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INTRODUCTION TO LOGGING TOOLS

1- SPONTANEOUS POTENTIAL (SP)

The Spontaneous potential survey, (sp) was one of the first measurements, which was carried out, in a well bore. The 'SP' log is a record of the naturally occurring potential in the well bore. This log utilizes a single moving electrode in the borehole and a reference electrode at the surface, usually located in the mud pit. The 'SP' curve therefore is a record of the potential difference, which exists between the surface electrode and the moving electrode in the borehole.

ORIGIN OF SPONTANEOUS POTENTIAL

The spontaneous potential is generated as result of current flowing in the mud in the borehole. This current flow is produced as a result of two types of potentials:

1- Electrochemical
2- Electrokinetic

1- ELECTROCHEMICAL POTENTIAL (Ec)

Electrochemical Potential is composed of two independent potentials referred to as:

- Shale or Membrane potential

- Liquid Junction potential

A-Shale or Membrane Potential (Em)

Consider a permeable formation sandstone, with thick shale beds above and below; assume, too, that the two electrolytes present, mud filtrate and interstitial water, contain NaCl only. Due to their layered clay structure, and the negative charges on the layers, shales are permeable to the Na-cations, but impervious to the Cl-anions. When shale separates NaCl solutions of different salinities, the Na cations move through the shale from the more concentrated to the less concentrated solution. This movement of charged ions is an electric current, and the force causing them to move constitutes a potential across the shale.
Since shales pass only the cations, they resemble ion-selective membranes, and the potential across the shale is called "membrane" or shale potential.

B-Liquid Junction Potential (Elj)

Another component of the electrochemical potential is produced at the edge of the invaded zone, where the mud filtrate and the formation water are in direct contact. Here Na+ and Cl- ions can transfer from either solution to the other. Since Cl-ions have a greater mobility then Na+ ions the result is a flow of negative charges from the more concentrated solution to the less concentrated solution. The current flowing across the junction between solutions of different salinity is produced by an 'emf', electromotive force, called the "liquid junction potential".

STATIC SP (SSP)

If the salinity of the mud filtrate is greater than that of the formation the situation will be reversed. The deflection on the 'SP' curve is a measurement of the potential drops in the bore hole due to the 'SP' currents. The total 'emf' due to all the potential drops in the formations is called the "Static Sp".

2- TYPES OF RESISTIVITY TOOLS

Various types of laterologs and induction logs are currently in the use; each designed to reduce adverse effects.

Laterolog Deep (LLD)

Laterolog tool are generally used for:

- High Resistivity Formation
- Saline Muds

Laterologs emit focusing currents to direct the path of the measured current through the mud and the invaded zone to the uninvaded formation. They reduce the effects of the borehole, adjacent formations and thin beds, but are still affected by hole diameter, mud resistivity and very thin formations with high resistivity contrasts between beds.

Laterolog Shallow (LLS) and Microspherically Focused (MSFL)

The dual Laterolog (DLL) consists of two advanced laterolog tools, which share the same electrodes on the primary sonde. One laterolog is used for deep investigation of the undisturbed zone (Rt) and the other for shallow investigation of the transition zone (Ri).
A Microspherically Focused Tool (MSF) on an optional secondary sonde, that measures flushed zone resistivity and permits the deep laterolog to be corrected for invasion. Gamma Ray, SP and Caliper curves may also be recorded with these tools.

Induction Focused Log

Induction logs are used for
:

- LOW TO MEDIUM RESISTIVITY FORMATIONS
- FRESH OR OIL-BASED MUDS
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They induce measured currents to the formation, which are focused both horizontally and vertically. The readings of ‘Rt’ are good for conditions of relatively shallow invasion and thick beds. However, these tools are less satisfactory when the bed thickness is only a few feet or when formation resistivities are over 100 ohmm.

Dual Induction Focused Tool

The dual Induction Focused Log has been designed to provide the resistivity measurement necessary to estimate the effect of invasion so that the true formation resistivity may be obtained. As long as the invasion is shallow, less than 40 to 50 inches, a good value for true formation resistivity may be determined.

3- SONIC (ACOUSTIC)

The Sonic (Acoustic) Velocity log was originally developed as an aid in the interpretation of seismic data, but it has been found so effective in the determination of porosity that it has now become the standard wireline tool for porosity estimation, fracture and Lithology determination. It is also an excellent tool for correlation, especially used in conjunction with the Gamma Ray log.

The sonic device measures the time of transit of a sonic impulse through a given length of rock, usually either 3 ft or 5 ft. The rate of propagation of the compression wave through the rock depends on the elastic properties of the rock matrix and its contained fluids. Specifically, it depends on the composition of the matrix, the particular fluid, which it contains, and the relative amounts of each that are present. When the first two of these factors are known, the porosity calculated from the sonic log and porosity determined by core analysis have excellent match in many cases.

Compressional Waves

Compressional wave measurement, used in acoustic logging, exhibits longitudinal particle motion and can be propagated in solids, liquids or gases. In acoustic logging, energies of the lower frequencies are employed. The acoustic wave alternately compresses the surrounding medium on a forward movement and rarefies it on a backward movement. The alternate forces are transferred by compressive action from one portion of the medium to the next in an outward movement away from the source. Such Compressional and extensional forces cause alternate changes in the pressure on the medium with accompanying changes in formation volume, all at high frequency. The ratio of the change in pressure on the medium to its fractional volumetric change is defined as the “Bulk Modulus of Electricity”.

THE BOREHOLE COMPENSATED (BHC) SYSTEM

Sonic tools in current use are of the BHC type. This type sonde substantially reduces spurious effects at hole size changes as well as errors due to sonde tilt. The 'BHC' system uses transmitter above and one transmitter below two pairs of sonic receivers. When one of the transmitter is pulsed, the sound wave generated enters the formation; the time elapsed between detection of the first arrival at the two corresponding receivers is measured.

Shale Correction

Most sands, whether compacted or unconsolidated, which contain appreciable amounts of dispersed shale or clay particles, will exhibit longer acoustic travel time than clean sands of identical porosity in the same borehole environment. The increase in travel time results primarily from the difference in the velocities of the shale or clay particles and the sand matrix. When applied to the time average formula, travel time measurements in shaly sands will yield values greater than the true effective porosity of the formation. For this reason, a correction must be introduced so a more reliable porosity value may be obtained.

4- DENSITY LOG

The density log is a continuous record of variations in the density of the lithologic column cut by the borehole. The term bulk density is applied to the overall or gross density of a unit volume of rock. In the case of porous rocks, it includes the fluid density in the pore spaces as well as the grain density of the rock. It is evident that there should be a relation between the contribution to bulk density by the fluid in the rock pores and the porosity of the rock. This relationship is the basis for the calculation of porosity from the density log.

To measure the formation bulk density, a beam of gamma ray is directed into the rock. At a fixed distance from the source a counting system detects changes in the intensity of the gamma ray beam resulting from changes in the bulk density of the formation. The higher the density the lower the intensity of gamma ray radiation at the detectors.

LITHO DENSITY LOG

This is an advanced version of the density log where the photoelectric cross-section curve, Pe, is recorded along with bulk density measurements. This is the measurement of effective atomic number of the formation.

Pe Log Measurement

The use of photoelectric absorption in measuring formation average atomic number, contributes to the identification of Lithology. This measurement is made simultaneously with a density log, each utilizing a different part of the spectrum of the gamma-ray current incident on the far detector. The pressure housing is fitted with a beryllium window in front of the detector, so the complete low energy portion of the spectrum is available for analysis.

The pulse-height spectrum produced by the scintillation detector is windowed in two energy bands. One window is set at the high energy Compton, or hard, part of the spectrum; the other is set on the low energy photoelectric, or soft part. The hard window, H, can be located between 180 and 540 KeV, for example, thereby yielding a counting rate which is a function of density only, and the soft window S, from 40 to 80 KeV. Taking the ratio S/H produce a quantity in which the 'RHOB' dependence is effectively cancelled.

5- GAMMA RAY LOG

Well Surveys Inc. developed the first practical tool that could make a well bore recording of the earth's natural radiation in 1953. It later become known as the Gamma Ray Log, and was the first through casing method for analyzing a formation's lithologic properties.

This service was offered to the oil industry on a commercial basis in 1940. Today, natural gamma ray measurements have become an accepted source of information in both the exploration and the production phases of the petroleum industry.

THEORY & PRINCIPLES

Natural radiation of unstable elements consists primarily of alpha, beta and gamma rays; but it is practical to measure only the gamma radiation in a well bore. Some rocks are naturally radioactive by virtue of the

disseminated unstable elements they contain. Most of the 65 unstable nuclides exist in nature so rarely that we can omit them from this discussion. Those of significant abundance are:

- Uranium-radium series
- Thorium series
- And radio Potassium 40

These elements contribute the major portion of the natural radiation detected in sedimentary rocks. One gram of potassium 40 emits an average of 3.4 photons per second at a fixed 1.46 MeV energy. But an equal weight of either thorium or uranium produces respectively 12,000 0r 26,000 gamma rays per second with a spectrum of energies that average 0.5 MeV. Radiation energies are measured in units of the electron volt, thousand electron volts and million electron volts.