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The scientific journal News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences has been indexed in the international abstract and citation database Scopus since 2016 and demonstrates stable bibliometric performance.

The journal is also included in the Emerging Sources Citation Index (ESCI) of the Web of Science platform (Clarivate Analytics, since 2018).

Indexing in ESCI confirms the journal's compliance with international standards of scientific peer review and editorial ethics and is considered by Clarivate Analytics as part of the evaluation process for potential inclusion in the Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI), and Arts & Humanities Citation Index (AHCI).

Indexing in Scopus and Web of Science ensures high international visibility of publications, promotes citation growth, and reflects the editorial board's commitment to publishing relevant, original, and scientifically significant research in the fields of geology and technical sciences.

«Қазақстан Республикасы Ұлттық ғылым академиясының Хабарлары. Геология және техникалық ғылымдар сериясы» ғылыми журналы 2016 жылдан бастап халықаралық реферативтік және ғылымиметриялық Scopus дерекқорында индекстеледі және тұрақты библиометриялық көрсеткіштерді көрсетіп келеді.

Сонымен қатар журнал Web of Science платформасының (Clarivate Analytics, 2018) халықаралық реферативтік және наукометриялық дерекқоры Emerging Sources Citation Index (ESCI) тізіміне енгізілген.

ESCI дерекқорында индекстелуі журналдың халықаралық ғылыми рецензиялау талаптары мен редакциялық этика стандарттарына сәйкестігін растайды, сондай-ақ Clarivate Analytics компаниясы тарапынан басылмды Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI) және Arts & Humanities Citation Index (AHCI) дерекқорларына енгізу қарастырылуда.

Scopus және Web of Science дерекқорларында индекстелуі жарияланымдардың халықаралық деңгейде жоғары сұранысқа ие болуын қамтамасыз етеді, олардың дәйексөз алу көрсеткіштерінің артуына ықпал етеді және редакциялық алқаның геология мен техникалық ғылымдар саласындағы өзекті, бірегей және ғылыми тұрғыдан маңызды зерттеулерді жариялауға ұмтылысын айқындайды.

Научный журнал «News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences» с 2016 года индексируется в международной реферативной и наукометрической базе данных Scopus и демонстрирует стабильные библиометрические показатели.

Журнал также включён в международную реферативную и наукометрическую базу данных Emerging Sources Citation Index (ESCI) платформы Web of Science (Clarivate Analytics, 2018).

Индексирование в ESCI подтверждает соответствие журнала международным стандартам научного рецензирования и редакционной этики, а также рассматривается компанией Clarivate Analytics в рамках дальнейшего включения издания в Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI) и Arts & Humanities Citation Index (AHCI).

Индексирование в Scopus и Web of Science обеспечивает высокую международную востребованность публикаций, способствует росту цитируемости и подтверждает стремление редакционной коллегии публиковать актуальные, оригинальные и научно значимые исследования в области геологии и технических наук.

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ANALYSIS OF PHYSICAL AND MECHANICAL PROPERTIES OF ROCKS UNDER AHFP CONDITIONS

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Abstract. *Relevance.* Drilling wells under conditions of geological and technological uncertainty requires reliable methods for predicting abnormal pressure zones and evaluating the physical and mechanical properties of rocks. Under abnormally high formation pressure (AHFP) conditions, porosity and hardness of rocks change significantly under the influence of elevated pore pressure and temperature, which directly affects drilling safety, wellbore stability, and the efficiency of drilling operations. *Purpose.* To analyze the regularities of changes in the physical and mechanical properties of rocks under AHFP conditions and to assess the applicability of integrated geological, geophysical, and technological data for forecasting abnormal pressure zones during drilling operations. *Methods.* The study was based on statistical analysis of geological, geophysical, and geological-technological data obtained during drilling operations at oil and gas fields in

Azerbaijan and Kazakhstan. Methods of statistical approximation, comparative analysis, d-exponent evaluation, sigma logging, lithological interpretation, and integrated drilling parameter analysis were applied to determine relationships between rock porosity, hardness, depth, and pore pressure gradients. Field data obtained from drilling monitoring systems and geological surveys were processed using probabilistic-statistical approaches to identify abnormal pressure intervals and evaluate reservoir properties in real time. *Results.* It was established that under normal compaction conditions rock porosity decreases with depth, whereas hardness increases due to compaction processes. In AHFP zones, deviations from these regularities were identified, including increased porosity and reduced hardness caused by undercompaction and abnormal pore pressure development. Predictive equations describing the dependence of porosity and hardness on depth and pore pressure gradients were obtained. The integrated use of drilling indicators significantly improved the reliability of AHFP prediction compared with methods based only on mechanical penetration rate. Validation using field data confirmed the applicability and effectiveness of the developed models under different geological conditions. *Conclusions.* The obtained results can be used for forecasting abnormal pressure zones, optimizing drilling parameters, improving well design reliability, reducing drilling risks associated with kicks and borehole instability, and increasing the overall safety and efficiency of drilling operations in complex geological environments.

Keywords: well drilling, abnormally high formation pressure (AHFP), porosity, hardness, geological and technological data, prediction models

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**АНОМАЛЬДЫ ЖОҒАРЫ ҚАБАТТЫҚ ҚЫСЫМ ЖАҒДАЙЫНДА
ТАУ ЖЫНЫСТАРЫНЫҢ ФИЗИКАЛЫҚ-МЕХАНИКАЛЫҚ
ҚАСИЕТТЕРІНІҢ ӨЗГЕРУ ЗАҢДЫЛЫҚТАРЫН ТАЛДАУ**

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Аннотация. *Өзектілігі.* Мұнай-газ ұңғымаларын бұрғылау кезінде геологиялық-технологиялық белгісіздік жағдайында аномальды жоғары қабаттық қысым (АЖҚК) аймақтарын болжау және тау жыныстарының физикалық-механикалық қасиеттерін бағалау ерекше өзектілікке ие болады. Қабаттық қысым мен температураның жоғарылауы тау жыныстарының кеуектілігінің, қаттылығының және орнықтылығының өзгеруіне алып келеді, бұл бұрғылау жұмыстарының қауіпсіздігіне, сенімділігіне және тиімділігіне, сондай-ақ бұрғылау процесіндегі асқынулардың алдын алуға елеулі әсер етеді. *Мақсаты.* Аномальды жоғары қабаттық қысым жағдайында тау жыныстарының физикалық-механикалық қасиеттерінің өзгеру заңдылықтарын талдау және мұнай-газ ұңғымаларын бұрғылау процесінде аномальды жоғары қабаттық қысым аймақтарын болжау үшін кешенді геологиялық, геофизикалық және геология-технологиялық деректерді қолдану мүмкіндігін бағалау. *Әдістері.* Зерттеу Әзербайжан және Қазақстан кен орындарында ұңғымаларды бұрғылау кезінде алынған кешенді геофизикалық және геология-технологиялық деректерді талдау негізінде жүргізілді. Деректерді өңдеу үшін статистикалық аппроксимация, салыстырмалы талдау, d-экспонент, сигма-каротаж және литологиялық интерпретация әдістері қолданылды. Тау жыныстарының кеуектілігі мен қаттылығының тереңдікке және қабаттық қысым градиентіне тәуелділігіне талдау жасалып, әзірленген модельдер бұрғылаудың кешенді көрсеткіштерін пайдалану арқылы нақты кәсіпшілік деректер негізінде апробациядан өткізілді. *Нәтижелері.* Қалыпты тығыздалған жыныстарда тереңдік артқан сайын кеуектіліктің төмендейтіні, ал тығыздалу процестерінің әсерінен қаттылықтың артатыны анықталды. Аномальды жоғары қабаттық қысым дамыған интервалдарда аталған заңдылықтардан ауытқулар анықталып, олар кеуектіліктің артуымен және тау жыныстары қаттылығының төмендеуімен сипатталды. Кеуектілік пен қаттылықтың тереңдікке және қабаттық қысым градиентіне тәуелділігін сипаттайтын болжамдық теңдеулер алынды. Технологиялық көрсеткіштерді кешенді пайдалану аномальды жоғары қабаттық қысым аймақтарын болжау сенімділігін арттыруға мүмкіндік берді. *Қорытынды.* Алынған нәтижелер аномальды қысым аймақтарын болжау, бұрғылау параметрлерін оңтайландыру, ұңғымаларды жобалау

сенімділігін арттыру, мұнай-газ көріністері тәуекелдерін төмендету және күрделі геологиялық жағдайларда бұрғылау жұмыстарының қауіпсіздігін арттыру үшін қолданылуы мүмкін

Түйін сөздер: ұңғымаларды бұрғылау, аномальды жоғары қабаттық қысым (АЖҚҚ), кеуектілік, қаттылық, геологиялық және технологиялық деректер, болжамдық модельдер

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АНАЛИЗ ЗАКОНОМЕРНОСТЕЙ ИЗМЕНЕНИЯ ФИЗИКО-МЕХАНИЧЕСКИХ СВОЙСТВ ГОРНЫХ ПОРОД В УСЛОВИЯХ АВПД

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Аннотация. *Актуальность.* В условиях геолого-технологической неопределенности при бурении нефтегазовых скважин особую актуальность приобретают прогнозирование зон аномально высокого пластового давления (АВПД) и оценка физико-механических свойств горных пород. Влияние повышенных пластовых давлений и температур приводит к изменению пористости, твердости и устойчивости пород, что оказывает существенное воздействие на безопасность, надежность и эффективность буровых работ, а также на предотвращение осложнений в процессе бурения. *Цель.* Проанализировать закономерности изменения физико-механических свойств горных пород в условиях аномально высокого пластового давления и оценить возможность применения комплексных геологических, геофизических и геолого-технологических данных для прогнозирования зон АВПД в процессе бурения нефтегазовых скважин. *Методы.* Исследование основано на анализе комплексных геофизических и геолого-технологических данных,

полученных при бурении скважин на месторождениях Азербайджана и Казахстана. Для обработки данных использованы методы статистической аппроксимации, сравнительного анализа, d-экспоненты, сигма-каротажа и литологической интерпретации. Выполнен анализ зависимостей пористости и твердости пород от глубины и градиента пластового давления, а также проведена апробация разработанных моделей на фактических промысловых данных с использованием комплексных показателей бурения. *Результаты и выводы.* Установлено, что в нормально уплотненных породах пористость уменьшается с увеличением глубины, тогда как твердость возрастает вследствие процессов уплотнения. В интервалах развития аномально высокого пластового давления выявлены отклонения от указанных закономерностей, проявляющиеся увеличением пористости и снижением твердости пород. Получены прогнозные уравнения, описывающие зависимости пористости и твердости от глубины и градиента пластового давления. Комплексное использование технологических показателей позволило повысить достоверность прогнозирования зон АВПД. Полученные результаты могут быть использованы для прогнозирования зон аномального давления, оптимизации параметров бурения, повышения надежности проектирования скважин, снижения рисков нефтегазопроявлений и повышения безопасности буровых работ в сложных геологических условиях.

Ключевые слова: бурение скважин, аномально высокое пластовое давление (АВПД), пористость, твердость, геолого-технологические данные, прогнозные модели

Introduction. In recent years, there has been intensive development of methods and systems for obtaining geophysical and geological-technological information during drilling. These systems make it possible to monitor the drilling process and make both geological (identification of productive formations, abnormally high formation pressure (AHFP) zones, lithological stratification, assessment of reservoir properties) and technological decisions based on complex data on operating parameters, drilling properties, and the analysis of core and cuttings. This enables the prompt resolution of both geological tasks (such as identifying productive layers, zones of abnormally high formation pressure (AHFP), lithological stratification and evaluating the reservoir properties of formations) and technological tasks, i.e., decision-making.

It should be noted that decision-making during well drilling most often occurs under conditions of uncertainty, where the quality of information plays a crucial role. Poor-quality data is one of the primary causes of erroneous decisions, which ultimately results in a decline in the technical and economic performance of drilling operations. Therefore, corresponding methods are employed that allow for the resolution of such tasks using the available data while considering the inherent uncertainties.

Despite numerous studies conducted in this field, the issues related to evaluating

geological section characteristics and making informed decisions remain highly relevant and demand further attention.

Current State of the Problem in Acquiring and Using Information for Decision-Making in Well Drilling. The properties of formations in geological sections have been studied by various researchers at different times. In the course of these studies, the authors have sought to determine both the nature of formation changes and the influence of specific factors on the properties under investigation.

In (Ikon et al., 2009) graphs were constructed for the central and northern regions of the West Siberian Lowland that confirmed the well-known trend of decreasing porosity and permeability with depth. In addition to developing a general model of these changes, attention was drawn to specific behavioral features of these parameters. For example, the graphs presented in the article delineated two zones: the upper zone, down to a depth of 2300 m, is characterized by the presence of reservoirs primarily classified as permeability Classes I-III, while the lower zone (below 2300 m) contains reservoirs of Classes IV-V (according to A.A. Khanin's classification). An explanation was provided for the deterioration of reservoir properties with depth.

- The influence of depth on the degree of change in filtration-capacity and mechanical properties, as well as the specific nature of this process, has also been investigated by other researchers. These studies helped to better understand the behavior patterns of core parameters in various types of geological sections (Abasov et al., 2007; Irbe and Shestakova, 1986; Sonich et al., 1997).

Differences in the geological features of most fields are largely attributable to the variations in how rock properties depend on depth.

Thus, with increasing depth, the presence of abnormally high formation pressure (AHFP) zones significantly influences the nature of changes in filtration-capacity and mechanical properties, which is typical for most oil and gas fields. Another group of studies focuses on methods and tools for evaluating the physical and mechanical properties of rocks based on integrated data obtained during the drilling process.

- When analyzing bit performance, it is advisable to divide the geological section into homogeneous intervals and to consider the trends of drilling parameter variations within them. Various classification methods exist. One simple method enabling such segmentation is the approach proposed by D.A. Rodionov (Rodionov, 1968; Rodionov D.A. 1981), which has been used in several studies, including (Efendiyev et al., 1991; Efendiyev et al., 2020; Dmitrievsky et al., 2020).

Studies (Efendiyev et al., 2020; Efendiyev et al., 2020; Isayev and Pereverdiyev, 2021), have demonstrated changes in rock hardness and abrasiveness with depth compared to mechanical penetration rates using different types of drill bits.

In recent years, fuzzy logic has been successfully applied in the assessment and utilization of reservoir properties (Efendiyev et al., 2020; Zadeh et al., 1965; Fang and Chen, 1997; Freund and Walpole, 1987; Cuddy and Glover, 2002; Brown et al., 2000).

In works (Efendiyev et al., 2020; Efendiyev et al., 2020; Isayev and Pereverdiyev, 2021; Freund and Walpole, 1987; Cuddy and Glover, 2002), these methods have been applied to predict the lithology of geological formations in wells drilled in Azerbaijan based on a set of indicators (hardness, abrasiveness, lithological index, porosity, permeability, etc.) obtained from geological, geophysical, and technological studies conducted during drilling. The analysis of property distributions in (Efendiyev et al., 2020; Efendiyev et al., 2020; Isayev and Pereverdiyev, 2021), showed that, except for permeability, all characteristics follow a normal distribution (permeability is known to follow a log-normal distribution, and thus its logarithmic values are used).

In this paper, using formulas based on probability theory and fuzzy logic methods described in (Efendiyev et al., 2020; Efendiyev et al., 2020; Isayev and Pereverdiyev, 2021; Cuddy and Glover, 2002), calculations of geological section characteristics were carried out. Lithology estimations were made, homogeneous intervals by drillability were identified, and overall, by generalizing the noted results and applying the corresponding computational schemes, an approach to information preparation for well drilling process modeling was demonstrated using selected wells as examples.

The computational schemes proposed in the referenced works can be summarized as follows (Efendiyev et al., 2020; Efendiyev et al., 2020; Isayev and Pereverdiyev, 2021; Cuddy and Glover, 2002):

- Calculate the arithmetic mean μ and standard deviation σ ;
- Determine the probability density function $P(x)$;
- Compute the relative fuzzy probability $R(x)$;
- Define the fuzzy probability $F(x)$ by multiplying $R(x)$ by the relative frequency;
- Calculate the reciprocals and then determine the harmonic mean C_f .

This process is repeated for each lithotype. The lithotype with the highest total fuzzy probability is considered the most probable for the given set of indicators. The corresponding fuzzy probability enhances the reliability of the lithological prediction.

In general, the literature review has demonstrated the possible approaches to decision-making in the evaluation of geological section characteristics based on integrated data usage. It has also helped refine the boundaries between lithological variations under conditions of uncertainty.

At the same time, the analysis of the current state of research into the modeling and decision-making processes in well drilling has revealed the following:

The issue of developing a methodology for rock classification, as well as modeling and decision-making methods that take into account the uncertainty of the relevant conditions, remains insufficiently addressed.

It should be emphasized that well drilling is complicated by various types of uncertainties. These are manifested as multicriteria decision-making, ambiguity of criteria, inaccuracies, and incompleteness of input data, as well as the need for

data processing. This situation necessitates the use of appropriate mathematical methods.

Summarizing the accumulated experience in geological section analysis and decision-making during drilling operations, the following can be stated: Existing studies present the results of geological section characterization, statistical analysis, and model building aimed at forecasting drilling speed and cost per meter of penetration for a given bit type in specific rock formations. However, the main limiting factor in applying current methodologies in this area is the insufficient utilization of integrated information obtained from geophysical and geological-technological studies during drilling. This shortfall is compounded by the inadequate use of modern methods in data processing and analysis, which could otherwise improve both data quality and the soundness of decisions made.

Overall, the analysis of the current research state regarding modeling and decision-making processes in drilling operations has identified several factors that hinder the acquisition of high-quality information and the making of informed decisions. These include the presence of various types of uncertainties, such as multicriteria nature of decisions, ambiguity of criteria, inaccuracies, incomplete input data, and the resulting need for comprehensive data processing. This necessitates the analysis of integrated information using appropriate mathematical methods.

Methods and Materials. Research indicates that under normal drilling conditions - where bit load, rotor speed, and hydraulic characteristics of the drilling fluid flow remain relatively stable - a decrease in mechanical penetration rate with depth is typically observed. This trend is attributed to the increasing density of rocks with depth. However, in zones of transitional and abnormally high formation pressure (AHFP), penetration rate increases (Karabalin et al., 1989). From the perspective of AHFP formation theories, regardless of their origin, undercompaction of rocks is observed in AHFP zones. This leads to an increase in rock porosity, causing the rocks to become softer and, thus, easier to drill at relatively higher rates. Furthermore, differential pressure - i.e., the difference between the hydrostatic pressure of the drilling mud column and the formation pressure - also influences the mechanical penetration rate. A reduction in this differential pressure results in an increase in drilling speed.

As mentioned earlier, these patterns form the basis for identifying AHFP zones based on mechanical penetration rates.

This method is used as a qualitative approach for AHFP prediction and, in many cases, provides a clear indication of the presence of such zones. However, it also has a number of significant limitations. For mechanical penetration rate to serve as a reliable AHFP indicator, drilling conditions must remain relatively constant, including bit load, rotational speed, and hydraulic parameters. In practice, maintaining such conditions is not always feasible. Secondly, bit wear has a considerable effect on penetration rate and must also be accounted for. Additionally, accurate knowledge of the lithology of the drilled formations is

necessary. The difficulty of identifying AHFP zones using mechanical rate alone is illustrated by the data in various studies, including (Karabalin et al., 1989; Sementsov G., et al., 1986).

Earlier in the review of geological section evaluation methods using technological data, different approaches were mentioned, including the d-exponent and sigma logging (Aghayev, 1989; Turksen I.B. 2013). Under normal conditions, the d-exponent typically increases proportionally with depth. Approaching an AHFP zone is characterized by a decrease in the d value and a deviation of the graph below the normal trend line. In (Karabalin et al., 1989; Shvedov A.S. 2013), patterns of d variation under drilling conditions at the eastern margin of the Pre-Caspian Basin were studied, and the suitability of the d-exponent method for AHFP prediction and determination in this region was confirmed.

During the drilling of wells, the following parameters were recorded either using drilling monitoring stations or manually: bit load, standpipe pressure, number of rotor revolutions per minute, number of pump strokes per minute, drilling fluid parameters, and mechanical drilling time for each meter of penetration.

A program was developed based on the well-known d-exponent formula. However, in many cases, using only this method proved insufficient due to the ambiguity in identifying AHFP zones. Therefore, a program was applied that included both d-exponent and sigma logging calculations. This is especially important in complex sections such as those found in the Pre-Caspian Basin, where a single method is not enough and supplementary data must be employed.

As shown in Figure 1, neither the d-exponent nor sigma logging curves alone are sufficient to clearly identify AHFP zones. The addition of a curve generated using the automatic selection method described earlier allows for more accurate determination of the relevant intervals. The spike in the L-statistic graph indicates system heterogeneity, in this case manifested by a transition to zones of elevated pressures.

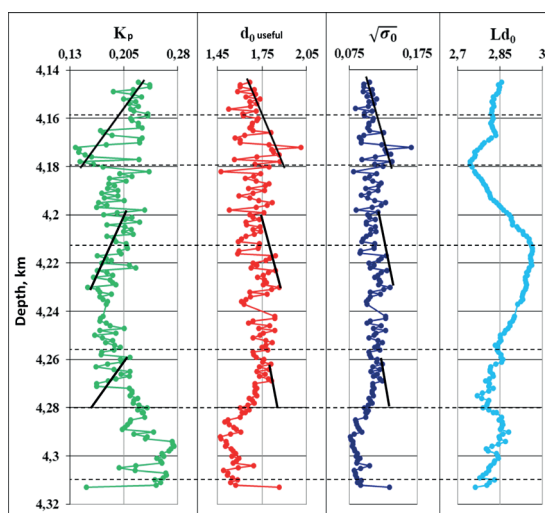


Figure 1. D-exponent and sigma logging data obtained during well drilling.

This article examines the patterns of variation in the physical and mechanical properties of rock formations at certain fields, using integrated geological, geophysical, and technological data. The analysis focused on data obtained from wells drilled in various locations, based on the results of geological and technological studies carried out during drilling and the implementation of a corresponding program. This program enabled the evaluation of various geological section characteristics, including key physical and mechanical properties of rocks such as porosity, permeability, Poisson’s ratio, hardness, and others.

As an example, Figure 2 illustrates the relationships between rock porosity and hardness with depth. Under the pressure of overlying strata, clays become compacted and release bound water. As a result, porosity should generally decrease with depth under normal conditions, while hardness typically increases. However, as shown in the figure - based on data from several nearby wells - these dependencies exhibit ambiguous behavior.

As noted in a number of studies, the analyzed geological section is characterized by the presence of AHFP zones, where a noticeable increase in porosity and decrease in hardness is observed. Therefore, in constructing these curves, values representative of normal zones were used first, while points corresponding to AHFP zones were highlighted in a different color.

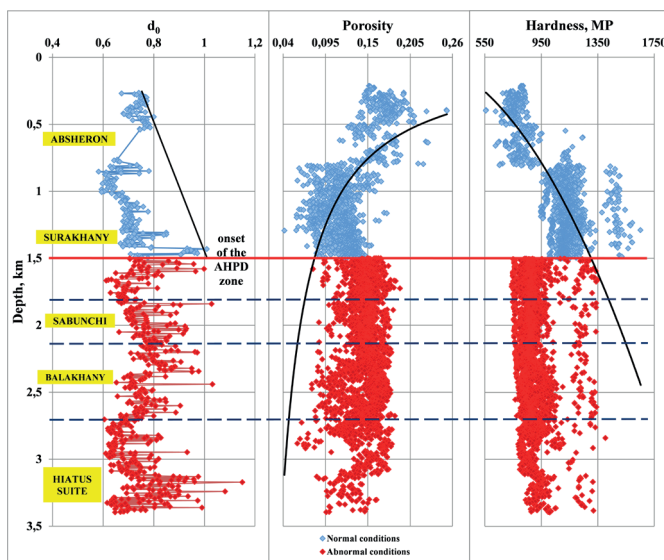


Figure 2. Changes in rock porosity and hardness with depth.

Results and Discussion. Statistical analysis made it possible to approximate the relationship between porosity and depth for the normal zone using the following expression:

$$k_p = 0,119H^{-0,29} \tag{1}$$

where k_p is rock porosity, and H is vertical depth.

The relationship between hardness and depth in the normal zone is expressed as:

$$P_{sh} = 1060H^{0,306}, \quad (2)$$

where P_{sh} is rock hardness and H is depth.

For AHFP zones, a clear dependence on depth could not be established. However, with an increasing pore pressure gradient, a consistent increase in porosity is observed, described by:

$$k_p = 0,132e^{0,453(-)}, \quad (3)$$

where $(-)$ is the difference between the actual and normal pore pressure gradients.

An increase in pore pressure gradient also leads to a consistent decrease in hardness, expressed by:

$$P_{sh} = 929,5e^{-0,20(-)}, \quad (4)$$

By combining equations (1) and (3), the following relationship for porosity as a function of depth and pore pressure gradient is obtained:

$$k_p = 0,19H^{-0,56}e^{0,88(-)}, \quad (5)$$

Likewise, combining equations (2) and (4), the relationship for hardness becomes:

$$P_{sh} = 820H^{0,126}e^{-0,084(-)}, \quad (6)$$

Statistical analysis and comparative calculations showed that the average error was approximately 8.5%.

Differences in the geological characteristics of most fields are also explained by variations in the nature of these depth-dependent relationships.

Similar calculations were also performed for one of the fields in Kazakhstan. Using the initial data, the previously obtained expression was adapted to the conditions under consideration, resulting in the following expression for estimating the porosity of the rocks in the section of the Aktum field:

$$K_p = 52H^{0,2} * e^{20,1(\eta - \eta_n)} \quad (7)$$

Figure 3 shows a plot of this relationship. The distribution of data points on the plot also allows for the identification of abnormally high formation pressure

zones. A well log section is also provided, which includes information on lithology, stratigraphy, porosity variation, and well design. As can be seen, the transition intervals to zones with abnormally high formation pressure are consistent across the results obtained from the different data types.

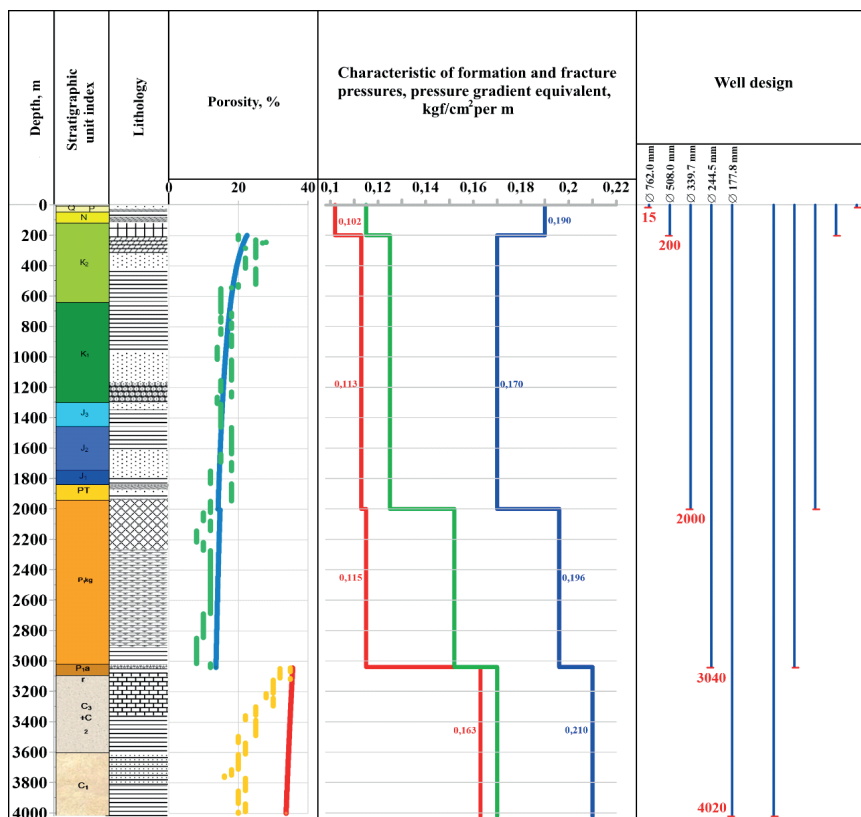


Figure 3. Stratigraphy, lithology, change in porosity of section rocks (green, orange – actual data; purple, red – calculated), characteristics of formation and fracture pressures, pressure gradient equivalent, well design of the Aktum field.

Conclusion. The presence of a correlation between pore pressure and porosity of clay rocks enables the prediction and quantitative assessment of abnormally high-pressure zones based on direct and indirect measurements of clay porosity changes with depth. The main procedure involves identifying the trend of porosity decrease with depth under normal conditions and detecting and quantifying deviations from this trend in AHFP zones. Currently, geological and technological research allows for obtaining such data during the drilling process, which in turn enables adjustment of drilling mud density to prevent oil, gas, and water shows and/or borehole wall instability directly during drilling.

Thus, with increasing depth, the presence of AHFP zones in the section significantly affects the character of filtration-capacity and mechanical property

changes - a pattern typical for most Azerbaijani fields. The obtained results can be used in the future to refine the data required for well design.

Equations have been derived to estimate rock porosity and hardness. These equations enable the prediction of these properties across different areas of the geological section.

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