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STUDY OF GEOLOGICAL CROSS-SECTIONS FOR MAKING DESIGN AND ENGINEERING DECISIONS WHILE DRILLING UNDER UNCERTAINTY

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Summary. To date, a large number of studies have accumulated on gathering and using information about well drilling. The quality of this information has a major influence on the decision-making process while drilling, as in most cases the drilling occurs under uncertainty. Numerous studies and the drilling experience show that the data obtained while drilling require statistical processing and in-depth analysis. The purpose of studies based on probabilistic methods and fuzzy logic is to predict the properties of rocks along the wellbore and to identify homogeneous intervals using a set of features. At the same time, various methods make it possible to assess the properties of rocks using core, cuttings, well logging, and mud logging data while drilling. This article considers the applicability of the proposed methods through examples of specific wells, since their successful application contributes to improving the efficiency of studying geological cross-sections and the quality of information obtained while drilling, as well as improving the quality of decisions. A computational scheme was proposed by the authors for estimating drillability of rocks associated with their properties predicted from integrated mud logging while drilling. Using the results of mud logging while drilling, the ways of building a refined lithological column are shown. The method proposed in the article which plays an important role in making decisions on the choice of process parameters, can be recommended for data analysis during drilling, clarification of lithology and boundaries of certain types of rocks.

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1. Introduction

In most cases, engineering decisions for drilling oil and gas wells are made under uncertainty and largely depend on the quality of the necessary information. This information can be obtained from geological and geophysical surveys, as well as mud logging while drilling. The poor quality of the information received is one of the reasons for making erroneous decisions, which ultimately leads to a decrease in the performance indicators of drilling. Drilling experience and numerous studies show that data collected while drilling require statistical processing and in-depth analysis. Earlier works proposed a computational scheme based on the use of probabilistic methods and fuzzy logic (Brown et al., 2000; Cuddy and Glover, 2002; Efendiyev et al., 1991; Efendiyev et al., 2021; Эфендиев и др., 2019; Efendiyev et al., 2020).

The purpose of these studies was to predict the properties of rocks along the wellbore and to identify homogeneous intervals through a set of features, taking into account the uncertainties that occur when making decisions. This article discusses the applicability of the proposed methods with case study of specific wells. Successful application of these uncertainty-based methods improves the efficiency of geological study and the quality of information obtained while drilling using probabilistic statistical methods and fuzzy logic, as well as the quality of decision-making.

2. Review of experience in gathering and using information when making decisions in drilling

To date, a large number of studies have accumulated on gathering and using information about well drilling. These studies propose various methods and tools for estimating the physical and mechanical properties of rocks based on integrated information obtained while drilling. As a result of these studies, methods were proposed that make it possible to assess the properties of rocks using core, cuttings, well logging and mud logging data while drilling. In general, an analysis of the work done shows that it is now possible to increase the quality of decisions made using integrated geological, geophysical and technological information, which is the basis for engineering solutions. Such information can be obtained in various ways; it contains uncertainties of various nature, which affects its quality. Thus, in

order to obtain and use such information, it is necessary to use modern methods of data processing and analysis, taking into account the uncertainties mentioned. This has been acknowledged in various papers. At the same time, it is very important to take into account the uncertainty of drilling conditions, namely: heterogeneity, fuzziness and randomness of factors. Decision-making methods in the context of insufficient information, which have recently been widely developed in various fields of science and technology, can provide a reliable basis for this.

It is known that processing and analyzing data of measurements of geological parameters are associated with errors and other uncertainties. Such problems arise when making drilling decisions due to the difficulties associated with the creation and use of more accurate tools for measuring drilling and reservoir characteristics, performance parameters, etc. It should be noted that data analysis reveals that in many cases useful information is hidden in each error. Error information can be used to create a robust tool that complements the traditional techniques that process engineers, geologists, and geophysicists need to solve the forecasting problems. When analyzing bit performance, it is advisable to break down the cross-section into homogeneous intervals and to take into account the behavior of drilling parameters within them. Various classification methods have been proposed for this purpose. One of the simple methods to perform this operation is the method proposed by D. A. Rodionov (Родионов, 1968), which was used in a number of works, in particular (Efendiyev et al., 1991; Efendiyev et al., 2020). According to the algorithm for a program that provides for this method, the proposed criterion is calculated, and the calculated value of the criterion proposed in (Родионов, 1968) is compared with the corresponding table value reflected in the literature on mathematical statistics. The criterion given in (Родионов, 1968) was used, depending on the task, in various works for dividing geological objects into homogeneous intervals based on several features. Earlier, we also used the criterion for the features characterizing the main properties of rocks which are necessary for selecting process parameters. These are the hardness characterizing the resistance of the rock to drilling, and the abrasiveness characterizing the wear resistance of the rock. These rock properties, in turn, depend on the rock lithology, porosity and mineralogical composition (Efendiyev et al., 1991; Efendiyev et al., 2020).

In the works (Efendiyev et al., 2020; Efendiyev et al., 2021), changes in hardness and abrasiveness with depth compared to the rate of penetration of various bits are shown. Fig. 1 shows a generalized cross-section of one of the wells drilled in Azerbaijan. Here, homogeneous intervals drilled with same-type bits are shown. The given data were processed by the "moving average" method, which reduces the data scattering and more clearly defines the trend of the parameter under consideration. Works of (Efendiyev et al., 2020; Эфендиев и др., 2019; Efendiyev et al., 2021) also show the change in the "d-exponent" parameter, which in an integrated manner characterizes the rock drillability and allows us to estimate the intervals of abnormal changes in reservoir pressure (this is evidenced by the deviation of points from a straight line called the "trend line").

In recent years, fuzzy logic has been successfully applied in the evaluation and use of formation characteristics (Zadeh, 1965; Fang and Chen, 1997; Freund and Walpole, 1980; Cuddy and Glover, 2002; Brown et al., 2000; Efendiyev et al., 2021).

In (Efendiyev et al., 2020; Efendiyev et al., 2021) the use of the noted provisions is exemplified by predicting lithology in wells drilled in Azerbaijan according to a set of features (hardness, abrasiveness, lithological index, porosity, permeability, etc.) obtained from geological and geophysical surveys and mud logging while drilling. Analysis of distribution of rock properties in (Efendiyev et al., 2020; Efendiyev et al., 2021) showed that for each of the listed property, with the exception of permeability, it obeys the normal law (permeability, as known, obeys the lognormal law, so the logarithms are taken as its values). In the present work, using expressions based on probability theory and fuzzy logic methods given in (Cuddy and Glover, 2002; Efendiyev et al., 2020; Efendiyev et al., 2021), calculations of the geological characteristics were performed, estimates of the rock lithology were given, and homogeneous intervals in terms of drillability were identified. In short, by summarizing the noted results and applying the corresponding computational schemes, by the example of some wells, ways of preparing information for modeling the drilling process are shown (Fig. 1).

3. Research method

The algorithm for assessing the rock properties and identifying homogeneous intervals (packs) was considered and proposed in previously performed works (Cuddy and Glover, 2002; Efendiyev et al., 2019; Piriverdiyev, 2020). In these works, first, the distribution density is calculated according to the expression known from the probability theory; then the characteristics are sequentially calculated (Cuddy and Glover, 2002; Brown et al., 2000), necessary for a comprehensive assessment of the rock properties that play a role in calculating drillability and breaking the cross-section into homogeneous intervals (Efendiyev et al., 2020; Эфендиев и др., 2019; Efendiyev et al., 2021). The expressions used in the calculations are summarized in Table 1.

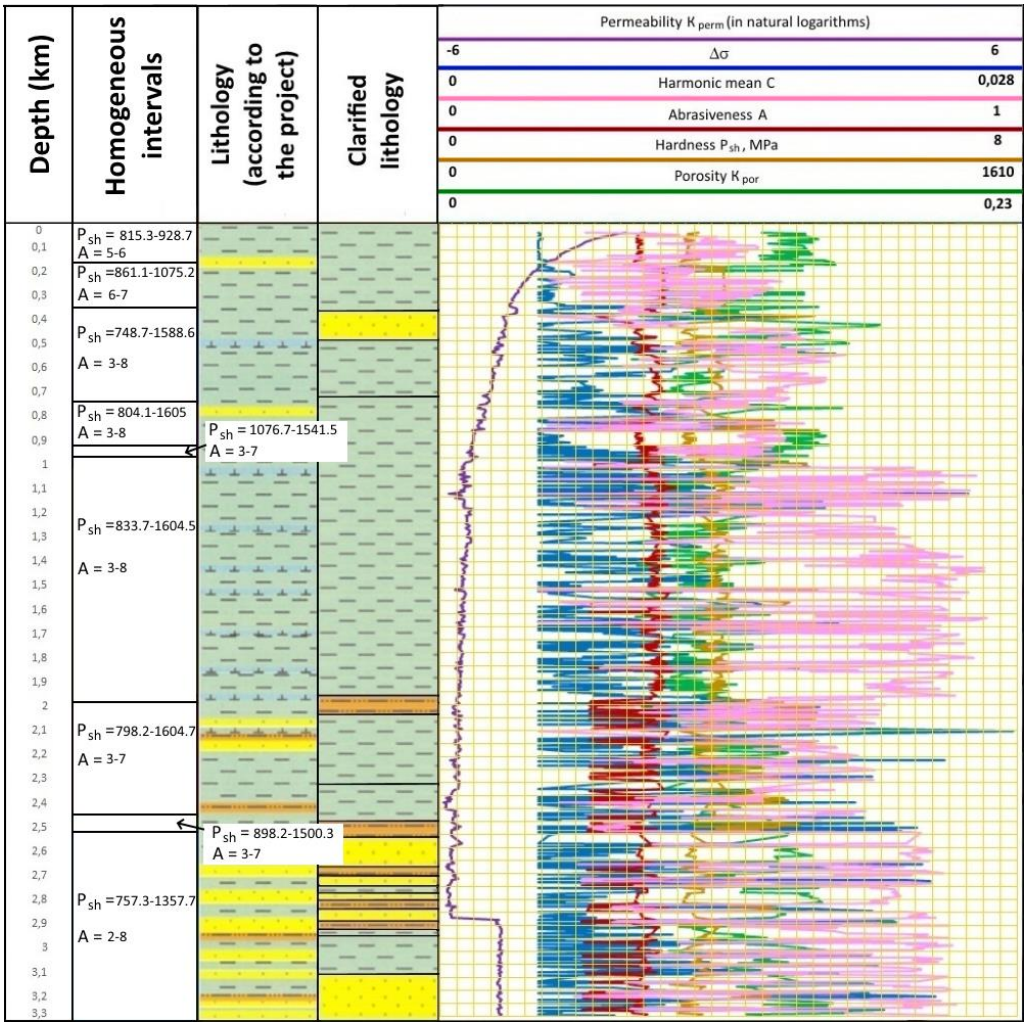


Fig. 1. Evaluations of lithological and reservoir properties and identification of homogeneous intervals

Table 1

Expressions used in calculations

Characteristics calculated during forecasting	*Calculation expression*
Distribution density	$P(x) = \frac{e^{-(x-\mu)^2/2\sigma^2}}{\sigma\sqrt{2\pi}}$
Normalized distribution density	$P(\mu) = \frac{e^{-(\mu-\mu)^2/2\sigma^2}}{\sigma\sqrt{2\pi}} = \frac{1}{\sigma\sqrt{2\pi}}$
Relative fuzzy probability	$R(x_f) = e^{-(x-\mu_f)^2/2\sigma_f^2}$
Fuzzy probability	$F(x_f) = \sqrt{n_f}\, e^{-(x-\mu_f)^2/2\sigma_f^2}$

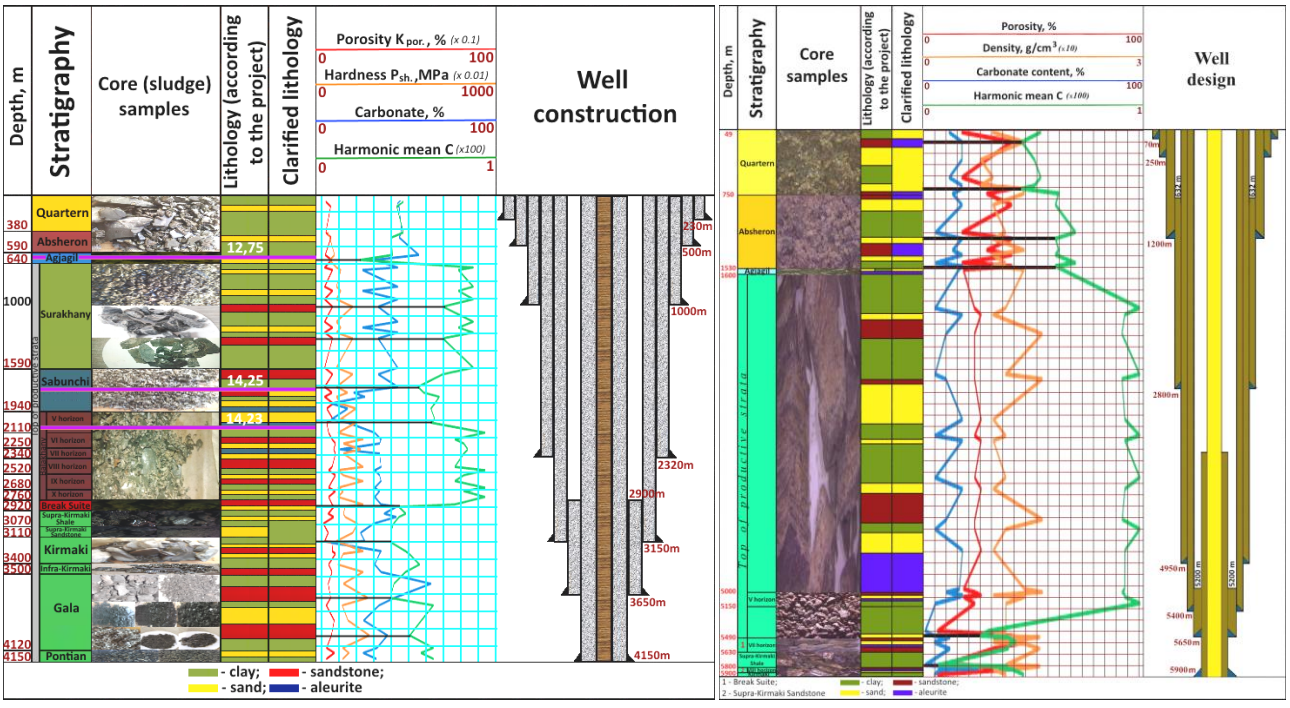
Depending on the available initial information and the task, it is possible to take certain characteristics of rocks.

In this paper, based on mud logging, we have considered examples of the use of the noted technique in separating rocks into homogeneous intervals by properties that affect drillability. In the first case, the following rock properties are selected as initial data: hardness, abrasiveness, lithology index, porosity, permeability. The mean and standard deviation of each of these properties were calculated accordingly. The arithmetic mean and standard deviation for each property are calculated based on the results of mud logging while drilling, core and geophysical studies for each lithological type of rock. The well cross-section is usually heterogeneous, i.e. it consists of several intermittent rock layers. For clarity, let us reformulate our task: we assume that we have many rock lithotypes, according to the lithological column given in the well design. It is necessary to further describe this column using a set of features characterizing a particular lithological rock difference. To do this, we have many characteristics that determine the rock type: these are the values of hardness, abrasiveness, lithology index, porosity and permeability. Based on these values, it is necessary to assign the selected rock to a particular lithological type. Using the above formulas and the computational scheme, a lithological column was built, which is shown in Fig. 1 in comparison with the design one. When building this column, as noted above, the data on porosity, permeability, hardness, abrasiveness and lithology index according to mud logging while drilling were taken as the initial ones. For each lithotype, fuzzy probabilities were determined according to (Cuddy and Glover, 2002; Efendiyev et al., 2020).

These fuzzy probabilities are then harmonically averaged to obtain a cumulative fuzzy probability (Cuddy and Glover, 2002; Efendiyev et al., 2020):

$$C_f = \frac{n}{\frac{1}{F(x_1)}+\frac{1}{F(x_2)}+\ldots+\frac{1}{F(x_n)}} \qquad (1)$$

This calculation process is performed for each lithology type *f*. The lithotype associated with the least cumulative fuzzy possibility is considered the most likely for this set of features. In the example of the well cross-section considered above, the calculations were carried out according to the specified scheme; the results are given in (Efendiyev et al., 2020). According to a similar scheme, using the above expressions, calculations were performed for wells also drilled in the fields of Azerbaijan. In (Efendiyev et al., 2021), hardness, porosity and carbonate content, in one case, while in another case, porosity, carbonate content and density (depending on the available initial information) were used as characteristics for the generalized assessment of rock drillability. The results of the calculations and the refined lithological column are shown in Fig. 2 (a, b).



a) b)

Fig. 2. Characteristics of the geological cross-section and results of identification of homogeneous intervals using: a) rock porosity, hardness and carbonate content, b) rock porosity, density and carbonate content

4. Conclusion

A computational scheme was proposed for estimating drillability of rocks associated with their properties predicted from integrated mud logging while drilling. Using the results of mud logging while drilling, the ways of building a refined lithological column are shown. Following calculations performed for the well cross-section intervals by harmonic averaging of fuzzy probabilities, intervals homogeneous in terms of rock properties affecting rock drillability were obtained. This technique which plays an important role in making decisions on selecting the process parameters can be recommended for analyzing data while drilling, clarifying the lithology and boundaries of individual types of rocks.

REFERENCES

Brown D.F., Cuddy S.J., Garmendia-Doval A.B., McCall J.A.W. The prediction of permeability in oil-bearing strata using genetic algorithms. In: Materials of the Third IASTED International Conference Artificial Intelligence and Soft Computing, Banff, Alberta, Canada, July 24-26, 2000, https: //www.researchgate.net/publication/220909228_The_Prediction_of_Permeability_in_Oil-Bearing_Strata_using_Genetic_Algorithms.

Cuddy S.J. and Glover P.W.J. The application of fuzzy logic and genetic algorithms to reservoir characterization and modeling. Soft Computing for Reservoir Characterization and Modeling, No. 1, 2002, pp. 219-241.

Efendiyev G.M., Djafarova N.M., Djevanshir R.D. The optimum decision in cutting-type drilling bits selection with regard to their operating conditions and the vagueness of the task posed. Energy sources, Vol. 13, No. 2, 1991, pp. 243-250.

Efendiyev G., Isayev R., Piriverdiyev I. Decision-making while drilling wells based on the results of modeling the characteristics of rocks using probabilistic-statistical methods and fuzzy logic. ISAIC 2020, Journal of Physics: Conference Series, Vol. 1828, 2021, https://iopscience.iop.org/article/10.1088/1742-6596/1828/1/012016/pdf

Efendiyev G.M., Kuliyev H.H., Piriverdiyev I.A. et al. Methods and tools to improve the quality of information in decision-making in well drilling management. In proceeding of scientific papers: Rock destruction and metalworking tools – techniques and technology for their production and use. Kiev, V. Bakul Institute for Superhard Materials, Vol. 22, 2019, pp. 52-62 (in Russian).

Efendiyev G.M., Mammadov P.Z., Piriverdiyev I.A. Modeling and evaluation of rock properties based on integrated logging while drilling with the use of statistical methods and fuzzy logic. 10th International Conference on Theory and Application of Soft Computing, Computing with Words and Perceptions – ICSCCW-2019. Advances in intelligent systems and computing book series (AISC), Vol. 1095, 2020, pp. 503-511.

Fang J.H. and Chen H.C. Fuzzy modeling and the prediction of porosity and permeability from the compositional and textural attributes of sandstone. Journal of Petroleum Geology, Vol. 20, No. 2, 1997, pp. 185-204.

Freund J.E. and Walpole R.E. Mathematical Statistics. Prentice-Hall. New Jersey, 1980, 548 p.

Piriverdiyev I.A. Division of the geological section into homogeneous drillability intervals based on the results of modeling the properties of rocks in the drilling process. ANAS Transactions, Earth Sciences, No. 2, 2020, pp. 33-39.

Rodionov D.A. Statistical methods of distinguishing geological objects by a set of features. Nedra. Moscow, 1968, 158 p. (in Russian).

Zadeh L. Fuzzy Sets. Information and Control, No. 8, 1965, pp. 338-353.

ЛИТЕРАТУРА

Brown D.F., Cuddy S.J., Garmendia-Doval A.B., McCall J.A.W. The prediction of permeability in oil-bearing strata using genetic algorithms. In: Materials of the Third IASTED International Conference Artificial Intelligence and Soft Computing, Banff, Alberta, Canada, July 24-26, 2000, https: //www.researchgate.net/publication/220909228_The_Prediction_of_Permeability_in_Oil-Bearing_Strata_using_Genetic_Algorithms.

Cuddy S.J. and Glover P.W.J. The application of fuzzy logic and genetic algorithms to reservoir characterization and modeling. Soft Computing for Reservoir Characterization and Modeling, No. 1, 2002, pp. 219-241.

Efendiyev G.M., Djafarova N.M., Djevanshir R.D. The optimum decision in cutting-type drilling bits selection with regard to their operating conditions and the vagueness of the task posed. Energy sources, Vol. 13, No. 2, 1991, pp. 243-250.

Efendiyev G., Isayev R., Piriverdiyev I. Decision-making while drilling wells based on the results of modeling the characteristics of rocks using probabilistic-statistical methods and fuzzy logic. ISAIC 2020, Journal of Physics: Conference Series, V. 1828, 2021, https://iopscience.iop.org/article/10.1088/1742-6596/1828/1/012016/pdf

Efendiyev G.M., Mammadov P.Z., Piriverdiyev I.A. Modeling and evaluation of rock properties based on integrated logging while drilling with the use of statistical methods and fuzzy logic. 10th International Conference on Theory and Application of Soft Computing, Computing with Words and Perceptions – ICSCCW-2019. Advances in intelligent systems and computing book series (AISC), Vol. 1095, 2020, pp. 503-511.

Fang J.H. and Chen H.C. Fuzzy modeling and the prediction of porosity and permeability from the compositional and textural attributes of sandstone. Journal of Petroleum Geology, Vol. 20, No. 2, 1997, pp. 185-204.

Freund J.E. and Walpole R.E. Mathematical Statistics. Prentice-Hall. New Jersey, 1980, 548 p.

Piriverdiyev I.A. Division of the geological section into homogeneous drillability intervals based on the results of modeling the properties of rocks in the drilling process. ANAS Transactions, Earth Sciences, No. 2, 2020, pp. 33-39.

Zadeh L. Fuzzy sets. Information and Control, No. 8, 1965, pp. 338-353.

Родионов Д.А. Статистические методы разграничения геологических объектов по комплексу признаков. Недра. Москва, 1968, 158 с.

Эфендиев Г.М., Кулиев Г.Г., Пиривердиев И.А. и др. Методы и средства повышения качества информации при принятии решений в управлении процессом бурения скважин. В сборнике научных трудов: Породоразрушающий и металлообрабатывающий инструмент – техника и технология его изготовления и применения. Киев, ИСМ им. В.Н. Бакуля НАН Украины, Т. 22, 2019, с. 52-62.

ИЗУЧЕНИЕ ГЕОЛОГИЧЕСКИХ РАЗРЕЗОВ ДЛЯ ПРИНЯТИЯ ТЕХНИКО-ТЕХНОЛОГИЧЕСКИХ РЕШЕНИЙ ПРИ БУРЕНИИ В УСЛОВИЯХ НЕОПРЕДЕЛЕННОСТИ

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Резюме. К настоящему времени накопилось большое количество исследований, посвященных получению и использованию информации о бурении скважин. Качество этой информации оказывает большое влияние на процесс принятия решений при бурении, т.к. в большинстве случаев оно происходит в условиях неопределенности. Многочисленные исследования и опыт бурения показывают, что данные, полученные в процессе бурения, требуют проведения статистической обработки и глубокого анализа. Целью исследований, основанных на применении вероятностных методов и нечеткой логики, является прогнозирование свойств пород, слагающих разрез скважины, и выделение однородных интервалов по комплексу признаков. При этом различные методы позволяют оценивать свойства горных пород как по керну, шламу, используя результаты геофизических исследований скважин, так и по данным геолого-технологических исследований при бурении. В настоящей статье рассматривается возможность использования предложенных методов на примерах конкретных скважин, т.к. их успешное применение способствует повышению эффективности изучения геологических разрезов и качества информации, получаемой в процессе бурения скважин, а также повышению качества принимаемых решений. Авторами была предложена расчетная схема для оценки буримости горных пород, связанной с их свойствами, прогнозируемыми по результатам комплексного каротажа во время бурения. По результатам ГИС при бурении показаны способы построения уточненной литологической колонны. Предложенная в статье методика может быть рекомендована для анализа данных при бурении, уточнения литологии и границ отдельных типов горных пород, что играет важную роль при принятии решений по выбору параметров процесса.

Ключевые слова: *пористость, твердость, плотность, математическая статистика, нечеткая логика, среднее гармоническое*

QEYRI-MÜƏYYƏNLİK ŞƏRAİTİNDƏ QUYULARIN QAZILMASI ZAMANI TEXNİKİ-TEXNOLOJİ QƏRARLARIN QƏBULU ÜÇÜN GEOLOJİ KƏSİLİŞLƏRİN ÖYRƏNİLMƏSİ

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Xülasə. Hal-hazırkı vaxta qədər quyuların qazılması haqqında məlumatların alınması və istifadə olunmasına dair çoxlu sayda tədqiqatların toplanması müşahidə olunur. Həmin məlumatların keyfiyyətindən qazıma zamanı qəbul edilən qərarların düzgünlüyü asılıdır. Qeyd etmək lazımdır ki, qazımada əldə edilən məlumatların keyfiyyətini burada mövcud olan müxtəlif növlü qeyri- müəyyənliklər nəzərəçarpan dərəcədə aşağı salır. Buna görə də alınan ilkin məlumatın statistik emala ehtiyacı vardır. Bu baxımdan təqdim olunmuş məqalə statistik üsullar və qeyri-səlis məntiq əsasında qazıma zamanı aparılan geoloji-texnoloji tədqiqat nəticələrindən istifadə etməklə kəsilişin litoloji-tutum parametrləri və mexaniki xassə göstəricilərinin proqnozu, bunların vasitəsilə kəsilişin bircins intervallara bölünməsi məsələsinə həsr olunmuşdur. Qeyd olunmuş üsullar və bir qədər əvvəl təklif olunmuş hesablama sxeminin tətbiqi ilə bir neçə quyu məlumatı üzərində hesablamalar aparılmışdır. Geoloji-texnoloji tədqiqat məlumatına əsasən süxurların qazılma qabiliyyəti göstəricisinin və müxtəlif bircins intervalların sərhədlərinin dəqiqləşdirilməsi üzrə hesablama nəticələri məqalədə öz əksini tapmışdır. Burada sərhədləri təyin edərkən süxurların xassə göstəriciləri üzərində müvafiq emal aparılmış, qeyri-səlis ehtimallar təyin edilmiş, nəticədə həmin ehtimallar arasında harmonik orta kəmiyyət təyin olunmuşdur. Bunun qiymətinin dəyişməsi əsasında kəsiliş üzrə bircins intervallar arasında sərhədlər müəyyənləşdirilmişdir. Məqalədə qazıma zamanı aparılan karotaj kompleksi əsasında süxurların xassələri ilə əlaqədar dağıdılma qabiliyyətinin qiymətləndirilməsi üçün hesablama sxemi təklif olunmuşdur. Qazıma zamanı quyuların geofiziki tədqiqatlarına əsasən kəsilişin litologiyası dəqiqləşdirilmişdir. Təklif olunmuş və konkret quyu timsalında həyata keçirilmiş metodika informasiya çatışmazlığı şəraitində qazıma zamanı geoloji kəsilişlərin daha dəqiq və dərindən öyrənilməsinə imkan verir və bu da qərarların qəbulu zamanı mühüm rol oynayır.

Açar sözlər: *məsaməlilik, sərtlik, sıxlıq, riyazi-statistika, qeyri-səlis məntiq, orta harmonik*