Seminar
Nuclear Measurements and Its Applications

SPWLA FRANCE CHAPTER

Date: Friday 15th December 2023

Location : Société Géologique de France (SGF), Paris.

Start time	End time	Presenter	Title	Company
13:45	14:00	Emmanuel CAROLI	Welcome and introduction	SPWLA France President
14:00	14:30	Youcef BENSEDIK, Romain MIESZKALSKI Hervé TOUBON	Outils de mesure nucléaire en diagraphie utilisés et en développement pour l'exploration et l'exploitation des mines d'Uranium	Orano
14:30	15:15	Bertrand PEROT Valentin FONDEMENT	Development of gamma and neutron probes for uranium mining applications	CEA
15:15	15:45	Rubi RODRIGUEZ	High resolution LWD spectroscopy and its new mineralogy derived from a neural network approach	SLB
15:45	16:15		Break	
16:15	16:45	Geoffrey VARIGNIER	Experimental Validation of a Sigma Log Simulator in a Cased-Hole Environment	TotalEnergies
16:45	17:15	Samira AHMAD	Pulsed Neutron logging applications	SLB

The seminar is free and registration is required by filling the form here

The abstracts of the presentations can be seen in the website

https://spwla-france.fr/

Outils de mesure nucléaire en diagraphie utilisés et en développement pour l'exploration et l'exploitation des mines d'Uranium

Youcef BENSEDIK , Romain MIESZKALSKI, Hervé TOUBON

Abstract

Depuis une quinzaine d'année Orano Mining utilisait des sondes de diagraphie équipée des compteurs Geiger Muller pour son exploration et le suivi de production. Avec l'abaissement des teneurs en Uranium des gisements mis en exploitation Orano Mining utilise désormais de manière récurrente de scintillateurs NaI beaucoup plus efficace.

Les sondes de diagraphie suivent un processus d'étalonnage et de validation à partir de mesures effectuées dans des blocs de béton de diverses teneurs sur l'établissement Orano de Bessines sur Gartempe. Les conditions de mesures en forage devenues plus variées (en diamètre, en tubage, etc). Les corrections initialement établies ont été revues et les outils de modélisation ont permis d'étendre le domaine de validité de ces facteurs correctifs. Cela a été la première étude confiée au sein d'un accord de partenariat R&D au Laboratoire de Mesure Nucléaires du CEA Cadarache.

D'autres sujets sont en cours de développement notamment avec des sondes de spectrométrie gamma pour la mesure du déséquilibre de l'Uranium avec ses descendants pour une meilleure caractérisation des gisements de type roll-front, et l'identification directe du Radon dans le cadre du suivi de production et d'exploitation des trous de tirs. Des mesures en neutrons actif sont également étudiées avec une nouvelle génération d'électronique permettant de caractériser in situ la porosité de l'encaissant et ainsi de corriger la mesure de la teneur en Uranium.

Gamma and neutron logging probes for uranium mining exploration

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Abstract

ORANO Mining and the **Nuclear Measurement Laboratory of IRESNE Institute at CEA Cadarache** are developing new techniques for uranium borehole logging. Natural gamma-ray probes based on total counting or gamma spectroscopy are widely used to determine the uranium content in boreholes. However, total count rate gamma probes, such as NGRS or KOBRA using NaI(Tl) scintillators, may provide an incorrect estimate of uranium grade in case of disequilibrium in the uranium radioactive decay chain, due to differential leaching of uranium and radium in roll fronts. Therefore, ORANO decided to implement a new spectroscopic $CeBr_3$ probe developed by ALT (Advanced Logic Technology) and to study innovative spectral analyses based on energy bands, Machine Learning, or Bayesian approaches, to estimate the U/Ra imbalance and thus reduce uncertainty on U grade. In this context, a fine Monte Carlo modelling of the $CeBr_3$ probe is necessary to correct for different effects such as the drilling diameter, casing material and thickness, filling fluids, density of the mineralization, position of the probe in the well, etc. We will present at SPWLA the experimental characterization in the concrete calibration blocks of

ORANO CIME, in Bessines, France, and in the Nuclear Measurement Laboratory. In view to complement gamma spectroscopy with a direct measurement of uranium, ORANO and CEA have also studied a new neutron probe based on a pulsed neutron interrogation and the detection of induced-fission prompt neutrons of ^{235}U, also known as "PFN" method. This probe also performs a neutron-backscattering measurement to estimate the "hydrogen-porosity", i.e. the quantity of hydrogen nuclei in the pores of the sand, generally saturated with water in ISR mines. The PFN and backscattered neutron signals are recorded with the same ^{3}He detection block, leaving room for a gamma detector in the probe to perform neutron activation analysis. The PFN detection limits are below 200 ppm of uranium in measurement times of 3 min, and the signal is not sensitive to the U/Ra disequilibrium. However, it is highly sensitive to hydrogen nuclei due to neutron moderation and absorption. Therefore, we have also studied a correction of the PFN signal based on the measured hydrogen porosity. We will present the principle of this innovative neutron probe, its performances estimated with MCNP, and the validation through laboratory tests at the Nuclear Measurement Laboratory.

Speakers

Bertrand Pérot holds an Engineer Degree of the Physics Engineers School of Grenoble, France (1992), a PhD of Grenoble University carried out at CEA Cadarache (1996), and an HDR accreditation to supervise PhD students (2012). He started his career at ORANO in the field of nuclear process monitoring for La Hague reprocessing plant, then he joined CEA Cadarache to developed nuclear measurements in the nuclear fuel cycle (from uranium mining to fuel reprocessing), radioactive waste characterization, dismantling and decommissioning nuclear facilities, homeland security, waste recycling, etc. Involved in about 10 European projects from FP6 to H2020 research programs, he was appointed CEA Senior Expert in 2009, International Expert in 2014, Research Director at CEA and CEA Fellow in 2022. He took part to more than 100 scientific publications or communications (H-index of 15), 11 patent applications, 20 internships supervision, 14 PhD theses, 2 CNAM theses, and 7 research positions in the frame of European projects. Currently, one of his most fruitful activities, in the Nuclear Measurement Laboratory of CEA Cadarache, is a collaboration launched with Hervé Toubon, R&D and Innovation Director of Orano Mining, in view to improve and develop nuclear measurements for uranium prospection and exploration.

Valentin Fondement holds a Master of Caen University (2018), France, an Engineer Degree of ENSICAEN (2020), and a PhD of Grenoble Alpes University (2023), carried out in the Nuclear Measurement Laboratory at CEA Cadarache in collaboration with ORANO Mining. During his PhD, he developed an active neutron probe to measure both the hydrogen porosity and uranium grade for ISR (in situ recovery) mines. He will continue his scientific career at University of Michigan, USA, in early 2024.

High resolution LWD spectroscopy and its new mineralogy derived from a neural network approach.

Rubi Rodriguez, Senior Petrophysicist, SLB

Abstract

An accurate knowledge of the mineralogy is essential for a deep understanding of the geological environment and petrophysical properties of reservoirs. It provides information about the composition and distribution of minerals within a reservoir rock, influencing its porosity and permeability. Understanding mineralogy allows a detailed evaluation of the opportunities not only in the oil and gas industry but also in new energy industry.

Advanced logging while drilling (LWD) measurements, such as capture spectroscopy provide an accurate evaluation of complex clastic and carbonate lithologies. The upgrade of the detector (from NaI to LaBr) for the commercial LWD tool, equipped with a pulsed neutron generator, provides the radical improvement needed to get lithology results approaching wireline quality. The use of an advanced lanthanum bromide (LaBr) detector allows to provide a High-resolution spectroscopy and the advanced mineralogy (AM) algorithm based on an artificial neural network (ANN). This framework provides several benefits for spectroscopy interpretation and is free of user input regarding model parameterisation, enabling real-time distinction between calcite and dolomite of dry-weight mineral fractions during drilling.

The LaBr detector and the advanced mineralogy interpretation approach have successfully been tested in 40 jobs around the world. One field test will be presented.

Speaker

Rubi Rodriguez is a Senior Petrophysicist working with the Interpretation Engineering Team at SBL Technology Center in Clamart, France. She joined SLB as a Petrophysicist in 2004 and has since held various positions in the Formation Evaluation domain, including Asset Evaluation and Field Development Planning (FDP), with assignments in Mexico, Paris, Abu Dhabi, Aberdeen, and London. Rubi holds an M.Sc. in Reservoir Geosciences and Engineering from the French Institute of Petroleum (IFP).

EXPERIMENTAL VALIDATION OF A SENSITIVITY FUNCTIONS SIGMA SIMULATOR IN A CASED-HOLE ENVIRONMENT WITH CALIBRATION FACILITY AND PRODUCTION WELL DATA

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Mature producing areas face the challenge to abandon safely numerous wells. Cased-hole logs can play a key role in the integrity and confinement assessment. Therefore, the industrial problem today is no longer to characterize some petrophysical properties of the formation (e.g. porosity; density; lithology; oil or gas saturation, etc.), but also some components of the well (e.g. drilling fluids ; casing ; cement). Due to the large number of variables, a multiphysics inversion considering simultaneously different nuclear log input is mandatory. During the past twenty years, the Austin University introduced the concept of sensitivity functions to simulate logs and allow the inversion of formation properties. It has been successfully tested in open hole. But, for cased hole, the robustness of sensitivity-function based inversions relies on the ability of the forward modeling to closely reproduce the nuclear tools responses in the broad variety of wellbore environments. This validation was performed with a dedicated experimental setup and results are detailed in this paper.

In a first part, the concept of sensitivity function is discussed for a neutron-gamma Sigma tool using nuclear Monte-Carlo simulations and measurements acquired in both open-hole and cased-hole with two geometrical perturbations (axial and radial), characterized rock standards and an O&G industry logging tool. This study also proposes to benchmark the numerical methods for calculating the sensitivity functions by comparing two different

approaches: "Importance method" using MCNP and "Particle Tracking method" using GEANT4, two independent Monte-Carlo modeling softwares. Sigma neutron-gamma tools are composed either of two detectors, three or four detectors. The apparent formation Sigma measured on the detectors are all different from the intrinsic Sigma value in the zone of investigation. These individual Sigma values are influenced at different degrees by the diffusion effect and the well components (i.e. casing, cement, etc.). The challenge for the log simulator is to correctly reproduce all of those effects and predict the accurate apparent Sigma values delivered by each detector. To that end, we compare in a second part the predicted Sigma logs, obtained from the the forward modeling using the sensitivity functions calculated using differents methods, and the measured Sigma logs acquired in laboratory rock standards having strong contrasts of petrophysical properties.

The result of the first part shows some discrepancies between the calculated sensitivity functions and the measured ones (i.e. using a commercial tool), both in radial and axial directions, according to the computation methods (i.e. "Importance method" or "Particle Tracking method"). Nevertheless, the overall agreement between the calculations and the measurements is sufficient to secure the fundamental physics behind the concept of sensitivity function applied to cased hole. In a previous work (in press), forward algorithms have proven their effectiveness to correctly predict neutron porosity logs measured in a cased-hole and open-hole laboratory rock standard, where casing and cement significantly impact the raw porosity measurement. The objective of the second part is to deploy the same workflow to secure the reliability of sensitivity functions based log simulator to predict relevant Sigma logs (considering the effects of casing and cement plus the effects of diffusion). Thus, Sigma logs forward predictions are compared with measurements in laboratory rock standard and real oilfield cased hole logs. The prospect of this work is to extend the qualification of sensitivity function forward modeling to other nuclear measurements such as Carbon/Oxygen and litho-density.

Keyword : Monte-Carlo modeling, neutron-gamma, Sigma tool, sensitivity function, cased-hole, forward modeling, radial and axial measurements, perturbation experiments.

Speaker

Varignier Geoffrey holds a DUT (2 years diploma) in Physical Measurements of the Grenoble Alpes University (2013), two professional degree in Geosciences and Petroleum Engineering of the Grenoble Alpes University and the Rennes University (2014 and 2015) and a Master in Geophysics of the Nice University (2018). He is doing a PhD at TotalEnergies and in collaboration with the Nuclear Measurement Laboratory at CEA Cadarache. During his PhD, he is developing a multiphysical method to predict nuclear logs in cased hole with the use of fast forward modeling algorithums based on the sensitivity function concept.

Pulsed Neutron Logging Applications

Samira Ahmad, Domain Head - Petrophysics and Acoustics, SLB

Abstract

Pulsed neutron technology has emerged as a versatile and indispensable tool in the realm of reservoir evaluation, finding applications in both conventional and unconventional reservoirs. This abstract provides a comprehensive overview of the various applications of pulsed neutron logging techniques in open and cased hole environments, elucidating their significance in formation evaluation, fluid identification, mineralogy determination, water flow logging, and completion quality assessment.

In conventional reservoir settings, pulsed neutron logging plays a pivotal role in characterizing formation properties. By analyzing the energy spectrum and time decay of neutrons, valuable insights into porosity, lithology, and permeability are gained. The method's adaptability to open and cased hole environments ensures its efficacy across diverse geological formations. In unconventional reservoirs, the application of pulsed neutron technology extends beyond traditional evaluation parameters. Fluid identification becomes a nuanced process, enabling discrimination between hydrocarbons and water with higher precision. Mineralogy determination becomes increasingly crucial in unconventional reservoirs, aiding in reservoir optimization and production forecasting.

The ability of pulsed neutron tools to provide water flow logs enhances reservoir management strategies by offering real-time information on fluid movements. This application is particularly relevant in both conventional and unconventional reservoirs, allowing for dynamic reservoir monitoring and optimization of production strategies. Furthermore, pulsed neutron tools find utility in assessing completion quality, offering valuable data on cement bond evaluation and casing integrity. This enhances the overall reliability and safety of well completions, ensuring sustainable and efficient reservoir exploitation.

Throughout this abstract, examples will be presented to illustrate the practical implementation and success stories of pulsed neutron applications in diverse reservoir scenarios. These examples will showcase the technology's efficacy in enhancing reservoir understanding, optimizing production strategies, and contributing to the overall success of oil and gas exploration and extraction endeavors.

Speaker

Samira Ahmad currently is the Analysis and Interpretation Domain Head for Petrophysics and Acoustics for SLB, based in Paris, France. She joined SLB as Wireline Field Engineering in Malaysia, 19+ years ago, and has held various positions in the company as wireline sales, technical manager, and domain expert. She has previously worked in US, Indonesia, Egypt, Brunei, and Malaysia.
