BULK MINERALOGY AND SPECTRAL PROPERTIES OF THE C2 CHONDRITE TAGISH LAKE: A CORRELATED X-RAY DIFFRACTION (XRD) AND BICONICAL REFLECTANCE INFRARED SPECTROSCOPY STUDY

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Introduction: Meteorites are typically grouped by mineralogy and geochemistry, and linked to possible parent bodies by comparison of their infrared reflectance spectra. In this study, Rietveld refinement of high-resolution powder X-ray diffraction (XRD) of bulk meteorite samples was used to determine quantitative major phase. Thermal IR (400-4500 cm^{-1}, 2-25 μm) spectra of the same samples were obtained using biconical (Diffuse) Reflectance Infrared Fourier Transform Spectroscopy (DRIFTS), which provides with higher signal-to-noise than emission IR measurements used in remote sensing [1]. This allows a direct comparison of bulk mineralogy with remote sensing properties, which will be valuable for the interpretation of asteroid spectra.

Tagish Lake: Tagish Lake is among the most primitive and physically weak meteorites ever studied and one of the few for which pre-entry orbital elements have been determined [6, 7]. The orbital and spectral data suggest an association with the primitive, organic-rich D or P asteroids of the outer main belt. The meteorite is an accretionary breccia with carbonate poor and carbonate rich endmember lithologies. The meteorite's matrix dominated is by phyllosilicates (intergrowths of Fe-bearing saponite and serpentine), magnetite, and Fe, Ni sulfides. Clasts including sparse chondrules, fine-grained aggregates and individual grains of olivine, phyllosilicates and minor pyroxene, rare CAIs, and irregular nodules of Fe-Mn-Mg-Ca carbonates [8]. The carbonate rich lithology has less magnetite, and only rare CAIs. Geochemical, isotopic, organic chemical and petrologic studies suggest a relationship between Tagish Lake and CI and CM chondrites [8]. Given the heterogeneity of this meteorite, it is prudent to examine the compositional and spectroscopic variations in Tagish Lake in a sample correlated manner.

Samples and Methodology: The samples investigated were disaggregated in meltwater, (termed 'slurp samples' due to the method of extraction from the ice with a grease gun [6, 7]). They are nearly clast-free and are probably dominated by matrix. Each sample was ~250 mg in total mass.

XRD: Powder XRD was performed using a Panalytical X'Pert diffractometer with Co Kα radiation (λ = 1.79030 Å), with 300s effective counting time per step and step size 0.008º. Samples were ground to ≤5 μm grain size and mounted on an oriented Si single-crystal zero-background plate. Rietveld refinement uses non-linear least-squares optimization to fit a calculated diffraction pattern to measured powder diffraction data. The theoretical diffraction pattern is a function of all relevant geometrical, specimen and experimental parameters. Phase abundances for crystalline material are derived from the refined scale factors, unit cell volumes, and densities [2]. Rietveld refinement was done using Bruker-AXS Total Pattern Analysis (TOPAS3) software [3]. Based on calibration studies using known mineral mixtures, the estimated uncertainty in the refined abundances is at most ~2-3%.

Reflectance IR: Reflectance IR spectra were collected with a Nicolet Nexus 670 FTIR with KBr beamsplitter, DTGS detector and a Pike autodiff DRIFTS accessory. Samples were diluted to ~5% with KBr. Scrubbed dry air was used as a purge gas. Spectra were collected for 500 scans at $4cm^{-1}$ spectral resolution. The samples were homogenized by crushing under air in an agate mortar. Three aliquots of 0.5 mg each were taken from each sample and the resulting spectra averaged.

Results and Discussion: Figure 1 shows the reflectance IR spectra of the Tagish Lake samples, with bands assigned based upon previous studies [4, 5, and references therein]. Following [4], vibrational bands are denoted as follows ν = stretching vibration, ν_{as} = asymmetric stretch, ν_{ss} = symmetric stretch, δ = bending vibration. Large variations are observed in the band ratio of the carbonate νC-O feature near 1480 cm^{-1} relative to the silicate mineral feature ν_{as}(Si, Al)-O feature near 1000 cm^{-1} (fig. 1). Rietveld refinement reveals that this ratio relates to the abundance of carbonate minerals realtive to the nearly constant silicates (table 1). The broad H_2O feature at 3000-3800 cm^{-1} varies

greatly between samples, likely due to variable non-structural water in the matrix. The structural H_2O feature near 1630 cm-1 changes little, suggesting that the amount of clay is constant. This is consistent with Rietveld refinement results, see table 1. The νC-H feature near 2900 cm^{-1} varies substantially due to organic content. However, the amount of extraterrestrial organic molecules versus terrestrial contamination is unknown [6, 7]. The mineral abundances as summarized in table 1 indicate that sample 2005c derives mainly from carbonate-rich material, MG02 and PM05 from the carbonate-poor. Silicate minerals have very similar abundances. Complementary variations are observed in carbonate and magnetite, with the carbonate rich lithology sample (2005c) containing less magnetite. Sulfides and oxides are inactive in the thermal IR.

	MG02	PM05	2005c
Saponite	59	60	58
Forsterite	8	7	10
Magnetite	16	14	4
Siderite	13	15	25
Calcite	≤3	≤3	≤3
Pyrrhotite	≤3	≤3	≤3
Pentlandite	≤3	≤3	≤3
Clinopyroxene	≤3	≤3	≤3
Total silicate	68	69	67
Total carbonate	15	16	26
Total oxide + sulfide	17	15	7
1480 cm^{-1}/1000 cm^{-1}	0.30	0.32	0.66

Table 1: Mineral abundances (in $\%_{wt}$) and carbonate to silicate/aluminosilicate (1480 cm^{-1} to 1000 cm^{-1}) band ratios. As stated above, the estimated uncertainty in the abundances is at most ~2-3%.

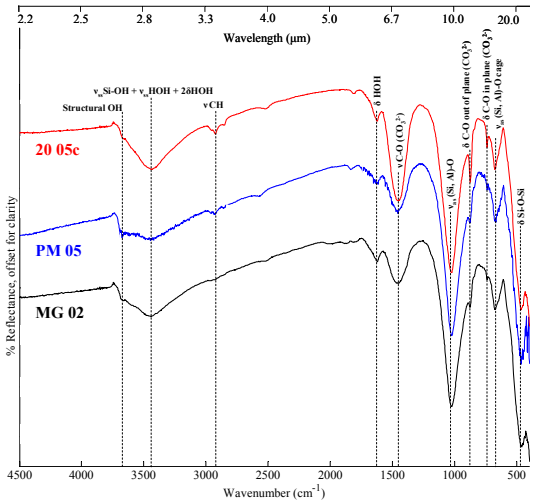

Fig. 1: Interpreted reflectance IR spectra of Tagish Lake disaggregated samples. Bands assigned following [4] and [5].

Summary, Conclusions and Future Work: XRD and reflectance IR show that the clay content of these samples is nearly constant. Variations in carbonate content of ~10% are detected using the ratio of the 1480 to 1000 cm^{-1} band depths. Future work will investigate a broader range of Tagish Lake material to determine if this continues to hold for samples with more varied carbonate and silicate contents. If this is the case, it may be possible to quantify this relationship empirically.

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