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MINING-WELL DRILLING TECHNOLOGIES AS THE MOST IMPORTANT DIRECTION FOR THE DEVELOPMENT OF SHALE OIL RECOVERY INNOVATIVE METHODS

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ШАХТНО-СКВАЖИННІ ТЕХНОЛОГІЇ – ВАЖЛИВІШИЙ НАПРЯМ РОЗВИТКУ ІННОВАЦІЙНИХ МЕТОДІВ ВИДОБУТКУ СЛАНЦЕВОЇ НАФТИ

Purpose. Establishment of the promising directions for development and creation of cost-effective and environmentally friendly methods of shale oil production from oil-and-gas bearing shale deposits of deep-laying rock massifs.

Methodology. The analysis of the occurrence and characteristics of shale oil deposits of the bazhenov rock formation in Western Siberia has been made.

Findings. As is shown, the development and mining of deep-laying shale oil-and-gas deposits through conventional down-hole oil production technologies necessitates a dramatic increase in drilling effort as for the output wells. They do not provide any increase in the low values of the oil recovery factor, and are associated with significant adverse ecological effect on the environment in the regions of occurrence of shale reservoirs. The innovative mining-well drilling technology for cost-effective and environmentally safe oil production from deep shale oil-and-gas deposits has been offered.

Originality. The proposed innovative technology allows drilling-in and preparation of hydrocarbon-bearing formation by mine shafts and mine permanent workings. Production of hydrocarbons is carried out by excavation blocks of the output wells with hydraulic fracturing and other impacts on the reservoir, which are drilled from underground chambers of major mine workings; pre-cleaning and separation of shale oil takes place in underground conditions, shale gas is used for power supply and enhancement of operating efficiency of the underground energotechnological complex. After final cleaning and preparation in the course of the surface work, shale oil is to be delivered to consumers.

Practical value. An opportunity to involve major shale oil and gas deposits for shale oil and gas production into the effective development is provided through the rational combination of well-established and widely used in mining methods and technologies of underground and borehole mining.

Keywords: *mining-well drilling method, shale oil, bazhenov formation, technological scheme*

The innovative development of the oil extraction is usually associated with the necessity of oil extraction intensification and increase in the oil-recovery ratio (ORR) owing to efficient implementation of different methods for oil-recovery increase (MORI). In the middle of the last century a significant increase in oil extraction was associated with the discovery and bringing into the development of a number of the biggest so called traditional oilfields, as well as with the usage on a mass scale of the new, for the domestic industry, method of oil recovery increase in strata, developed on the basis of theoretical notions about the mechanism of the piston displacement of oil by water in the uniform permeable layers – reservoirs. In particular, a wide introduction of methods of waterflooding largely predetermined the development of the domestic theory of oilfields working, which contributed to successful realization of a great number of the development systems differentiated by the types of waterflooding (edge, block, areal, selective, etc), pattern arrangement, placement of operation and injection wells, intensity and schedules for operation and injection, etc. However, the limit of the resource base and exhaustion of oil deposits on traditional oilfields has led in recent years to the search and attempts for industrial development of new sources and reserves of hydrocarbons to which the oil of bituminous sand, high-viscosity oil, fissured reservoirs, hydrocarbons of pyroshale oil, as well as oil and gas of the shale deposits (plevs), sometimes considered within the concept of unconventional oil and gas, are relevant. It is quite natural that for non-traditional oil development it is necessary to use not only the whole accumulated arsenal of knowledge of techniques and technologies when mining the traditional deposits, but also the solution of principally new scientific technological tasks valid to the character and level of the problem complexity arising at that as well.

As is known, the whole range of technologies, methods and ways currently in use to develop the oil containing layers are divided into two large groups [1]: open-cut mining (methods) of development and the development by means of well drainage of the oil-gas deposits with the wells drilled from the earth surface. First, it is necessary to point out that practically all existing and everywhere applied the well drilling technologies of oil and gas extraction refer to the group of technologies with the wells drilled from the earth surface. Open-cut mining technologies involve thoroughly known, though less widespread open-cast and shaft technologies; the former, applied when developing bituminous sands and pyroshale oil for the future extraction of hydrocarbons from them, and the latter, applied for the thermal recovery of the high-viscosity oil, for example [2], when developing relatively shallow layers (up to 300–400 m) of productive deposits.

The existing different evaluations, forecasts, as well as the real facts, show that the most promising perspectives as for the non-traditional oil and gas extraction in the near future will be associated, first of all, with the development of the shale oil-and-gas-bearing deposits. In this way, the stabilization of the oil extraction levels in Western Siberia and its future development is connected with drawing into mining of so called hard-to-recover reserves (HtRR) and, above all, with oil extraction from shale deposits of the bazhenov rocks formation. The bazhenov formation is a unique oil and gas object with the high heterogeneity of the formation and the tessellated character of low filtration-capacitive properties, formation isolation, high hydrophoby and other geological characteristics. The deposits of the bazhenov formation become widespread in the Western-Siberian part of the oil-and-gas-bearing basin. In average, they are deposited at the depth of 1500–3000 m, the bazhenov formation thickness in the normal cut constitutes 25–30 m, and in a number of cases (the abnormal cut) it reaches 90–100 m. The deposit thickness of the bazhenov formation containing hydrocarbons fluctuates from 10–12 to 35–40 m, and amounts to 60 m in some area.

At present, as the result of researches carried out by many authors the following peculiarities of the bazhenov rocks formation are found out: comparatively low thickness when the square of extension exceeds 1 mln. km^2; thin-layer, stratum capacity and folium structure, the abnormal high values of apparent resistance exceeding 500 Om-m (quite often reaching 1000 Om-m); high and abnormal high values of natural gamma activity; abnormal low formation density; the underspeed of the acoustic and seismic wave transition through the thickness of the bazhenov clay stone; the abnormal high stratum pressure in deposits; the confinement of the wells with the most significant production rate within the high temperature areas reaching 135°C; the low porosity and permeability of the bazhenov formation reservoirs; the availability of the vertical and horizontal cavities.

The low reservoir`s characteristics, especially poor rock permeability of adjacent strata, is the main obstacle for industrial development of the oil-gas potential of the bazhenov formation, which is one of the world`s largest shale deposits (plevs) notable for the high oil-and-gas-bearing. According to the optimistic evaluations, the deposits of the bazhenov formation, the size of about 1mln.square kilometers, on the territory of Western Siberia contain several tens of milliard tons of high quality light crude oil with the great amount of accompanying shale gas. The development of the shale oil deposits in the bazhenov formation will allow preventing already started decrease in oil extraction from the non-traditional oil-gas deposits in Western Siberia and could become a real alternative to a rather cost intensive and far from indubitable development of the hard-to-reach oil-and-gas deposits in the Arctic and Eastern Siberia.

The existing at present the well drilling technologies for exploration, prospecting and workings of traditional oil-and-gas deposits to a large extent are of a random character with a sufficient portion of contingency and rather poor coefficient of oil extraction. That is why, when developing deep-seated shale oil-and-gas-bearing deposits, in particular, such as the bazhenov formation in Western Siberia, it is necessary to apply principally new approaches that, on the one hand, minimize the elements of randomness and the costs of mining operations and, on the other hand, provide maximization of the oil-and-gas extraction coefficient and in this way, in general, lead to the economic efficiency increase in oil-and-gas production. But as it was shown above as well as it comes from the current events, ad verbum, in all parts of the world when conducting a large-scale development of oil-and-gas shale deposits, the problems of ecological purity of hydrocarbons are coming to the fore with simultaneous provision of requirements on economic efficiency of such production.

All the above mentioned proves that de facto, the matter concerns the necessity of transition to the technology of the broadwall or, let us say, “stripping” of the shale deposits to some extent, as it was during the last several centuries put into practice by the underground workings of the formation deposits of the solid fuel – coal. The fact is that according to the available data, due to the tessellated character of the oil-and-gas-bearing of the shale deposits in the bazhenov formation, only 30% of the hydrocarbons resources are concentrated in so called the intervals of high oil-and-gas recovery. At present, it is natural that oil companies make efforts towards the search and involvement in the development of these “inclusions” through the existing well drilling technologies. At the same time, of course, the remaining 70% are not taken into account.

As shown by our studies, the final decision making on the main problems of the oil extraction from the deep seated oil-and gas-bearings of shale deposits, with the problem of large scale development of oil and gas reserves of the bazhenov rock formation in Western Siberia primarily kept in mind, calls for the rational multipurpose use, within the framework of an integrated power complex, both the above mentioned opencast (namely, the shaft) mining method of development in order to open and prepare the deposit for working, and the simultaneously applied subsequent method of draining of the productive deposit, but by means of the wells drilled from the underground drill chambers.

In fact, the case in point is, let us say, the development of the third group, as we call it the mining-well drilling innovative technology, which helps rationally combine the whole experience accumulated over the centuries concerning the development technology for the underground (shaft) mining of the bedded deposits, mainly of solid fuels such as coal,

and on the other hand, takes into account all achievements in the contemporary oil and gas business.

The basic idea of the proposed innovative mining-well drilling technology for the oil and gas extraction from the shale deposits of the bazhenov rocks formation in Western Siberia is that the drilling-in and preparation of the productive formation is carried out by mine shafts and underground permanent workings; production of hydrocarbons is carried out by means of excavation blocks/units of the production wells with the hydraulic fracturing and other impacts on the reservoir, which is drilled from underground chambers of major mine development workings. Pre-treatment and separation of shale oil are in underground conditions, and the shale gas is used for power supply and efficiency increase in the operation of the underground power technological complex, and shale oil after the final cleaning and preparation at the surface is delivered to consumers. The proposed innovative technology, in fact, is adequate to the given problem of combining the two main at present technologies of the mining production, namely, the technology of the underground (mine) workings of the bedded deposits and the technology of the well extraction of oil and gas.

Fig. 1 shows the integrated technological scheme of the underground power technological complex for the mining-well oil extraction from deep seated shale deposits, where: *1* – shale oil-and-gas bearing formation (deposit); *2* – the main vertical mine shaft; *3* – auxiliary (ventilation) mine shaft; *4* – pit bottom; *5* – the main preparatory underground drift; *6* – auxiliary (ventilation) preparatory underground drift; *7,8* – underground chambers and drilling installations (rigs) correspondingly; *9* – drill pipe string; *10* – underground accumulating workings-chambers (pools) for the flowback of the liquid after hydraulic fracturing of the productive formation.

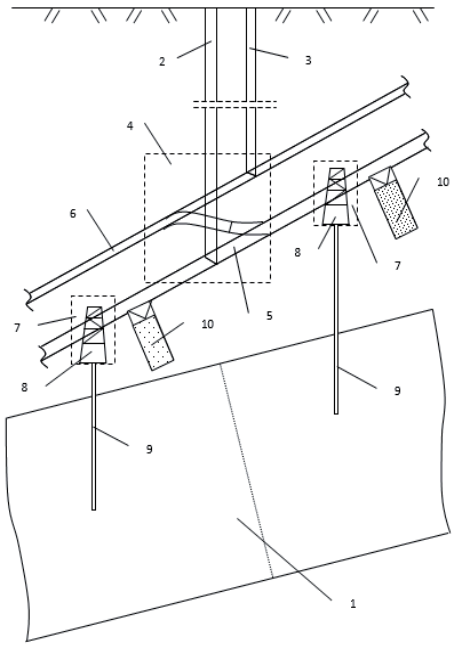

Fig.1. The integrated technological scheme of the underground energotechnological complex for the mine-well oil extraction form deep seated shale deposits

The integrated technological scheme takes into account specific peculiarities and characteristics of the formation bedding on the territory of the shale oil (within the limits of the mine field) as well as the specific goals and peculiarities for the creation of such complexes and may be realized with the help of a number of so called basic material and technical floods, technologically different as for their types and combinations, and circulating (passing) between the daylight surface and the underground space in the mine part of the power complex.

One of the basic technological schemes of the underground energotechnological complex for the mine-well oil extraction from the shale deposits of the bazhenov formation of rocks with the help of the mine- well technology is given in Fig. 2, where: 1_1, 1_2 – excavation (extraction) units of the shale deposits; *2* – the basic (main) mine shaft of the technological complex; *4* – pit bottom mining; 5_1,5_2 – the basic underground preparatory excavations; *14* – production tree and wellhead assembly for underground output wells operation 15_1, 15_2 – pipelines for well-stream gathering; *16* – underground equipment for the shale oil separation (the degassing) and pretreatment; *17* – shaft pipeline for the shale oil; *18* – supply pipeline of the shale gas; *19* – underground steam-boiler; *20* – supply water pump; *21* – underground pumped storage tank; *22* – shaft heat-insulated steam pipe line; *23* – steam turbine of the surface steam-turbine department; *24* – electric generator; *25* – the waste steam condenser; *26* – the onsetter pipeline for spillway; *27* – underground hydro generator; *28* – the onsetter discharge pipeline for flue gases; *29* – surface cleaning filters; *30* – flue-gas pump; *31* – flue funnel; *32* – surface equipment (department) for refining and preparation of shale oil; *33* – outlet pipelines for the liquid of the flowback after hydraulic fracturing. This Figure does not show conventional positions of *11*–*13*.

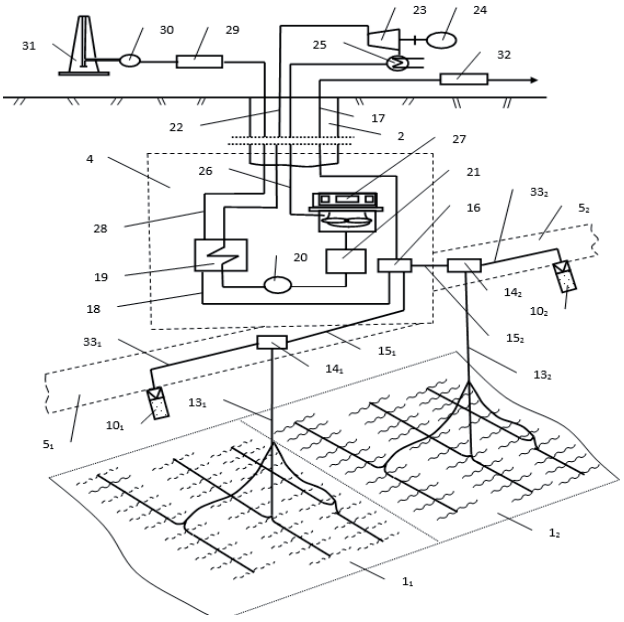

Fig. 2. The basic technological schemes of the underground energotechnological complex for extraction, processing and use of oil and gas under the mine-well working of the deep seated shale deposits

We consider them as technological elements for creation and preparation of efficient draining system of the output wells in the excavation units1_1, 1_2 – of the shale deposit, which is one of the decisive conditions for economic efficient environmentally friendly development and working of the deep-seated oil-and-gas bearing shale deposits. In view of exceptional difficulty and importance, this problem requires individual (independent) consideration. The general ideology and main principles of construction and operation of the underground energotechnological complexes were presented in details earlier, in a number of works with reference to the mining of bedded deposits of the solid fuel, i.e. coal-fields, for example in [3], though, owing to both objective and subjective reasons and factors, they still do not get a proper development and practical implementation. In conclusion, it is worth mentioning one more, all-important, in our opinion, problem, which the contemporary oil and gas production business increasingly tackles. The matter is that the creation of the infrastructure and funds necessary for developing and working of the oil and gas fields, especially in the remote and northern regions of Russian Federation, calls for rather high capital intensity and considerable initial costs. On the other hand, with a high intensity of fields' development, the life duration of the latter is reducing and is for 25–30 years because of exhaustion of excavated deposits; afterwards, this expensive infrastructure becomes practically useless and the residual value of the created capital fund tends close to zero.

In this term, with the mine-well working of the deep seated oil and gas shale deposits, the situation is more favorable since the developed (formed) underground space in the mine part of the energotechnological complex could receive another, quite often, long life from the point of other goals of usage and possibilities for rational application. It is becoming especially important for Western Siberia where in fact, the whole infrastructure necessary for oil and gas extraction has been created, and where there is one of the world's largest oil-and-gas bearing fields of the shale deposits of the bazhenov rocks formation, not mentioning the fact that inexhaustible resources of oil and gas as well as the other minerals are concentrated even in deeper seated productive strata in the depths of Western Siberia.

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Мета. Встановлення перспективних напрямів розробки та створення економічно вигідних і екологічно безпечних методів видобутку сланцевої нафти з нафтогазовміщуючих сланцевих покладів глибокозалягаючих масивів гірських порід.

Методика. Виконано аналіз умов залягання та характеристик сланцевих покладів баженовскої свити гірських порід Західного Сибіру.

Результати. Показано, що освоєння й відпрацювання глибокозалягаючих сланцевих нафтогазоносних покладів за допомогою традиційних свердловинних технологій видобутку нафти диктує необхідність різкого збільшення обсягу робіт з буріння видобувних свердловин, не забезпечує підвищення низьких значень коефіцієнта вилучення нафти та пов'язане зі значними екологічно несприятливими впливами на навколишнє середовище в регіонах залягання сланцевих продуктивних пластів. Запропонована інноваційна шахтно-свердловинна технологія економічно ефективного та екологічно безпечного видобутку нафти з глибокозалягаючих сланцевих нафтогазоносних покладів.

Наукова новизна. Наукова новизна запропонованої інноваційної технології полягає в тому, що розкриття та підготовку продуктивного пласта здійснюють шахтними стовбурами й капітальними підземними гірничо-підготовчими виробками, а видобуток вуглеводнів здійснюють виїмковими блоками видобувних свердловин з гідророзривом та іншими видами впливу на пласт, що бурять з підземних камер основних гірничо-підготовчих виробок. Попередню очистку й сепарацію сланцевої нафти ведуть у підземних умовах, сланцевий газ використовують для енергозабезпечення та підвищення ефективності функціонування підземного енерготехнологічного комплексу, а сланцеву нафту після остаточного очищення та підготовки на денній поверхні постачають споживачам.

Практична значимість. Забезпечення можливості залучення до ефективної розробки великих сланцевих нафтогазоносних покладів для видобутку сланцевих нафти й газу шляхом раціонального поєднання добре відпрацьованих і широко використовуваних у гірничій справі методів і технологій шахтного та свердловинного видобутку корисних копалин.

Ключові слова: *шахтно-свердловинний метод, сланцева нафта, баженовська свита, технологічна схема*

Цель. Установление перспективных направлений разработки и создания экономически выгодных и экологически безопасных методов добычи сланцевой нефти из нефтегазосодержащих сланцевых залежей глубокозалегающих массивов горных пород.

Методика. Выполнен анализ условий залегания и характеристик сланцевых залежей баженовской свиты горных пород Западной Сибири.

Результаты. Показано, что освоение и отработка глубокозалегающих сланцевых нефтегазоносных залежей с помощью традиционных скважинных технологий добычи нефти диктует необходимость резкого увеличения объема работ по бурению добывающих скважин, не обеспечивает повышения низких значений коэффициента извлечения нефти и сопряжено со значительными экологически неблагоприятными воздействиями на окружающую среду в регионах залегания сланцевых продуктивных пластов. Предложена инновационная шахтно-скважинная технология экономически эффективной и экологически безопасной добычи нефти из глубокозалегающих сланцевых нефтегазоносных залежей.

Научная новизна. Научная новизна предлагаемой инновационной технологии заключается в том, что вскрытие и подготовку продуктивного пласта осуществляют шахтными стволами и капитальными подземными горно-подготовительными выработками, а добычу углеводородов осуществляют выемочными блоками добычных скважин с гидроразрывом и другими видами воздействия на пласт, которые бурят из подземных камер основных горно-подготовительных выработок. Предварительную очистку и сепарацию сланцевой нефти ведут в подземных условиях, сланцевый газ используют для энергообеспечения и повышения эффективности функционирования подземного энерготехнологического комплекса, а сланцевую нефть после окончательной очистки и подготовки на дневной поверхности поставляют потребителям.

Практическая значимость. Обеспечение возможности вовлечения в эффективную разработку крупных сланцевых нефтегазоносных залежей для добычи сланцевых нефти и газа путем рационального сочетания хорошо отработанных и широко используемых в горном деле методов и технологий шахтной и скважинной добычи полезных ископаемых.

Ключевые слова: *шахтно-скважинный метод, сланцевая нефть, баженовская свита, технологическая схема*

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