Records of past climate events: A Hitchhiker's Guide to the Earth system

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A prerequisite for making informed predictions about future climate change is to understand the fundamental climate system-carbon cycle feedbacks underlying the response of the Earth System to perturbations. Unfortunately, the time period of modern observations is too short to provide a complete picture of all those feedbacks. Paleoclimatic studies provide information on a variety of time scales and therefore have a unique opportunity to contribute to comprehending the Earth System. In this keynote talk, I will review selected past climate events, which may guide our understanding of climate, biogeochemical cycles, and ecosystem functioning. Of particular interest here are abrupt events such as the onset of the Paleocene-Eocene Thermal Maximum (PETM, ~55 Ma ago), which, in terms of pace and magnitude, may be comparable to the current anthropogenic perturbation. One of the most intriguing aspects of the PETM is that the current generation of climate models appears unable to explain the magnitude of global warming during the event. Archives of those and other past climate events represent chapters of a "Hitchhiker's Guide to the Earth System" that is invaluable to our present civilization, which, on geologic time scale, has arrived on this planet only a blink of an eye ago.

Finding needles in the haystack: Coordinated analyses on planetary materials

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Primitive meteorites, interplanetary dust particles (IDPs), presolar grains, and the recently returned Stardust samples from comet Wild-2 provide a wealth of information on the chemical and physical processes that shaped our solar system and galaxy. Here we report on coordinated analytical studies of these materials using secondary ion mass spectrometry (SIMS), focused ion beam scanning electron microscopy (FIB-SEM), transmission electron microscopy (TEM), and X-ray absorption near-edge spectroscopy (XANES).

Figure 1 illustrates our coordinated approach to studying insoluble organic matter (IOM) in primitive meteorites. SIMS analysis of a fragment of IOM from the GRO 95577 CR2 chondrite reveals large anomalies in D (Fig. 1a) and ^{15}N. These isotopic anomalies suggest that GRO 95577 contains remnants of presolar organic material. We used the FIB-SEM to extract, *in situ*, electron-transparent sections of the IOM in order to investigate its structure and composition at higher spatial scales. Bright-field imaging with TEM reveals that the organic material occurs in both monolithic and nanoglobular forms (Fig. 1b). XANES spectra show that this organic material contains aromatic, carbonyl, imine, and nitrile functional groups. The ^{15}N enrichments correlate with a higher abundance of imine and nitrile functional groups, suggesting that they could be molecular carriers of the ^{15}N anomaly. The implications of these results for solar and interstellar processes will be discussed.