EFFECTS OF SHORT-TERM THERMAL ALTERATION ON ORGANIC MATTER IN EXPERIMENTALLY-HEATED TAGISH LAKE OBSERVED BY RAMAN SPECTROSCOPY

Q. H. S. Chan¹, A. Nakato², M. E. Zolensky¹, T. Nakamura¹, and Y. Kebukawa¹, ¹ARES, NASA Johnson Space Center, Houston, TX 77058, USA (hscchan@nasa.gov), ²JAXA, Kanagawa 252-5210, Japan, ³Tohoku University, Miyagi 980-8578, Japan, ⁴Faculty of Engineering, Yokohama National University, Yokohama, Japan.

Introduction: Carbonaceous chondrites exhibit a wide range of aqueous and thermal alteration characteristics. Examples of the thermally metamorphosed carbonaceous chondrites (TMCCs) include the C2-unG/CM2TIVs Belgica (B)-7904 and Yamato (Y) 86720. The alteration extent is the most complete in these meteorites and thus they are considered typical end-members of TMCCs exhibiting complete dehydration of matrix phyllosilicates [1, 2]. The estimated heating conditions are 10 to 10⁷ days at 700°C to 1 to 10 hours at 890°C, i.e. short-term heating induced by impact and/or solar radiation [3]. The chemical and bulk oxygen isotopic compositions of the matrix of the carbonate (CO₃)-poor lithology of the Tagish Lake (hereafter Tag) meteorite bears similarities to these TMCCs [4]. We investigated the experimentally-heated Tag with the use of Raman spectroscopy to understand how short-term heating affects the maturity of insoluble organic matter (IOM) in aqueously altered meteorites.

Analytical methods: The CO₃-poor lithology of Tag (#11) was located with X-ray computed tomography at the University of Texas. Subsamples (~100 mg) of the CO₃-poor lithology were subjected to heating experiments: (1) 600°C/1h, (2) 600°C/96h, (3) 900°C/1h, and (4) 900°C/96h. The samples were studied with Raman spectroscopy at NASA JSC using a Jobin-Yvon Horib LabRam HR Raman microprobe. At least 12 spectra were collected on each raw matrix grain (flattened between two glass slides) with 514 nm excitation wavelength and a spot size of ~1 μm. The laser power at the sample surface was ≤450 μW and the total acquisition time was 450s. The peak parameters were determined by peak fitting to Lorentzian and Breit–Wigner–Fano profiles [5] and linear baseline correction.

Results and Discussion: The Raman parameters of the unheated Tag vary from previous studies [6, 7], probably due to different analytical methods, peak fitting algorithm, and/or sample heterogeneity due to the brecciated nature of Tag which contains two other major lithologies: CO₂-rich lithology and foreign clasts [8]. Nevertheless, the Raman parameters of the three adjacent unheated subsamples of the CO₃-poor lithology are comparable, indicating that the organic content is consistent within this lithology.

Heating experiment: A reduction in the intensity of the fluorescence background was observed after the samples were subjected to heating. A similar effect of heating on the fluorescence background has been observed for the thermally-altered CMs [e.g., 7]. The D band parameters show a clear correlation to the heating temperature, however heating duration does not appear to induce much change. Decreases in the fluorescence intensity and the D band full-width half-maximum (Γ) indicate that the IOM gains maturity through thermal annealing by losing hydrogen and heteroatoms to form polyaromatic structures such as hydrogenated amorphous carbons (a-C:H). The D peak center (ωD) and ΓD of the heated (≥700°C) Y-86720 are ~1349 and ~245 cm⁻¹ respectively [6], which is placed between the 600°C and 900°C experiments on the ωD vs ΓD plot (Figure 1). Our experimental data also indicate that with increasing temperature (with short heating duration), the ΓD first increases and then falls. However, the G band parameters show only negligible variation between the unheated Tag and the heated Y-86720 [6], which indicates that the G band is more sensitive to short-term heating. The IOM maturation grade strongly depends on the time/temperature history, although heating effects are rapid as the difference between the 1h and 96h experiments is insignificant.

Conclusions: We studied the experimentally-heated Tag with Raman spectroscopy. ωD and ΓD decrease with increasing temperature; ΓG first increases and then falls. Despite the chemical similarities between Tag and the Belgica-like meteorites and the comparability of their D band parameters, a variation in G band parameters was only observed for the experimentally-heated (short-term) Tag but not the naturally metamorphosed Y-86720, which suggest that the IOM maturity and graphitization time is dependent.