In situ instrumentation for sub-surface planetary geochemistry

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Instrumentation Development

Novel instrumentation is under development at NASA's Goddard Space Flight Center, building upon earth-based techniques for hostile environments [1, 2], to infer geochemical processes important to formation and evolution of solid bodies in our Solar System. A prototype instrument, the Pulsed Neutron Generator – Gamma Ray and Neutron Detectors (PNG-GRAND), has a 14 MeV pulsed neutron generator coupled with gamma ray and neutron detectors to measure quantitative elemental concentrations and bulk densities of a number of major, minor and trace elements at or below the surfaces with approximately a meter-sized spatial resolution down to depths of about 50 cm without the need to drill. PNG-GRAND's *in situ* meter-scale measurements and adaptability to a variety of extreme space environments will complement orbital kilometer-scale and *in situ* millimeter-scale elemental and mineralogical measurements to provide a more complete picture of the geochemistry of planets, moons, asteroids and comets.

Preliminary Testing and Results

We are optimizing the PNG-GRAND instrument configuration and refining our analysis techniques through experimentation at our unique outdoor test facility. We will present results (Fig. 1) that demonstrate PNG-GRAND's capabilities for elemental composition measurements.

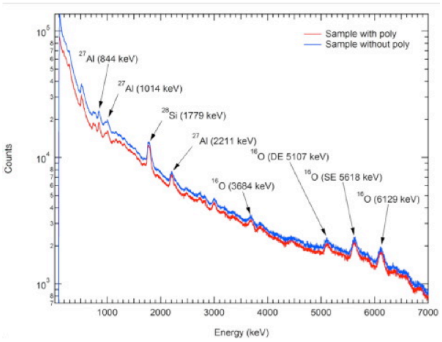

Figure 1. Gamma ray spectra obtained with PNG-GRAND on a 2x2x2 m granite structure with and without a simulated water layer.

[1] Grau *et al*. (1993) *Nucl. Geophys*. **7**, 173–188.
[2] Schweitzer (1993) Subsurface Measurements for Geochemical Analysis. In *Remote Topics in Remote Sensing 4* (eds. Pieters & Englert) Cambridge Univ. Press, Cambridge. pp. 485–505.

Isotopic variation in terrestrial perchlorate and associated nitrate

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Perchlorate and nitrate are well known anthropogenic contaminants as well as common natural constituents of soil and groundwater. Natural perchlorate and nitrate are relatively abundant in arid regions, where low infiltration rates promote evapotranspirative concentration in the unsaturated zone. Nitrate isotopes in such environments commonly exhibit systematic isotopic variations indicating varying mixtures of atmospheric nitrate (e.g. high $\Delta^{17}O$ indicating formation reactions involving ozone; relatively abundant in areas of low moisture and limited biological activity) and biogenic nitrate (e.g. low $\Delta^{17}O$ consistent with nitrification; dominant in most other settings). Recent studies indicate similar isotopic distribution patterns for perchlorate, but these patterns are more difficult to interpret based on current knowledge of perchlorate formation and degradation mechanisms. Natural perchlorate from the Atacama Desert, Chile and Death Valley, USA has high $\Delta^{17}O$ indicating formation reactions involving ozone, whereas other occurrences in arid and semi-arid regions of the western USA have relatively low $\Delta^{17}O$. As with nitrate, the perchlorate $\Delta^{17}O$ variations appear to be related to the prevalence of moisture and biological activity (e.g. plants, soil microbial communities). In contrast to nitrate, however, perchlorate does not have a well-established biogenic source. These data could indicate either (1) perchlorate has a biogenic source that has not been identified; (2) perchlorate has an abiogenic source, not involving ozone, that is relatively important in the presence of moisture or biological activity; or (3) perchlorate is subject to isotopic exchange in moist terrestrial environments. Other perchlorate isotopic data ($\delta^{18}O$, $\delta^{37}Cl$, and $^{36}Cl/Cl$) permit partial combinations of these hypotheses. Despite uncertainty in the explanations, terrestrial perchlorate and nitrate isotopes appear to respond similarly to climate variation, yielding clues about sources and preservation, and providing distinguishing characteristics for practical applications such as isotope forensics.