LITHIUM ISOTOPIC COMPOSITION OF CHONDRITIC METEORITES. W. F. McDonough[1], F- Z. Teng[1], P. B. Tomascak[1], R. D. Ash[1], J. N. Grossman[2], and R. L. Rudnick[1], [1]Department of Geology, University of Maryland, College Park, MD 20742, (mcdonough@geol.umd.edu), [2]U.S. Geological Survey, 954 National Center, Reston, VA 20192.

Introduction: Li isotope studies can provide insights into low temperature alteration processes involving aqueous fluids, given the potential solubility of lithium [1]. In this respect, Li isotope studies of meteorites may help to elucidate fluid processes on meteorite parent bodies.

The Li isotopic composition of solar system materials, however, remains poorly understood, with data available for only a few chondrules and CAI, selected phases from SNC meteorites, and one bulk chondrite (Orgueil) [2-4]. These data show a wide range in δ^7Li values with no obvious systematic variation. Chondrules possess up to 100‰ (expressed at the 2 sigma level) variation in δ^7Li values, whereas CAI have up to 200‰ variation. In addition, CAI are lighter, on average, than chondrules (–20‰ and +10‰, respectively [2]). Chaussidon et al. [2] suggested that the lower δ^7Li values of CAI materials may reflect the addition of spallogenic Li.

Earth materials show ~60‰ total variation in δ^7Li, with much of this variation attributed to water-rock reactions at low temperatures. Based on studies of rocks and fluids from the Earth only low temperature (<700 K) processes are recognized as having any significant effect in fractionating the Li isotopic compositions [1,5]. Chan et al. [1] established that the δ^7Li of fresh, mantle-derived basalts increases from values of about +4 to values as high as +14 ‰, as the amount of low temperature alteration and clay formation increases. Recently, Zack et al. [6] demonstrated that metamorphic dehydration at slightly higher temperatures will shift the Li isotopic compositions of rocks to light values, as low as –12‰.

Given these observations, we have carefully selected a suite of chondritic meteorites that reflect a broad range of petrological types and degrees of aqueous alteration in order to characterize their Li isotopic variation and to understand this variation in a petrological context. We selected only samples that are falls, not finds, to avoid any uncertainties that might accompany Earth-based aqueous processing. By characterizing the Li isotopic composition of chondritic meteorites we place into context the wide variation of ^{7}Li/^{6}Li values observed in chondrules and CAI. In addition, these data will provide insights into (1) fluid-rock interactions on meteorite parent bodies, and (2) the relative effects of dehydration versus thermal metamorphism on chondritic parent bodies.

Analytical Method: Samples were ground to a fine powder with an agate mortar, dissolved in high pressure bombs and fluxed with perchloric acid. Chromatographic separation of Li was accomplished using a published procedure [7]. Total procedural blanks are negligible. The Li isotopic measurements were performed on a Nu Plasma multi-collector ICP-MS at the University of Maryland. The δ^7Li values for all samples are determined by comparison to the standard L-SVEC (assumed to have ^{7}Li/^{6}Li$_{L\text{-}SVEC}$ = 12.175), measured before and after each sample analysis [5]. In addition to monitoring the variation in L-SVEC, precision and accuracy of analyses are constrained to be better than ±1‰, by analyses of 2 or more standard reference materials with each batch of samples. We have also calibrated our procedure with mixed spikes developed from purified metals of ^{7}Li and ^{6}Li.

Results: The results for repeat analyses are shown in Figure 1; error bars for δ^7Li values are ±1‰ at the 2 sigma level. The heavily hydrated meteorites Orgueil (CI1) and Murchison (CM2) have significantly higher δ^7Li than the types 3-4 CV, CO, and CK carbonaceous chondrites and the single type 3 ordinary chondrite (Chainpur) we measured. The possible exception to this trend is Allende, which is the only nonhydrated meteorite that shows a positive δ^7Li.

Despite these resolvable differences between chondrites that are aqueously altered and those that are not, there is only a limited spread in δ^7Li values relative to that seen between chondrules and CAI.

Discussion: The variation we observe in the δ^7Li isotopic composition of bulk chondrites is likely to be due to aqueous alteration processes. Nuclear effects, such as that resulting from the decay of ^{7}Be (λ= 52 days) to ^{7}Li, have been reported in CAI [1,9] but these effects are minor and are not expected to control the δ^7Li values of chondrites. Moreover, spallogenic production and trapped solar wind products are also unable to explain the δ^7Li values in these bulk chondrites [10]. Differences in the proportions of chondrules and CAI among the chondrite groups also cannot account for the variations in δ^7Li that we observe among chondrite groups. If chondrules are isotopically heavy and CAIs are light, we would expect the CAI-rich CV, CM and CO meteorites to have lower δ^7Li than the chondrule-rich ordinary chondrite, but this is not observed.

The negative trend in δ^7Li values with petrologic grade for the carbonaceous chondrites is consistent with isotopically heavy water interacting with parent body materials to produce clays enriched in δ^7Li. This process is commonly observed at mid-ocean ridges [4]. Allende may have somewhat higher δ^7Li than other CV3/CO3/CK3 meteorites as the result of an early period of aqueous processing [e.g., 11], which was preserved when dehydration occurred at higher metamorphic temperatures.

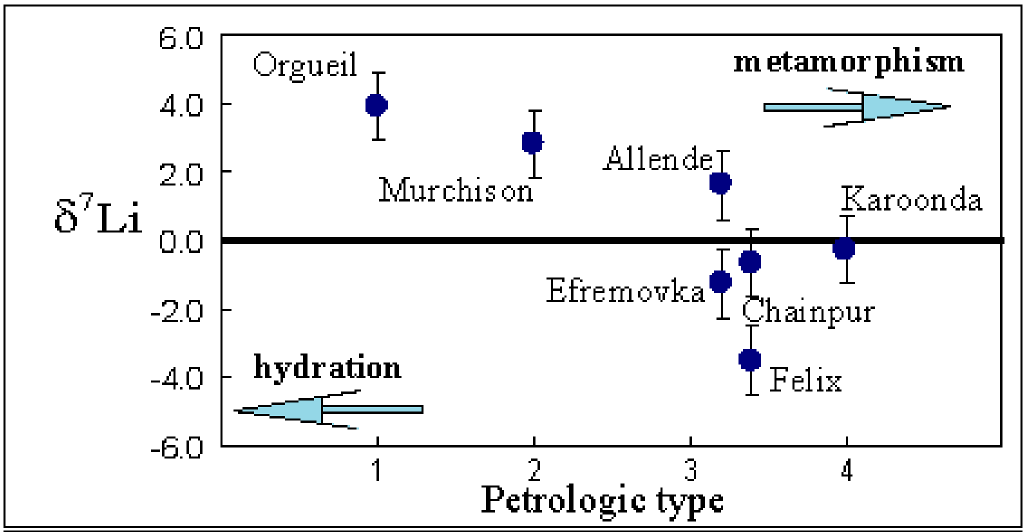

Figure 1. δ^7Li chondritic meteorites versus petrologic type. There is a general trend of higher δ^7Li isotopic compositions with increasing degree of aqueous processing. Data are from this study, excepting data for Orgueil, which is from James and Palmer [4]. Petrologic type values are from Grady [8].

The results for the carbonaceous chondrites can also be used to reassess the δ^7Li value of the bulk solar system. Prior to this the only modern δ^7Li measurement for a bulk meteorite was that for Orgueil [4], with a value of +3.9. Chaussidon et al. [2] assumed an average chondritic δ^7Li value of +10±3‰, presumeably based on their data for chondrules. Our isotopically lighter values may reflect, more reliably, the bulk solar system's δ^7Li value, assuming that aqueous processing has shifted some samples to heavier compositions. A lower bulk solar system δ^7Li value of ~ 0 remains consistent with nucleosynthesis models that predict the abundance of Li and the ^{7}Li/^{6}Li in the solar system [12]. However, assuming a lower solar system δ^7Li value of ~ 0 has significant implications for the Earth [1, 4-7] and Mars [3]. Typically the bulk silicate system in these planets is assumed to have an average δ^7Li value of +4, comparable to that seen in MORB [1].

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