HIGH SENSITIVITY ISOTOPE GEOCHEMISTRY

D. A. Papanastassiou
Earth and Space Sciences Division, Jet Propulsion Laboratory, Caltech
dap@mail1.jpl.nasa.gov/Fax: +1-818-393-6546

There is general agreement that planetary exploration proceeds from orbital reconnaissance of a planet, to surface and near-surface in situ exploration, to sample return missions, which bring back samples for detailed investigations in terrestrial laboratories, using a panoply of state-of-the-art analytical techniques. The choice of applicable techniques may depend on the nature of the returned material and complementary techniques can be used to the best advantage. Detailed and high precision techniques also serve to provide the "ground truth" and calibrate orbital and in situ measurements on a planet. It is also recognized that returned samples may continue to be analyzed by novel techniques as the techniques become available and as they are designed to address specific characteristics of returned samples. Characteristics such as the detailed chemical composition and isotope compositions (as an indication of chemical and physical processes and for age dating of samples) almost always require returned samples. Many key details of lunar composition and evolution became possible only with the analysis of returned samples. Key lunar process characterization, such as planet-wide differentiation into crust and mantle, identification if distinct isotope reservoirs within the planet, based on minor and on trace elements (e. g., rare earths, alkalis, alkaline earths, platinum group elements, actinides), had to await the return of Apollo samples. The demonstration of the absence of a biologic component also required investigation of returned samples. Some analyses, e. g., age determinations and the determination of key isotope indicators (such as the isotope compositions of carbon, nitrogen, oxygen, and sulfur) require precision (at the part per 10,000 and below levels) not attainable by any foreseeable in-situ instrumentation. The analysis of returned samples can provide complete paradigm changes. A key example was the dating of lunar samples and the inferences for the thermal evolution of the planet, including the unique significance of the terminal lunar cataclysm both for the moon and the earth. We are now entering an era of analytical sensitivity whereby essentially every atom in a sample can be detected. For example, for thermal ionization mass spectrometry, sensitivity is up to 40% Mg and Nd, and up to 25% for Re and Os. Sensitivity for multiple collector inductively coupled plasma mass spectrometry is approaching the percent level with wide applicability. Analytical developments in isotope geochemistry will allow the measurement of trace elements, well below the parts per million level, on mg-sized samples.