ACCRETION AND DISRUPTION HISTORIES OF THE ORDINARY CHONDRITE PARENT BODIES.

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Introduction: The thermal histories of ordinary chondrite (OC) parent bodies are recorded by temperature-dependent diffusion controlled systems such as U-Pb phosphate thermochronology and metallographic cooling rates (Ni-metal). The apparent cooling histories provided by these two systems, however, are in direct conflict with one another despite sharing similarly calculated nominal closure temperatures (~500 °C). While the metallographic data are interpreted to record cooling in small, post-disruption "rubble piles" [1], Pb-phosphate records point to cooling in larger concentrically zoned bodies [2-5]. Moving beyond closure temperature calculations, numerical simulations for each system reveal that the onset of Pb retention can exceed any response from the Ni-metal system by more than 175 °C, defining a window where the Pb-system can record cooling of a concentrically zoned body prior to disruption and subsequent closure of the Ni-system within a rubble pile [5].

Methods & Results:

Thermal Numerical Modelling: Thermal models of parent body cooling followed by parent body disruption, over a 10-100 My range, are fed into numerical simulations for both cooling-rate sensitive systems. For disruptions occurring 30-70 My after Solar System formation, 90-50% of the body by volume will yield Ni-metal records of the subsequent rubble pile (i.e., disruption occurred prior to Ni-metal closure), while the higher temperature partial closure of the Pb-phosphate system will result in an apparent onion shell structure (i.e., shallower samples always exhibit older dates than deeper samples). Further, for disruptions within this timeframe, the deepest 30-90% of a body by volume will yield a nearly uniform Pb-phosphate age that corresponds to the timing of disruption. This "age uniformity" reflects quenching of a catastrophically disrupted body and is consistent with the available data for the deepest chondrites, where all but one of the H6 and L6 OCs (n=8) yield a shared age that points to rapid cooling through phosphate closure temperatures at ~60 My after Solar System formation.

In addition to parent body disruption, the combination of thermal models and thermochronologic data may be used to inform OC parent body accretion time and limit estimates of parent body diameter. Assuming homogenous $^{26}Al/^{27}Al$ in the protoplanetary disc, accretion time is the primary control on the maximum temperature attained within the body. Thermal models place parent body accretion between 2.0-2.35 My after CAIs based on the thermometry of Type 6 chondrites [e.g., 6]. Further, the size of a parent body directly controls the timescales of cooling, which is provided by the Pb-phosphate ages of the deepest (Type 6) chondrites. The minimum estimate for H and L chondrites is ~275km in diameter, a conclusion that is independent of the occurrence of parent body disruption.

Phosphate Extraction and Pb-Pb age determinations. Several techniques have been developed and applied to the extraction and radioisotopic measurement of OC phosphates as steps to maximize the quality and accuracy of thermochronologic data. A gain-corrected static Faraday-Daly collection methodology is applied to isotope dilution Thermal Ionization Mass Spectrometric (TIMS) analyses of phosphate Pb isotopes to improve measurement precision. We report improved physical yield of phosphate crystals by recrushing coarse-grained (>500 µm grain diameter) residua and highly magnetic separates of previously crushed OC samples. Leach tests utilizing 5% acetic acid are used to target surficial labile common Pb on phosphate crystals, reducing analytical blank.

OC Phosphate Thermochronologic Measurements. New phosphate experiments are planned for Big Rock Donga (H6) and Cherokee Springs (LL6). These Type 6 dates will contribute to the expanding dataset [2-5] that directly tests two hypotheses: 1) that the deepest H, L, and LL chondrite samples record the timing of disruption and rapid cooling at ~60 My and 2) if observed on the LL body, that this catastrophic event was widespread within the asteroid belt. We also explore the application and utility of bulk phosphate U-Pb measurements to further refine thermochronologic constraints on the timing and thermal effects of disruption events.

Conclusions: Numerical thermal models show that temperature histories recorded by the Pb-phosphate and Ni-metal systems for OC parent bodies measurably decouple within 30-70 My after Solar System formation. This decoupling accommodates evidences from the Ni-metal system recording cooling histories not correlated with petrologic types, indicative of cooling in a "rubble pile" [1], and from Pb-phosphate ages recording the apparent cooling of concentrically zoned "onion shell" bodies [2-5]. Further, under such early disruption scenarios, Pb-phosphate ages of the deepest samples (Type 6) record the age of the disruption event, constraining catastrophic disruption of the H and L OC parent bodies to ~60 My after Solar System formation.

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