Water abundance in the Tagish Lake meteorite from TGA and IR spectroscopy: Evaluation of aqueous alteration. C. M. Gilmour[1], C. D. K. Herd[1], E. A. Cloutis[2], M. Cuddy[2], and P. Mann[2]. [1]Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton, AB, Canada. E-mail: cgilmour@ualberta.ca. [2]Department of Geography, University of Winnipeg, Winnipeg, Manitoba, Canada.

Introduction: The Tagish Lake meteorite is a unique, organic-rich, ungrouped carbonaceous chondrite breccia that bears similarities to CI and CM chondrites [1]. Petrological variations have been reported among three different Tagish Lake specimens (5b, 11h, and 11i) which represent different degrees of aqueous alteration in the order 5b < 11h << 11i [2,3]. Aqueous alteration studies have revealed that it is possible to determine the extent of alteration in carbonaceous chondrites from phyllosilicate water abundances and the ratios between phyllosilicates and mafic silicates [4,5]. By studying these attributes in Tagish Lake we seek to address two significant unknowns: 1) whether the phyllosilicate water abundance in Tagish Lake corresponds to the reported degree of alteration; 2) which alteration phases are the primary reservoirs for water.

If the degree of aqueous alteration among 5b, 11h, and 11i can properly be represented by water abundance studies, then two new specimens – 4 and 10a – can be introduced into the reported alteration sequence based on their water content; the detailed mineralogy of these two samples is unknown. Sample 4 is of particular interest due to its unusually high grain density and porosity relative to other Tagish Lake samples [6].

Methods: Thermogravimetric analysis (TGA) was used to quantify the amount of water in the five different Tagish Lake samples (5b, 11h, 11i, 4, and 10a). Samples were collected (12 - 20 mg) and analyzed on two separate occasions using a Perkin Elmer STA 6000 instrument. The samples were heated from 30°C to 900°C at a rate of 10°C/min under an inert N_2 atmosphere of 20 ml/min. For the first TGA run, 5b, 4, and 10a were crushed with a mortar and pestle to homogenize the samples. The remaining samples for the first run and all samples for the second run were used as collected, i.e., a loose, heterogeneous mixture of chondrules and matrix. Derivative thermogravimetry (DTG) curves were calculated to identify mineral hosts for water based on characteristic temperature peaks. Mineral standards were also analyzed with TGA to aid in identifying mineral phases that house water in Tagish Lake, with standards selected based on prior work [2].

Transmission infrared (IR) spectroscopy was collected for the Tagish Lake samples to determine phyllosilicate/mafic silicate ratios based on absorption band depths. Transmission spectra were collected at the University of Winnipeg Planetary Spectrophotometer Facility (UWPSF) using a Bruker Vertex 70, Fourier Transform Infrared (FTIR) spectrometer equipped with an infrared glow-bar light source, pyroelectric DLaTGS detector, and potassium bromide (KBr) broadband beamsplitter over the range of 7000-400 cm^{-1}. Tagish Lake powdered samples were mixed with KBr to make a 0.75 g pressed pellet with 1% Tagish Lake. No heating of samples was done prior to analysis. Transmission spectra were acquired relative to a 100% KBr pressed pellet. A total of 100 scans were averaged to improve the signal to noise ratio.

Results:

TGA Results. Table 1 lists the total water abundances and phyllosilicate water abundances for all TGA runs. Total water abundances account for absorbed water, organics, and phyllosilicates. Samples 11h and 11i show the greatest variability in phyllosilicate water. Corresponding DTG curves reveal that saponite and serpentine (likely greenalite) are the main phyllosilicate hosts for water in Tagish Lake.

	Total Water (wt. %)		**Phyllosilicate Water (wt. %)**	
Sample	**1st Run**	**2nd Run**	**1st Run**	**2nd Run**
5b	15.3 18.8*	15.1	9.0 9.0*	9.4
11h	17.0	10.9	10.6	7.1
11i	15.4	15.0	8.9	10.5
4	11.8*	11.1	6.1*	7.2
10a	16.0*	15.1	9.6*	10.1

Table 1. TGA total water and phyllosilicate water abundances for all analytical runs. *Indicates samples that were crushed and homogenized by grinding in a mortar and pestle prior to analysis.

IR Spectroscopy Results. Transmission spectra (absorbance) of the different Tagish Lake samples are shown between 5 µm and 25 µm (Fig. 1). Absorption features at wavelengths greater than 15 µm are saturated, but there is evidence of possibly two different phyllosilicate features around 15 µm and 16.5 µm, as well as a 22 µm serpentine feature. Due to the saturated nature however, not much information can be extracted from these features. Two features that can be utilized are the 9.8 µm phyllosilicate (likely saponite [5]) band and the 11.4 µm olivine band. The ratio between these two can be used to assess the extent of aqueous alteration among samples. The five Tagish Lake samples are stacked in Fig. 1 based on intensity of the 11.4 µm olivine band; the olivine band increases in intensity from bottom to top. As the olivine band increases, the sample is considered to be less altered [5].

Discussion: If Tagish Lake specimens behave similarly to e.g., CM chondrites, the relative IR ratio of phyllosilicates to mafic silicates should reflect the TGA results, where the greater the phyllosilicate water abundance, the greater the phyllosilicate/olivine band ratio [4]. Fig. 2 reveals that the Tagish Lake samples do not follow this trend.

Sample 11h shows the greatest variability in phyllosilicate water between the two TGA runs, even though similar amounts of material were used in each run, indicating that 11h is lithologically quite heterogeneous at the scale of sampling. The same can be said for 11i as similar sample sizes were also used in the two runs. In contrast, sample 4 shows less variability than 11h and 11i in its phyllosilicate water abundance in spite of a greater difference in sample amounts between the two runs (13 mg and 18 mg). Whether samples were homogenized prior to analysis does not appear to have a significant effect (Fig. 2).

The fine-grained matrix in Tagish Lake consists of saponite and serpentine that composes 50 vol% of 11i but only 20 vol% of 5b (11h is similar in abundance to 11i) [2]. Given that 11i has a greater abundance of phyllosilicates it should have a greater phyllosilicate/olivine band depth ratio than 5b, but that is not the case here (Fig. 2). Also, the phyllosilicate water abundance of 11i is relatively similar to that of 5b (notably the first 11i TGA run). This suggests that the alteration of 5b, 11h, and 11i are better represented by their petrological differences rather than their phyllosilicate water abundances, in contrast to typical CM carbonaceous chondrites in which phyllosilicate water abundances reflect alteration degrees [4].

The variability of the results precludes incorporating samples 4 and 10a into the previously proposed alteration sequence. However, it is evident that sample 4 has an unusual combination of a low phyllosilicate water abundance and a high phyllosilicate/olivine band depth ratio (Fig. 2). Along with its above-average grain density and porosity [6], it seems that sample 4 may represent a new lithology. A petrological study of sample 4 is underway to confirm this.

Conclusions: The TGA and IR results for Tagish Lake are variable and do not agree with the previously proposed alteration sequence for 5b, 11h, and 11i. The variability observed may be due to the scale of sampling relative to the scale of lithological variation. It is likely that some samples contained more olivine chondrules than phyllosilicates, which would cause the variability among the results. To properly sample Tagish Lake for TGA and IR spectroscopy, at least 1 g of sample may be necessary to best represent the overall lithology of these samples.

References: [1] Zolensky M. E. et al. (2002) *Meteoritics & Planet. Sci., 37*, 737–761. [2] Blinova A. I. et al. (2014) *Meteoritics & Planet. Sci., 49*, 473–502. [3] Herd C. D. K. et al. (2011) *Science, 332*, 1304–1307. [4] Garenne A. et al. (2014) *Geochim. et Cosmochim. Acta, 137*, 93–112. [5] Beck P. et al. (2014) *Icarus, 229*, 263–277. [6] Ralchenko M. et al. (2014) *LPSC XLV*, Abstract #1021.

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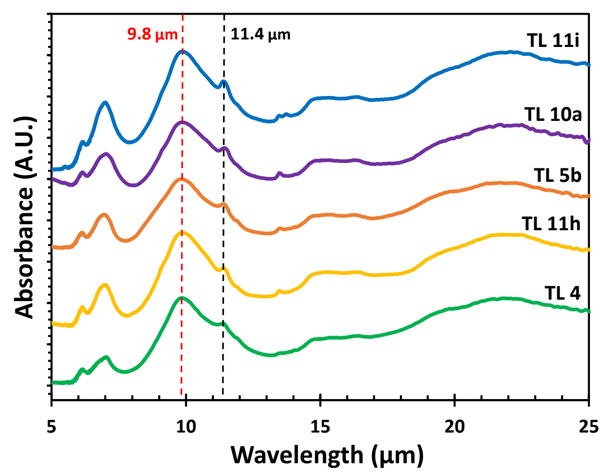

Fig. 1. IR spectra from transmission analysis of Tagish Lake. Olivine (11.4 µm) band intensities increase from bottom to top. The 9.8 µm band corresponds to a phyllosilicate feature.

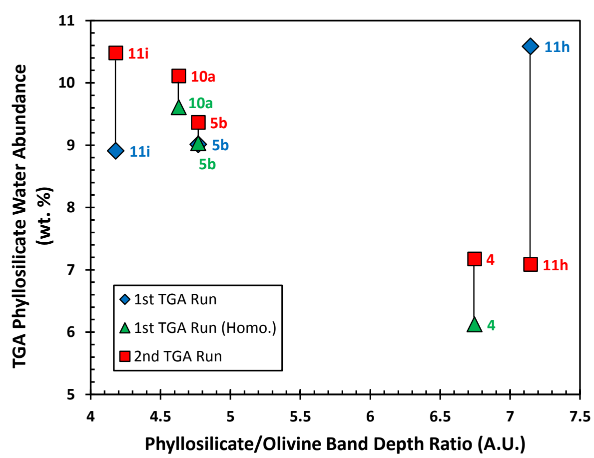

Fig. 2. Comparison of the IR phyllosilicate (9.8 µm)/olivine (11.4 µm) band depth ratios to the TGA phyllosilicate water abundances.