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Integrated Application of Mud Logging, Elements and Geosteering in Horizontal Wells-Example of the Weiyuan Shale Gas a Well in the Sichuan Basin

Xiaojing Zhou[1], Ming Wang[1], Sijin He[2]

[1]CCDC Geological Exploration & Development Research Institute, CNPC, Chengdu, Sichuan, 610051, China
[2]BGP INC., China National Petroleum Corporation, Chengdu, Sichuan, 610051, China

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Abstract: The horizontal section of the horizontal well is drilled to a certain length in the target, which increases the exposed area of the oil and gas reservoir. The basic purpose of the horizontal well is to increase oil and gas production or oil and gas recovery. With the development of Weiyuan shale gas horizontal wells, the development of drilling technology and the demand for higher precision formation analysis, as well as the demand of oil field companies to improve quality, efficiency and cost, the integration of various professional models has mushroomed. Several aspects, geological guidance based on petroleum geology, as well as practical applications, characteristics, and mud logging relationships are summarized. The cooperation of the three factors improves the comprehensive technical ability and production and management efficiency of the field geology.

1. Introduction

Logging, elements and geosteering are closely linked to oil and gas drilling and are all based on petroleum geology. The historical development of each of the three is outlined and the specific links between them in practical application are analysed to make a contribution to oil and gas exploration and development.

2. Well Logging

Well logging technology has been used in oil and gas drilling for over 60 years. Early logging technology used manual recording of well depth, drilling, visual description of cuttings and core to determine formation rocks, distinguish the horizon, observation of returned drilling fluid and cuttings to determine oil and gas reservoir. With the progress and development of science and technology, especially the application of computer and network technology, new research, new technology, new equipment applied to logging, as well as all relevant units, are drilling wells all networked, images, data transmission, comprehensive monitoring of the drilling process, become a modern diversified, timely, refinement of high-quality logging technology.

Drilling site logging technology is of great importance in the entire oil drilling by diversifying and comparing various types of logging projects (such as core logging, well wall coring logging, rock chip logging, drilling fluid logging, integrated logging (gas logging, engineering logging), fluorescence logging, geochemical logging, carbonate analysis, mud shale density, acid hydrocarbon and tank gas, pressure testing and other logging), establishing comprehensive geological information, and quickly analysing and accurately evaluating and interpreting oil and gas water leakage layers. One of the key points of logging is to analyze and summarize the well location, display, lithology, formation pressure, drilling fluid performance, structure, etc. by comparing adjacent well and block structure, grasp the downhole static and dynamic conditions, and provide reliable and effective suggestions to relevant parties, which makes the drilling process calmly cope with and achieve safe production with controllable well control safety as the goal. The industry commonly compares logging to the eyes of drilling. By collecting logging project information to obtain relevant information about the well in a timely manner and analyse it quickly, oil, gas and water leakage displays and engineering anomalies can be detected, informing drilling operators to deal with them in a timely manner in order to improve drilling efficiency and achieve a safe drilling process [1-2].

One of the professional techniques of field logging is to obtain accurate geological rock information, observe, analyse and study the physical and chemical properties and electrical characteristics of rocks using instrumental analysis, and evaluate and interpret oil and gas formations based on gas logging displays, lithological characteristics and results of instrumental analysis of rock chips. The physical properties of rocks are optical properties (colour, streak, transparency, lustre, etc.); mechanical properties (hardness, decomposition, fracture, brittleness, etc.); and relative density (gypsum light, such as quartz, orthoclase, calcite medium). Some rocks have radioactive, is the rock containing radioactive elements (radioactive minerals), radioactive rocks available with special techniques to obtain reliable data, in recent years Elemental logging has developed rapidly [3,4].

3. Elements

The discovery of the naturally radioactive elements Po and Ra in 1898 by Madame Curie and her husband Pierre Curie, who worked together under extremely difficult conditions, was of epochal and historical importance. Radioactive nuclear elements are capable of spontaneously emitting a number of charged particles from within the nucleus, mainly emitting alpha, beta and gamma rays. The alpha and beta rays emitted are often absorbed and the gamma rays are rarely absorbed, so it is mainly the gamma rays that are utilised. The elements in the list of atomic number chemical elements above 84 are radioactive, such as U, Th, Ra, etc., of which the first nuclide of Ra, 235U, has a very low abundance in nature and its radioactive contribution is minimal; elements such as K and Rb, which are below 83 in the list of atomic number chemical elements, are also radioactive, of which Rb has no gamma radiation.

There is a wide variety of minerals in nature, and their distribution is uneven, with rocks consisting of a collection of one or several minerals, and minerals consisting of chemical elements. x-ray diffraction (XRD), x-ray fluorescence (XRF) elemental logging techniques are often referred to as XRD or XRF logging. XRD uses the principle of diffraction to directly determine the presence in rock chips of dolomite, calcite, quartz, potassium feldspar, plagioclase, pyrite and The XRF logging instrument stimulates the energy of rock chip logging samples by irradiating them with X-rays, and the specific energy and wavelength characteristics of the elements can be analysed for Na, Mg, Al, Si, P, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Rb, Sr, Y, Zr, Nb Mo, Ag, Cd, In, Sn, W, Pb, Th, U, Ba 35 elements to determine the fraction, relative content and distribution pattern of chemical elements in rock chip logging samples.

The energy and intensity of gamma rays are measured by natural gamma spectrometry. The content of U, Th, K and gamma dose rate are obtained from the analysis of the spectrum. These data can be used to calculate the shaly content, identify the reservoir with high natural gamma activity (shale), and evaluate the source rocks. Elemental and natural gamma-ray logging can identify different formation lithologies by the changes in the content of different elements in cuttings logging samples. It can effectively analyze small or even powdery or mixed cuttings that are difficult to identify, identify and describe, and become a more accurate means to identify lithologies and divide stratigraphic segments. Analysis of sedimentary environment and abundance of organic matter in source rocks according to rock types provides support for hydrocarbon accumulation conditions and quantitative evaluation of hydrocarbon resources. TOC=f(U), (clay/quartz/ feldspar/ calcite/dolomite/pyrite) content =f(Mg, Al, Si, K, Ca, Fe, S), gas content =f(total hydrocarbon, drilling time), etc. The element and gamma spectrum characteristics of well A were synthesized. The elements are closely linked to rock components and electrical characteristics. Elemental logging is a development of logging technology by analysing rock chips in more detail on the basis of rock chip logging, and the elements play a more favourable role in supporting geological guidance to control the borehole trajectory [5-7].

Elemental and natural gamma energy spectrum analysis samples are rock chips from the formation obtained from rock chip logging. Actual drilling has proven that when the rock chips are poorly represented (relatively high in natural gamma energy spectrum logging), such as the addition of too much solid phase (e.g. barite), treating agent (e.g. bitumen) and large changes in shear force during drilling operations, the rock chips are particularly mixed when the shear force becomes small and other factors cause poor rock chip representation, therefore there are limitations to the composition and component content data and drilling fluid performance of the treated drilling fluid materials.

4. Geosteering

The concept of geosteering was first introduced by Ana drill in 1992 and the first logging tool specifically designed for geosteering was developed in 1993, while the PSOLOG geosteering tool was developed by Statiol in 1995. Currently, the three major oil service companies, Schlumberger, Halliburton and Baker-Hughes, are in control of the advanced LWD (Logging While Drilling) logging technology [8].

Horizontal well geological guidance is based on seismic, logging, elemental, logging and other information data to track the formation structure and reservoir encountered by the bit during the drilling process, comprehensive analysis, real-time prediction, adjustment of the borehole trajectory, real-time borehole trajectory adjustment notice to the directional party, guide the borehole trajectory accurate landing, horizontal section to maintain the target body drilling to completion of the control process, directly affect the horizontal well drilling effect. The MWD (Measure While Drilling) and LWD (Logging While Drilling) instruments are used to measure MWD data (well slope, azimuth and formation temperature) and LWD data (gamma, resistivity and density) to obtain specific borehole trajectory parameters and formation information for the corresponding well depth. trajectory parameters and stratigraphic information.

The focus of geosteering is to accurately land and maintain horizontal drilling in the hydrocarbon target in the presence of uncertain stratigraphic factors, for which the pre-construction design (geosteering construction plan) is the basis and prerequisite.

4.1 Construction programme

The geologically oriented construction plan is based on geological studies, seismic section slices expected to enter the target vertical depth, establish the initial geologically oriented model, extract the dip angle of the formation, and consider factors such as tectonic, reservoir, orientation, formation rocks and other factors to make a prediction of the formation [9].

According to the predicted vertical depth of point A and the stratigraphic situation, the directional construction scheme close to the actual borehole trajectory construction is used. Taking into account geological factors, the scheme has small errors with the actual, which is conducive to reducing the difficulty of controlling the directional borehole trajectory and drilling costs [9]. For example, the Sichuan Basin Mill Creek Formation has a light two-section reservoir target area for wells, and composite drilling with stable well slope in this section solves the problem of low mechanical drilling speed for directional construction. A well in the horizontal section of shale gas can be drilled to a lesser depth in silica-bearing shale with the same directional approach.

The landing control measures are based on the location of the electrical characteristics of the neighbouring wells, the vertical thickness from design point A, combined with the borehole inclination data of each characteristic point of the planned borehole trajectory, if the location of the characteristic point is advanced or delayed, take measures to increase or stabilise the borehole inclination, and then re-optimise the borehole trajectory to control a reasonable angle to enter the target area when it is close to the location of point A.

After the borehole trajectory enters the reservoir target body according to the extracted formation inclination degree, the change of electrical characteristics of the target body and the change of logging, element, LWD and MWD values, correct and adjust to the best position of the target body reservoir horizontal drilling at any time; if the target body reservoir location is uncertain for exploration wells, detection after entering the target body shows that the reservoir is low, with the full angle change rate slowly increasing the slope down to better show increasing the slope along the formation inclination drilling In the case of a reservoir with a low angle, it is better to drill at a full angular rate of change and slowly increase the slope downwards to show an increase in slope to follow the dip of the formation.

The stratigraphy is complex and diverse, and the difficulties, risks and countermeasures are specifically analysed in terms of tectonics, reservoir spreading characteristics and directional tool capabilities. For example, the landing section or reservoir section is thicker, it is more difficult to find the true dip angle of the formation; directional in the implementation of well slope control, taking into account the orientation of the borehole trajectory to meet the design requirements; horizontal section of the reservoir target body is small, and the target body is uncertain in the longitudinal and transverse upward spreading; drilling out of the top and bottom of the reservoir target body or drilling to the non-reservoir interlayer; carbonate reservoir spreading non-homogeneity; downhole temperature is high, anti-high temperature directional tools or measures to reduce the temperature. The main countermeasures are the use of recorded rock chips, drilling time, carbonate rock analysis, elemental analysis, hydrocarbon gas display and other comprehensive judgment and the performance of the directional tools to ensure that the reservoir target drilling encounter rate. In terms of controlling borehole trajectory tools, compared to MWD (with LWD) + curved screw directional, rotary guidance has the characteristics of detecting zero length of the instrument, faster and more accurate operation, and rotating the ground while sliding, which is conducive to better completion of geological guidance to the formation tracking instructions, and can also provide support for drilling speed and efficiency [10-12].

4.2 Accurate landing

The horizontal well landing section is the section of the well from the obliquity increasing point (KOP) to the reservoir target area, and its basic route is obliquity increasing, compared to the target area location well obliquity angle is the maximum, and azimuth to meet the design requirements, obliquity increasing drilling is the main feature of landing control, accurate vertical depth into the target point is the key and result of landing control, real-time analysis, calculation, and adjustment of trajectory parameters is the technical means of landing control [13].

The geological guide takes over from the oblique point and drills down to the electrical characteristics point above the target body in accordance with the planned borehole trajectory increasing obliquity, adjusts the vertical depth of point A in real time, and optimises the borehole trajectory in real time. The adjustment is also based on real-time logging rock chips, drilling time, carbonate analysis, elemental analysis, hydrocarbon gas display and follow-up logging data (MWD, LWD) comprehensive analysis, comparing the data of neighbouring wells, especially the standard electrical characteristics. The vertical depth of the entry point has an amplifying effect on the slope angle of the well, and the greater the slope of the well, the smaller the distance between the slope angle and the vertical depth of the well depth, to achieve the purpose of accurate landing [14-15].

4.3 Horizontal section

The horizontal section is the section of the well that extends within the predetermined reservoir target to the completion point B after landing into point A. The completion forms a geologically guided drilling map. The horizontal section is mainly an up and down adjustment of the borehole trajectory, i.e. the number of degrees of well slope, so that the horizontal section is parallel to the curved reservoir level and does not penetrate the top and bottom interfaces of the target. The crustal movement will leave behind the geological structure of the formation inclination, bending and fracture and other situations, therefore, the horizontal section is a curved spatial three-dimensional curve. During the drilling of the horizontal section, real time analysis through a combination of logging rock chips, drilling time, carbonate rock analysis, elemental analysis, hydrocarbon gas display and follow-up logging data (MWD and LWD), considering formation dip, formation orientation, target body thickness variation and well quality, remains the main technical tool.

During live drilling, a high level of accuracy is required for predicting stratigraphic dip and small faults, and some progress has been made in recent years in predicting micro-amplitude structures using seismic data. Using seismic attributes can extract methods such as coherence, curvature, ant body, and great likelihood to predict microstructures, among which the ant body tracking algorithm can further enhance fracture information based on fracture monitoring attributes and suppress non-fracture information. Compared with other methods, ant body attributes can describe the details of fracture development with high accuracy and large manipulability[16] .

5. Conclusion

(1) The logging technology at the drilling site collects and analyses various geological related information during the drilling process to discover hydrocarbons under the premise of ensuring the safety of the well, and to make a professional study of the rock properties and characteristics of the strata several kilometres downhole with the first-hand recorded information to comprehensively analyse and interpret the status and distribution pattern of hydrocarbon resources.

(2) Due to the uncertainty of geological and tectonic factors such as stratigraphic thickness changes, dip angle changes, thin high-quality reservoirs, fault factors, reservoir non-uniformity, etc., for the purpose of accurate access to the target body and horizontal section penetration in the target body, geological guidance technology becomes a guarantee for the comprehensive benefits of horizontal well exploration and development.

(3) Elemental logging on the basis of the original logging, can analyze the composition of the fine elements of the rock, further accurate downhole formation rock characteristics and evaluation

of hydrocarbon resources, to provide a fuller basis for oil and gas exploration arguments.

(4) Horizontal well logging, elemental and geosteering are all based on petroleum geology, respectively, outlining the historical development and analysis of the three currently in the process of practical application is coordinated, interconnected and complementary to each other as a close whole, and its integrated mode plays an important role in improving oil and gas production or oil and gas recovery rate (Figure 1).

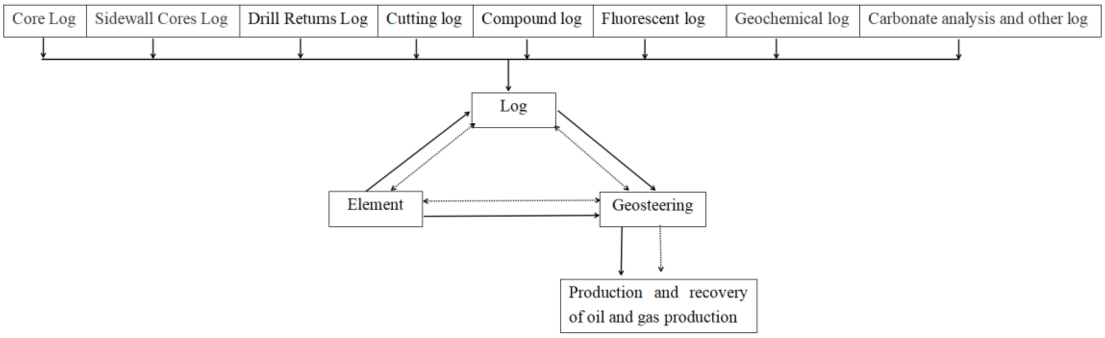

Figure 1: The relationship of horizontal well, element and geosteering

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