Organic Analysis of Extraterrestrial Materials at the Sub-Micron Scale

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Chondritic meteorites, hydrated and anhydrous interplanetary dust particles (IDPs) all contain organic matter. The detailed characterization of this organic matter, including its abundance and type(s), is important in inferring the origin of the pre-biotic organic matter of the Solar System and in determining the extent of the contribution organic matter delivered to Earth by asteroids, comets, and IDPs makes to the origin of life on our planet. Organic matter, which is a minor component (≤4% of the mass) in meteorites, is generally studied by first concentrating this material by either water extraction or acid dissolution of the major silicate phases. The organic-rich concentrate is then analyzed with conventional instruments. Concentration allows the detection of rare organic compounds, some present at the ppm level. However, the concentration techniques mix together organic matter from all locations, thus all geological context is lost.

We employ a Scanning Transmission X-ray Microscope (STXM) on beamline X1A of the National Synchrotron Light Source (Brookhaven National Lab) to map carbon and determine the functional groups by X-ray Absorption Near-Edge Structure (XANES) spectroscopy on meteorites and IDPs. This technique allows us to determine the abundance and types of C, N, and O in ultramicrotome sections, typically ~80 to 150 nm thick, on particles as small as a few micrometers in size. STXM analysis preserves the geological context of each C-rich region, allowing us to separately analyze the carbon at different sites in the sample. In a single ~20 micrometer sample of the Tagish Lake meteorite we detected four spectroscopically distinct types of carbon: two areas of organic carbon with different C=C to C=O ratios, carbonate, and amorphous carbon (Flynn et al., Lunar & Planet. Sci. XXXII, #1593). In 10 micrometer IDPs we identified several different morphologies of carbon – thin coatings on minerals, sub-micron C-rich units, and larger organic regions (Flynn et. al., Geochim. Cosmochim. Acta, 67, 4791-4806).

Organic analysis using the STXM will be important for two extraterrestrial sample return missions – STARDUST and HAYABUSA. NASA's STARDUST spacecraft collected small particles, most <15 micrometers in size, from Comet Wild-2. These samples will be delivered to Earth on January 15th, 2006. Because of the small size, the traditional organic concentration techniques cannot be used. High-resolution analytical techniques, such as the STXM, will be critical to the identification and analysis of the very primitive organic matter expected from this comet. The Japanese Space Agency's HAYABUSA spacecraft is enroute to the asteroid Itokawa, where it is expected to collect a few grams of material. The organic content of Itokowa is not known, but meteorites with similar reflection spectra have low carbon. Thus sample size and carbon content suggest the STXM will be vital to characterization of this asteroid sample.