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In-situ soil composition and moisture measurement by surface neutron activation analysis

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Neutron activation analysis is widely known as a laboratory technique dependent upon a nuclear reactor to provide the neutron flux and capable of precise elemental analysis. Less well known in-situ geochemical analysis is possible with isotopic (252Cf & 241Am) or compact accelerator (D-T, D-D fusion reaction) neutron sources. Prompt gamma neutron activation analysis (PGNAA) geophysical borehole logging has been applied to mining issues for >15 years (CSIRO) using isotopic neutron sources and more recently to environmental and hydro-geological applications by ANSTO. Similarly, sophisticated geophysical borehole logging equipment based on inelastic neutron scattering (INS) has been applied in the oil and gas industry by large oilfield services companies to measure oil saturation indices (carbon/oxygen) using accelerator neutron sources.

Recent advances in scintillation detector spectral performance has enabled improved precision and detection limits for elements likely to be present in soil profiles (H, Si, Al, Fe, Cl) and possible detection of many minor to trace elements if sufficiently abundant (Na, K, Mg, Ca, S, N, +). To measure carbon an accelerator neutron source is required to provide fast neutrons above 4.8 MeV.

CSIRO and ANSTO propose building a soil geochemical analysis system based on experience gained from building and applying PGNA borehole logging equipment. A soil geochemical analysis system could effectively map the 2D geochemical composition of the top 50cm of soil by dragging the 1D logging equipment across the ground surface. Substituting an isotopic neutron source for a D-T accelerator neutron source would enable the additional measurement of elemental carbon.

Many potential ambiguities with other geophysical proxies for soil moisture may be resolved by direct geochemical measurement of H. Many other applications may be possible including time series in-situ measurements of soil moisture for differential drainage, hydrology, land surface parameter models, fertiliser distribution, leaching and mobility characteristics and measuring carbon sequestration or loss from different land use practices.