TRACKING METEORITE INFALL THROUGH TIME: THE PICTURE OF THE JURASSIC FROM REMNANT CHROME-SPINELS. C. E. Caplan[1,2*], G. R. Huss[2], B. Schmitz[3,2], and K. Nagashima[2], [1]Department of Geology and Geophysics, University of Hawaiʻi at Mānoa, 1680 East-West Road, Honolulu, HI 96822, [2]Hawaiʻi Institute of Geophysics and Planetology, University of Hawaiʻi at Mānoa, 1680 East-West Road, Honolulu, HI 96822, [3]Department of Physics, University of Lund, P.O. Box 118, Lund SE-22100, Sweden. *caplance@hawaii.edu.

Introduction: Studying meteorites that fell in the distant past provides a way to understand various solar-system processes. However, finding these meteorites is a challenge because they begin weathering as soon as they land. Fortunately, extraterrestrial chrome-spinels resist weathering and retain their original characteristics [1-2]. The grains are collected from terrestrial limestone and originate from meteorites or micrometeorites. The parent meteorite type of each grain is determined from their characteristic element (major and minor) and oxygen-isotope abundances. The overall objective of studying chrome-spinel grains throughout Earth's history is to determine how meteorite populations have changed over time. Here we report data for additional chrome-spinel grains from the Callovian-Oxfordian boundary (~160 Ma) in Southern Spain, near Carcabuey. This period of the Jurassic was chosen because it may contain evidence of the breakup of the Baptistina asteroid family, estimated to have occurred ~160 Myr ago (plus 30, minus 20 Myr) [3].

Experimental: Grains for this study were recovered at Lund University from four Spanish limestone samples (~100 kg each), see [1] for methods. The chrome-spinels were mounted in quarter-inch-diameter steel cylinders using epoxy at the University of Hawaiʻi (UH). The mounts were ground flat and polished using various diamond lapping papers.

Element abundances were determined using the JEOL JXA-8500F field emission electron microprobe at UH using an accelerating voltage of 20 keV, a beam current of 20 nA, and varying beam diameters (1-10 µm). The Cameca ims 1280 ion microprobe (SIMS) at UH was used to measure oxygen-isotopes, with Stillwater chromite as the standard, see [4] for details.

Results and Discussion: Here we present data for sixty-two grains from the 63 to 220 µm size fraction. Electron microprobe and SIMS analyses were performed with one to four spots per grain. Measurements for each grain typically showed good reproducibility. The data were evaluated for instrumental errors and the pits were examined in detail using the scanning electron microscope. Data from pits that intersected cracks or secondary alteration were eliminated from the data set.

Data for the chrome-spinels are plotted in Figure 1, with oxygen-isotope compositions in $\Delta^{17}O$ ($\Delta^{17}O = \delta^{17}O - 0.52\times\delta^{18}O$) indicated by color. Grains consistent with ordinary chondrites (OCs, orange-red) cluster separately from the other grains in each figure. Figure 1a shows that OC grains have high V_2O_3 (> 0.5%) and no Fe_2O_3. OC grains also have relatively low Al_2O_3 and MgO abundances (Fig. 1b,c). Grains with negative $\Delta^{17}O$ have lower V_2O_3 and a range of Fe_2O_3 content (Fig. 1a). The teal-blue grains ($\Delta^{17}O \approx -1‰$) tend to have higher Al_2O_3 and MgO content and uniformly low TiO_2 abundances (Fig. 1b,c). Figure 1c shows that Al_2O_3 and MgO abundances correlate positively with each other and both correlate with $\Delta^{17}O$. This correlation is supported

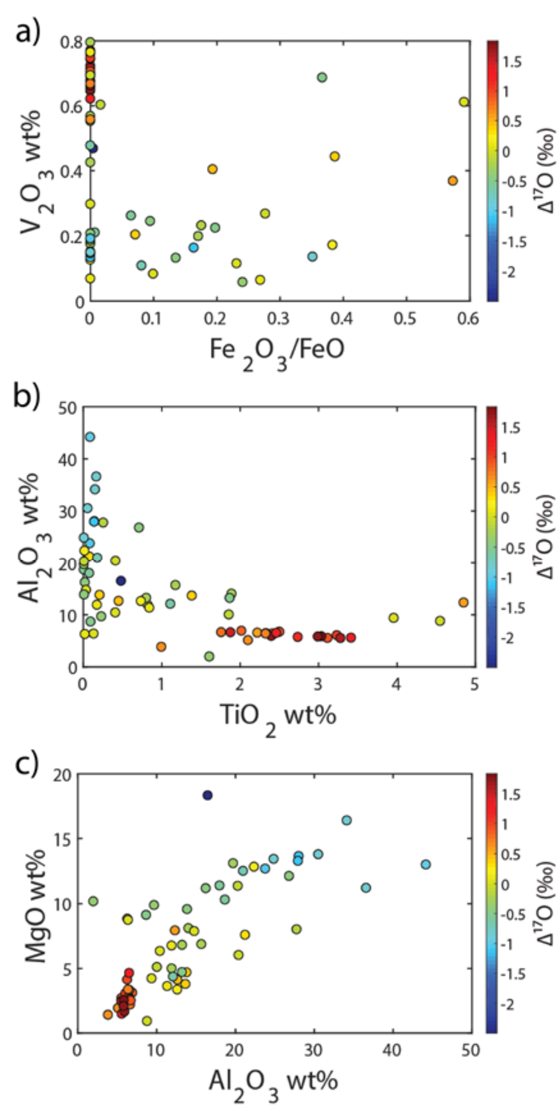

Figure 1: *Major and minor element abundances for chrome-spinels. The $\Delta^{17}O$ color bar is the same for all figures. $\Delta^{17}O$ error is ±0.36‰ (2σ).*

by the tendency of spinels in OCs to be more Fe and less Mg-Al rich, while spinels in carbonaceous chondrites and achondrites tend to be more Mg-Al rich [5,6].

The grains were classified based on major and minor elements and oxygen-isotope abundances and are summarized in Figure 2. An initial subdivision was based on Fe_2O_3 content and oxygen-isotopes. We originally thought that all iron oxide in extraterrestrial chrome-spinels would be FeO, but we found that this is only the case for OC samples (Fig. 1a). The next step was to look at $\Delta^{17}O$ values: $\Delta^{17}O > 0$, $\Delta^{17}O \sim 0$, and $\Delta^{17}O < 0$. Grains in each oxygen-isotope group were then screened using element compositions. If a grain had at least 5 out of 8 element matches (Cr, Fe, Mg, Al, Ti, V, Mn, Zn) for a known meteorite type then it was classified as such.

Using these criteria, the grains in this study were organized into 6 groups: OCs, terrestrial, ambiguous, HEDs or Brachinites, Ureilites, and extraterrestrial (Fig. 2). OCs have positive $\Delta^{17}O$ values, no Fe_2O_3 content, and element abundances that match known OCs. Some grains have positive $\Delta^{17}O$ values with no Fe_2O_3, but their element abundances were unlike OCs; we call them "Ambiguous" for this study (Fig. 2). Terrestrial grains have ~0‰ $\Delta^{17}O$ and Fe_2O_3 abundances up to ~18 wt.%. Grains which meet the minimum element criteria and have negative $\Delta^{17}O$ were classified into known meteorite types. Thus far, 5 grains seem to be from two meteorite types: 2 HEDs or Brachinites and 3 Ureilites (Fig. 2). Grains with negative $\Delta^{17}O$ values that do not meet the minimum element requirement are termed Extraterrestrial in Figure 2. The Extraterrestrial grains are unclassified, in part because our database is incomplete.

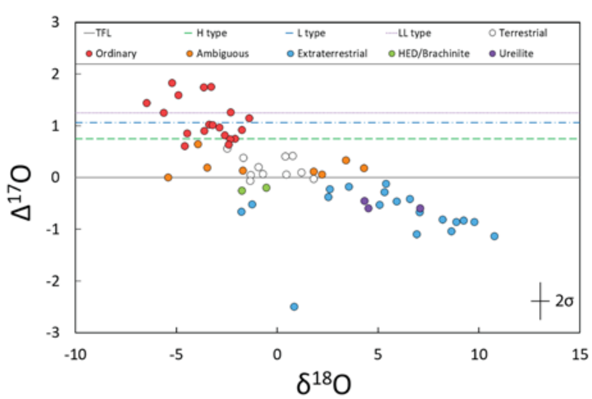

Figure 2: *Oxygen isotope data for chrome-spinels (averaged for grain). Horizontal lines are Terrestrial Fractionation Line (TFL) and lines of constant $\Delta^{17}O$ passing through the mean H, L, and LL chondrite values [7].*

A thorough chrome-spinel database is necessary to classify the ambiguous and extraterrestrial grains in this study. We are continuously adding new data to fill in gaps and update old data with new methods and technology.

Samples from the Jurassic show relative abundances of meteorite types that are unlike today and other time periods being studied. Using the criteria discussed, this study contains ~44.2% OC grains and ~55.8% extraterrestrial (including HEDs or Brachinites and Ureilites) grains (percentages exclude terrestrial and ambiguous grains). For comparison, 90.6% of the meteorites falling today are OCs. The difference between today and the Jurassic samples may provide insights into a gradual increase of OCs overtime, representing a dominance of OCs with time or a loss of other meteorite types. Differences in meteorite relative abundances can also be seen in other time periods. Approximately 466 Ma, >99% of infalling material was L-chondritic due to the breakup of the L-chondrite parent body [2]. One million years prior to this, the meteorite abundances were ~ 56% OCs and ~ 44% achondrites [8]. A study of the Early Cretaceous supports an increase in OCs abundance from the Jurassic to today, with ~ 80% OCs and ~ 10% achondrites falling [9]. With just a few time periods studied to date, we already see significant differences among the time frames, as well as a possible trend of OCs.

Conclusions: We have now analyzed enough extraterrestrial spinel grains from our Jurassic section to give a picture of what was falling at that time. OCs made up a considerably smaller fraction of infalling material in the Jurassic compared to today. Some of the unclassified grains may come from meteorite types that we do not see today. Much work remains to be done, but it is clear that remant chrome-spinels provide and important window into the collisional history of the solar system [1].

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