SPECTRAL VARIATIONS IN THE TAGISH LAKE CARBONACEOUS CHONDRITE IN THE ULTRAVIOLET, VISIBLE, AND NEAR-INFRARED. M. R. M. Izawa[1*], M. A. Craig[2], E. A. Cloutis[1] [1]Hyperspectral Optical Sensing for Extraterrestrial Reconnaissance Laboratory, Department of Geography, University of Winnipeg, 515 Portage Ave., Winnipeg, Manitoba, Canada, R3B 2E9; [2]Department of Earth Sciences/Centre for Planetary Science and Exploration, Western University, 1151 Richmond St., London, Ontario, Canada, N6A 5B7. [*]matthew.izawa@gmail.com

Introduction: Tagish Lake is a type-2 chondrite with affinities to CM, CI and CR chondrites. The first spectral studies of Tagish Lake indicated spectral similarities to D- or P-type asteroids [1]. Since the recovery and initial description of Tagish Lake [2], significant lithological variations have been discovered [3-5]. We have conducted a UV, visible, and near-IR spectroscopic study of Tagish Lake samples for which the mineralogy has previously been determined by X-ray diffraction and Rietveld refinement [4]. Similar to [6], we find that absorption bands are present in the spectra of Tagish Lake samples, albeit at a much suppressed level due to the presence of abundant fine-grained opaque phases (e.g., magnetite, sulphides) and organic compounds intimately associated with the matrix phyllosilicates.

Methods: Spectra were measured with an Analytical Spectral Devices FieldSpec Pro HR spectrometer which acquires data from 350 to 2500 nm, with a spectral resolution of between 2 and 7 nm. The 350-2500 nm spectra were measured at a viewing geometry of i = 30º and e = 0º. Incident light was provided by an in-house built 50 W quartz-tungsten-halogen collimated light source. Sample spectra were measured relative to a Spectralon® (Labsphere, North Sutton, NH) standard and corrected for minor (< ~2%) irregularities in its absolute reflectance. In each case, 1000 spectra of the dark current, standard, and sample were acquired and averaged, to provide sufficient signal-to-noise for subsequent interpretation. Straight-line continua were removed and 3rd-order polynomial fitting was used to find probable band centre locations.

Samples: The Tagish Lake samples studied here were collected in spring 2000 and consist of very fine-grained powders (<45 μm nominal particle size). The modal mineralogy of the samples investigated here (as reported by [5]) are summarized in Table 1, along with the modal mineralogy reported by [7] for comparison. Sample PB-02 has a very high carbonate content, with 24 wt. % siderite and minor (1-3 wt. %) calcite, while MG-02 and MM-02 are more representative of 'average' Tagish Lake material and probably represent mixtures of the 'carbonate-rich' and 'carbonate-poor' lithologies [2, 8].

Results: Spectra (in absolute reflectance) of the three Tagish Lake samples investigated are shown in Figure 1. Figure 2 shows details of the ~ 2300 nm feature. Albedo and spectral slope parameters are given in Table 2.

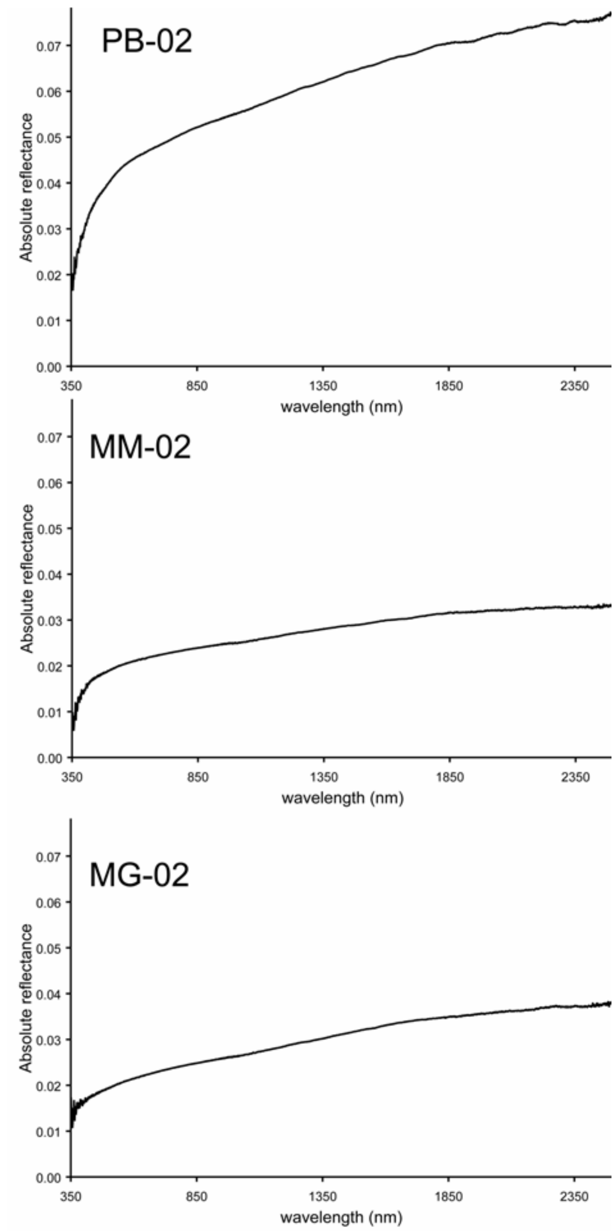

Figure 1: Spectra of Tagish Lake samples PB-02 (carbonate-rich, siderite-dominated [4]), MM-02, and MG-02 (mixtures of carbonate-rich and carbonate-poor lithologies [2, 4, 8]) from 350 to 2500 nm.

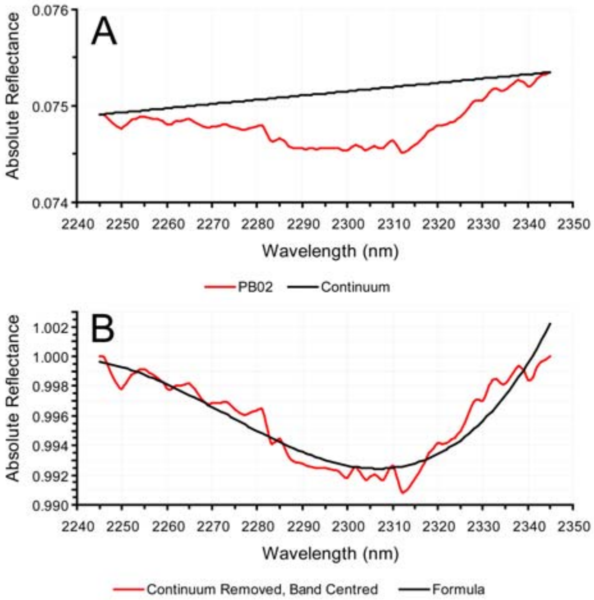

Figure 2: Details of the 2307 nm feature in sample PB-02. A) spectrum with straight-line continuum. B) Continuum removed, band centred spectrum with 3rd-order polynomial fit.

Table 1: Tagish Lake modal mineralogy

	PB-02	MM-02	MG-02	[7]
saponite	48	49	52	60.3
olivine	9	9	12	7.9
magnetite	6	8	13	8.9
siderite	24	11	9	14.4
calcite	≤3	≤3	≤3	n.d.
dolomite	n.d.	≤3	≤3	n.d.
pyrrhotite	13	18	13	5.3
pentlandite	≤3	≤3	≤3	0.6
grain density	2.97	2.95	2.92	2.84

PB-02, MM-02 and MG-02 modal mineralogy from Izawa et al. [6], Bland et al. values for bulk Tagish Lake from Bland et al., [7]; n.d. = mineral not detected.

Table 2: Albedo and spectral slope parameters

	PB-02	MM-02	MG-02
Reflectance at 560 nm	4.38%	2.04%	2.07%
Slope ($I_{2400\,nm}$/ $I_{1800\,nm}$)	1.074	1.048	1.071
Slope ($I_{1800\,nm}$/ $I_{560\,nm}$)	1.598	1.534	1.668

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Discussion: The Tagish Lake samples studied here are very dark with albedo (here defined as reflectance at 560 nm) ranging from ~2-4%, and with very red spectral slopes. Sample PB-02, a very carbonate-rich lithology, has a much higher albedo than previously reported for Tagish Lake materials [1, 6]. A probable broad feature appears in the spectra of sample PB-02 near ~1000 nm and is likely the result of Fe^{2+} in octahedral co-ordination with O, occurring in matrix phyllosilicates (poorly-crystalline disordered saponite-serpentine), olivine, and siderite. Variations in site geometry between the $^{VI}Fe^{2+}$-bearing minerals lead to a large number of overlapping peaks which produce the observed broad band. Possible features at ~1400 and ~1900 nm are attributable to overtones of H_2O and OH fundamental vibrations in hydrous minerals and adsorbed water. A possible feature at ~1700 nm is attributable to overtones of C-H fundamental stretching modes in organic compounds. Tetrahedral Fe^{2+} in magnetite may contribute to possible features near ~2100 nm. A possible feature near ~2200 nm is likely attributable to Al-OH combination bending plus stretching feature in matrix phyllosilicates. The feature centred at 2307 nm (the only feature deep enough to be fit reliably) is likely due to Mg-OH bending plus stretching combination in matrix phyllosilicates, with a possible contribution from overtones of the fundamental stretches of the carbonate anion.

Summary and conclusions: Detailed analysis of UV-Vis-nIR spectra of Tagish Lake has revealed a diversity of probable spectral features that in part reflect mineralogical differences between Tagish Lake lithologies. This type of spectral analysis can aid in the interpretation of spectral data returned by spacecraft observing planetary surfaces containing carbonaceous chondrites or material similar to them, for example, 1999 RQ_{36} (OSIRIS-REx), Ceres (Dawn), comet nuclei (ROSETTA) and others.

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References: [1] T. Hiroi, et al., *Science, 293*, 2234 (2001); [2] P. G. Brown et al., *Science, 290*, 320 (2000). [3] A. Blinova, et al., *AGU Joint Assembly*, Toronto (2009). [4] M. R. M. Izawa, et al., *MAPS, 45*, 675 (2010). [5] M. R. M. Izawa et al., *Planet. Sp. Sci., 58*, 1347 (2010). [6] E. A. Cloutis, et al., *Icarus, 221*, 984 (2012). [7] P. Bland et al., *MAPS, 39*, 3 (2004). [8] M. E. Zolensky *MAPS, 37*, 737 (2002).