OXYGEN ISOTOPE ANALYSIS OF FINE-GRAINED COMETARY MATERIAL FROM THE BULB OF A STARDUST TRACK

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Introduction:

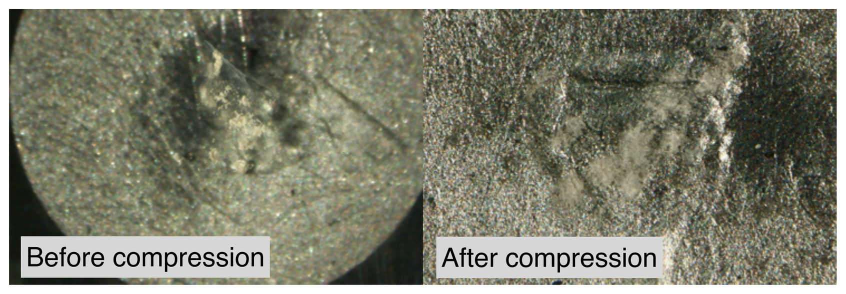
Cometary material captured in aerogel by the Stardust mission spans a size range from sub-μm dust in the bulbs of type B and C tracks [1] to several-μm particles that tend to be found at or near track termini. The larger particles from comet Wild 2 are mostly high-temperature objects [2], including CAI and chondrule fragments [3, 4]. The O isotopic composition of a sample of these particles shows similarities to chondrules in CR meteorites [5], with LIME olivines clustering at $\Delta^{17}O \approx -23$‰ and FeO-rich particles ranging from −1.5‰ to +2.5‰.

The fine-grained material in the bulbs of Stardust tracks is not as well-studied due to the condition it is in—dispersed and intimately mixed with melted, insulating aerogel. However, this material likely contains pristine, unprocessed cometary material [6] that is not well represented by the larger Stardust fragments.

Here, we report a technique to measure the O isotopic composition of fine-grained Stardust material in aerogel by SIMS. We present data for multiple standards to verify the accuracy of our technique, and measurements from the bulb of a type B Stardust track.

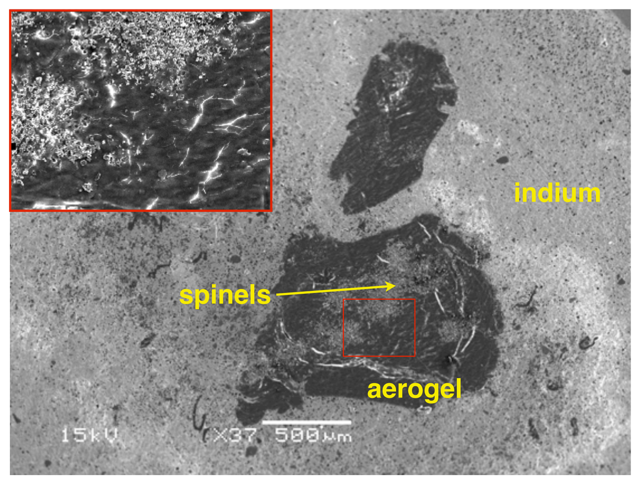
Sample Preparation:

Analog #1: Powdered basalt and aerogel pressed into indium.



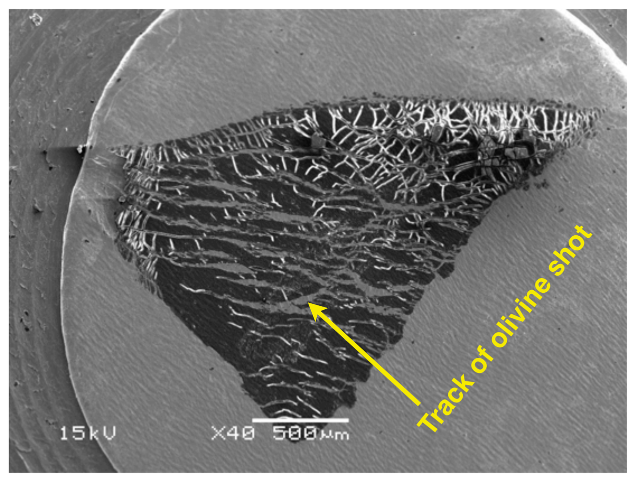
Goal: To reproduce terrestrial O isotopic composition in material that has not experienced high-speed capture.

Analog #2: Spinel separates from Allende in compressed aerogel.



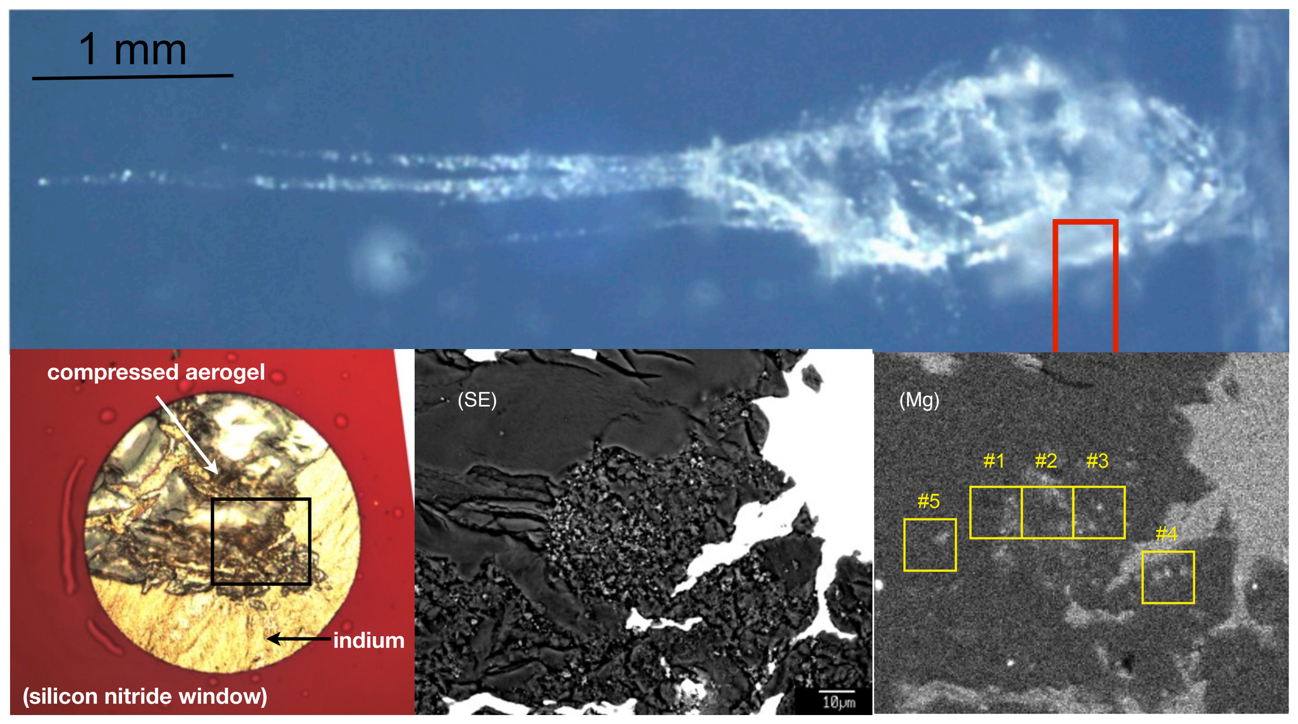
Goal: To reproduce non-terrestrial O composition in material that has not experienced high-speed capture.

Analog #3: Olivine shot at ~6 km/s into aerogel, compressed track.



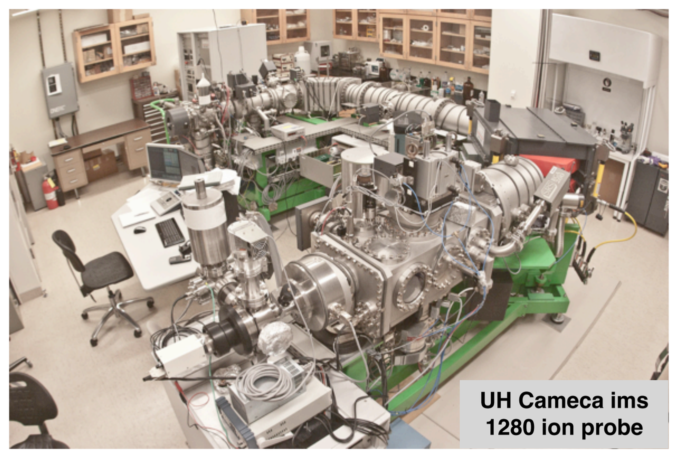
Goal: To reproduce terrestrial O composition in material that has experienced high-speed capture.

Stardust track C2052,2,74 (type B): Small section removed from bulb.



We located five 15×15μm areas that were rich in Mg, indicating they contained some cometary material.

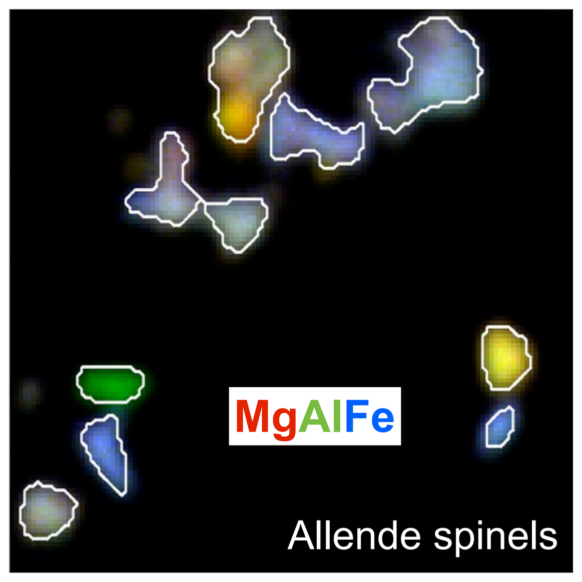
Measurement Conditions:



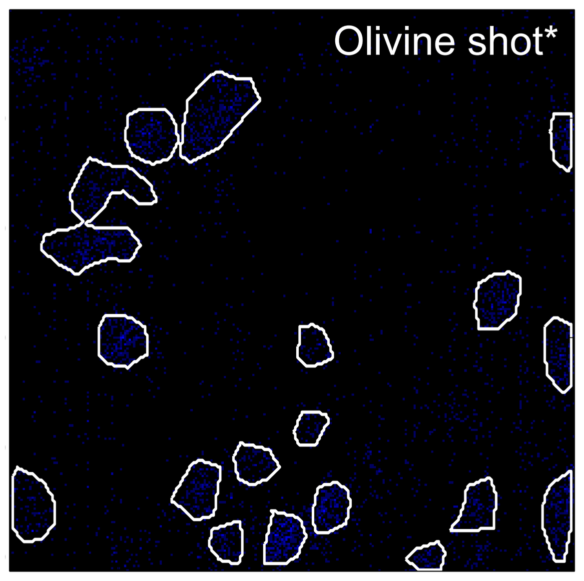
- 15×15μm raster images, 128×128 pixels, ~3 pA primary beam of Cs^+ for ~15 hours, 720 frames.
- Measured: ^{16}O-^{17}O-^{18}O (60s), ^{27}Al, ^{28}Si, $^{24}Mg^{16}O$, ^{56}Fe (4s) (all on electron multipliers).
- Mass resolving power for $^{17}O \approx 5500$.
- ^{16}O: ~3e5 cps.

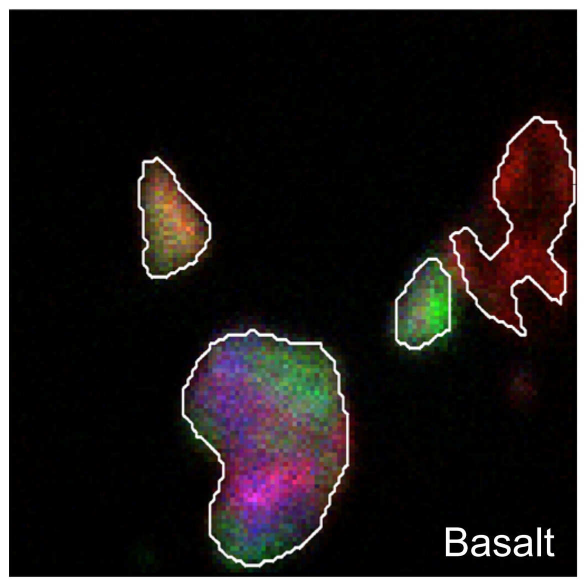
Analysis:

- Corrected for detector background & deadtime.
- Corrected for $[^{18}O/^{16}O, ^{17}O/^{16}O] = f(^{16}O)$.
- Registered individual frames.
- ^{17}O registration to ^{16}O (TOF tables?).
- Applied threshold on Al, MgO, Fe to distinguish spinels from aerogel.
- Computed $\delta^{18}O$, $\delta^{17}O$ in “spinel” regions normalized to the aerogel.
- Uncertainties by Monte Carlo: For each n-pixel spinel region, randomly draw n pixels from the aerogel region, compute $\delta^{18}O$, $\delta^{17}O$. Repeat 10^5 times, compute uncertainties from percentiles of Monte Carlo runs.

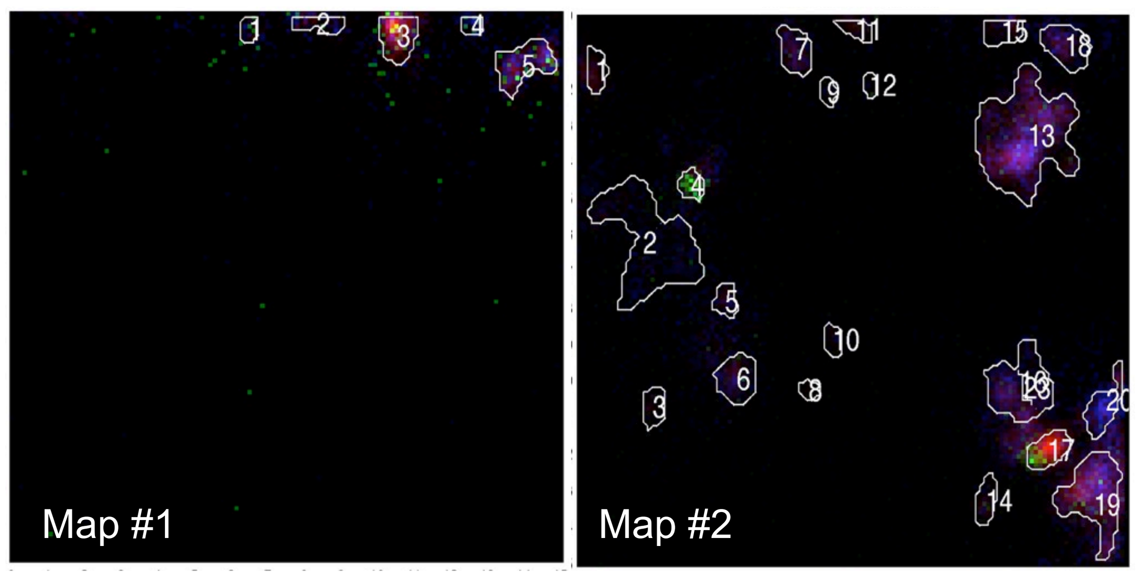


The aerogel is differentiated from the embedded material by threshholding on the Fe, Mg, Al maps. **It is not in the least bit difficult to differentiate the cometary material from the surrounding aerogel.**

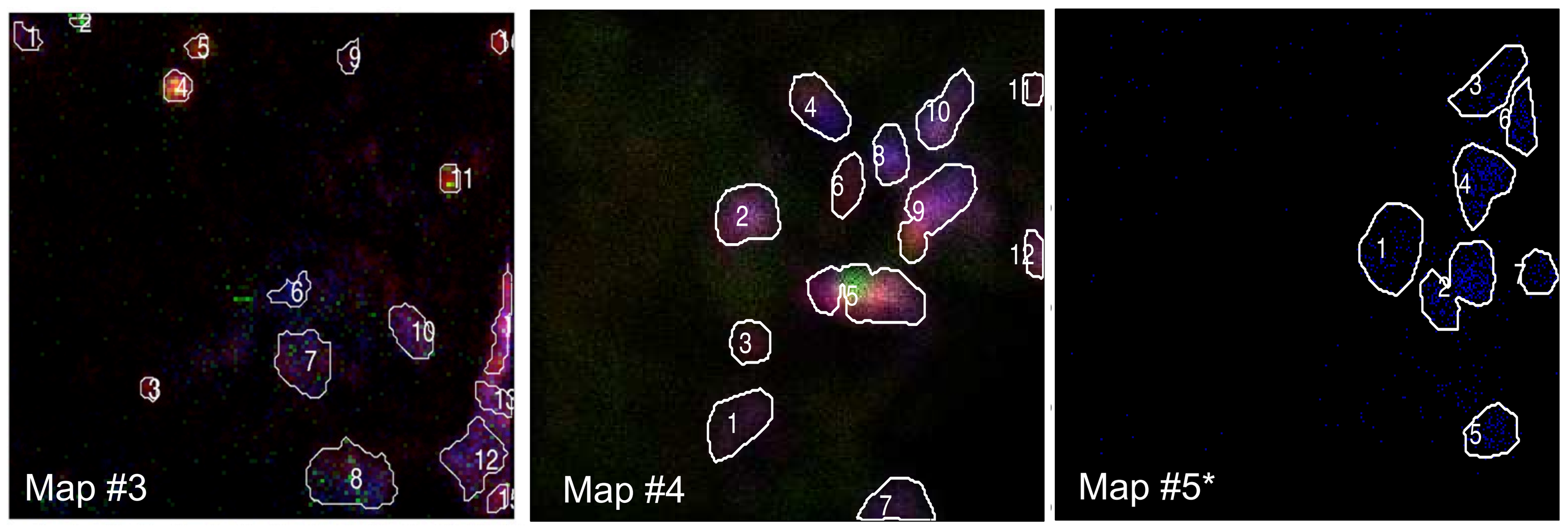




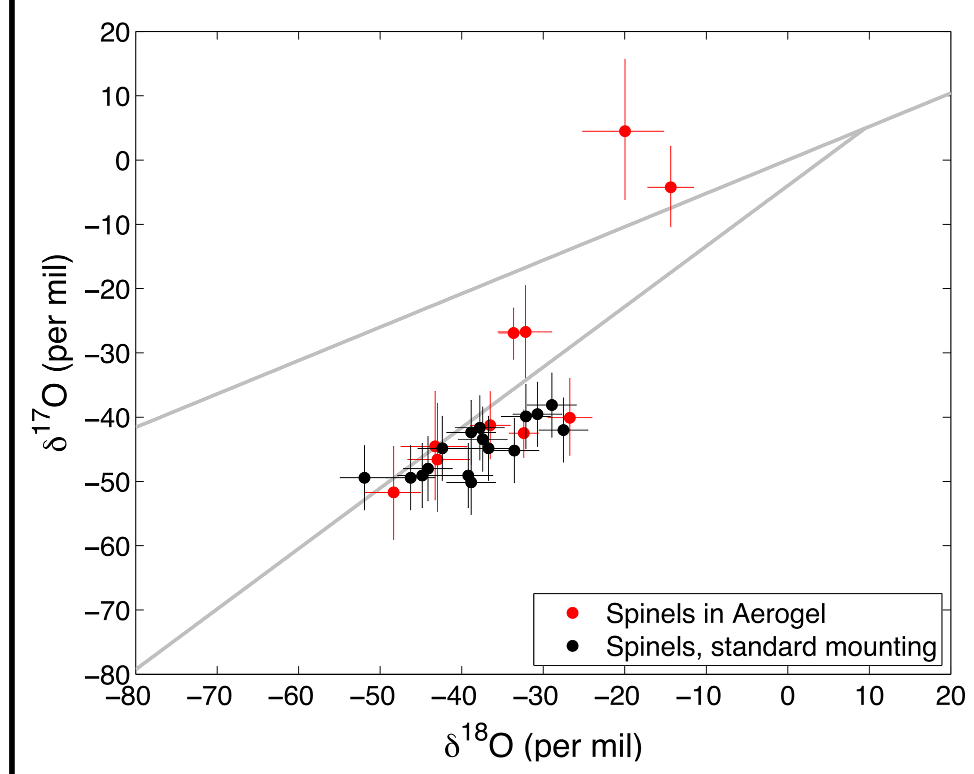
These maps are: R-G-B=Mg-Al-Fe & 15×15μm. Two maps (indicated by *) have invalid Mg channels, caused by mass-calibrating on the wrong peak.



We collected five maps from Stardust track C2052,2,74. We identified 65 distinct regions based on their Mg, Al, Fe signals far above the background aerogel.

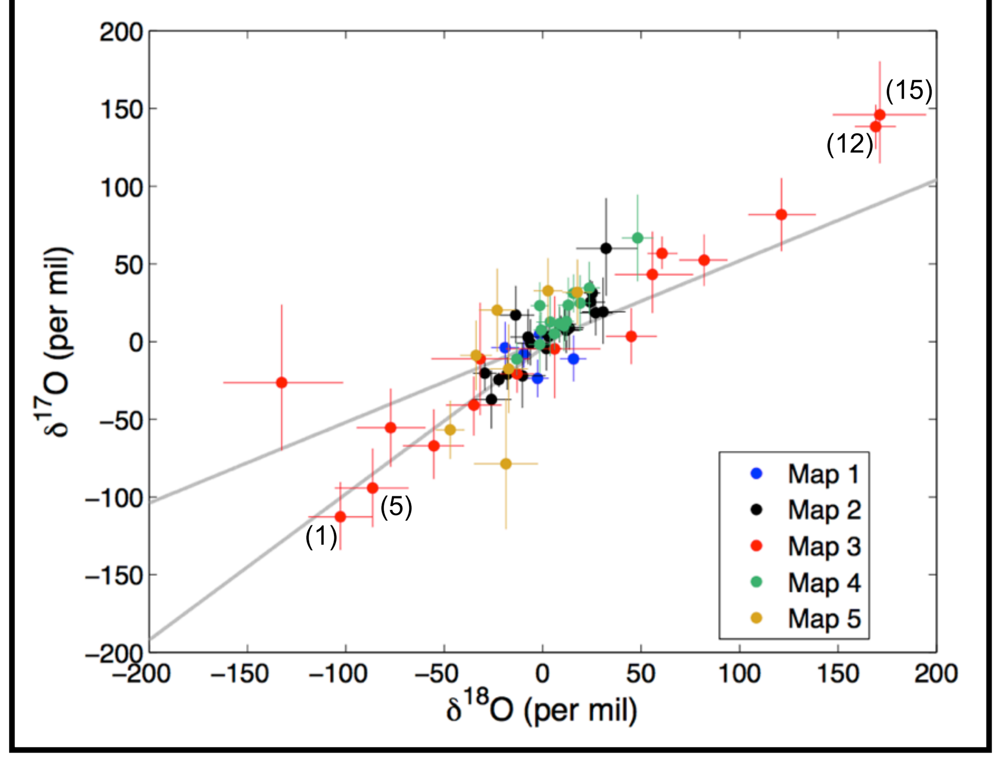


Results



Most Allende spinels showed O isotopic composition consistent with that measured for individual spinels distributed onto Au foil [7]. Basalt and olivine shot also had O isotopic composition consistent with expectations.

The range of O compositions seen in this fine-grained Wild 2 material span the range of all known SS materials, from very ^{16}O-rich (mostly in Mg-rich, Fe-poor particles) to very ^{16}O-poor (in a Fe-rich region). The fine-grained material in this track appears to sample more diverse O compositions than seen in larger grains in other Stardust tracks (e.g., [5]). We found no presolar grains (5.8% 2σ 1-sided upper bound).



Conclusions and *Future Work*

- We’ve developed a technique to prepare and measure the O isotope composition of fine-grained cometary material in the bulb Stardust tracks.
- This technique is very efficient: we measured the O composition of 65 grains while consuming a very small portion of a track.
- Our technique is sufficiently accurate, as proven by analog measurements.
- The fine-grained Stardust material contains material that formed in a wide range of O isotopic reservoirs in very close (tens of μm) proximity.
- *Determine elemental composition of the grains we measured by SIMS.*
- *Analyze the bulbs of smaller tracks which could have better-preserved fine-grained material.*

References
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