ABUNDANT ^{16}O-RICH OLIVINES IN CHONDRULES FROM ORDINARY CHONDRITES: IMPLICATIONS TO OUTWARD TRANSPORT OF DUST IN THE PROTOPLANETARY DISK.

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Introduction: Ca, Al-rich inclusions (CAIs) and amoeboid olivine aggregates (AOAs) are thought to have formed in a gas of ~solar composition in a hot innermost region of the protoplanetary disk at the birth of the solar system. The presence of these objects in chondrites and 81P/Wild 2 comet suggests CAIs and AOAs were subsequently transported outward from this region and dispersed throughout the disk. The exact mechanism of this transport, however, is not understood: radial transport by disk wind and by disk expansion and turbulent diffusion are being discussed [e.g., 1–3]. We have recently described abundant relict ^{16}O-rich olivine grains, most likely related to AOAs, in agglomeratic olivine chondrules and igneous rims around chondrules; both types of objects experienced melting to a very minor degree [4–7]. In CR chondrules, the abundance of ^{16}O-rich relict grains is several % [6]. Because chondrules in different chondrite groups formed in different disk regions, the abundances of ^{16}O-rich relict grains in chondrules could potentially provide important constraints on the efficiency of radial transport of refractory solids. Here, we report on distribution of ^{16}O-rich olivines in chondrules from the least metamorphosed unequilibrated ordinary chondrites (UOCs).

Results and Discussion: Three chondrules from Semarkona (LL3.01) and MET 00452 (L/LL3.05) chondrites were investigated. Two of them are composed of fine-grained (largely <20 μm) FeO-rich olivine, Na-bearing feldspathic glass, and rare low-Ca pyroxenes, and are texturally similar to agglomeratic olivine objects [7–8]. Some relatively large olivine grains have MgO-rich cores. One microporphyritic/agglomeratic olivine chondrule from Semarkona has a layered structure with a type I chondrule host surrounded by a type II chondrule-like igneous rim. Two to four δ^{18}O isotope maps per chondrule were obtained using the Isotope Microscope system [5]. All δ^{18}O maps revealed ^{16}O-rich (δ^{18}O ~ −40‰) olivine grains (Fig. 1). These are typically from MgO-rich cores in olivine crystals. This result clearly indicates AOA-like olivines were a common precursor of chondrules in UOCs.

The 2D disk model [9] show μm-sized grains can be efficiently transported outward by turbulent diffusion. The recent models of protoplanetary disk evolution, including formation of a gap due to an early accretion (0.6 Myr after CAIs) of a proto Jupiter [10], and radial transport of CAIs by disk expansion and turbulent diffusion along the disk midplane suggest CAIs initially transported throughout the disk would have been subsequently removed from the disk inside Jupiter's orbit by aerodynamic drag and thus could explain the virtual absence of CAIs in ordinary and enstatite chondrites [3]. The model of [3] predicts abundant CAIs (~1–5 vol%) in the inner disk region within 1 Myr, which would have accreted to early formed asteroids such as the HED parent asteroid. However, these achondrites do not show stable isotope anomalies that CAIs often carry (e.g., ^{50}Ti, ^{95}Mo). The nearly complete absence of refractory inclusions with ^{16}O-rich μm-sized olivine grains in UOCs may suggest two different mechanisms for outward transport of refractory solids: small ^{16}O-rich olvines were transported throughout the disk mid-plane by disk expansion and turbulent diffusion, while larger CAIs were transported beyond Jupiter by the disk wind.

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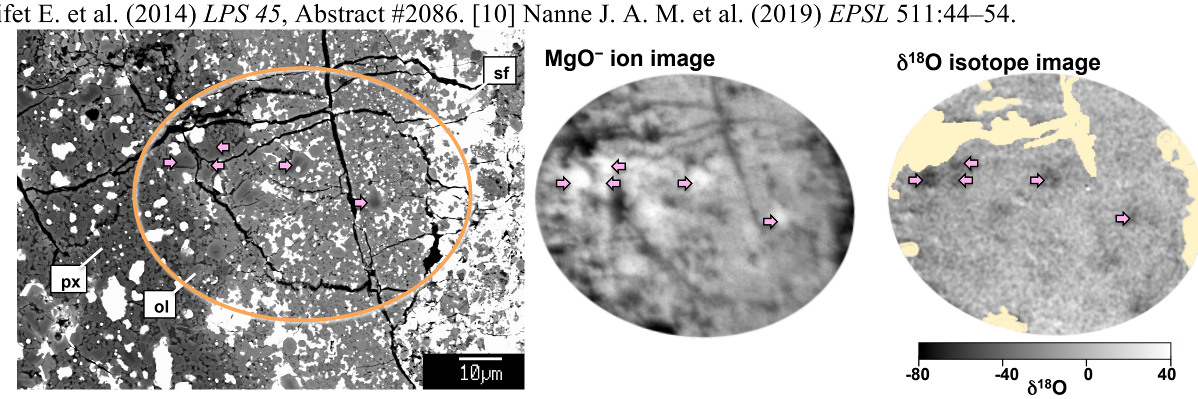

Figure 1. BSE and isotope images (MgO and δ^{18}O) in AO#1 chondrule from Semarkona (UNM312). Pink arrows indicate ^{16}O-rich olivine grains. Yellow regions in δ^{18}O map are masked due to unstable/low oxygen signals.