OXYGEN ISOTOPE SYSTEMATICS OF CHONDRULES AND ISOLATED OLIVINE GRAINS FROM THE TAGISH LAKE C2 CHONDRITE.

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Introduction: Recent studies on oxygen isotope systematics of chondrules show that chondrules in individual chondrite groups have characteristic distributions in their oxygen isotope ratios and Mg# (molar % of MgO/(MgO+FeO)) [e.g., 1-10]. The observed correlations between Mg# and Δ^{17}O values (= $\delta^{17}O_{VSMOW} - 0.52 \times \delta^{18}O_{VSMOW}$) of chondrules can be explained by mixing of ^{16}O-rich anhydrous dusts and an ^{16}O-poor oxidizing agent (most likely H_2O ice) in chondrule forming regions, suggesting existence of redox and oxygen isotopic heterogeneity in the protoplanetary disk [8]. Based on similar Mg# - Δ^{17}O correlations between CR chondrite chondrules and cometary silicate particles from comet Wild 2, it has been proposed that many of cometary silicate particles formed in the outer regions of the asteroid belt [11-14].

The Tagish Lake meteorite (ungrouped C2) is an appropriate sample to investigate the Mg# - Δ^{17}O systematics of silicate particles formed in the outer regions of the asteroid belt because the Tagish Lake meteorite probably derived from a D-type asteroid [15]. Previous oxygen isotope studies on olivine grains from Tagish Lake [16] and Tagish Lake-like meteorites (WIS 91600, MET 00432)[17] show that their Mg# - Δ^{17}O systematics are similar to that of CR chondrite chondrules. Here, we report new oxygen isotope data of olivine grains from the Tagish Lake meteorite for better understandings of the Mg# - Δ^{17}O systematics of silicate particles in the outer regions of the asteroid belt.

Samples and Methods: Two polished epoxy mounts of the Tagish Lake meteorite, TL-KC-1 (8mm × 5mm) and TL-KC-2 (4mm × 3mm), were prepared for this study. Frequent occurrence of magnetite in the matrix indicates that most of polished sections consist of the carbonate-poor lithology [18]. Due to extensive aqueous alteration in the Tagish Lake parent body, phyllosilicates and other secondary phases such as magnetite and carbonates replace primary anhydrous silicates [18]. However, remaining olivine grains in chondrules and matrix tend to have sharp grain boundaries and no apparent evidence for the Mg-Fe exchange between olivine grains and matrix was observed (Fig. 1). Forty chondrules and isolated olivine grains (hereafter "ferromagnesian inclusions") were selected for oxygen isotope measurements (olivine's Mg# = 99.6 to 55.8). Petrographic observation and preliminary major element measurements were performed with the Hitachi SU1510 SEM equipped with an EDS system at Kochi Institute.

Oxygen isotope ratios of olivine grains were measured with a SIMS, CAMECA IMS 1280-HR at Kochi Institute. A focused Cs$^+$ primary beam (~30 pA, ~3 μm in diameter) with 20 kV total accelerating voltage was used. Secondary ions were detected with multiple collectors (a Faraday cup for $^{16}O^-$, two electron multipliers for $^{17}O^-$ and $^{18}O^-$, respectively). A typical count rate of the $^{16}O^-$ signal was ~3×10^7 cps. The mass resolving

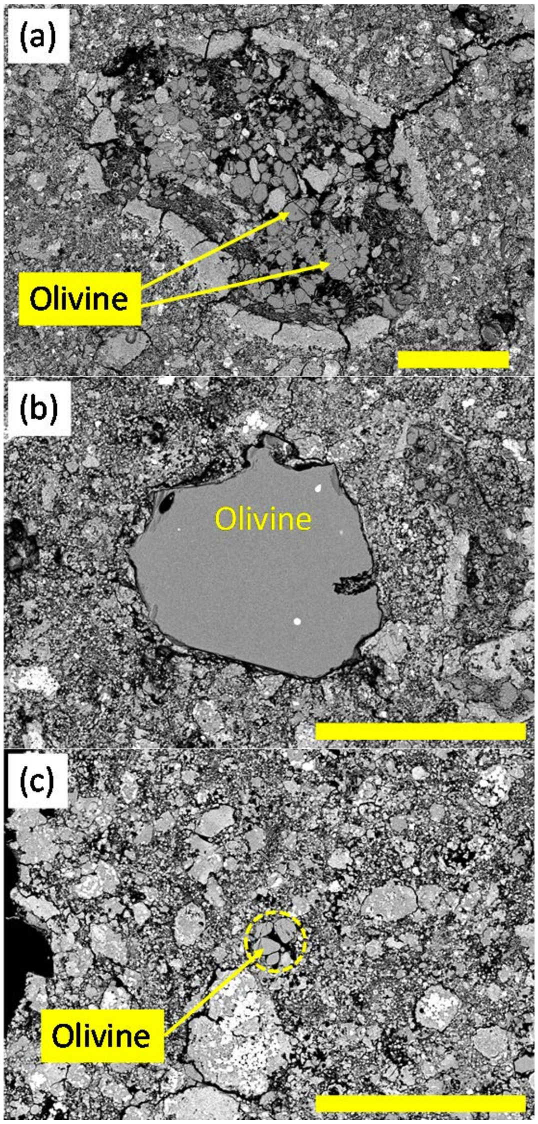

Figure 1. Backscattered electron (BSE) images of (a) a chondrule, 1-G5, and isolated olivine grains (b) 1-G13, and (c) 2-G16. Scale bars are 200μm.

power (M/ΔM) was ~6000 for $^{17}O^-$ and ~2200 for $^{16}O^-$ and $^{18}O^-$, respectively, and the $^{16}OH^-$ contribution to $^{17}O^-$ was less than 0.1‰. The analytical conditions were similar to those in [4, 19]. Measured $^{18}O/^{16}O$ and $^{17}O/^{16}O$ ratios were normalized to those of bracketing analyses of San Carlos olivine ($\delta^{18}O_{VSMOW}$= 5.37±0.14‰). Typical reproducibility (2 SD) was ±0.74‰ for $\delta^{18}O$ and ±0.87‰ for $\Delta^{17}O$, respectively.

Results and Discussion: One to four analyses were performed for each inclusion. Average values are calculated (excl. relict grain's data) and shown in figures if multiple data were obtained.

Distribution of oxygen isotope ratios. Oxygen three-isotope ratios of ferromagnesian inclusions from Tagish Lake are distributed along the PCM (primitive chondrule minerals) line [4] (Fig. 2), which are consistent with previous studies on chondrules from carbonaceous chondrites. Relatively ^{16}O-enriched relict olivine grains were recognized from three chondrules. One isolated olivine grain (or olivine aggregate?), 2-G16 (Fig. 1c), has a very ^{16}O-rich signature like CAIs and AOAs (Fig. 2).

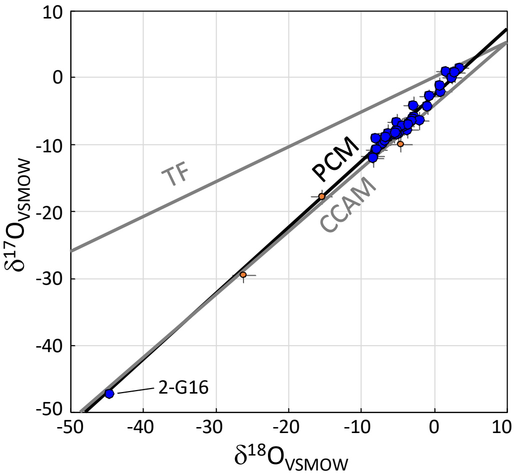

Figure 2. Oxygen three-isotope ratios of chondrules and isolated olivine grains (blue symbols), and relict olivine grains (orange symbols). Errors are 2SD.

The Mg# - $\Delta^{17}O$ systematics. Figure 3 summarizes the Mg# - $\Delta^{17}O$ systematics of ferromagnesian inclusions in this study. Most type I (Mg# ≥ 90) ferromagnesian inclusions are relatively ^{16}O-rich ($\Delta^{17}O$ = -7.4 to -3.9‰) and type II (Mg# < 90) ferromagnesian inclusions are relatively ^{16}O-poor ($\Delta^{17}O \geq -3$‰). These are consistent with previous studies on Tagish Lake/Tagish Lake-like meteorites [16, 17]. In addition, type II ferromagnesian inclusions with $\Delta^{17}O$ ~ 0‰ were found in Tagish Lake (Fig. 3). Such type II ferromagnesian inclusions are recognized in Tagish Lake-like meteorites [16], CR chondrites [2, 5, 7, 8], and cometary silicate particles [13, 14], but are almost absent in other carbonaceous chondrites (typically $\Delta^{17}O$ ~ -2.5‰) [e.g., 3, 4, 6, 9, 10]. Results of this study are further evidence for the link between ferromagnesian inclusions accumulated into asteroids in the outer regions of the asteroid belt (possibly D-type asteroids) and silicate particles accumulated into cometary nuclei in the Kuiper belt.

As discussed in [13, 14], type II (Mg# < 90) and ^{16}O-poor ($\Delta^{17}O \geq -3$‰) silicates are common, but type I (Mg# ≥ 90) and ^{16}O-rich ($\Delta^{17}O$ = -9 to -4‰) silicates are much less common than minor very ^{16}O-rich ($\Delta^{17}O$ < -20‰) silicates in cometary silicate particles. These are distinct from ferromagnesian inclusions in Tagish Lake(-like) meteorites and CR chondrites. Most cometary silicate particles formed in H_2O ice enriched oxidizing regions. Such regions were probably farther than where typical ^{16}O-rich type I chondrules of carbonaceous chondrites formed. Due to limitation of time and outward transfer mechanisms, ferromagnesian inclusions formed in remote H_2O ice enriched regions and early CAI-related inclusions could have reached to the cometary nuclei formed region before their accretion.

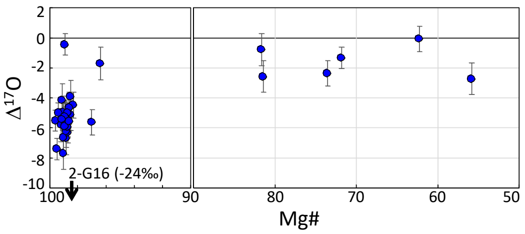

Figure 3. The Mg# - $\Delta^{17}O$ systematics of Tagish Lake chondrules and isolated olivine grains. Errors are 2SD.

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