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- DIAGRAPHIES UTILISANT LA SPECTROMETRIE GAMMA -

par

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RESUME

La spectrométrie gamma permet d'accroître la précision des mesures portant sur les rayonnements naturel, diffusé (gamma-gamma) ou artificiel (n-gamma).

Une sonde a été développée au Centre d'Etudes Nucléaires de Saclay pour permettre l'exécution de la spectrométrie gamma en forage. Elle peut être utilisée notamment pour la détermination de la teneur en uranium des minerais par la méthode gamma naturel sélectif, la mesure de la teneur en cendre des charbons par la méthode de gamma-gamma sélective et pour l'analyse élémentaire par activation neutronique.

Pour effectuer l'étalonnage et l'interprétation de ces diagraphies, il est très utile de connaître sous forme statistique les paramètres photoniques et neutroniques des roches concernées.

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GAMMA-RAY SPECTROMETRY APPLIED TO DOWN-HOLE LOGGING

by

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SUMMARY

Gamma-ray spectrometry permits to improve the accuracy of natural gamma, gamma-gamma and neutron-gamma geophysical measurements. The probe developed at Centre d'Etudes Nucléaires de Saclay allows down-hole gamma-ray spectrometry. Among others, this probe can be applied to the uranium content determination by selective natural gamma method, down-hole determination of the ash content in the coal by gamma-gamma selective method and elemental analysis by neutron-gamma method.

For the calibration and an exact interpretation of the measurements it is important to know the gamma-ray and neutron characteristics of the different kinds of rocks considered as probabilistic variables.

GAMMA-RAY SPECTROMETRY APPLIED TO DOWN-HOLE LOGGING

1. - INTRODUCTION

The need for more accurate measurements in geophysics has resulted in an application of the methods based on gamma-ray spectrometry. These spectrometric methods are used as well for natural gamma radiation as for gamma-gamma and neutron--gamma measurements.

For down-hole gamma ray spectrometric logging a spectrometric probe is needed. There are two possibilities to perform the gamma spectral log :

- the first one, more conventional and widely applied, consists in transmitting an amplified analog pulse through the logging cable to the pulse-height analyser on the surface ;

- in the second case the pulse amplitude is converted in the probe into binary number and the latter is transmitted by a cable in digital form.

In the first case the pulse shape modification during transmission through the cable is the source of the additional errors. For the standard logging cable these errors could be important. Digital transmission between the probe, and surface unit, suppreses the errors introduced by the logging cable.

2. - EQUIPMENT DESCRIPTION

The spectrometric gamma tool developed at Centre d'Etudes Nucléaires de Saclay performs the pulse height digital coding down-hole inside the probe.

The probe has an external diameter of 33.7 mm and a length of 1.90 m. It contains four main subsets : conversion, transmission and control logic, and power supply. The description of these subsets will be given hereafter.

Detection subset - It consists in a NaI (Tl) 21 mm by 46 mm crystal, a photomultiplier (a XP 1910 type of RTC), a regulated high voltage supply and a pulse amplifier. The design of this subset is rather conventional. At the output the amplitude of the electric pulses is proportional to the energy of the incident gamma radiation.

A/D conversion subset - It contains a sample and hold amplifier, a peak detector, and the analog to digital converter (ADC) delivering the binary coded pulse height measure.

Transmission and control unit. It controls and synchronises the operations of the sample and hold amplifier, AD converter and transmission circuits. The binary signal is transmitted on two wires in a differential mode.

The surface equipment used for the tests of the probe consists in a specific interface adapter, the memory block of the SILENA selector, and a HP 85 computer. The spectres can be treated on line or recorded on magnetic cartridges.

3. - APPLICATIONS OF THE SPECTRAL GAMMA-RAY PROBE

The gamma-ray spectrometric down-hole probe gives accurate results in different field of nuclear logging. These are :

- natural gamma-ray spectrometry for uranium content determination by selectve gamma logging proposed by Czubek (1),

- gamma-gamma spectrometric measurements to determine the heavy elements content, coal ash content or for lithology determination,

- neutron activation down-hole analyses to determine specific elements content.

There does not exist any standard facility for the calibration of the probes for different tests as mentioned below. In many cases the only calibration method is to compare the measurements performed in the holes with the results of core sample analysis.

To interpret the results of natural gamma or gamma-gamma spectrometric measurements correctly it is important to know the gamma ray attenuation coefficient and the build-up factor as a function of energy. The chemical composition of the different kinds of rock is not constant, but can be considered as a multidimensional random variable, thus the attenuation coefficient and build up factor are also the random variables.

The random variable is characterized by the probability distribution function or less precisely can by approximated by first two moments of this function i.e. the mean value and the standard deviation.

The computation of the attenuation coefficient starting from the microscopic cross-sections for different elements needs the exact knowledge of the chemical composition of the rock of interest.

There are two possibilities : either to determine the probabilistic parameters of the chemical composition for the different kinds of rocks and next to compute the macroscopic parameters on the basis of microscopic cross-sections for each element, or to determine the probabilistic distribution of the macroscopic parameters for different kind of the rock directly. It is not clear which approache is best.

In the case of the determination of the neutron parameters of the rock (i.e. thermalisation length, diffusion coefficient, and macroscopic absorption cross-section) a little change of the trace elements content can result in a significant variation of these parameters, thus in this case the determination of the chemical composition of the rock is much more important.

CONCLUSIONS

Down-hole gamma-ray spectrometry to deal with the natural gamma, gamma-gamma and neutron-gamma logging gives much more precise results, than the standard measurements. Spectrometric measurements also permits to determine the properties of the rock which cannot be determined otherwise.

For an exact interpretation of the measurements and the determination of the precision of the results obtained it is important to know the gamma and neutron caracteristics of the rock considered as probabilistic variable.