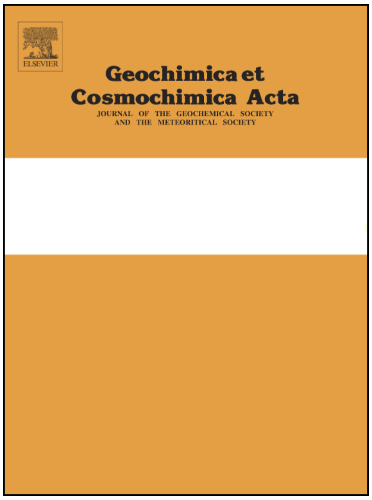

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PII: S0016-7037(16)30691-3
DOI: http://dx.doi.org/10.1016/j.gca.2016.11.038
Reference: GCA 10046

To appear in: *Geochimica et Cosmochimica Acta*

Received Date: 12 February 2016
Revised Date: 17 November 2016
Accepted Date: 24 November 2016

Please cite this article as: Blackburn, T., O'D. Alexander, C.M., Carlson, R., Elkins-Tanton, L.T., The accretion and impact history of the ordinary chondrite parent bodies, *Geochimica et Cosmochimica Acta* (2016), doi: http://dx.doi.org/10.1016/j.gca.2016.11.038

The accretion and impact history of the ordinary chondrite parent bodies

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Abstract: A working timeline for the history of ordinary chondrites includes chondrule formation as early as 0-2 Ma after our Solar System's earliest forming solids (CAIs), followed by rapid accretion into undifferentiated planetesimals that were heated internally by ^{26}Al decay and cooled over a period of tens of millions of years. There remains conflict, however, between metallographic cooling rate (Ni-metal) and radioisotopic thermochronometric data over the sizes and lifetimes of the chondrite parent bodies, as well as the timing of impact related disruptions. The importance of establishing the timing of parent body disruption is heightened by the use of meteorites as recorders of asteroid belt wide disruption events and their use to interpret Solar System dynamical models. Here we attempt to resolve these records by contributing new ^{207}Pb-^{206}Pb data obtained on phosphates isolated from nine previously unstudied ordinary chondrites. These new results, along with previously published Pb-phosphate, Ni-metal and thermometry data, are interpreted with a series of numerical models designed to simulate the thermal evolution for a chondrite parent body that either remains intact or is disrupted by impact prior to forming smaller unsorted "rubble piles".

Our thermal model and previously published thermometry data limit accretion time to 2.05-2.25 Ma after CAIs. Measured Pb-phosphate data place minimum estimates on parent body diameters of ~260-280 km for both the L and H chondrite parent bodies. They also consistently show that petrologic Type 6 (highest thermal metamorphism) chondrites from both the H and L bodies have younger ages and, therefore, cooled more slowly than Type 5 (lesser metamorphism) chondrites. This is interpreted as evidence for Type 5 chondrite origination from shallower depths than Type 6 chondrites within initially concentrically zoned bodies. This contrasts metallographic cooling rate data that are inconsistent with such a simple onion shell scenario. One model that can reconcile these two data sets takes into account subtle differences in temperature to which each system responds. This working model requires that disruption occur early enough such that the Ni-metal system can record the cooling rate associated with a rubble pile (<70 Ma), yet late enough that the Pb-phosphate system can record an onion shell structure (>30 Ma). For this 30-70 Ma timeline, reaccretion into smaller rubble piles will ensure that the originally deeply buried and hot Type 6 samples will always cool faster as a result of disruption, yielding nearly uniform ages that record the time of parent body disruption. This is consistent with the available Pb-phosphate data, where all but one Type 6 chondrite (H, n=3; L, n=4) yields a cooling age within a narrow 4505 ± 5 Ma timeframe. These data collectively imply that both the H and L chondrite parent bodies were catastrophically disrupted at ~60 Ma. In addition, combined Ni-metal and Pb-phosphate models confirm that a subset of Type 4 chondrites record early rapid cooling likely associated with erosional impacting of the H and L parent bodies on ~5 Ma timescales.

1. Introduction: Ordinary chondrites (OCs) provide a record of planetesimal formation in the asteroid belt through the accretion of some of the Solar System's earliest formed solids, including silicate chondrules, metallic Fe, Ni grains and fine-grained matrix. They preserve an early stage of planetesimal assembly that can guide our understanding of early Solar System processes, including how planetesimal accretion times and parent body sizes varied within the