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UTILIZATION OF LOGGING METHODS IN GEOLOGICAL DRILLING EXPLORATION IN LOCALITIES OF MOSTECKÁ UHELNÁ A.S.

1. INTRODUCTION

Geological drilling exploration is an essential activity when gaining information, which is important for control of the mining process. Quality of the quarried raw material, its spatial lay and its rock environment, which goes with the quarried mineral, have a decisive influence on the choice of the mining method, the way of quarrying, limitation of mining area and on process of following modification of raw material up to its final fabrication. With regard to the fact that geological exploration is always a very expensive matter, it is useful to gain as much necessary information as possible from every borehole, which makes it easier to make the right decision. To achieve this goal, primarily laboratory analyses performed from the drill core are used. In deposits of the North Bohemian coal field, geophysical documentation of the borehole (the so called logging or log) became another important part of drilling exploration.

First attempts to employ logging were undertaken already in the 60s of the 20th century. The first method, which was employed in coal mining, was the so called method of electricity log. In the 70s, further new methods started to be employed stepwise – methods of nuclear log. These methods were gradually improved and mutually combined, which made them an integral part of deposit exploration within few years.

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2. UTILIZATION OF LOGGING IN COAL DEPOSITS

The main task of logging in coal deposits is to [1, 2]:

a) detect the presence of a coal bed in the drill log;
b) determine the depth of placing of the coal bed, its thickness with 0,1 m accuracy;
c) carry out a detailed division of the coal bed;
d) determine the technological properties of coal, particularly ash content.

Further tasks of logging in coal deposits are [1, 2]:

e) control and completion of data about the lithologic succession of lays in the off-bed section;
f) determination of physical and geochemical properties of rocks (volume weight, porosity etc.);
g) detection of elementary hydrogeological proportions in the borehole (earmarking of collectors, isolating lays, determination of clay content, mineralization of underground waters, temperature, examination of inflow places, cubical vertical flowage, yield of individual inflows etc.);
h) detection of technical parameters of the borehole (borehole diameter, spatial course of drilling).

To ensure the set of tasks dealing with the coal bed itself and its parameters (tasks a–d), an efficient complex of several logging methods was developed gradually. Mutual combination of these methods brings the most accurate results.

At present time, there are three following methods: gamma log GL, gamma gamma density log GGL-D, neutron – neutron log NNL and caliper log CL.

For control and completion of data concerning the lithologic succession of lays in the off-bed section (task e), this complex of methods is widened by logging of magnetic susceptibility. This method is inevitable in case of demand on delimination of firm locations. For determination of elementary physical and geochemical properties of rocks (task f), it is essential to take GGL-D and NNL measurements. For detection of hydrogeological proportions in the borehole (task g), it is necessary to employ resistivimetry RM and thermometry TM measurements. Key technical parameters of the borehole (task h) are detected by caliper log CL and inclinometry IM measurements.

With regard to the physical character of coal and dead rocks, the presence of a coal bed in the drill log approves itself by increased frequency (low density) in GGL – D records, the lowest rates of frequencies (high neutron porosity) in NNL records and minimum rates of exposure input in GL records.

3. FUNDAMENTAL PRINCIPLES OF INDIVIDUAL LOGGING METHODS

Logging measurement is carried out by an automatic logging unit. A subsurface probe is let down into the borehole on a logging cable, either freely or pressed to the borehole face. When it is pulled out from the borehole, a specific physical property is registered continuously on a recording material (analogue record) in a chosen measuring scale. Profundity measuring scale makes generally 1:100.

After digitalizing the logging measurement, the logging record undergoes further data processing. Final evaluation is displayed as a printed log record (logging drill log) and in digital form in STG data format (measured curves by step 0,05 m) and in JPG data format (log profile in all).

Essential devices for nuclear log are logging or subsurface radiometers for gamma radiation detection or for neutrons' detection. They always consist of a subsurface probe and a surface panel. By gamma log GL, exposure input of natural gamma activity of rocks is measured continuously. Method of gamma-gamma log, which is based on the measurement of exposure input of dispersed gamma radiation of an artificial gamma ray source (Cs 137), is used to determine the volume weight of rocks in the drill log.

Gamma Log (GL)

Under this term we understand the measurement of total exposure input of gamma radiation, which is caused by natural radioelements (U, Ra, Th) contained in rocks affected by drilling. The measured magnitude is stipulated in units of exposure input ($A.kg^{-1}$) the record represents the curve of exposure input depending on the depth. Calibration of log radiometers is realized with help of point standard Ra, the way of calibration and construction of the graph are the same as in case of surface prospecting.

Quantitative interpretation of the GL record represents the calculation of the total content of radioactive matter in the rock, which is stipulated in ur,% or ppm eU. The interpretation can be realized in two possible ways.

GL records are used for determining the total content of U, Th, for stating the U content in deposits of radioactive raw materials, for lithologic division of lays, predominantly in sedimentary rocks, for mutual correlation of lays between the boreholes, for an analysis of the degree of clay content, i. e. clayey fraction representation in sedimentary rocks, for detection of radioactive matter content of various types of rocks in situ.

Gamma – Gamma Log (GGL)

There are two modifications of gamma gamma log, i. e. the density one and the selective one. In case of the density modification GGL–D, we register exposure input of dispersed gamma radiation, which is influenced by Compton's dispersion. Gamma-emitters: ^{60}Co or ^{137}Cs tracers, source activity: 10^8–10^9 Bq, distance from the detector: 40–60 cm in case of sedimentary rocks exploration, 20–30 cm in ore bore holes. The measurement is influenced significantly by a change of the borehole diameter, caliper log as a subsidiary method is indispensable. To reduce the influence of the drilling mud and of borehole diameter changes, a pressure probe is used, with a source and a detector shielded from the side of the drilling mud, the probes are often equipped with a collimation apparatus. For an accurate determination of volume density ρ of rocks, a special GGL–D probe construction is used additionally. Only a bail arm with a ^{137}Cs emitter and two detectors – scintillation crystals is pressed to the borehole wall hydraulically. Exposure input of gamma radiation registered by the nearer detector is more dependent on roughness of the borehole wall than on density. This information is then processed and used for correction (in relation to borehole diameter) of the other information registered by the farther detector.

Density modification GGL–D is used mainly for setting volume density of rocks (maximum accuracy 10^{-2} g cm^{-3}), porosity, identification of beds (ρ = 1,40 g·cm^{-3}) or, by contrast, ores in the drill log. When we take measurement using pressure probes with shielding, it is possible to determine the ash content of coal AS with ±3 accuracy (= absolutely) from the GGL–D record. In case of mono-mineral ores, it is possible to determine the percentage content of ore in rock (accuracy maximum 1% of ore content). GGL–D is also used to control the borehole completion and for determination of the cementing head behind casings.

Neutron – Neutron Log (NNL)

There are two versions : neutron – neutron log when measuring the density of thermal neutrons NNL–T and when measuring the density of over-thermal neutrons NNL–OT. The functional difference between both versions is as follows. When over-thermal neutrons are registered, a detector is put into a shielding filter (e.g. made of Cd), which shades thermal neutrons.

On principle, the measurement is taken as follows: In a certain distance from fast neutrons' source (L = 0,5–0,8 m), we measure the density of decelerated neutrons, which is due to neutron properties of the measured environment, especially by the content of elements with a bigger effective cross-section for neutrons' deceleration (H) and for radiation capture (B, Cl). Proportional B tubes, corona tubes ^{3}He or scintillation crystals Li (Tl) are used as detectors. Neutrons' sources are as follows: Po-Be, Pu-Be, Am-Be, Ac-Be types with $7–20 \cdot 10^{10}$ Bq activity, in case of distance of neutrons' source from the detector L = 0,5–0,8 m we talk about a sphere of indirect dependence. With an increasing content of H, the registered density of neutron flow sinks.

The NNL method is used for two purposes:

1) for determination of porosity and for examination of the character of liquid infilling poruses of rock in oil and gas deposits,
2) for B, Cl, Mn, Hg, Tr content determination.

To determine the porosity of rocks, it is optimal to employ the NNL–OT method with a probe, if possible with a pressure one, shielded from the side of the drilling mud B_2O_3 (geometry 2π). In this case, the density of neutrons is only set by the content of hydrogen, which is an element with a maximum effective cross-section for neutrons' deceleration. Hydrogen occurs in poruses of rock, predominantly in form of H_2O (or oil). When the rock does not contain any clayey infusion or gypsum, its porosity is set by the total water content. In case of clayey rocks, it is necessary to apply correction to the clay content V_{sh}. Accuracy of porosity determination r is slightly dependent on lithology ($\Delta\rho$ = ±3% absolutely).

Magnetic Log (ML)

There are two versions of magnetic log. In the first version we measure magnetic susceptibility of rocks χ (magnetic susceptibility log), in the second one we measure individual elements of Earth's magnetic field (X, Y, Z), or at least the Z element (borehole's magnetometry).

When measuring magnetic susceptibility, we use either a single-coil system, which is a part of an a. c. bridge, or a double-coil system, similarly as in case of induction log.

Magnetic susceptibility log is used in exploration of ores with magnetite and pyrhotin content, further when segmenting the geological profile in igneous and metamorphic rocks, and also when exploring oxidation zones with content of limonite in carbonates. Very sensitive instruments are used in sedimentary rocks for delimitation of significant correlation horizons.

Caliper Log (CL)

Instruments measuring the borehole diameter – calipermeters have various mechanical constructions, however the principal scheme is similar in all cases. Three or four mechanical sensors are pressed by a spring to the borehole wall and during the measurement they detect all changes in the borehole diameter. Changes in position of the arm are transferred by a wheel system between the cursor of the potentiometer, so that potential difference ΔV (mV) measured between the cursor of the potentiometer and its extreme position is directly proportional to the borehole diameter.

Inclinometry (IM)

To determine the accurate spatial position of the place, in which the well impacted the deposit, it is necessary to know the spatial course of bore hole, which often inflects from the vertical, which occurs even in boreholes, which were designed as vertical ones. To achieve this, we use inclinometers, which can be subdivided into three types: electricity resistance inclinometers with a magnetic needle, electricity resistance inclinometers with a gyroscope and photoinclinometers (e.g. from the former Democratic Republic of Germany – Monograf, Multigraf).

Resistivity Log (RL)

In case of resistivity log we measure electric resistivity of liquid in the borehole continuously. The measured magnitude's extension is Ωm, instruments used for the measurement are called resistivimeters. The logging probe – resistivimeter is very simple. In all cases it includes three minimal electrodes with a very little reach depth, in order to eliminate the influence of surrounding rocks. One of the electrodes (A) is plugged in a stream circle, the other two ones (M, N) in a measuring circle. For the resistivimeter's stabilized power supply (mA) and for the measurement of potential difference ΔV (mV) on electrodes M, N, we use usual equipment for simple electricity logging measurements.

4. FINAL SUMMARY

Results gained by logging measurement are a very important addition to the information gained by laboratory analyses of the drill core and by its macroscopic description. Because logging measurements are not independent on human factor, they represent another view of each borehole for the evaluating geologist.

This is important for assessment of geological situation in a deposit in case of a substance of coal, as well as of a associated rock environment. On the basis of evaluated log measurement, it is possible to carry out correlations of overlaying complex of strata, both in terms of one deposit, and in terms of more deposits mutually. In this way it is possible to trace the course of characteristic coal sheds. After mutual combination of the macroscopic description of the drill core and logging, it is possible to earmark in advance consolidated horizons or sand horizons saturated by water, which always bring risk into the mining process. With help of logging, it is possible to monitor morphology of a coal bed and its approximate quality (Ad content). Thanks to characteristic curves of individual methods in specific sections of a deposit, it is possible to deduce, which parts were influenced by anomalous geological evolution (e.g. zones in a part of a coal deposit without coal seams).

Logging measurements became a part of a complex geological classification of coal deposits within a few decades for the reasons listed above.

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