X-Ray Fluorescence - XRF Core Scanning  
(Acquires high-resolution elemental data)

X-ray fluorescence (XRF): A material analysis technique that detects elemental composition by measuring the emission of X-ray-induced fluorescent radiation from the analyzed sample. Fluorescence is a type of radiation that occurs when the vacancy from an ejected inner electron (photo-electron) generates an unstable atomic state and an electron transfers from an outer shell to the inner vacancy (Figure 1). This electron transfer from an outer to inner shell yields emission of a fluorescent X-ray photon, and its energy is related to the atomic number (Moseley’s law) of the element of its origin. While numerous emissions from different energy lines are possible by transfer between various electron shells, each electron transition yields a specific energy line; hence their detection is a quantitative measure of the chemical composition of the analyzed material.

Figure 1: Fluorescent X-ray photon

XRF Core Scanning: A non-destructive technique that uses the principles of X-ray fluorescence with automation to continuously or incrementally scan for elemental composition of slabbred rock or split sediment core. Mechanization moves an X-ray source and detector down the length of the core, or alternatively the core moves under the detector at a specified logging rate or incremental step. At each step, photons from X-ray fluorescence emission are binned and counted yielding elemental spectra (Figure 2). The energy (horizontal scale) and photon counts (vertical axis) within each spectrum are quantitatively related to elemental composition and their concentration within the sample.

Figure 2: XRF spectrum, Ka, Kβ, element emission lines
**MCS-1000 XRF Core Scanner:** The XRF Mobile Core Scanner System, MCS-1000 (Figure 3), is a complete XRF core scanning system that includes components from DeWitt Engineering and Bruker Elemental. This system is capable of measuring over 30 elements (Na to U), with optimized XRF scanning parameters for (1) majors from Na to Fe and (2) traces from Co to U. A precision track is used to position the core under the Bruker TRACER IV XRF unit for automated core scanning, with track accuracy within 1 µm. The use of helium gas supply at the point of contact between the core and instrument provides the highest sensitivity possible for light elements (Na and Mg). This system provides raw XRF spectrum for important quality-control purposes, which are then converted into weight percent elemental data using established mud-rock calibrations included with the Tracer IV XRF unit from Bruker Elemental.

**Figure 3:** MCS-1000, 96-inches L by 14-inches W, takes 3-ft core sections

**Industry Application:** The following are examples for the utility of high-resolution chemical data for cored wells. The XRF scanning resolution is adjustable and can be up-sampled or averaged to match industry standard logs; hence it has direct application for calibration of logging data, along with other uses (see below list).

1. Calibration of Elemental Capture (ECS) logs
2. Calibration of log-based matrix mineralogy
3. Chemostratigraphy and chemical zonation
4. Mineral & multimineral volumetric modeling
5. Calibration of elemental proxies for kerogen

**XRF Core Scanning Deliverables:** Elements will be converted to weight percent (wt.%) and provided in tabulated form along with two depth plots, majors and traces in order from lightest to heaviest element, left to right. Conversion to oxides or any other changes to raw data will be provided per client request. Major elements are reported with minor elements as they are inclusive of a major element XRF scan spanning Na to Fe; these rock-forming elements represent, on average 0.1 wt.% or more of the earth’s crust. Traces generally account for less than 0.1 wt.% or 1000 ppm of the earth’s crust, thus they are reported in ppm.

**Majors and Minor Elements:** Na, Mg, Al, Si, P, S, K, Ca, Ti, Mn and Fe
**Trace Elements:** V, Cr, Co, Ni, Cu, Zn, As, Rb, Sr, Y, Zr, Nb, Mo, Pb, Ba, Th and U

**Element to Mineral Modeling:** This is additional interpretation, which uses deterministic modeling solutions.
**Multimineral Modeling:** This is additional interpretation; converts weight percent mineral values to volumes.