ADVANCES IN SLIMLINE BOREHOLE GEOPHYSICAL LOGGING

EEGS Annual Meeting/SAGEEP 2018
Nashville, Tennessee USA
March 25-29, 2018

Abstract

The last 10 years in slimline borehole geophysics has seen numerous advancements. Borehole imagery logging has reached resolutions that allow investigators to visualize true-color borehole wall attributes, grain size features, rock fabric, and structural integrity. These slimline tools allow us to perform high resolution fracture characterization, casing thickness evaluation, along with many other applications. Acoustic televiewer amplitude logs are semi-quantitative and proportional to rock strength. Advances in data acquisition systems allow increased logging speeds, even at very high circumferential and vertical sampling intervals.

Nuclear Magnetic Resonance (NMR) logging has evolved with much smaller diameter tools, running on standard commonly available geophysical wirelines, thus allowing entry into the mining and ground water communities. These tools operate in a borehole like an inside-out MRI scanner, where hydrogen nuclei align themselves with an induced directional magnetic field, then relaxing proportional to the presence and movement of hydrogen (groundwater and hydrocarbons) through pore space when the magnetic field is cycled or removed. A pair of large opposing magnets within the sonde project this magnetic field several inches beyond the borehole axis, creating a cylindrical-shaped “sensitive region” from which the NMR signal is captured. This thin sensitive region is ideally located within the undamaged region of the formation, where the rocks and sediments are not disturbed by drilling. Direct detection and quantification of groundwater (including capillary and clay-bound water) is possible, along with detection and quantification of hydrocarbons and fluid diffusion, precise determination of porosity and water content, Estimation of permeability, mobile/bound water fraction, pore-size distributions, and sensitivity to geometric and geochemical pore-scale properties.

Advances in slimline borehole gravity tools over the past several years has found importance in mining applications, including bulk density determination, rock properties, and verification of surface and airborne gravity anomalies. Borehole gravity measurements have been used for detecting the presence of oil and gas & reservoir mapping, delineating salt domes, in addition to typical applications to determine density with greater investigative area than traditional radioactive source tools.

Advances in borehole Spectral Induced Polarization (SIP) are revealing its unique sensitivity to interfacial properties of porous materials. SIP is sensitive to fundamental pore geometric properties controlling fluid flow and recent case histories indicate the measurement can be a good estimation of permeability. Numerous authors have described links between SIP parameters and permeability. SIP methods are also very sensitive to changes in the interfacial properties that result from biogeochemical processes occurring in porous media due to natural and enhanced mechanisms. Many papers that link SIP properties to biogeochemical alterations of mineral surface area and/or mineral surface chemistry have been published in recent years. It is now considered a unique geophysical method regarding its sensitivity to geochemical and biogeochemical processes. This provides unique opportunities to monitor geochemical and biogeochemical processes associated with remediation strategies for example. One of

the most exciting opportunities is related to biomineral transformations resulting in sulfide mineral formation.

New generation downhole Energy Dispersive X-ray Fluorescence (EDXRF) spectrometry tools have been developed further in the determination of minor and major concentrations of elements in borehole. These instruments can aid in ore body/seam mapping (Ni, Cu, Zn) and the estimation of tracer elements, blast hole profiling, and grade control. EDXRF can also potentially help address issues related to mineral recovery programs.

Well-calibrated slimline downhole spectral gamma geophysical logging tools are yielding near quantitative results in real time. Advances is scintillation material and tool characterization have contributed to recent advancements. Borehole properties such as diameter, fluid, casing and probe diameter strongly influence the outcome spectral gamma logging tools. From recent Monte Carlo simulations, it appears that borehole diameter, probe diameter, borehole fluid and casing thickness have a significant effect on the observed gamma spectrum, above 300 keV. Calibrations for these effects are now implemented in newer tools built over the last decade or so.

Geophysical well-log analysis and presentation software, along with 3D modeling and database programs have advanced significantly, becoming an advanced universal borehole, mine site or well-field data toolbox. It’s more common nowadays for petrophysicists, mining engineers, geologists, researchers, and drillers to combine data into one layered summary for use and interpretation in multidisciplinary applications.