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Thermal metamorphic history of Antarctic CV3 and CO3 chondrites inferred from the first- and second-order Raman peaks of polyaromatic organic carbon

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Abstract

Parent body thermal metamorphism is an important process that alters the structure of organic matter in the parent asteroid of meteorites. Increasing and progressing thermal metamorphism results in carbonization and graphitization of carbonaceous matter in the parent body. Such modifications in the carbon structures can be studied by Raman microspectroscopy, thanks to its high sensitivity to structure and bonding within carbonaceous molecules. We have characterized polyaromatic carbonaceous matter in a total of 24 Antarctic CV3 and CO3 chondrites using micro-Raman imaging spectroscopy in an effort to better understand parent body thermal metamorphism and assess its effects on the carbon structures. Raman spectral parameters of the first-order carbon peaks (D and G) were extracted from at least 200 spectra for each meteorite and were compared to deduce relationships that yield information regarding the thermal metamorphism conditions. We also show, for the first time, spectral trends and relations of the second-order carbon peaks (2D and D+G) within the 2500–3200 cm^{-1} with thermal metamorphic history. The second-order peaks appear to contain information that is lacking in the first-order peaks. Based on the second-order carbon peak parameters, we tentatively classify four CV3 chondrites into subtypes, and reclassify another. Peak metamorphic temperatures of the investigated meteorites have been estimated based on the width of the D band as well as the calculated Raman spectral curvature. Estimated temperatures appear to correlate well with the assigned petrologic types. We have calculated higher peak metamorphic temperatures for the CV3 chondrites than for the considered CO3 chondrites and further showed that the peak metamorphic temperatures of $CV3_{oxA}$ chondrites are higher than those of $CV3_{oxB}$, indicating possibly different metamorphic conditions for the two oxidized subtypes. We observe that there is a relatively larger temperature increase going from CO3.2 to CO3.4 (150 °C increase) compared to CO3.4–CO3.6 (20 °C), which may indicate that the graphitization and structural ordering of carbon reach a critical temperature regime around petrologic type CO3.3.

Keywords: Carbonaceous chondrites, organic matter, Raman spectroscopy, thermal metamorphism; Origins of Our Solar System and Its Organic Compounds