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Practical Application of Geophysical Logging in Coalbed Methane Exploration and Development

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Abstract: *Geophysical logging technology is indispensable in resource development and reservoir evaluation. Through logging curves, physical characteristics of formation lithology can be accurately reflected, so as to effectively solve geological problems. It can not only be used to explain and evaluate the geological parameters of coalbed methane in a single well, but also to comprehensively evaluate the indicators of coal seam physical property and gas content in this area. With the development of social science and technology, logging technology is constantly improved, increasing the research on logging technology and methods is very beneficial to the exploration and development of coalbed methane. Based on this, this paper focuses on geophysical logging analysis and discusses its practical application in coalbed methane exploration and development.*

Keywords: *Geophysical logging; Coalbed methane; Exploration and development; Practical application*

1. Introduction

Coal bed methane is a kind of efficient and clean mineral resources, which mainly refers to the associated product of coalification of plants in a long geological period. According to the investigation, the total amount of coalbed methane resources buried at about 2000 meters is close to 32*1012 cubic meters, which is considerable both in development prospect and utilization value. With the application of modern science and technology, geophysical logging technology has been widely used in the exploration and development of coalbed methane, and has been highly concerned by the industry. However, the type and use scope of geophysical logging during the period of coal bed gas exploration and development have not been clearly defined, so our country should increase the exploitation and exploration of geophysical logging.

2. Overview of Geophysical Logging

2.1. Concept of Geophysical Logging

Geophysical logging is an indispensable part of the exploration and development of oil and gas fields. It can help us quickly discover, evaluate and identify the physical characteristics of oil and gas reservoirs, such as radioactivity, conductivity, electrochemical characteristics, etc., which can be effectively compared with the physical properties of rock porosity, saturation, etc. Logging is a method of measuring geophysical parameters through the use of specific instruments and equipment that can help us better understand what is going on underground. [1]

2.2. The Role of Geophysical Logging in Oil and Gas Field Exploration and Development

For geophysical logging, systematic analysis and continuous description of formation characteristics are the core advantages, and these advantages mainly depend on the multi-parameter and high resolution of logging information. Nowadays, conventional logging data can solve the following problems in oil and gas field exploration and development. First, scientific division of rock strata can accurately measure the thickness, depth and other indicators. Second, the lithology and porosity are defined. The percentage of lithology and porosity curve can be obtained by combining various porosity logging methods. Furthermore, a reasonable division of reservoirs and a comprehensive assessment of their oiliness involves effective thickness of oil and gas reservoirs, oil or gas saturation, and estimated

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permeability. [2] Using formation correlation and logging technology, we can not only gain an in-depth understanding of geological structures, but also obtain real-time information about the development of oil and gas fields, such as water injection well profile, reservoir recovery efficiency, reservoir flooding degree, etc. Finally, geophysical logging allows us to more accurately measure parameters well, such as perforation quality, well temperature, well inclination, and casing corrosion.

3. Common Methods and Status Quo of Geophysical Logging

3.1. Common Methods of Geophysical Logging

Geophysical logging is the main means to discover coal and coalbed methane resources. In the exploration and development of coalbed methane, technicians actively learn from the efficient petroleum logging technology by combining the physical characteristics of coalbed methane resources and the characteristics of reservoir cap, etc., and explore different geophysical logging methods for coal fields, including electric logging, acoustic logging, nuclear logging and so on. First of all, electrical logging means to comprehensively measure the changes of electrical parameters such as conductivity and dielectric constant by means of the electrical differences between coal bed methane or other detection targets and surrounding media, so as to make accurate identification of target horizon. [3] At present, electrical logging includes spontaneous potential logging, laterolog logging, dielectric logging, array induction logging, etc.

Secondly, acoustic logging is to identify and evaluate formation lithology and cementing quality according to the changes of acoustic response characteristic parameters such as acoustic wave propagation speed and frequency in different coal formations. The commonly used acoustic logging methods include acoustic velocity logging, cement bond evaluation logging, noise logging and acoustic amplitude logging.

Finally, nuclear logging, namely radioactive logging, takes advantage of the differences of nuclear physical properties such as formation lithology and pore fluid, and establishes geological profiles through radioactive logging to discover target horizons. Nuclear logging is an indispensable physical logging method which has been widely used in coal field geological exploration. For nuclear logging, it includes nuclear magnetic resonance logging, neutron logging and gamma logging, and gamma logging includes isotope tracer logging, density logging and other methods. NMR logging includes spin echo method and prepolarization method. Neutron logging involves C or O ratio logging, superthermal neutron logging and so on.

3.2. Analysis of The Status Quo of Geophysical Logging

Since the 1990s, logging technology has developed rapidly, from imaging logging, NMR logging, and logging while drilling to modular formation dynamic testers and logging interpretation workstations. Each technology has improved significantly, providing strong support for geological exploration. Since the 1970s, China has not introduced any foreign logging equipment and technology. Although China has made great progress in science and technology in recent decades and many advanced equipment and technology have been introduced into China. However, due to the low popularity of technology, China's logging technology is still far behind other countries, with a big gap. The development of the global oil industry since 1986 shows two significant changes. On the one hand, there is an increasing reliance on lower-cost technologies. On the other hand, there is increasing reliance on the use of vertical and horizontal wells to identify thin and unconventional reservoirs. This change not only limits the development of logging technology, but also promotes its reform and innovation. Wireline, measurement while drilling, electromagnetic, acoustic, and nuclear logging technologies developed rapidly in the early 1990s and have made significant gains, and this trend will continue. [4]

4. Practical Application of Geophysical Logging in Coalbed Methane Exploration and Development

4.1. Aspects of Open Hole Completion

Gamma ray logging and high resolution induction logging are frequently used to determine the thickness of coalbed methane reservoir in open hole completion. In addition, in order to better

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industrial analysis and prediction of coal and rock, as well as calculation of physical and mechanical properties and gas content in coal reservoirs, methods such as density logging, microresistivity scanning logging and geochemical logging can be used to obtain more accurate information of coalbed methane reservoirs, so as to better develop coalbed methane resources. More accurate and reliable interpretation results can be obtained through comprehensive analysis and comparison of physical logging data.

4.2. Aspects of Casing Completion

Cementing is a process by which cement slurry is inserted into a coalbed methane well to ensure a tight connection between the well wall and the casing. Once cementing is complete, the cementing quality of the coalbed methane well, especially the cementing of the cement ring, must be examined to ensure the safety of the pumping system. In coal exploration, variable density logging, ultrasonic pulse reflection and acoustic amplitude logging are three important cementing quality detection technologies. Acoustic logging, in particular, can provide accurate data, which can ensure better cementing quality for casing completions in CBM exploration and development, and provide more reliable logging data.

4.3. Evaluation of Coalbed Methane Reservoir

According to the geological theory of coalbed methane reservoir and the logging response characteristics, we can interpret the coalbed methane reservoir more accurately, as shown in figure 1 below. In addition, because coal seams have unique electrical characteristics, they are also very useful for reservoir identification. In coal seam, due to the influence of coalbed methane, the acoustic wave and density porosity are at an appropriate level, but with the passing of time, the neutron porosity will gradually decrease, and the acoustic wave and density porosity will increase, which will lead to the neutron porosity of coalbed methane reservoir is lower than the acoustic wave and density porosity. Therefore, using this theory, we can effectively identify and divide the reservoir of coal seam.

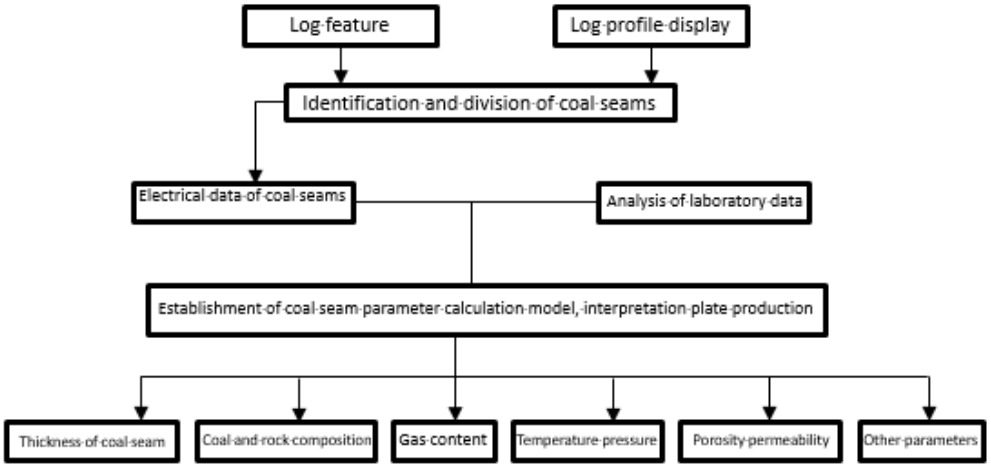

Figure 1: Interpretation Flow of Coalbed Methane Reservoir Logging

With the continuous development of technology, the logging methods used to determine the thickness of coal seam have become more and more mature, and their resolution has reached the centimeter level. In the process of determining the thickness of coal seam, the dual laterolog method can effectively improve the measurement accuracy. However, due to the low resolution, the response effect of the gamma logging method will be affected by the high ash content at the top interface of coal seam. Therefore, a more accurate measurement method is needed. Acoustic, density and neutron logging methods are used to obtain more accurate results, with volume density being the most important indicator.

4.4. Coal-bed Gas Exploitation

In order to effectively realize the safe exploitation of coalbed methane wells, we need to conduct in-depth analysis of the fluid condition in the wellbore and its replenishment capacity, and combine relevant technical means, such as flow logging, fluid identification logging, well temperature logging,

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and so on, to accurately master various parameters in the wellbore, so as to formulate perfect drainage management measures. By using advanced technologies such as reflective acoustic wall imaging and downhole photography, we are able to comprehensively monitor the operation status of coalbed methane wells, so as to effectively prevent the occurrence of downhole accidents such as sand burial and casing deformation, thus providing reliable and accurate data support for safe production. [5]

4.5. CBM Enrichment Prediction

With the continuous progress of coalbed methane exploration and development technology, seismic data has become an important basis for the prediction and delineation of coalbed methane, which can help us predict and delineate the rich areas of coalbed methane more accurately, thus improving the reliability and practicability of coalbed methane. Therefore, more and more attention has been paid to the application of seismic data in the exploration and development of coalbed methane, and a variety of technical methods based on seismic data have been formed to predict and delineate the high-yield and rich areas of coalbed methane.

By studying the AVO property of coal seam, we find that it can predict the high yield and rich area. The advantage of this method is that it can reflect the geological characteristics of coal seam and accurately predict the location of high-yield and rich areas. Through the study of overseas coalbed methane fields and the Daning-Jixian coalbed methane block in Shanxi Province, AVO detection technology has been proved to be a very effective method, which can accurately detect high-yield and enriched coalbed methane, and has a broad application prospect.

5. Conclusions

In a word, many geophysical logging methods, such as electric logging, acoustic logging and nuclear logging, are often used in the exploration and development of coalbed methane. These logging methods carry out all the stages of exploration and development, and provide technical support for the healthy and sustainable development of China's coalbed methane industry. At the same time, due to the different logging tasks and objectives of coalbed methane exploration and development, the geophysical logging methods applied are also different. In order to further improve the rationality and reliability of logging and obtain more logging response parameters, it is necessary to choose logging methods reasonably based on the actual situation, or combine various methods organically, which can improve the quality and efficiency of logging.

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