



## Supplementary Information for

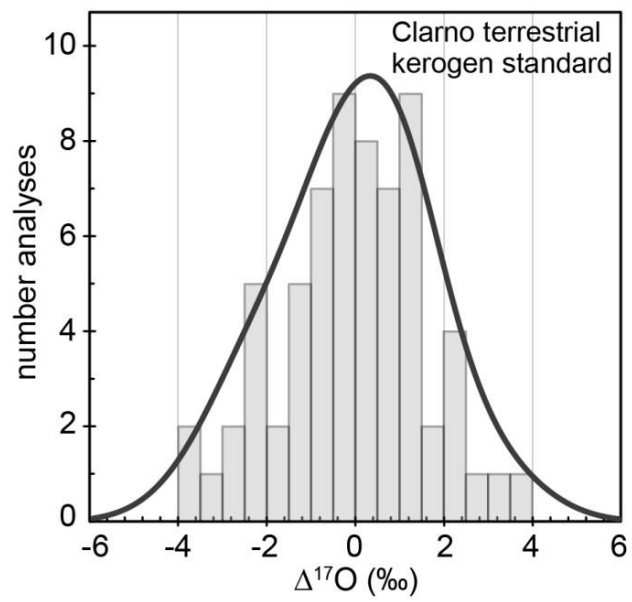
### **Insights into the origin of carbonaceous chondrite organics from their triple oxygen isotope composition**

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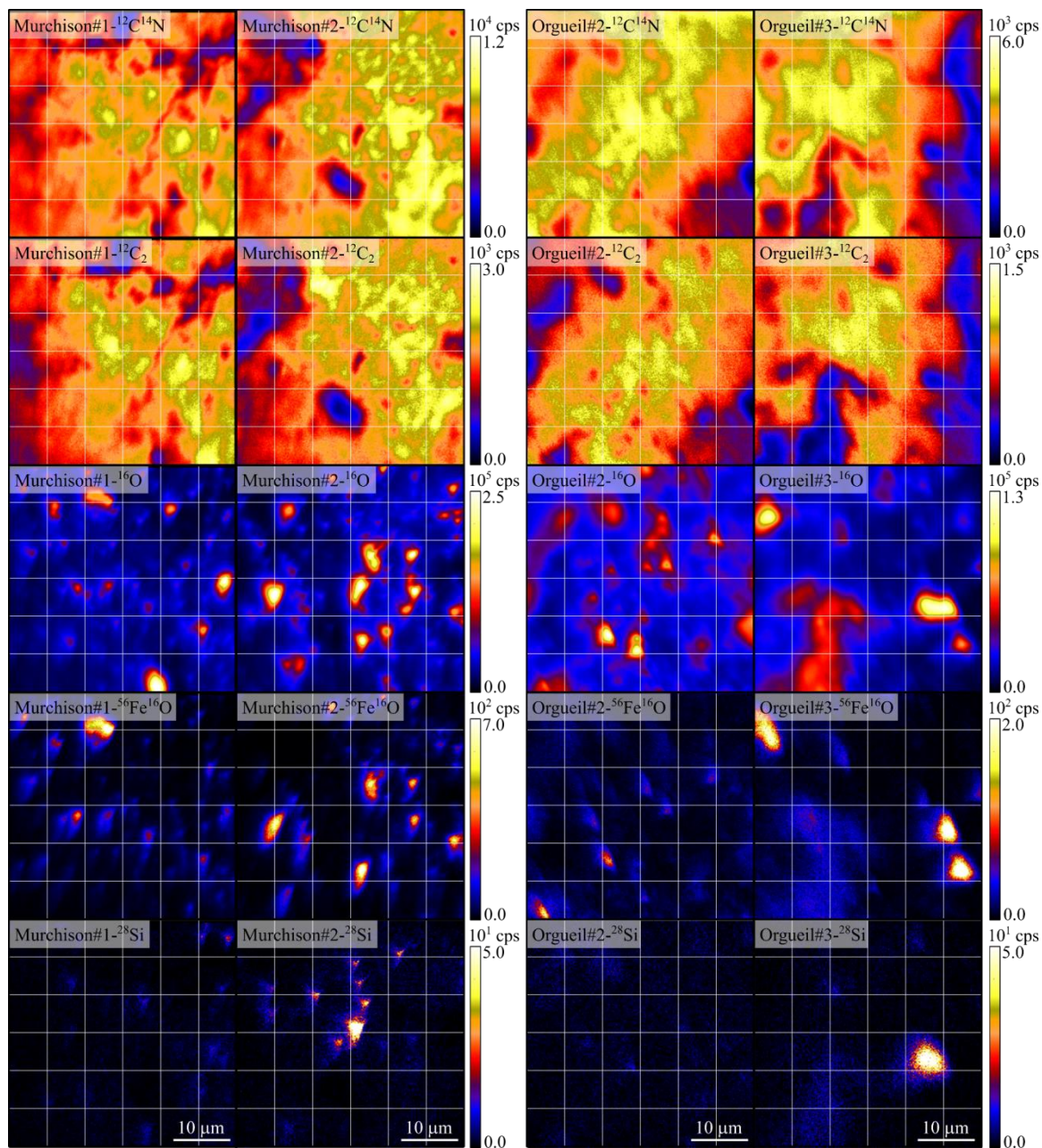
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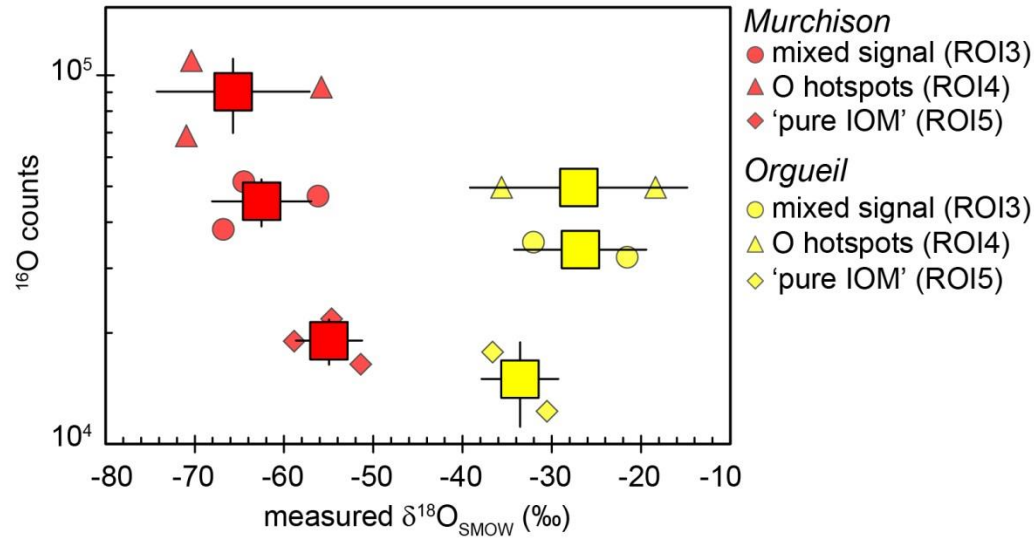
Figs. S1 to S3  
Tables S1 to S2



**Fig. S1.** Histogram and probability distribution of  $\Delta^{17}\text{O}$  values measured on the Clarno kerogen standard over all the L-SIMS analytical sessions.



**Fig. S2.** NanoSIMS images obtained on  $40 \times 40 \mu\text{m}$  areas in Murchison and Orgueil IOM showing the distribution of  $^{12}\text{C}^{14}\text{N}$ ,  $^{12}\text{C}_2$ ,  $^{16}\text{O}$ ,  $^{56}\text{Fe}^{16}\text{O}$  and  $^{28}\text{Si}$  secondary ion species.



**Fig. S3.** Plot showing the NanoSIMS  $^{16}\text{O}$  intensity versus the measured  $\delta^{18}\text{O}$  values for regions of interest corresponding to areas with a mixture of IOM and O-rich residual minerals (ROI3), O-rich hotspots (ROI4), and 'pure IOM' areas (ROI5) for five areas analyzed in Murchison and Orgueil acid-residues.

**Table S1.** L-SIMS oxygen isotope results. \* Indicates the contribution of the  $^{16}\text{OH}^-$  peak tail on the measured  $^{17}\text{O}^-$  intensity.

Analysis	Secondary ion intensity (cps nA <sup>-1</sup> primary current)			$^{16}\text{OH}$ (‰)*	Isotope ratios (‰ vs. SMOW)					
	$^{16}\text{O}^-$	$^{17}\text{O}^-$	$^{18}\text{O}^-$		$\delta^{18}\text{O}$	2 $\sigma$	$\delta^{17}\text{O}$	2 $\sigma$	$\Delta^{17}\text{O}$	2 $\sigma$
<i>Orgueil IOM</i>										
Orgueil_3iso@4	3.80E+06	1.40E+03	7.21E+03	1.7	-4.2	2.9	-6.2	2.0	-4.0	2.3
Orgueil_3iso@5	3.98E+06	1.47E+03	7.57E+03	1.3	-1.6	2.9	-5.5	1.9	-4.7	2.1
Orgueil_3iso@7	4.07E+06	1.50E+03	7.75E+03	0.8	1.0	2.9	-6.9	1.9	-7.4	1.9
Orgueil@2	3.02E+06	1.13E+03	5.82E+03	2.4	5.9	2.3	2.3	2.4	-0.8	2.2
Orgueil@3	2.56E+06	9.59E+02	4.94E+03	2.3	6.5	2.3	3.1	2.5	-0.3	2.5
Orgueil@4	2.33E+06	8.72E+02	4.49E+03	2.3	6.0	2.3	2.8	2.5	-0.3	2.5
Orgueil@5	6.27E+06	2.37E+03	1.21E+04	1.5	10.9	2.3	10.5	2.5	4.9	2.4
Orgueil@6	7.54E+06	2.87E+03	1.46E+04	1.5	16.3	2.3	18.9	2.4	10.4	2.2
Orgueil@9	4.10E+06	1.55E+03	7.99E+03	2.2	16.9	2.3	15.2	2.4	6.4	2.3
Orgueil@11	2.64E+06	9.92E+02	5.12E+03	2.0	11.8	2.3	6.1	2.5	0.0	2.5
Orgueil@12	4.28E+06	1.59E+03	8.22E+03	1.3	2.5	2.3	-4.2	2.4	-5.5	2.2
Orgueil@13	3.64E+06	1.37E+03	7.03E+03	1.4	8.2	2.3	4.2	2.4	-0.1	2.2
Orgueil@16	2.44E+06	9.12E+02	4.71E+03	1.8	6.5	2.3	0.3	2.5	-3.1	2.4
Orgueil@17	2.61E+06	9.79E+02	5.08E+03	1.7	15.2	2.3	5.8	2.4	-2.1	2.3
Orgueil@19	1.50E+07	5.57E+03	2.84E+04	2.1	7.3	2.3	-2.0	2.4	-5.7	2.3
<i>Murchison IOM</i>										
Murchison_3iso@1	2.57E+07	9.40E+03	4.71E+04	1.7	-6.5	2.9	-10.1	1.9	-6.7	1.7
Murchison_3iso@2	4.42E+07	1.61E+04	8.14E+04	0.7	-7.5	2.9	-16.1	1.9	-12.2	1.8
Murchison_3iso@3	2.55E+07	9.45E+03	4.81E+04	1.1	1.9	2.9	-0.7	1.9	-1.7	2.0
Murchison_3iso@4	9.77E+06	3.66E+03	1.86E+04	1.9	7.4	2.9	6.6	1.9	2.7	1.7
Murchison_3iso@5	3.05E+07	1.11E+04	5.53E+04	1.1	-13.4	2.9	-17.8	1.9	-10.9	1.7
Murchison_3iso@7	1.36E+07	4.96E+03	2.51E+04	1.5	-14.4	3.0	-14.7	2.0	-7.2	2.9
Murchison_3iso@8	1.55E+07	5.70E+03	2.89E+04	1.0	-4.6	2.9	-7.3	1.9	-4.9	1.8
Murchison@1	1.66E+07	6.10E+03	3.10E+04	2.8	-4.7	2.3	-8.8	2.4	-6.3	2.2
Murchison@2	1.42E+07	5.17E+03	2.64E+04	2.8	-18.0	2.3	-23.3	2.4	-14.0	2.2
Murchison@5	2.06E+07	7.51E+03	3.82E+04	1.9	-11.8	2.3	-18.6	2.4	-12.5	2.0
Murchison@6	1.34E+07	4.92E+03	2.52E+04	2.5	-9.3	2.3	-17.2	2.4	-12.4	2.1
Murchison@8	7.39E+06	2.73E+03	1.40E+04	4.9	-10.3	2.3	-14.5	2.5	-9.1	2.4
Murchison@9	1.73E+07	6.31E+03	3.21E+04	2.0	-14.3	2.3	-19.7	2.4	-12.2	2.2
<i>Cold Bokkeveld IOM</i>										
CB_3iso@1	1.41E+07	5.12E+03	2.61E+04	1.5	-13.1	2.9	-19.8	2.0	-13.0	2.3
CB_3iso@2	1.56E+07	5.70E+03	2.90E+04	1.4	-9.4	2.9	-14.9	2.0	-10.0	2.2
CB_3iso@3	1.11E+07	4.07E+03	2.06E+04	1.6	-14.5	2.9	-8.8	1.9	-1.3	2.0
CB_3iso@4	1.35E+07	4.91E+03	2.52E+04	1.3	-10.9	2.9	-23.0	1.9	-17.3	1.9
CB_3iso@5	1.20E+07	4.42E+03	2.24E+04	1.3	-9.8	2.9	-10.9	1.9	-5.8	1.7
CB_3iso@6	1.52E+07	5.59E+03	2.83E+04	1.3	-5.9	2.9	-5.6	1.9	-2.5	1.6
CB_3iso@7	8.59E+06	3.16E+03	1.61E+04	1.8	-10.0	2.9	-12.1	1.9	-6.9	1.9
CB_3iso@8	1.71E+07	6.32E+03	3.19E+04	1.1	-5.2	2.9	-4.7	1.9	-2.0	1.8

**Table S2.** NanoSIMS results obtained on Murchison and Orgueil acid-maceration residues.

ROI	Area ( $\mu\text{m}^2$ )	Intensity (cps)							Ratio (in ‰ vs. SMOW for $\delta^{17,18}\text{O}$ )								IMF corrected (‰)			
		$^{16}\text{O}$	$^{17}\text{O}$	$^{18}\text{O}$	$^{12}\text{C}_2$	$^{12}\text{C}^{14}\text{N}$	$^{28}\text{Si}$	$^{56}\text{Fe}^{16}\text{O}$	$\delta^{18}\text{O}$	$1\sigma$	$\delta^{17}\text{O}$	$1\sigma$	$^{12}\text{C}^{14}\text{N}/^{12}\text{C}_2$	$1\sigma$	$^{16}\text{O}/^{12}\text{C}_2$	$1\sigma$	$\delta^{18}\text{O}$	$2\sigma$	$\delta^{17}\text{O}$	$2\sigma$
<i>Murchison #1</i>																				
All area	1517	31880	11.6	59.7	1607.5	6399.7	0.9	36.0	-65.7	0.6	-50.6	1.5	3.88	0.04	19.8	0.2				
Broad O rich	1091	38251	13.9	71.6	1704.2	6710.0	1.1	45.2	-66.8	0.7	-51.7	1.6	3.84	0.04	22.4	0.3				
O hotspot	270	68513	24.7	127.7	1591.3	6259.3	1.1	94.6	-70.9	1.0	-58.6	2.3	3.84	0.04	43.0	0.5				
'pure' IOM	314	18985	6.9	35.8	1736.2	6985.5	0.9	14.5	-58.8	1.9	-50.2	4.4	3.92	0.04	10.8	0.2	-0.3	11.7	-8.1	14.8
<i>Murchison #2</i>																				
All area	1529	39379	14.5	74.5	1669.1	7047.1	1.8	40.7	-56.6	0.7	-40.5	1.7	4.10	0.05	23.1	0.4				
Broad O rich	1191	47012	17.2	89.0	1772.4	7463.7	2.0	50.8	-56.2	0.8	-40.7	1.7	4.10	0.05	26.0	0.4				
O hotspot	268	92795	33.9	175.7	1688.2	7168.4	3.1	123.6	-55.8	1.1	-46.0	2.6	4.14	0.04	52.9	1.0				
'pure' IOM	475	21818	8.1	41.4	1833.6	7867.2	1.3	15.9	-54.7	1.8	-31.2	4.1	4.17	0.05	11.6	0.2	3.8	11.7	10.9	14.4
<i>Murchison #3</i>																				
All area	1548	38520	14.1	72.4	1550.8	7138.4	1.0	23.8	-62.6	1.0	-44.6	1.7	4.44	0.06	24.7	0.4				
Broad O rich	999	51440	18.8	96.5	1622.3	7371.6	1.1	32.2	-64.5	1.0	-45.9	1.9	4.39	0.05	31.6	0.4				
O hotspot	249	109608	39.7	204.4	1445.1	6530.8	1.0	64.9	-70.4	1.5	-53.0	2.5	4.37	0.05	76.4	0.7				
'pure' IOM	400	16439	6.1	31.3	1640.8	7863.2	0.8	9.7	-51.4	2.2	-36.7	5.2	4.64	0.05	9.5	0.2	7.1	12.0	5.4	15.8
<i>Orgueil #3</i>																				
All area	1548	27211	10.1	52.8	816.5	3682.9	1.3	9.8	-32.5	0.9	-35.0	2.0	4.27	0.07	33.2	0.4				
Broad O rich	745	35271	13.0	68.4	756.8	3574.5	1.5	13.2	-32.1	1.1	-34.2	2.5	4.47	0.07	46.4	0.6				
O hotspot	191	49642	18.3	96.0	672.7	3345.4	1.7	19.9	-35.6	1.8	-44.4	4.1	4.72	0.07	73.2	1.1				
'pure' IOM	314	17747	6.6	34.3	946.2	4072.3	1.1	5.4	-36.6	2.4	-34.9	5.6	4.08	0.07	18.6	0.2	21.9	12.2	7.2	16.3
<i>Orgueil #4</i>																				
All area	1531	23537	8.9	46.1	712.6	3273.8	2.0	15.3	-22.8	1.0	-12.3	2.3	4.26	0.09	32.1	0.6				
Broad O rich	901	32093	12.2	62.9	661.0	3333.3	2.9	23.1	-21.6	1.1	-12.2	2.5	4.65	0.11	48.0	0.8				
O hotspot	323	49644	18.9	97.8	465.2	2801.3	5.4	42.5	-18.4	1.5	-3.2	3.5	5.53	0.13	106.5	1.6				
'pure' IOM	272	12251	4.6	23.8	993.2	4146.7	0.7	3.8	-30.5	3.3	-19.5	7.5	3.89	0.08	11.5	0.3	28.0	13.0	22.6	19.2