INTERPRETING THE ISOTOPIC DICHOTOMY AMONG SOLAR SYSTEM MATERIALS.

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Introduction: In recent years, an extensive database has been produced that separates meteorites into two groups based on their isotopic systematics [e.g., 1-5; Fig. 1]. Various models have been proposed to explain this dichotomy [e.g., 2-6]. A dominant theme in these models is the need for rapid Jupiter formation, separating the region where carbonaceous chondrites and associated iron meteorites formed from that where other chondrites and iron meteorites and the terrestrial planets formed. This separation is often accompanied by a postulated evolution of the dust accreting to the solar nebula as the chondrites are forming, generating different reservoirs. The data set that drives these models is robust and requires explanation. But models involving Jupiter and time-dependent isotopic nebular evolution have serious problems and are distracting from approaches that are more likely to explain the dichotomy.

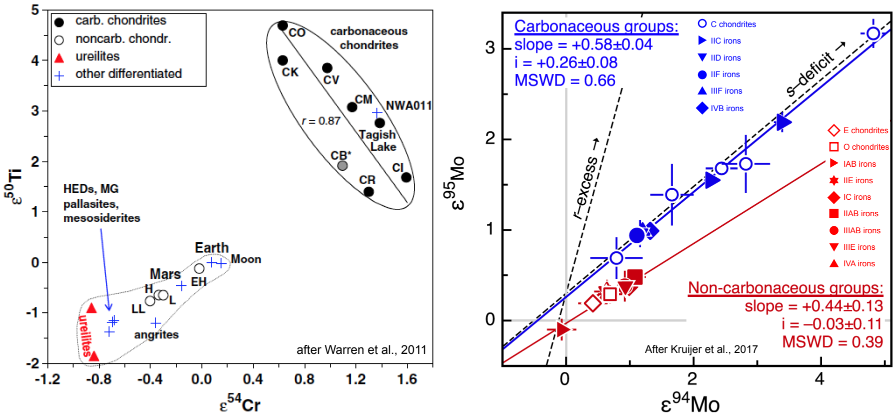

Figure 1: Some of the data that drives the inference that there are two different groups of chondritic and associated differentiated meteorites. The same groupings appear in O, Ca, Ni, and W data.

Problems with current models: The idea that carbonaceous chondrites accreted in the outer solar system has several serious problems. For example, carbonaceous chondrites include meteorites that are chemically unfractionated (CI), and meteorites that have experienced the most extreme thermal processing among chondrites (CV, CO). CV, CO, and CM chondrites, contain the highest abundances of CAIs, materials that reflect the highest-temperature processing of chondritic materials. Why should the most extreme thermal processing have been in the outer solar system, and where is the environment outside of Jupiter that can drive such variable and extreme thermal processing? Second, the formation times of most chondrite classes are both early and overlapping, starting as early as 1 my after CAIs and ending at the latest by 3-4 my after CAIs. Some iron meteorite parent bodies apparently accreted before that. Early accretion within distinct isotopic reservoirs would, in this model, require Jupiter to have open a gap in the disk very early (<<1 my after CAIs). Time-dependent isotopic variation of accreting material is also problematic. The processes that generate molecular clouds work to mix and spatially homogenize the raw materials for the solar system, and the presolar grains complexes that were accreted by ordinary and carbonaceous chondrites appear to have been the same [7,8]. Other major problems can also be enumerated.

A better interpretive framework: There is no requirement that the isotopic dichotomy reflect accretion in widely separated regions of the disk. What is necessary is that each package of material underwent a specific set of processes and then accreted to form an asteroid. The dust that made up the Sun's parent molecular cloud consisted of stellar condensates from a wide variety of stars and dust that formed in the interstellar medium after their precursors were evaporated by supernova shocks. The behavior of an element during solar system processing depends of the mineralogy of the carriers, and only very generally on its equilibrium condensation temperature. There is no reason to expect that any single source will dominate the budget of an element, or that any mineral phase will be dominated by a single nucleosynthetic source. It is not valid to infer that because a refractory element and a volatile element show the isotopic dichotomy, nebular processing could not have generated the two components. A first-order observation is that carbonaceous chondrites experienced primarily volatility-based fractionation in the nebula, while ordinary and enstatite chondrites and related objects experienced volatility-based fractionation, variable oxygen fugacity, and metal-silicate fractionation. Why should these processing histories not produce different outcomes?

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