts analyzed in this study have somewhat lower $\Delta^{17}O$ values ($\Delta^{17}O = 6 \pm 2$ ppm (2 SEM)). As discussed in the main article, this small $\Delta^{17}O$ difference (3 to 4 ppm) appears to be statistically robust and may reflect post-giant impact additions to the Earth's upper mantle. In Fig. 5 and fig. S4, a variety of chondritic components are plotted in relation to our new lunar and terrestrial oxygen isotopic data in order to evaluate their potential contributions as part of the late veneer. The data for the water content and $\Delta^{17}O$ composition of the various chondritic components plotted in these figures are given in table S5 (see separate file). Details of the calculations for the late veneer contributions of each of the five chondritic components (CI, CM, CV3, Tagish Lake, ordinary chondrite) are given in tables S6a,b,c,d,e (see separate files). Various literature estimates for the total water budget of the Earth are given in table S7 (see separate file).

CM chondrites are the most abundant class of carbonaceous chondrites and are known to be widely distributed as clasts in a range of inner Solar System materials *(56)*. However, a 0.5 % Earth mass input of CM-like material would result in an approximately 16 ppm negative shift in the Earth's original oxygen isotope composition, as defined by lunar basalts (Fig. 5), which is clearly not compatible with the results of this study. Similar additions of CV3, OC or CI chondrites at late veneer levels (0.5 % terrestrial mass) would also result in $\Delta^{17}O$ shifts outside the range seen in our terrestrial basalt data. We can therefore exclude CM, CV3, OC or CI chondrites as significant single components within the late veneer. However, the presence of these components within a mixed late veneer is permissible from an oxygen isotope perspective. Thus, it would be entirely possible to produce a mix of CI and CM chondritic material that could account for the 4 ppm $\Delta^{17}O$ shift seen in terrestrial basalts. However, as discussed in the main text, Ru isotope constraints indicate that carbonaceous chondrite material was not a major constituent of the late veneer and would have been subordinate to enstatite chondrites, which have the closest average ε^{100} Ru composition to terrestrial materials of any chondritic group (31). Enstatite chondrites are extremely heterogeneous with respect to $\Delta^{17}O$ (Fig. 1), however, the average $\Delta^{17}O$ values of the EH and EL groups are close to that of the aubrites *(20,26)* and hence somewhat heavier than lunar basalts. A late veneer composed exclusively of enstatite chondrite-like material would leave the $\Delta^{17}O$ values almost unchanged, or slightly shifted towards higher $\Delta^{17}O$ values, rather than to the lower values that we have measured. This demonstrates that the late veneer must have also contained a chondritic component with a significantly negative $\Delta^{17}O$ composition; the most obvious candidates being the carbonaceous chondrites (CCs), excluding CIs (Fig, 5, fig. S4). The Ru isotope constraints dictate that this CC contribution needs to be subordinate to the enstatite chondrite component present in the late veneer *(31)*. The two obvious candidates based on the evidence displayed in Fig. 5 are CV3 and CM chondrites, both of which would need to form about 20% of the total late veneer in order to account for the 4 ppm shift seen in terrestrial basalts relative to lunar rocks. The main difference between these two CC components is that CV3s are essentially dry and so would not significantly contribute to the Earth's water budget. In contrast, a CM late veneer fraction of 20% would deliver about 0.7 of a global ocean unit (global ocean unit = total mass of hydrosphere = 1.38×10^{21} kg) *(35)*.

As can be seen from table S7, estimates of the present-day Earth's water content vary enormously, from less than two global ocean units *(33)* to nearly twelve *(32)*. This uncertainty reflects our relatively poor understanding of how much water may be present in the lower mantle and overlying transition zone. Recent evidence from kimberlites suggests that the transition zone and lower mantle may have relatively high water concentrations *(57,58)*, which in turn is taken by some as evidence favoring higher estimates for Earth's overall water content *(59)*. It is clear from experimental data that lower mantle phases have the capacity to store significant quantities of water and there is seismic evidence that the transition zone may be water-rich *(59)*. However, translating this evidence into an overall water budget for the Earth is not a straightforward task and hence significant variation between estimates is unsurprising.

Despite the uncertainty in the estimates of Earth's global water content, it is clear from our data that the main phase of terrestrial water delivery must have predated the giant impact event. The best-case scenario for the late veneer is provided by CM chondrites coupled with relatively conservative estimates of the Earth's overall water content *(33)*. A late veneer composition containing a 20% CM component fits the $\Delta^{17}O$ and Ru isotope constraints, but would still account for only about 0.7 of a global ocean unit. Obviously, the fraction of Earth's water delivered by the late veneer would be significantly diminished if more water-rich estimates of Earth's global inventory prove to be realistic *(32, 59)*. So, for example, if we use the estimate of *(32)* that the Earth contains about 12 global ocean units, this would require approximately 2.2 % of a terrestrial mass of CM chondrite. A late veneer that delivers only about 0.1 % of a terrestrial mass is therefore providing only about 5 % of Earth's water.

As discussed earlier, it is possible that some of the 4 ppm $\Delta^{17}O$ Earth-Moon difference represents a differential impactor component in one of the two bodies, in keeping with the predictions of some of the high energy giant impact scenarios of (2) and (3). This is a more difficult case to evaluate, as the starting composition of the Earth is no longer constrained to be that of the present day Moon. It is possible to theorize that the present day composition of the Earth is essentially unchanged from that of the Earth immediately after the giant impact. If that were correct then the amount of water that could be added by a CM-like component is limited, as just a 0.1 wt% late veneer addition would shift the $\Delta^{17}O$ composition outside the error envelope shown in Fig. 3. In contrast, a CI component could in principle comprise a very high fraction of the late veneer without shifting the oxygen isotope composition of the Earth outside the ± 2 ppm error envelope in Fig. 3. A CI late veneer component of 0.5 % of the terrestrial mass would add about 3 global ocean units to the Earth and would be more than sufficient to satisfy the 2 global ocean units of (33). However, as discussed above, a high content of CI material within the late veneer appears to be unlikely on the basis of the suprachondritic Ru/Ir and Pd/Ir ratios of the Bulk Silicate Earth *(29, 55).* Instead, there is evidence that the late veneer was predominantly composed of enstatite chondrite-like material (17, 29).

Supplementary Figures and Tables

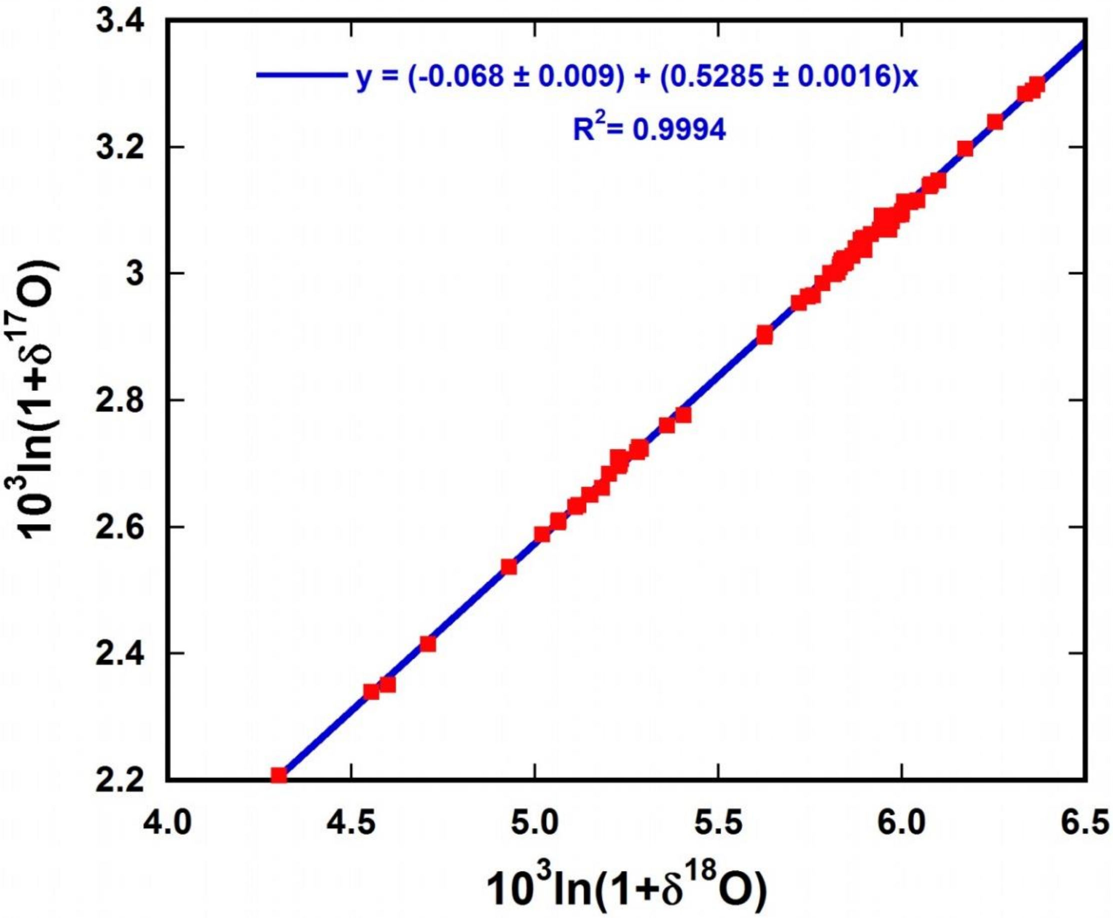

fig. S1. Linearized oxygen isotope plot for all terrestrial and lunar samples analyzed in this study (*n* = 68), including the terrestrial olivines (*19*). Errors for the slope and y-axis intercept are standard error values. The lower and upper 95 % confidence limits for the y-axis intercept are -0.087 and -0.050 respectively, and for the slope 0.5252 and 0.5317 respectively.

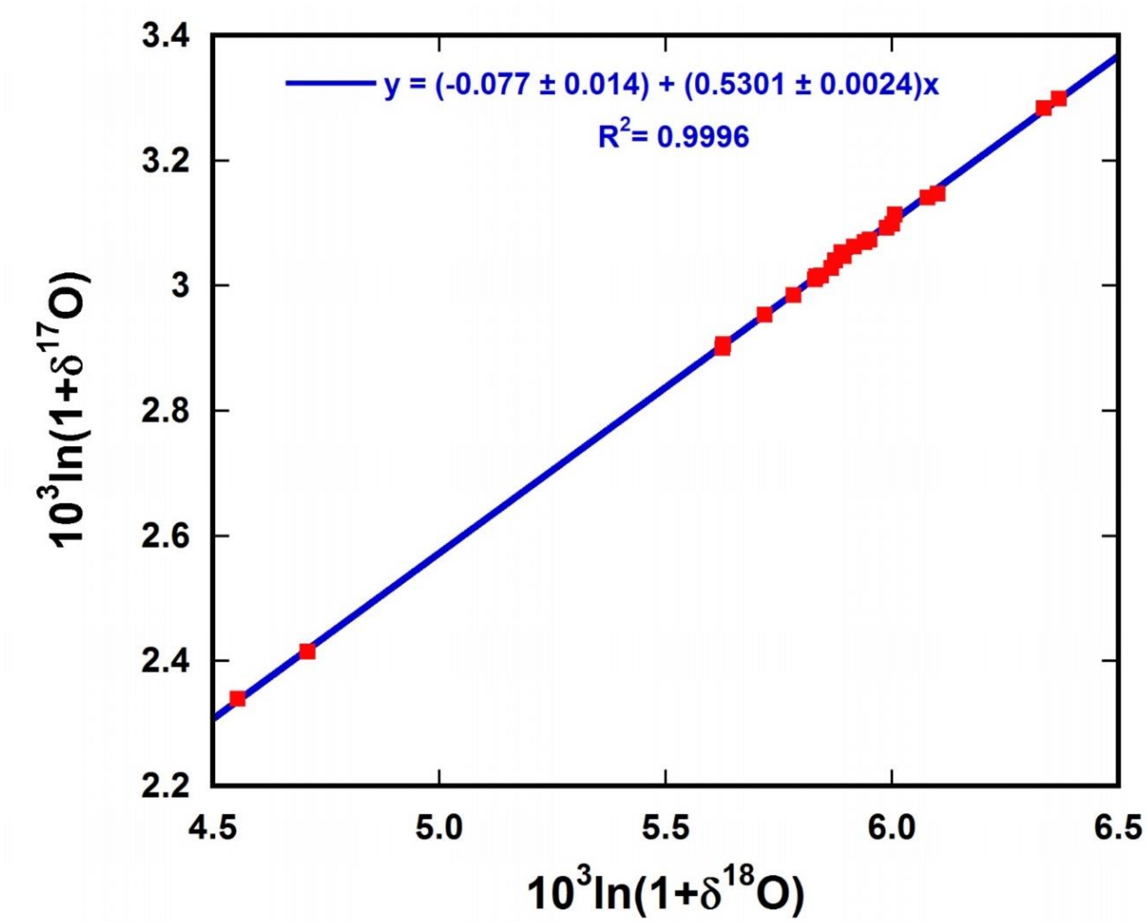

fig. S2. Linearized oxygen isotope plot for all filtered lunar samples (*n* = 24) analyzed in this study. Errors for the slope and y-axis intercept are standard error values. The lower and upper 95 % confidence limits for the y-axis intercept are -0.105 and -0.049 respectively, and for the slope 0.5252 and 0.5349 respectively.

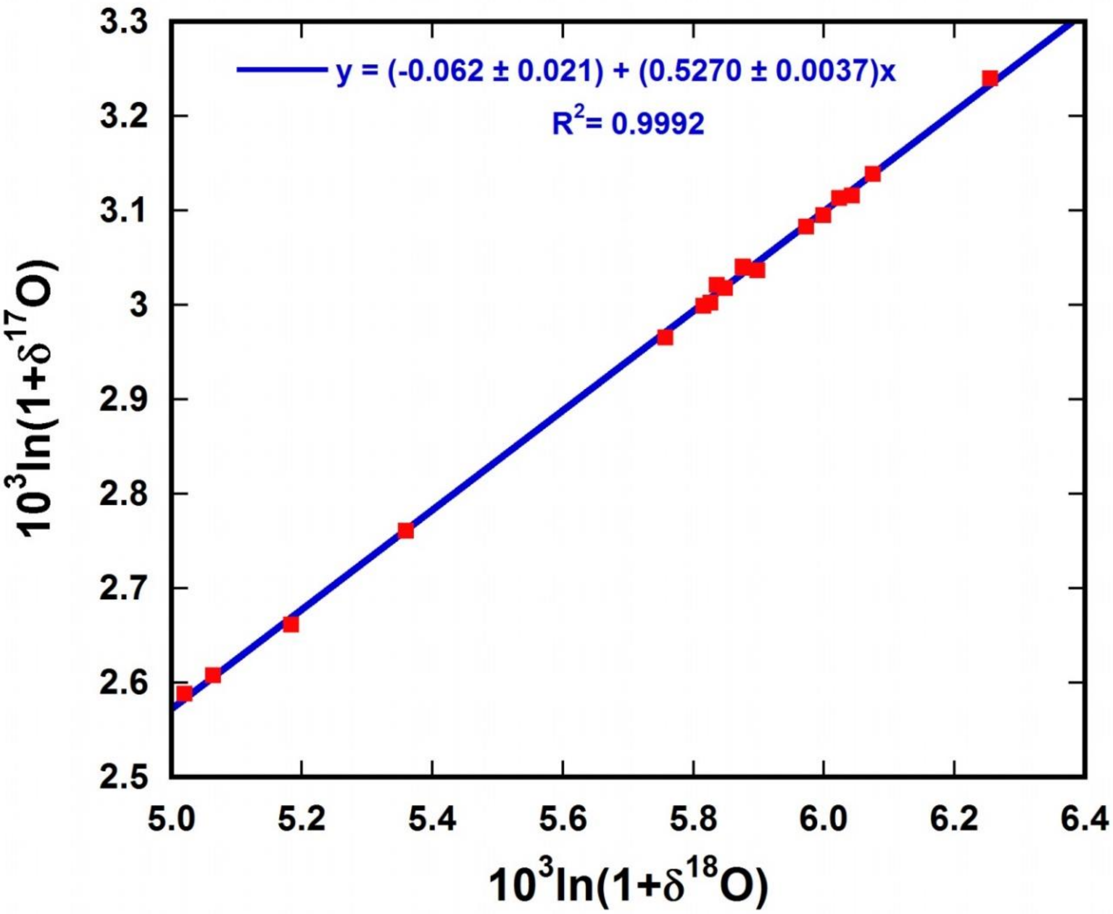

fig. S3. Linearized oxygen isotope plot for all filtered terrestrial basalt samples (*n* = 18) analyzed in this study. Errors for the slope and y-axis intercept are standard error values. The lower and upper 95 % confidence limits for the y-axis intercept are -0.108 and -0.017 respectively, and for the slope 0.5191 and 0.5348 respectively.

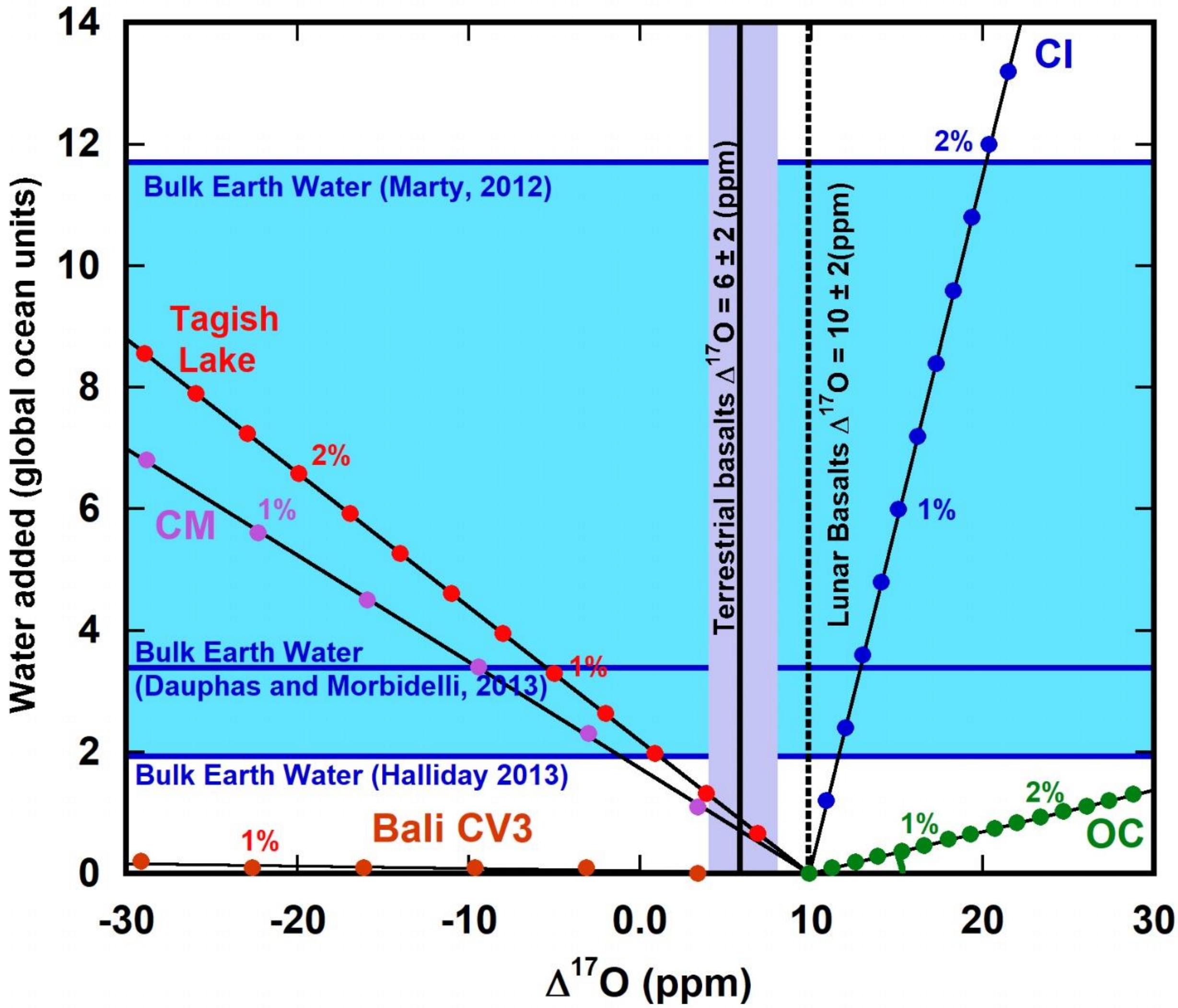

fig. S4. Diagram showing how addition of various chondritic components would alter the isotopic and water abundance compositions of the post–giant impact Earth. The $\Delta^{17}O$ composition of the Earth after the giant impact, but before the addition of the late veneer, is taken as being that defined by lunar basalts. Terrestrial basalts analyzed in this study have a somewhat lighter $\Delta^{17}O$ composition ($\Delta^{17}O = 6 \pm 2$ ppm (2 SEM)) than lunar basalts. This small $\Delta^{17}O$ difference (3 to 4 ppm*) appears to be statistically robust and may reflect post-giant impact additions to the Earth's upper mantle. HSE element data indicates that, compared to the Moon, the Earth preferentially received a post-giant impact chondritic input, equivalent to 0.5 % of the terrestrial mass *(29).* Dots on lines refer to 0.2 % of terrestrial mass. *Exact difference depends on statistical treatment, see main text**.**

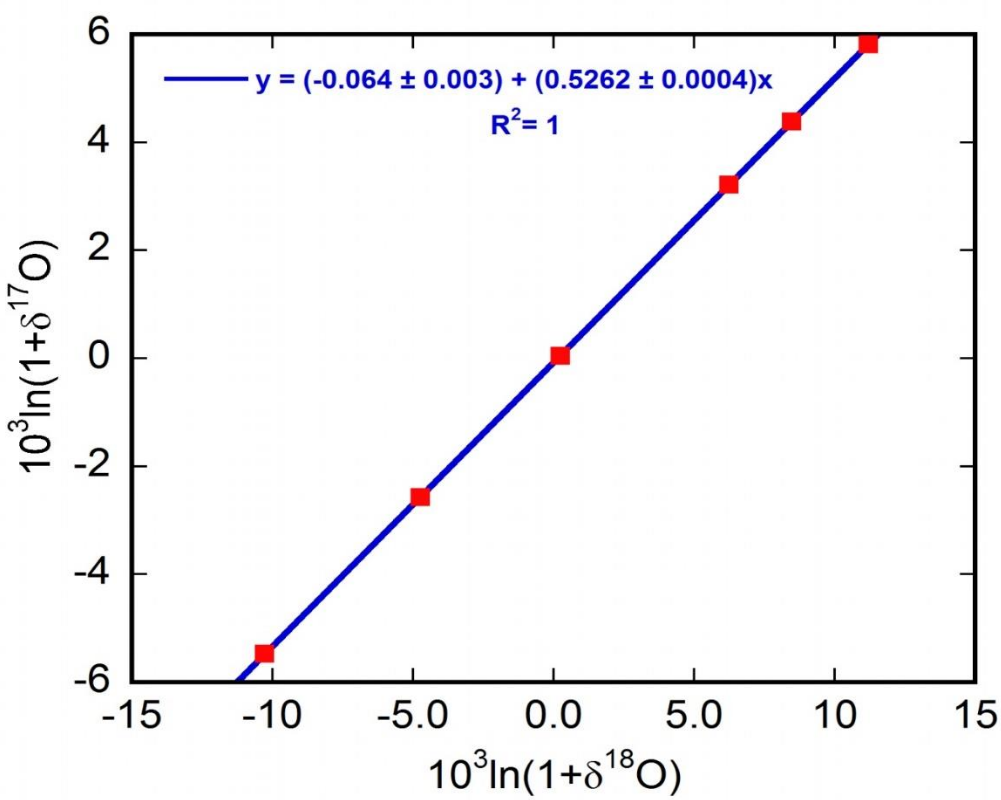

fig. S5. Oxygen isotope composition of eclogitic garnets. Reanalysis of eclogitic garnets for this study gave an identical slope to our previously published analyses of these samples *(48)*. Errors for the slope and y-axis intercept are standard error values. The lower and upper 95 % confidence limits for the y-axis intercept are -0.072 and -0.056 respectively, and for the slope 0.5252 and 0.5273 respectively.

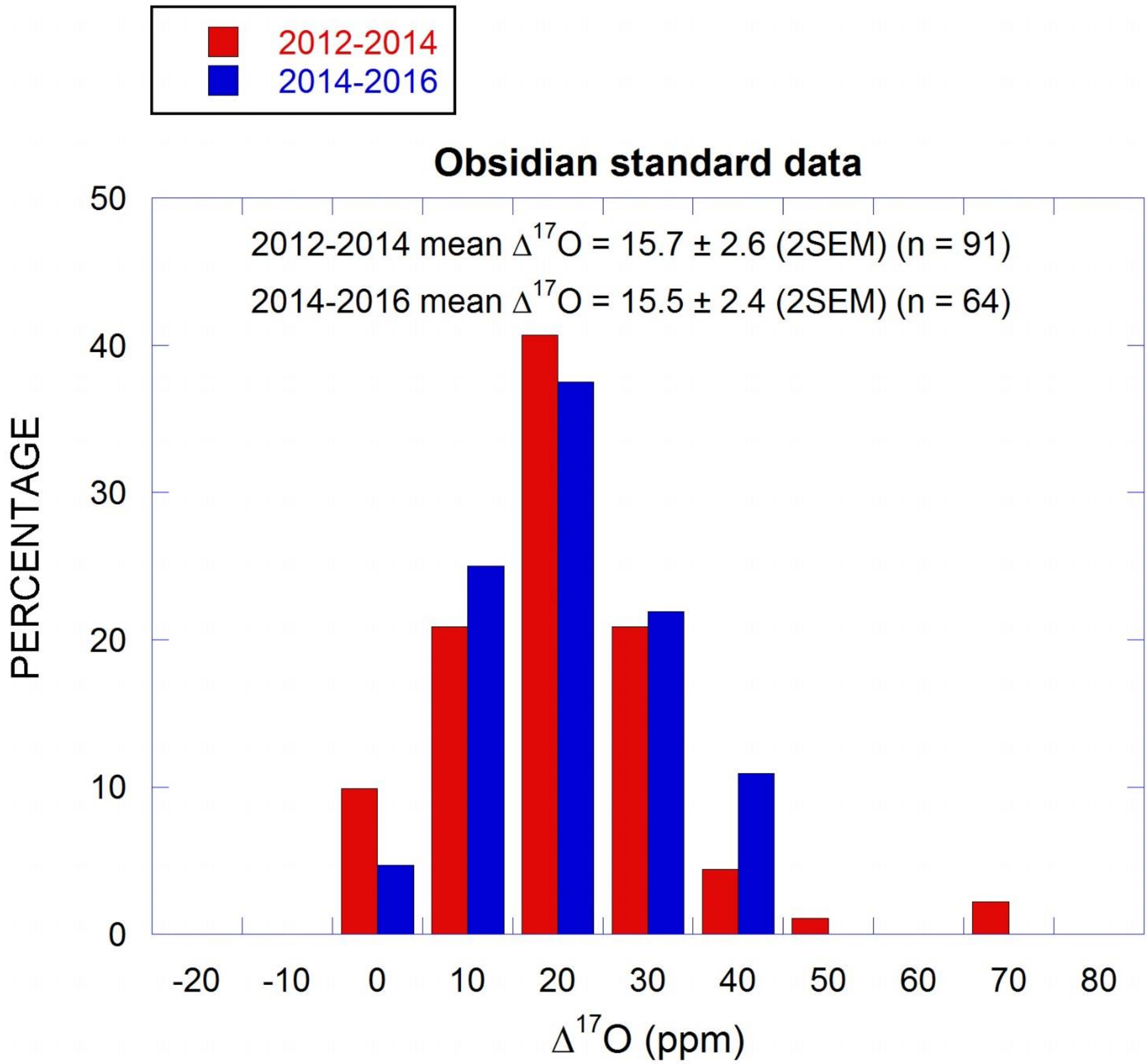

fig. S6. Obsidian standards data collected during this study compared to data collected during the earlier terrestrial olivine study (*19*). See Materials and Methods for further discussion.

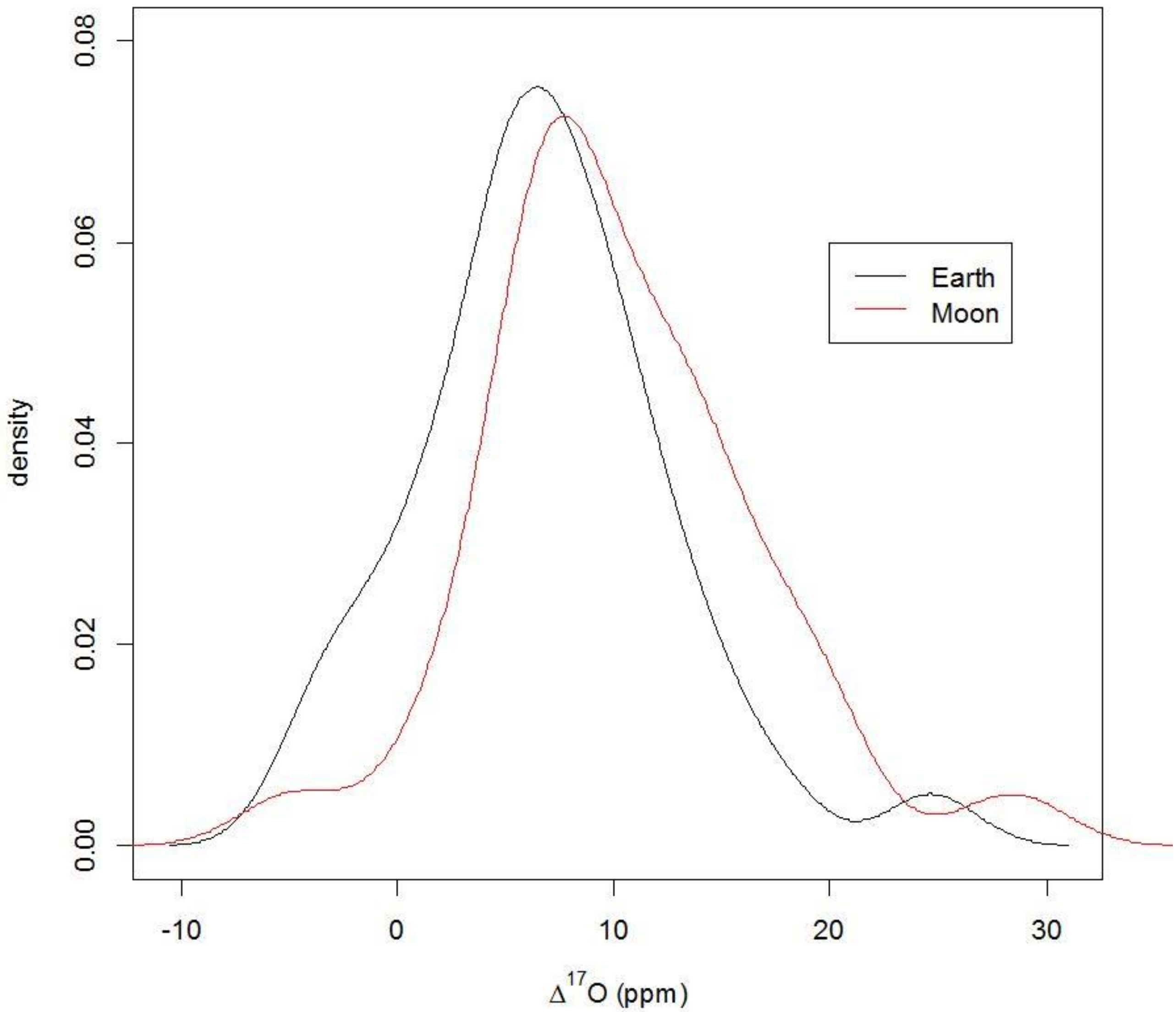

fig. S7. Kernel estimate densities from samples' average values.

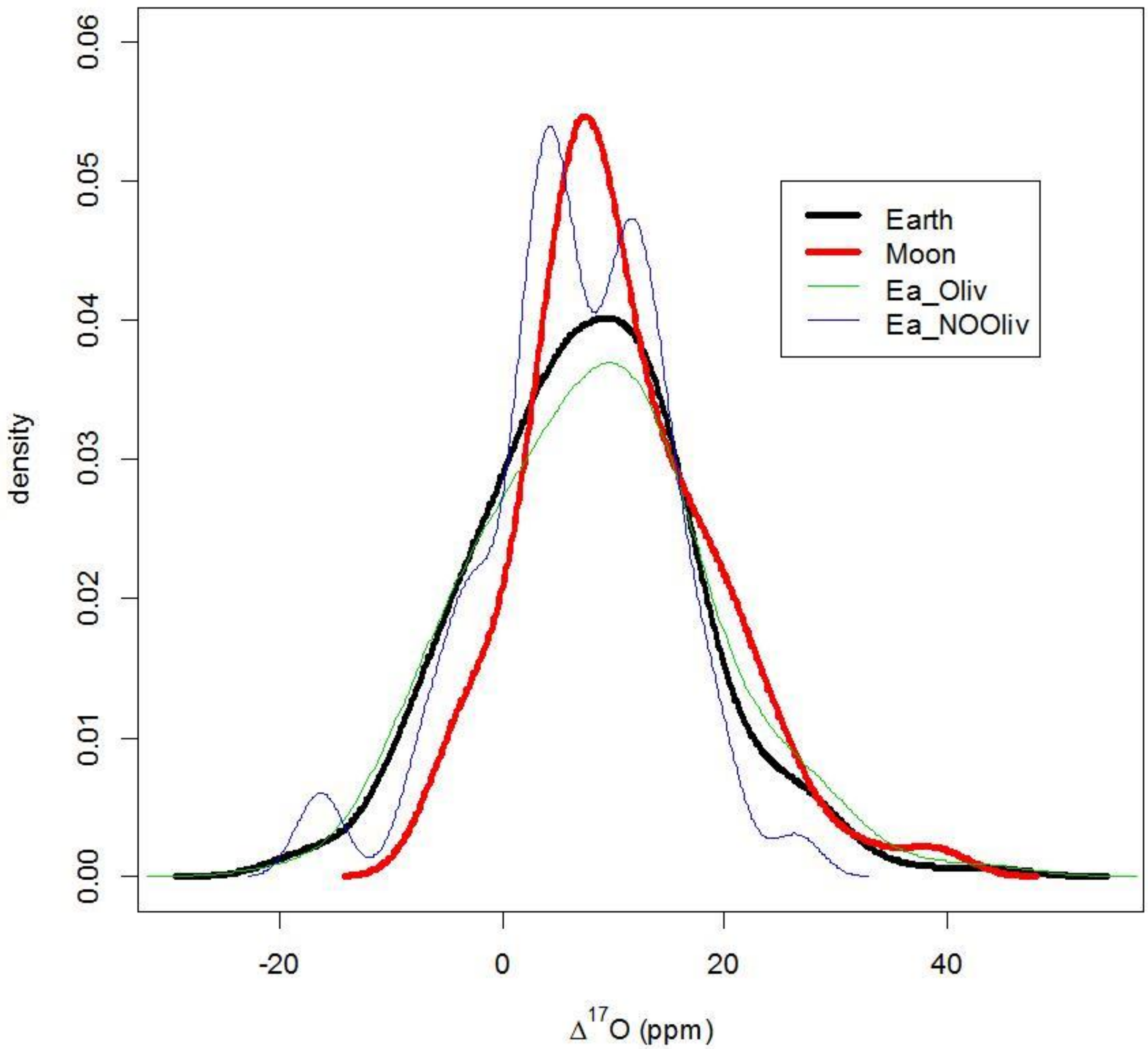

fig. S8. Kernel estimate densities from raw data (all replicates run for all samples).

table S1. Full listing of oxygen isotope data.

SUMMARY

N = Number of samples

n* = number of replicates

SAMPLE / COMMENTS		N	n*	$\delta^{17}O$ (‰)	1σ	SEM	$\delta^{18}O$ (‰)	1σ	SEM	$10^3\ln(1+\delta^{17}O)$	$10^3\ln(1+\delta^{18}O)$	offset -64 ppm $\Delta^{17}O_{0.5262}$	1σ	SEM	2 SEM
TERRESTRIAL BASALTS ONLY															
BASALT AVERAGE ALL SAMPLES	A	20	57	2.984	0.181	0.041	5.790	0.345	0.077	2.980	5.773	6	5	1	2
BASALT AVERAGE ALL (excluding samples with SEM of Δ17O >6PPM)	B	18	53	2.979	0.190	0.045	5.779	0.361	0.085	2.974	5.762	6	5	1	3
GARNET-RICH XENOLTH TARIAT															
GARNET-RICH XENOLTH TARIAT	E	1	5	3.075	0.096	0.043	5.983	0.189	0.084	3.070	5.965	-4	13	6	12
OLIVINES (Starkey et al., 2016)[24]															
HIGH 3He/4He OLIVINE, Ra > 20 (all samples)	F	10	89	2.630	0.151	0.038	5.107	0.287	0.072	2.626	5.094	10	6	1	3
HIGH 3He/4He OLIVINE, Ra > 20 (excluding samples with SEM of Δ17O >6PPM)	G	9	86	2.620	0.158	0.039	5.092	0.300	0.075	2.617	5.079	8	2	1	1
LOW 3He/4He OLIVINE, Ra < 20	H	4	16	2.715	0.059	0.015	5.274	0.120	0.030	2.712	5.260	8	9	2	4
SAN CARLOS OLIVINE AVERAGE ALL	I	2	28	2.600	0.108	0.020	5.057	0.210	0.040	2.597	5.044	7	10	1	3
OLIVINES AVERAGE ALL (F+H+I)	J	16	133	2.652	0.131	0.033	5.151	0.249	0.062	2.648	5.137	9	6	2	3
OLIVINE AVERAGE ALL (excluding samples with SEM of Δ17O >6PPM) (G+H+I)	K	15	130	2.647	0.134	0.035	5.145	0.257	0.066	2.644	5.131	8	4	1	2
BULK EARTH															
BULK EARTH ALL SAMPLES (A+E+J)	L	37	195	2.843	0.231	0.040	5.519	0.443	0.076	2.839	5.503	7	6	1	2
BULK EARTH ALL SAMPLES (excluding samples with SEM of Δ17O >6PPM) (B+E+K)	M	34	188	2.835	0.235	0.040	5.505	0.449	0.077	2.831	5.490	6	5	1	2
LUNAR ROCKS AND MINERALS															
AVERAGE (ALL LUNAR SAMPLES)	N	31	67	3.010	0.233	0.042	5.831	0.439	0.079	3.005	5.814	10	6	1	2
AVERAGE ALL LUNAR, EXCLUDING SAMPLE WITH SEM OF Δ17O >6PPM	O	24	55	3.011	0.216	0.044	5.834	0.408	0.083	3.007	5.817	9	5	1	2
AVERAGE LUNAR WHOLE_ROCK	P	17	38	3.057	0.074	0.018	5.921	0.141	0.034	3.053	5.904	10	5	1	2
AVERAGE LUNAR WHOLE-ROCK (excluding replicates with SEM >6ppm)	Q	15	34	3.051	0.067	0.017	5.910	0.129	0.033	3.047	5.893	10	5	1	3
AUBRITES (Barrat et al., 2016)[28]															
AVERAGE (ALL AUBRITES)	R	8	31	**2.919**	0.081	0.029	**5.623**	0.150	0.053	**2.914**	**5.607**	**28**	4	1	3
AVERAGE ALL AUBRITES, EXCLUDING SAMPLE WITH SEM OF Δ17O >6PPM	S	7	29	**2.914**	0.086	0.033	**5.613**	0.160	0.060	**2.909**	**5.598**	**28**	4	2	3

FULL DATA

N = Number of samples

n* = number of replicates

SAMPLE	COMMENTS	N	n*	$\delta^{17}O$ (‰)	1σ	SEM	$\delta^{18}O$ (‰)	1σ	SEM	$10^3\ln(1 + \delta^{17}O)$	$10^3\ln(1 + \delta^{18}O)$	offset -64 ppm $\Delta^{17}O_{0.5262}$	1σ	SEM	2 SEM
TERRESTRIAL BASALTS (This Study)															
PC1/DR11-1	Basaltic glass		2	3.100	0.037	0.026	6.016	0.070	0.050	3.095	5.998	3	0	0	0
CH31-DR2	Basaltic glass		2	3.007	0.039	0.028	5.843	0.072	0.051	3.003	5.826	1	1	1	1
Searise 1 DR4 (SR1 DR 04)	Basaltic glass		2	3.088	0.030	0.021	5.990	0.059	0.042	3.083	5.972	5	1	1	2
C13 (Jan Mayen C13)	Trachybasalt		2	3.004	0.030	0.021	5.832	0.059	0.042	2.999	5.815	4	1	1	2
HYAMS/DR3-10	Benmoreitic glass		2	3.246	0.041	0.029	6.274	0.075	0.053	3.241	6.254	14	2	1	2
CH98 DR 11 (MAPCO DR11)	Basaltic glass		2	3.144	0.004	0.003	6.093	0.004	0.003	3.139	6.074	7	2	1	3
PIF-2	Picrite		2	2.765	0.017	0.012	5.374	0.028	0.020	2.761	5.359	5	2	1	2
PC1/DR03-1	Basaltic glass		2	3.023	0.001	0.001	5.866	0.008	0.006	3.018	5.848	5	3	2	4
CY84/DR1-3	T-MORB basaltic glass		7	3.045	0.036	0.014	5.894	0.067	0.025	3.040	5.876	12	3	1	2
HYAMS/DR9-7	Basaltic glass		2	3.118	0.004	0.002	6.042	0.013	0.009	3.114	6.023	8	3	2	4
PC2/DR32 (PAC2-32)	Basaltic glass		2	3.121	0.035	0.025	6.061	0.075	0.053	3.116	6.042	1	4	3	6
CY84/103-1 (103-1)	T-MORB basaltic glass		7	3.046	0.029	0.011	5.893	0.057	0.022	3.041	5.876	13	4	2	3
BHV02	Basalt		2	2.970	0.009	0.006	5.773	0.008	0.006	2.966	5.756	1	5	4	7
PC1/DR13-2	Basaltic glass		2	3.026	0.007	0.005	5.852	0.004	0.003	3.021	5.835	15	5	4	7
CH31-DR5	Basaltic glass		3	3.042	0.032	0.018	5.915	0.066	0.038	3.037	5.898	-2	6	3	7
PIF-1	Picrite		2	2.665	0.052	0.037	5.196	0.086	0.060	2.662	5.183	-1	7	5	9
CY84/124-2 (124-2)	T-MORB basaltic glass		7	2.592	0.027	0.010	5.032	0.060	0.023	2.589	5.020	11	9	3	7
BIR 1	Olivine Tholeiite		3	2.612	0.021	0.012	5.076	0.042	0.024	2.608	5.064	8	10	6	11
A127 299 DR55	Basaltic glass		2	2.968	0.005	0.004	5.760	0.011	0.008	2.964	5.743	6	11	8	15
DR02-105 (Le Cap Brest)	Basaltic glass		2	3.099	0.002	0.002	6.017	0.022	0.016	3.095	5.999	2	14	10	19
AVERAGE ALL		**20**	**57**	**2.984**	**0.181**	**0.041**	**5.790**	**0.345**	**0.077**	**2.980**	**5.773**	6	**5**	**1**	**2**
AVERAGE, EXCLUDING SAMPLES WITH SEM OF $\Delta^{17}O$ >6PPM		**18**	**53**	**2.979**	**0.190**	**0.045**	**5.779**	**0.361**	**0.085**	**2.974**	**5.762**	**6**	**5**	**1**	**3**
GARNET-RICH XENOLITH TARIAT		**1**	**5**	**3.075**	**0.096**	**0.043**	**5.983**	**0.189**	**0.084**	**3.070**	**5.965**	**-4**	**13**	**6**	**12**

OLIVINES (Recalibrated from Starkey et al. 2016)

N = Number of samples

n* = number of replicates

												offset			
												-64 ppm			
SAMPLE	COMMENTS	N	n*	$\delta^{17}O$ (‰)	1σ	SEM	$\delta^{18}O$ (‰)	1σ	SEM	$10^3\ln(1+\delta^{17}O)$	$10^3\ln(1+\delta^{18}O)$	$\Delta^{17}O_{0.5262}$	1σ	SEM	2 SEM
PIT 8	Pitcairn (Ra = 8.0)		2	2.781	0.020	0.014	5.420	0.045	0.031	2.777	5.405	-3	4	3	5
PIT 16	Pitcairn (Ra = 16.0)		2	2.730	0.020	0.014	5.297	0.028	0.019	2.726	5.283	10	5	4	8
SK1	Iceland (Ra = 37.7)		12	2.211	0.076	0.022	4.312	0.148	0.043	2.208	4.302	8	8	2	5
BI/P1/27	Baffin Island (Ra = 43.1)		9	2.722	0.050	0.017	5.291	0.088	0.029	2.718	5.277	5	11	4	7
BI/CS/7	Baffin Island (Ra = 43.9)		3	2.714	0.032	0.018	5.239	0.060	0.035	2.711	5.226	25	13	8	16
400230	West Greenland (Ra = 47.6)		12	2.655	0.069	0.020	5.161	0.130	0.038	2.652	5.148	7	7	2	4
400485	West Greenland (Ra = 40.3)		11	2.655	0.058	0.017	5.164	0.104	0.031	2.651	5.151	5	11	3	7
HSDP2-SR36-1.22	Hawaii (Ra = 8.4)		6	2.712	0.103	0.042	5.248	0.186	0.076	2.708	5.234	18	11	5	9
HSDP2-SR-964-4.31	Hawaii (Ra = 12.5)		6	2.639	0.045	0.018	5.131	0.092	0.038	2.635	5.118	6	8	3	7
HSDP2.SR741.90	Hawaii (Ra = 23.9)		6	2.614	0.054	0.022	5.078	0.106	0.043	2.610	5.065	9	12	5	10
OFU.04.03	Samoa (Ra = 24.0)		7	2.635	0.069	0.026	5.122	0.119	0.045	2.632	5.109	7	15	6	11
OFU-04-14	Samoa (Ra = 24.0)		10	2.688	0.058	0.018	5.216	0.107	0.034	2.684	5.202	11	7	2	4
OFU.04.15	Samoa (Ra = 29.6)		11	2.703	0.063	0.019	5.246	0.108	0.032	2.699	5.232	10	15	4	9
OFU.04.17	Samoa (Ra = 26.4)		8	2.700	0.047	0.017	5.241	0.095	0.034	2.696	5.227	10	10	3	7
San Carlos Olivine	$\delta^{18}O$ = 4.88‰		19	2.540	0.067	0.015	4.941	0.133	0.030	2.537	4.929	8	10	2	4
San Carlos Olivine	$\delta^{18}O$ = 5.23‰		9	2.727	0.054	0.018	5.303	0.096	0.032	2.723	5.289	5	10	3	6
OLIVINES AVERAGE ALL		**16**	**133**	**2.652**	**0.131**	**0.033**	**5.151**	**0.249**	**0.062**	**2.648**	**5.137**	**9**	**6**	**2**	**3**
OLIVINE AVERAGE ALL (excluding samples with SEM of Δ17O >6PPM)		**15**	**130**	**2.647**	**0.134**	**0.035**	**5.145**	**0.257**	**0.066**	**2.644**	**5.131**	8	**4**	**1**	**2**
HIGH $^3He/^4He$ OLIVINE, R_a > 20 (all samples)		**10**	**89**	**2.630**	**0.151**	**0.038**	**5.107**	**0.287**	**0.072**	**2.626**	**5.094**	**10**	**6**	**1**	**3**
HIGH $^3He/^4He$ OLIVINE, R_a > 20 (excluding samples with SEM of Δ17O >6PPM)		**9**	**86**	**2.620**	**0.158**	**0.039**	**5.092**	**0.300**	**0.075**	**2.617**	**5.079**	**8**	**2**	**1**	**1**
LOW $^3He/^4He$ OLIVINE, R_a < 20		**4**	**16**	**2.715**	**0.059**	**0.015**	**5.274**	**0.120**	**0.030**	**2.712**	**5.260**	**8**	**9**	**2**	**4**
SAN CARLOS OLIVINE AVERAGE ALL		**2**	**28**	**2.600**	**0.108**	**0.020**	**5.057**	**0.210**	**0.040**	**2.597**	**5.044**	**7**	**10**	**1**	**3**

LUNAR ROCKS AND MINERALS

N = Number of samples

n* = number of replicates

SAMPLE	COMMENTS	N	n*	$\delta^{17}O$ (‰)	1σ	SEM	$\delta^{18}O$ (‰)	1σ	SEM	$10^3\ln(1 + \delta^{17}O)$	$10^3\ln(1 + \delta^{18}O)$	offset -64 ppm $\Delta^{17}O_{0.5262}$	1σ	SEM	2 x SEM
10,044,647	Ilmenite Basalt (Low K)		2	3.020	0.021	0.015	5.850	0.041	0.029	3.015	5.833	10	0	0	0
70,035,194	ilmenite basalt		2	3.033	0.022	0.016	5.883	0.041	0.029	3.029	5.865	6	0	0	1
62237,14	Troctolitic anorthosite		3	3.146	0.053	0.031	6.097	0.102	0.059	3.141	6.078	7	1	0	1
12,040,219	Olivine basalt		2	2.911	0.007	0.005	5.643	0.012	0.009	2.907	5.627	10	1	1	1
12,040,206	Olivine basalt		2	2.989	0.012	0.008	5.799	0.025	0.018	2.985	5.782	6	1	1	1
70017, 543	ilmenite basalt		2	2.959	0.008	0.006	5.736	0.020	0.014	2.955	5.719	9	2	1	3
10020,231	Ilmenite Basalt (Low K)		2	3.045	0.016	0.011	5.891	0.035	0.025	3.040	5.874	13	3	2	4
12016,37	ilmenite basalt		2	3.058	0.009	0.006	5.911	0.012	0.008	3.054	5.894	16	3	2	4
67435,147	Polymict breccia		2	3.152	0.018	0.013	6.119	0.040	0.028	3.147	6.100	2	3	2	4
78235, 120	Shocked norite		4	3.120	0.024	0.012	6.024	0.052	0.026	3.115	6.006	19	3	2	3
15059, 291	Regolith Breccia		2	3.104	0.018	0.013	6.018	0.040	0.028	3.100	6.000	6	3	2	5
15016,223	vesicular olivine-normative basalt		2	3.052	0.039	0.028	5.910	0.067	0.047	3.048	5.893	11	4	3	5
15555, 1026	Olivine-normative basalt		2	3.058	0.012	0.008	5.905	0.030	0.021	3.054	5.888	20	4	3	6
70017 (Clayton)	ilmenite basalt		3	3.022	0.018	0.010	5.860	0.041	0.024	3.017	5.843	7	4	3	5
14053,260	Basalt		2	3.098	0.008	0.006	6.006	0.029	0.021	3.093	5.988	6	7	5	9
15386,54	KREEP Basalt		2	3.203	0.010	0.007	6.192	0.010	0.007	3.198	6.173	14	15	11	21
15016 (Clayton)	vesicular olivine-normative basalt		2	3.006	0.010	0.007	5.821	0.057	0.040	3.001	5.804	11	20	14	28
70017 Plagioclase	ilmenite basalt		2	3.289	0.006	0.004	6.355	0.015	0.011	3.284	6.335	14	1	1	2
71055 Ilmenite	Vesicular ilmenite basalt		2	2.343	0.072	0.051	4.565	0.134	0.095	2.340	4.554	8	2	1	3
70017 Orthopyroxene	ilmenite basalt		2	3.079	0.010	0.007	5.968	0.025	0.018	3.074	5.950	7	3	2	5
15016 Clinopyroxene	vesicular olivine-normative basalt		2	3.015	0.004	0.003	5.847	0.001	0.000	3.010	5.830	7	4	3	5
72155 Olivine	ilmenite basalt		2	2.905	0.009	0.006	5.642	0.025	0.018	2.901	5.626	5	4	3	6
15016 pigeonite	vesicular olivine-normative basalt		3	3.074	0.025	0.014	5.957	0.056	0.032	3.070	5.939	8	6	3	6
72155 Ilmenite	ilmenite basalt		2	2.419	0.045	0.032	4.720	0.097	0.069	2.416	4.709	2	6	4	8
71055 Pyroxene	Vesicular ilmenite basalt		4	3.068	0.020	0.010	5.933	0.025	0.013	3.063	5.916	14	9	4	9
72155 Plagioclase	ilmenite basalt		2	3.305	0.006	0.004	6.389	0.026	0.019	3.299	6.369	12	8	6	11
70017 Clinopyroxene	ilmenite basalt		2	3.097	0.034	0.024	5.962	0.037	0.026	3.092	5.944	28	15	10	21
71055 Plagioclase	Vesicular ilmenite basalt		2	3.295	0.030	0.021	6.377	0.021	0.015	3.289	6.357	8	19	13	27
71055 Clinopyroxene	Vesicular ilmenite basalt		2	3.029	0.030	0.021	5.860	0.008	0.006	3.024	5.842	14	25	18	36

LUNAR ROCKS continued

N = Number of samples

n* = number of replicates

SAMPLE	COMMENTS	N	n*	$\delta^{17}O$ (‰)	1σ	SEM	$\delta^{18}O$ (‰)	1σ	SEM	$10^3\ln(1 + \delta^{17}O)$	$10^3\ln(1 + \delta^{18}O)$	offset -64 ppm $\Delta^{17}O_{0.5262}$	1σ	SEM	2 x SEM
70017 Ilmenite	ilmenite basalt		1	2.354			4.609			2.351	4.599	-5			
72155 Clinopyroxene	ilmenite basalt		1	3.062			5.913			3.057	5.895	19			
AVERAGE LUNAR WHOLE_ROCK		17	38	3.057	0.074	0.018	5.921	0.141	0.034	3.053	5.904	10	5	1	2
AVERAGE LUNAR WHOLE-ROCK (excluding replicates with SEM >6ppm)		15	34	3.051	0.067	0.017	5.910	0.129	0.033	3.047	5.893	10	5	1	3
AVERAGE (ALL LUNAR SAMPLES)		31	67	3.010	0.233	0.042	5.831	0.439	0.079	3.005	5.814	10	6	1	2
AVERAGE ALL LUNAR, EXCLUDING SAMPLE WITH SEM OF $\Delta^{17}O$ >6PPM		24	55	3.011	0.216	0.044	5.834	0.408	0.083	3.007	5.817	9	5	1	2

AUBRITES (Recalibrated from Barrat et al., 2016)

SAMPLE	N	n*	$\delta^{17}O$ (‰)	1σ	SEM	$\delta^{18}O$ (‰)	1σ	SEM	$10^3\ln(1 + \delta^{17}O)$	$10^3\ln(1 + \delta^{18}O)$	$\Delta^{17}O_{0.5262}$	1σ	SEM	2 x SEM
Aubres		1	2.924			5.639			2.920	5.623	25			
Bishopville		2	3.049	0.019	0.013	5.869	0.037	0.026	3.045	5.851	30	0	0	0
Bustee		2	2.861	0.050	0.035	5.522	0.099	0.070	2.857	5.506	24	2	1	2
Khor Temki		2	2.954	0.018	0.013	5.690	0.077	0.055	2.950	5.674	28	22	16	31
Mayo Belwa BM 1976, M11		4	2.976	0.063	0.032	5.720	0.117	0.059	2.972	5.703	35	6	3	6
Norton County Aubrite		12	2.880	0.097	0.028	5.551	0.189	0.054	2.876	5.536	27	11	3	6
Pena Blance Spring		6	2.778	0.111	0.045	5.362	0.207	0.084	2.774	5.348	24	9	4	7
Pesyanoe matrix		2	2.926	0.097	0.069	5.632	0.168	0.119	2.922	5.616	31	9	6	12
AVERAGE (ALL AUBRITES)	**8**	**31**	**2.919**	**0.081**	**0.029**	**5.623**	**0.150**	**0.053**	**2.914**	**5.607**	**28**	**4**	**1**	**3**
AVERAGE ALL AUBRITES, EXCLUDING SAMPLE WITH SEM OF $\Delta^{17}O$ >6PPM	**7**	**29**	**2.914**	**0.086**	**0.033**	**5.613**	**0.160**	**0.060**	**2.909**	**5.598**	**28**	**4**	**2**	**3**

table S2. Results of Student *t* tests for unpaired data with equal variance.

TEST 1 Unfiltered lunar data (all samples) and unfiltered terrestrial data (all samples): "Bulk Earth"

GROUP 1 (Lunar data): 10, 6, 7, 10, 6, 9, 13, 16, 2, 19, 6, 11, 20, 7, 6, 14, 11, 14, 8, 7, 7, 5, 8, 2, 14, 12, 28, 8, 14, -5, 19,
GROUP 2 (Bulk Earth): 3, 1, 5, 4, 14, 7, 5, 5, 12, 8, 1, 13, 1, 15, -2, -1, 11, 8, 6, 2, -4, -3, 10, 8, 5, 25, 7, 5, 18, 6, 9, 7, 11, 10, 10, 8, 5,

	Group 1 (Lunar data)	Group 2 (Bulk Earth)
Count	31	37
Mean	10.1	6.9
95% conf. limit	8.0 – 12.3	4.9 – 8.9
High	28	25
Low	-5	-4
Median	9	7
Std. Dev.	6.3	5.9
Std. Error	1.1	1.0

Mean Difference	3.2
Degrees of Freedom	66
t Value	2.19
t Probability (p-value) (two-tailed)	0.032 (the result is significant at $p < 0.05$)
F-Test	
F Value	1.15
F Probability	0.342 (>0.05 therefore no significant diff. between variances of the two samples).

Notes: In this test the t probability (p) value of 0.032 is below the 0.05 threshold suggesting that there is a statistically significant difference between the two group means. Taken at face value the principal conclusion of this test would be that the 3.2 ppm difference between the data for the Moon and Earth is statistically significant. Test 1 includes data that has a high SEM, indicating relatively poor reproducibility of the replicate data. In Test 2 (below), data with SEM > 6ppm have been eliminated, as have two mineral separate analyses for which only 1 replicate was undertaken (due to the insufficient sample material).

TEST 2 Filtered lunar data and filtered terrestrial data (as Test 1 but samples with SEM > 6 ppm excluded)

GROUP 1 (Lunar data): 10, 6, 7, 10, 6, 9, 13, 16, 2, 19, 6, 11, 20, 7, 6, 14, 8, 7, 7, 5, 8, 2, 14, 12,
GROUP 2 (Bulk Earth): 3, 1, 5, 4, 14, 7, 5, 5, 12, 8, 1, 13, 1, 15, -2, -1, 11, 8, -4, -3, 10, 8, 5, 7, 5, 18, 6, 9, 7, 11, 10, 10, 8, 5,

	Group 1 (Lunar data)	Group 2 (Bulk Earth)
Count	24	34
Mean	9.4	6.5
95% conf. limit	7.3 – 11.4	4.8 – 8.2
High	20	18

Low	2	-4
Median	8	7
Std. Dev.	4.7	5.2
Std. Error	1.0	0.9

Mean Difference	2.9
Degrees of Freedom	56
t Value	2.14
t Probability (p-value) (two-tailed)	0.037 (the result is significant at $p < 0.05$)

F-Test

F Value	1.2
F Probability	0.328 (>0.05 therefore no significant diff. between variances of the two samples).

Notes: In this test the t probability (p) value of 0.037 is below the 0.05 threshold suggesting that there is a statistically significant difference between the two group means. Taken at face value the principal conclusion of this test would be that the 2.9 ppm difference between the data for the Moon and Earth is statistically significant.

TEST 3 Unfiltered lunar whole-rocks data and unfiltered terrestrial basalts.

GROUP 1 (Lunar whole-rocks): 10, 6, 7, 10, 6, 9, 13, 16, 2, 19, 6, 11, 20, 7, 6, 14, 11,
GROUP 2 (Terrestrial basalts): 3, 1, 5, 4, 14, 7, 5, 5, 12, 8, 1, 13, 1, 15, -2, -1, 11, 8, 6, 2,

	Group 1 (Lunar whole-rocks)	Group 2 (Terrestrial basalts)
Count	17	20
Mean	10.2	5.9
95% conf. limit	7.7 – 12.6	3.6 – 8.2
High	20	15
Low	2	-2
Median	10	5
Std. Dev.	4.9	5.1
Std. Error	1.2	1.1

Mean Difference	4.3
Degrees of Freedom	35
t Value	2.59
t Probability (p-value) (two-tailed)	0.014 (the result is significant at $p < 0.05$)

F-Test

F Value	1.05
F Probability	0.466 (>0.05 therefore no significant diff. between variances of the two samples).

Notes: In this test the t probability (p) value of 0.014 is well below the 0.05 threshold suggesting that there is a statistically significant difference between the two group means. The principal conclusion of this test would be that the 4.3 ppm difference between the data for the lunar whole-rocks and terrestrial basalts is statistically significant.

TEST 4 Filtered lunar whole-rocks data and filtered terrestrial basalts (as Test 3 but samples with SEM > 6 ppm excluded)

GROUP 1 (Lunar whole-rocks): 10, 6, 7, 10, 6, 9, 13, 16, 2, 19, 6, 11, 20, 7, 6,
GROUP 2 (Terrestrial basalts): 3, 1, 5, 4, 14, 7, 5, 5, 12, 8, 1, 13, 1, 15, -2, -1, 11, 8,

	Group 1 (Lunar whole-rocks)	Group 2 (Terrestrial basalts)
Count	15	18
Mean	9.9	6.1
95% conf. limit	7.1 – 12.6	3.6 – 8.6
High	20	15
Low	2	-2
Median	9	5
Std. Dev.	5.2	5.3
Std. Error	1.3	1.2

Mean Difference	3.8
Degrees of Freedom	31
t Value	2.06
t Probability (p-value) (two-tailed)	0.048 (the result is significant at $p < 0.05$)
F-Test	
F Value	1.04
F Probability	0.476 (>0.05 therefore no significant diff. between variances of the two samples).

Notes: In this test the t probability (p) value of 0.048 is just below the 0.05 threshold suggesting that there is a statistically significant difference between the two group means. The principal conclusion of this test is that the 3.8 ppm difference between the filtered data for the lunar whole-rocks and terrestrial basalts is statistically significant.

TEST 5 Unfiltered lunar data (whole-rocks and mineral separates) and unfiltered terrestrial olivines

GROUP 1 (Lunar data): 10, 6, 7, 10, 6, 9, 13, 16, 2, 19, 6, 11, 20, 7, 6, 14, 11, 14, 8, 7, 7, 5, 8, 2, 14, 12, 28, 8, 14, -5, 19
GROUP 2 (Terrestrial olivines): -3, 10, 8, 5, 25, 7, 5, 18, 6, 9, 7, 11, 10, 10, 8, 5,

	Group 1 (Lunar data)	Group 2 (Terrestrial olivines)
Count	31	16
Mean	10.1	8.8
95% conf. limit	7.9 – 12.4	5.7 – 12.0
High	28	25
Low	-5	-3
Median	9	8
Std. Dev.	6.3	6.1
Std. Error	1.1	1.5

Mean Difference	1.3
Degrees of Freedom	45
t Value	0.69
t Probability (p-value) (two-tailed)	0.496 (the result is not significant at $p < 0.05$)
F-Test	
F Value	1.11

F Probability 0.429 (>0.05 therefore no significant diff. between variances of the two samples).

Notes: In this test the t probability (p) value of 0.496 is well above the 0.05 threshold suggesting that there is not a statistically significant difference between the two group means. No terrestrial basalt data are included in the test and the lunar samples are compared with the recalibrated olivine separate data from Starkey et al. (2016) *(19).* The olivines included in this test are from basalts that have both high and low $^{3}He/^{4}He$ values. The principal conclusion of this test is that the 1.3 ppm difference between the unfiltered data for lunar whole-rocks and mineral separates and terrestrial olivines is not statistically significant.

TEST 6 Filtered lunar data (whole-rocks and mineral separates) and filtered terrestrial olivines (as Test 5 but samples with SEM > 6 ppm excluded)

GROUP 1 (Lunar data): 10, 6, 7, 10, 6, 9, 13, 16, 2, 19, 6, 11, 20, 7, 6, 14, 8, 7, 7, 5, 8, 2, 14, 12,

GROUP 2 (Terrestrial olivines): -3, 10, 8, 5, 7, 5, 18, 6, 9, 7, 11, 10, 10, 8, 5,

	Group 1 (Lunar data)	Group 2 (Terrestrial olivines)
Count	24	15
Mean	9.4	7.7
95% conf. limit	7.5 – 11.3	5.3 – 10.2
High	20	18
Low	2	-3
Median	8	8
Std. Dev.	4.7	4.4
Std. Error	1.0	1.1

Mean Difference	1.7
Degrees of Freedom	37
t Value	1.08
t Probability (p-value) (two-tailed)	0.288 (the result is not significant at $p < 0.05$)

F-Test

F Value	1.17
F Probability	0.389 (>0.05 therefore no significant diff. between variances of the two samples).

Notes: In this test the t probability (p) value of 0.288 is well above the 0.05 threshold suggesting that there is not a statistically significant difference between the two group means. No terrestrial basalt data are included in the test and the lunar samples are compared with the recalibrated olivine separate data from Starkey et al. (2016) *(19).* The olivines included in this test are from basalts that have both high and low $^{3}He/^{4}He$ values. The principal conclusion of this test is that the 1.7 ppm difference between the filtered data for lunar whole-rocks and mineral separates and terrestrial olivines is not statistically significant.

TEST 7 Comparing unfiltered high $^{3}He/^{4}He$ terrestrial olivines (Starkey et al., 2016) to unfiltered lunar whole-rock and mineral separates data.

GROUP 1 (Lunar data): 10, 6, 7, 10, 6, 9, 13, 16, 2, 19, 6, 11, 20, 7, 6, 14, 11, 14, 8, 7, 7, 5, 8, 2, 14, 12, 28, 8, 14, -5, 19

GROUP 2 (high $^{3}He/^{4}He$ olivines): 8, 5, 25, 7, 5, 9, 7, 11, 10, 10,

	Group 1 (Lunar data)	Group 2 (high $^3He/^4He$ olivines)
Count	31	10
Mean	10.1	9.7
95% conf. limit	7.9 – 12.4	5.7 – 13.7
High	28	25
Low	-5	5
Median	9	8.5
Std. Dev.	6.3	5.8
Std. Error	1.1	1.8

Mean Difference	0.4
Degrees of Freedom	39
t Value	0.19
t Probability (p-value) (two-tailed)	0.850 (the result is not significant at $p < 0.05$)
F-Test	
F Value	1.29
F Probability	0.360 (>0.05 therefore no significant diff. between variances of the two samples).

Notes: In this test the t probability (p) value of 0.850 is well above the 0.05 threshold suggesting that there is not a statistically significant difference between the two group means. No terrestrial basalt data are included in the test and the unfiltered lunar samples are compared with the recalibrated high $^3He/^4He$ values olivine separate data from Starkey et al. (2016) *(19)*. The principal conclusion of this test is that the 0.4 ppm difference between the unfiltered data for lunar whole-rocks and mineral separates and high $^3He/^4He$ terrestrial olivines is not statistically significant.

TEST 8 Comparing filtered high $^3He/^4He$ terrestrial olivines (Starkey et al., 2016) to filtered lunar whole-rock and mineral separates data (as Test 7 but samples with SEM > 6 ppm excluded)

GROUP 1 (Lunar data): 10, 6, 7, 10, 6, 9, 13, 16, 2, 19, 6, 11, 20, 7, 6, 14, 8, 7, 7, 5, 8, 2, 14, 12,
GROUP 2 (high $^3He/^4He$ olivines): 8, 5, 25, 7, 5, 9, 7, 11, 10, 10,

	Group 1 (Lunar data)	Group 2 (high $^3He/^4He$ olivines)
Count	24	9
Mean	9.4	8.0
95% conf. limit	7.6 – 11.1	5.1 – 10.9
High	20	11
Low	2	5
Median	8	8
Std. Dev.	4.7	2.2
Std. Error	1.0	0.7

Mean Difference	1.4

Degrees of Freedom	31
t Value	0.83
t Probability (p-value) (two-tailed)	0.412 (the result is not significant at $p < 0.05$)

F-Test

F Value	5.09
F Probability	0.01 (<0.05 therefore is a significant diff. between variances of the two samples).

T-test assuming unequal variances

t Value	1.14
Degrees of Freedom	29
t Probability (p-value) (two-tailed)	0.265 (the result is not significant at $p < 0.05$)

Notes: In this test the t probability (p) value of 0.412 is well above the 0.05 threshold, suggesting that there is not a statistically significant difference between the two group means. However, the results of the F-Test indicate that there is a significant difference between the variances of the two populations. A T-test assuming unequal variances gave a t probability (p-values) of 0.265, which is above the 0.05 threshold value. No terrestrial basalt data are included in the test and the filtered lunar samples are compared with the recalibrated filtered high $^3He/^4He$ values olivine separate data from Starkey et al. (2016) *(19).* The principal conclusion of this test is that the 1.4 ppm difference between the filtered data for lunar whole-rocks and mineral separates and high $^3He/^4He$ terrestrial olivines is not statistically significant.

table S3. Whole rock terrestrial samples.

Sample #	type	Area	Latitude N	Longitude E	(La/Sm)n
Mid ocean ridge lavas					
CH98 DR11	basaltic glass	Mid Atlantic Ridge	30.677	-41.809	0.520
CH31-DR2	basaltic glass	Mid Atlantic Ridge	36.790	-33.238	1.49
CH31-DR5	basaltic glass	Mid Atlantic Ridge	36.767	-33.275	1.32
A127 299 DR55	basaltic glass	Mid Atlantic Ridge	33.73	-37.78	0.847
DR02 - 105	basaltic glass	Mid Atlantic Ridge	-7.868	-13.450	0.671
SR1 DR04	basaltic glass	E Pacific Ridge	6.73	-102.6	0.703
PC1/DR03-1	basaltic glass	Pacific-Antarctic Ridge	-62.316	-156.083	0.912
PC1/DR11-1	basaltic glass	Pacific-Antarctic Ridge	-57.633	-146.798	0.601
PC1/DR13-2	basaltic glass	Pacific-Antarctic Ridge	-56.570	-145.743	0.592
PC2/DR32	basaltic glass	Pacific-Antarctic Ridge	-45.393	-112.432	0.741
CY84/103-1	basaltic glass	Tadjoura Gulf	43.634	11.977	1.23
CY84/DR1-3	basaltic glass	Tadjoura Gulf	43.657	11.958	1.22
CY84/124-2	basaltic glass	Tadjoura Gulf	42.94	11.714	1.44
HYAMS/DR3-10	benmoreitic glass	E Indian Ridge	-37.542	78.419	2.48
HYAMS/DR9-7	basaltic glass	E Indian Ridge	-30.34	75.755	0.744
Ocean Island basalts					
BIR1	Ol tholeiite[1]	Iceland, Reykjanes Peninsula			0.375
C13	basalt[2]	Jan Mayen	71.1	-8.1	4.83
PIF -1	picrite[3]	Reunion, Piton de la Fournaise	-21.28	51.79	1.99
PIF -2	picrite[3]	Reunion, Piton de la Fournaise	-21.28	51.79	1.99
BHV02	basalt[4]	Hawaii, Kilauea, Halema'uma'u	19.412	-155.286	1.63
Mantle xenoliths					
Garnet-rich xenolith Tariat					

NOTES

1: USGS standard collected from interglacial lava flow, Reykjavik, Iceland

2: A very fresh evolved lava - trachybasaltic composition

3: PIF-1 and PIF-2 are separate fractions of a vesiculated lave with a black, glassy groundmass collected about one month after eruption

4. USGS Standard 1911 Pahoehoe lava from Hawaii collected in 1995

table S4. Analyses of eclogitic garnet samples.

	$\delta^{17}O$	$\delta^{18}O$	$10^3\ln(1 + \delta^{17}O)$	$10^3\ln(1 + \delta^{18}O)$
F-430	0.084	0.294	0.084	0.294
F-430	0.027	0.188	0.027	0.188
AVERAGE	**0.055**	**0.241**	**0.055**	**0.241**
A12	5.816	11.208	5.799	11.145
A12	5.853	11.282	5.836	11.218
AVERAGE	**5.835**	**11.245**	**5.818**	**11.182**
GMTNcrs	3.207	6.203	3.202	6.183
GMTNcrs	3.244	6.287	3.239	6.267
AVERAGE	**3.225**	**6.245**	**3.220**	**6.225**
A15	4.378	8.462	4.368	8.426
A15	4.418	8.523	4.408	8.487
AVERAGE	**4.398**	**8.493**	**4.388**	**8.457**
95-QL-2H	-5.444	-10.202	-5.458	-10.255
95-QL-2H	-5.465	-10.256	-5.480	-10.309
AVERAGE	**-5.454**	**-10.229**	**-5.469**	**-10.282**
95-YS-1	-2.580	-4.766	-2.584	-4.778
95-YS-1	-2.549	-4.708	-2.553	-4.719
AVERAGE	**-2.565**	**-4.737**	**-2.568**	**-4.748**