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BACH HO FIELD GEOLOGICAL FEATURES IDENTIFICATION USING WELL LOGGING DATA

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The relevance. *Well geophysics is considered as a typical method that can assist in determining the petrophysics properties of reservoirs and further location of the petroleum product-containing reservoirs. For reservoirs formed from fractured basement rock, studies on the petrophysics properties of fracture zones can contribute to the identification of petroleum products.*
The main aim. *The study applied the cross-plotting method based on raw well-logging data to identify the possible correlation between the gamma-ray logging with well-logging including neutron porosity, sonic transient time, and bulk density in three wells (BH-433, BH-809, and BH-905) of Bach Ho field in the Cuu Long Basin, Vietnam.*
Methods. *To deploy this study, well-logging data were integrated into formation of micro images and neutro, speed of sound, and density of the basement at the surveyed reservoir positions.*
Results. *The results indicated that granite in the investigated zones responds to the two tight value ranges (no-oil exist zones) neutro (0,000–0,100) and speed of sound (46–64), and neutro (0,000–0,100) and density (2,375–2,750) while the value ranges deviate from 0,000–0,100, 46–64, and 2,375–2,750, respectively for neutro, speed of sound, and density are closely related to the good permeability and porosity zones (oil exist zones). Based on the findings, it can be confirmed that the cross-plotting analysis has contributed positively to the initial assessment of potential ranges of the oil reservoirs in Bach Ho field. The application of the cross-plotting method will contribute to enhancing the predictability of oil and gas in the reservoirs.*

Key words:
Bach Ho field, Cuu Long Basin, cross-plotting, density, well-logging.

Introduction

Oil and gas exploration and exploitation activities for new reserves as well as recovery from prevailing accumulations are facing increased challenges due to the lack of essential seismic and geophysical information [1, 2]. The grasp of reservoir characteristics, therefore, plays an important role in quantifying producible oilfields [3]. They are considered as important input parameters for determining the location and reserves of oil reservoirs [4]. The challenges in oil reserve determination are commonly supposed to be the effects of lithology ingredients on the reservoirs [5, 6]. In addition, they are related to poor forecasting methods of reservoir properties as well as lithological constituents in the reservoirs [5]. The main reason for these problems may be caused by poor-quality core [7] or sample preservation techniques [8, 9]. According to [10] poor input information can lead to fewer correlations with seismic or well-logging data. The cross-plotting method based on well-logging data analysis is considered as a useful solution to decipher the reservoir properties when other traditional forecast methods of the reservoir properties have not been as effective as expected. Nowadays, cross-plotting approaches based on well-logging data analysis are evaluated as one of the effective methods to determine reservoir properties as well as their other lithological constituents [2, 11]. The cross-plotting is known as a typical visualization analysis method that is applied in well-logging data interpretation, and to identify or detect anomalies that could be interpreted as the presence of hydrocarbon, fluids, or other lithologies in the reservoirs [12]. Cross-plotting is, therefore, considered as one of the typical methods that can assist in determining the petrophysics properties of reservoirs and the location of the petroleum product-containing reservoirs [13, 14]. For instance, in Nigeria [10] the cross-plotting method is applied to determine the reservoir properties of three wells in the Daura oilfield. The results indicated that the cross-plotting method can support delineating correctly the reservoir features. According to [10], understanding of the reservoir's geophysical properties will contribute to determining the location of the petroleum-containing reservoirs. The geophysical properties are important because they play a role of input information for reservoir location determination [1, 2]. These parameters are commonly applied in the petroleum relationship industries to evaluate the potential spatial distribution of the oil reservoir [13].

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Cuu Long Basin is considered as the major reservoir for Vietnam's oil production activities [14, 15]. As a part of the actual requirement, petrophysical estimation is commonly required for optimizing production [14, 16]. It is difficult to apply traditional methods for determining the reservoir properties thereby identifying the potential oil reservoirs. In order to assist in the exploration and exploitation of petroleum products, the application of cross-plotting to determine the reservoir properties is very necessary and the aim of this study is, therefore, to apply the cross-plotting method to determine the petrophysics properties of Bach Ho field in the Cuu Long Basin.

Materials and method

Materials

The Cuu Long Basin is an oil and gas basin formed on the southern shelf of Vietnam, spanning an area estimated at approximately 25000 km^2 (Fig. 1). It is assumed to have been formed during the rifting in the Early Oligocene based on the main source rocks being Oligocene lacustrine mudstones [17, 18].

The major reservoir rocks in the Cuu Long Basin are weathered and fractured with granite and granodiorite basement up to 1000 m layer thickness below the seabed surface [9, 16]. Cuu Long Basin is estimated to contain up to 20 % of the total hydrocarbon resources of Vietnam and it is considered to be the major source of Vietnam's oil production with 90 % of which is from fractured basements [14, 17]. Fracture zones in the basement are commonly formed along the vertical direction with the porosity of the basement stone around 1,0–5,0 % [11, 14]. The major petroleum bodies in the basin consist of the tertiary granite-fractured basement on tilted fault blocks [14, 18].

Methods

In terms of petrographic composition, Bach Ho foundation rock is a magmatic rock with a complex rock-forming mineral composition [14, 18]. Therefore, the traditional methods for porosity determination are prone to errors because of the difficulty in determining the matrix parameters of the rock [2, 8]. The cross-plotting method is widely used in assessing the petrographic composition of sedimentary rocks [16, 17]. It is, therefore, very appropriate to determine the correlation between the geophysical values of the well-logging with the permeability characteristics of the granite foundation rock of Bach Ho field in the Cuu Long Basin of Vietnam (Fig. 2, *a–c*).

Fig. 1. *Illustrations of Cuu Long Basin in the Southeast Continental Shell of Vietnam [17]*

Рис. 1. *Иллюстрации бассейна Куу Лонг в юго-восточной континентальной части Вьетнама [17]*

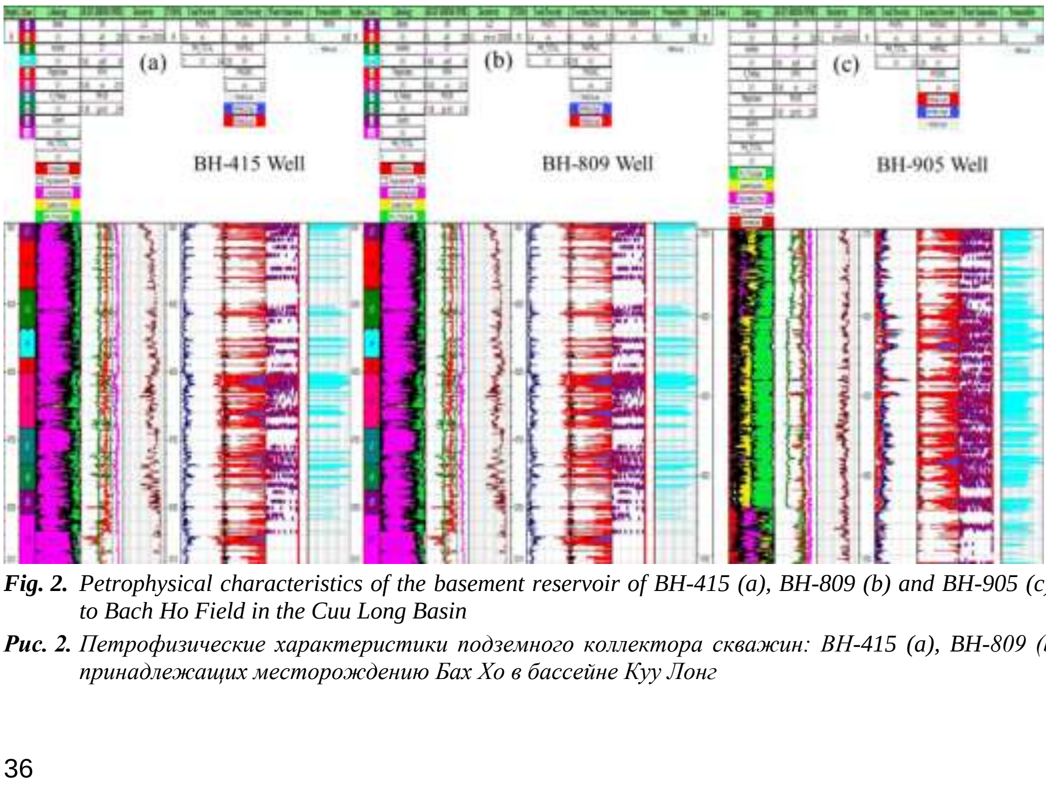

Fig. 2. *Petrophysical characteristics of the basement reservoir of BH-415 (a), BH-809 (b) and BH-905 (c) wells belonging to Bach Ho Field in the Cuu Long Basin*

Рис. 2. *Петрофизические характеристики подземного коллектора скважин: BH-415 (a), BH-809 (b) и BH-905 (c), принадлежащих месторождению Бах Хо в бассейне Куу Лонг*

Cross-plotting is a typical visualization analysis method which is commonly applied in well-logging data interpretation [10, 11]. The cross-plotting method is considered as visualization analysis of the correlation between two or more reservoir attributes, and it is commonly applied to identify or detect anomalies of lithological constituents in the reservoirs [8]. The cross-plotting approach based on well-logging data is an efficient tool for analyzing responses to identify the correlation between geophysical properties [2]. The two-dimension (2D) image interpretation of a cross-plotting and the well-logging form data are assessed as the ideal method of analysis for reservoir engineers [19, 20]. In geophysical study, analysis of cross-plotting well-logging data can actively assist in determining the exact location of oil and gas fields in the reservoirs [2]. In addition, cross-plotting analysis does not only enhance knowledge of the reservoir behaviour, but researchers are able to take advantage of those insights to appraise the productivity of the well [13, 20]. An advantage of applying seismic cross-plotting for assessing the permeability and porosity characteristics of the basement is based on the ability of the technique to extract more information from well-logging data to better discriminate the geological tectonic zones that are not well responded to other approach methods.

Results and discussion

The results of cross-plotting analysis of the BH-415, BH-809 and BH-905 wells (BH-809 and BH-905 wells are not presented) in Bach Ho field are shown in Fig. 3.

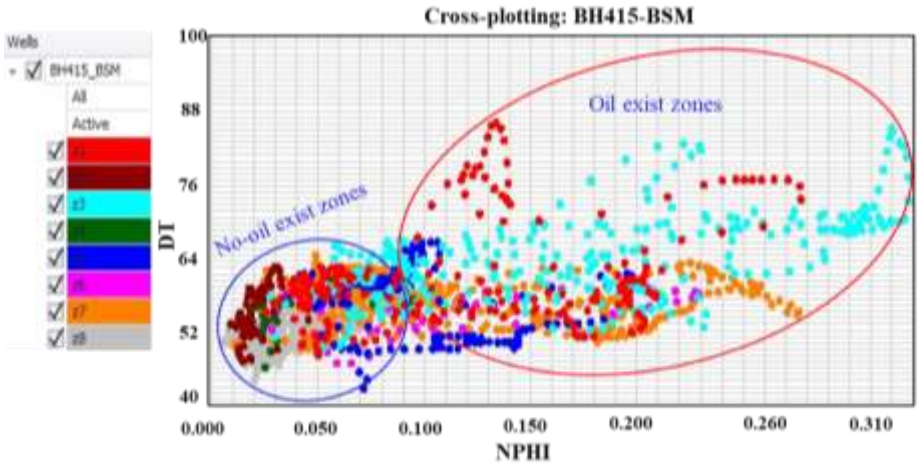

Fig. 3. *Results of cross-plotting speed of sound (DT)–neutron (NHPI) analysis of BH 415 well in Bach Ho Field*
Рис. 3. *Результаты перекрестного анализа DT–NHPI скважины BH 415 на месторождении Бах-Хо*

The results of cross plotting speed of DT–NPHI analysis for fresh and fractured rock zones (e.g., 2, 4 and 8 zones) indicated that the obtained value ranges of DT (46–64) and NPHI (0,000–0,100) are corresponded to no-oil exist zones while the obtained value ranges around 46–64 for DT and 0,000–0,100 for NPHI (e.g., 1, 3, 5, 6 and 7 zones) are recorded as the presence of oil exist zones. For cross-plotting gamma ray (GR) – neutron (NPHI) analysis the results pointed out that the obtained value ranges of NPHI and GR corresponding to 0,000–0,100 and 75–120, respectively did not recorded the oil exist zones while the obtained value ranges of NPHI and GR deviate from 0,000–0,100 for the NPHI and 46–64 for DT detected the presence of oil exist zones (Fig. 4).

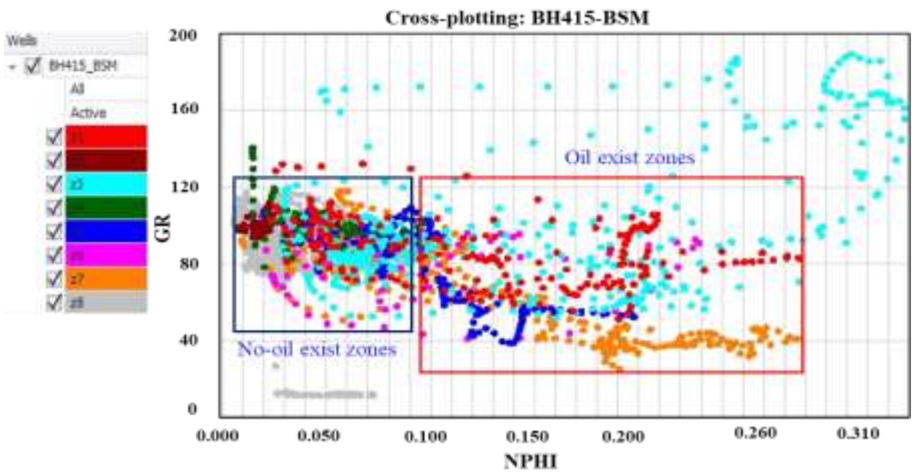

Fig. 4. *Results of cross-plotting GR–NHPI analysis of BH 415 well in Bach Ho field*
Рис. 4. *Результаты перекрестного анализа GR–NPHI скважины BH 415 на месторождении Бах-Хо*

For cross-plotting analysis of deep resistivity (LLD)–neutron (NHPI), the results also pointed out that the fresh or fractured rock zones (e.g., 2, 4 and 8 zones) responded with the value ranges of 1000–100000 for LLD and 0,000–0,100 for NPHI. It implies that no. 2, 4 and 8 zones did not record the existence of oil wells. While no. 1, 3, 5, 6 and 7 zones responded the value ranges exceeded beyond 0,000–0,100 for NPHI and 1000–100000 for LLD (Fig. 5). It means that no. 1, 3, 5, 6 zones recorded the presence of oil wells.

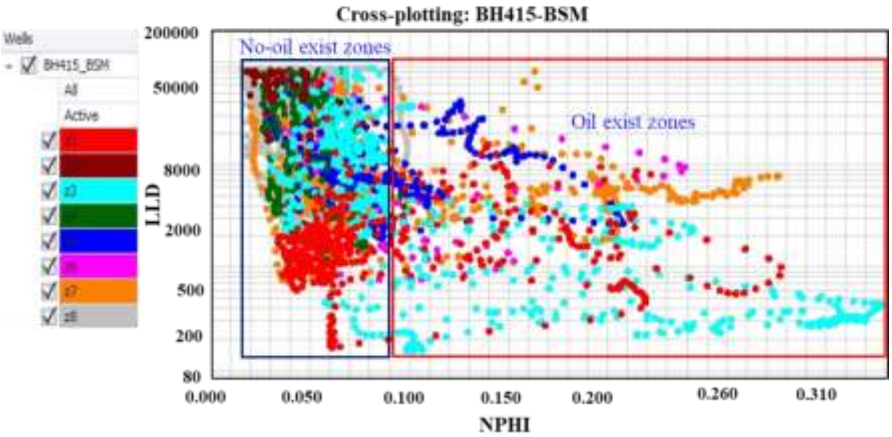

***Fig. 5.** Results of cross-plotting LLD–NHPI analysis of BH415 well in Bach Ho field*
***Рис. 5.** Результаты перекрестного анализа LLD–NPHI скважины BH415 на месторождении Бах-Хо*

A similar cross-plotting analysis of RHOB–NPHI is presented in Fig. 6. The results indicated that the fresh or small fractured rock zones responded the value ranges varying from 0,000–0,100 for NPHI and 2,375–2,750 for RHOB. This means that no. 2, 4 and 8 zones did not record the presence of oil wells in the reservoir. While no. 1, 3, 5, 6 and 7 zones responded the value ranges more than 0,090 for NPHI noted the appearance of oil wells (Fig. 6).

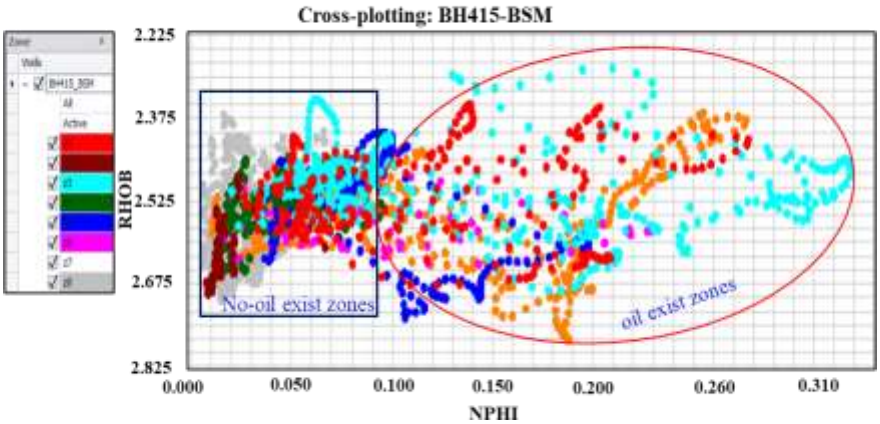

***Fig. 6.** Results of cross-plotting RHOB–NHPI analysis of BH415 well in Bach Ho field*
***Рис. 6.** Результаты перекрестного анализа RHOB–NPHI скважины BH415 на месторождении Бах-Хо*

For cross-plotting analysis of GR–DT, the results noted that the fresh or small fractured rock in no. 2, 4 and 8 zones resolved the value ranges varying from 75–120 for GR and 46–64 for DT. This implies that no. 2, 4 and 8 zones are formed by fresh and small fractured rock, and there are no existing oil wells. While no. 1, 3, 5, 6 and 7 zones responded the value ranges around 38–65 for GR and 65–75 for DT to the subsistence of oil wells (Fig. 7).

In a similar cross-plotting analysis, the results of DT–LLD analysis pointed out that the fresh and fractured rocks in no. 2, 4 and 8 zones responded to the value ranges of 75–120 for GR and 46–64 for DT (Fig. 8). This means that no. 2, 4 and 8 zones did not detect the oil exist wells. While no. 1, 3, 5, 6 and 7 zones obtained the value ranges deviated below 75–120 for GR and to 46–64 for DT. These values imply that no. 1, 3, 5, 6 and 7 zones recorded the subsistence of oil wells. Especially, no. 1 and 3 zones have significantly lower value ranges compared to 160–450 and they are recorded as the main oil reservoirs in the Bach Ho Field (Fig. 8).

Through the cross-plotting analysis, the study found that two combinations of speed of sound with neutron measurement and neutron with density measurement responded to granite bedrock in the Bach Ho Field the value ranges of (0,000–0,100; 46–64) and (0,000–0,100; 2,375–2,750) corresponding to the no-oil exist zones while the value ranges of right deviation of both NPHI– DT and NPHI–RHOB are closely related to the oil exist zones.

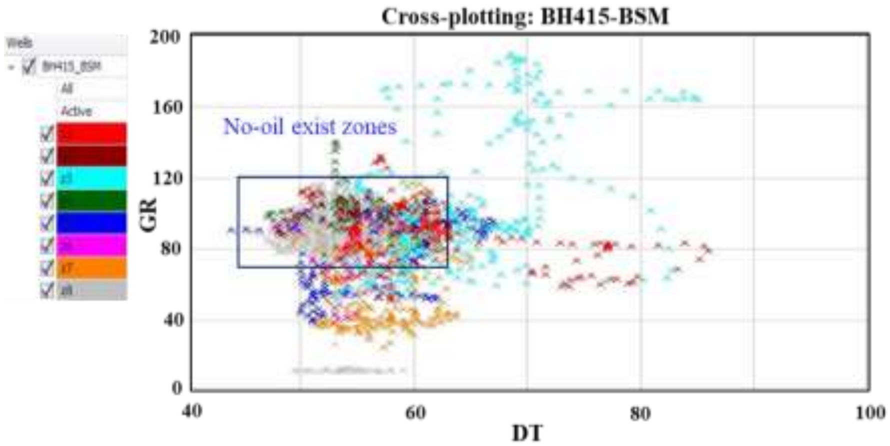

Fig. 7. Results of cross-plotting GR–DT analysis of BH415 well in Bach Ho Field

Рис. 7. Результаты перекрестного анализа GR–DT скважины BH415 на месторождении Бах-Хо

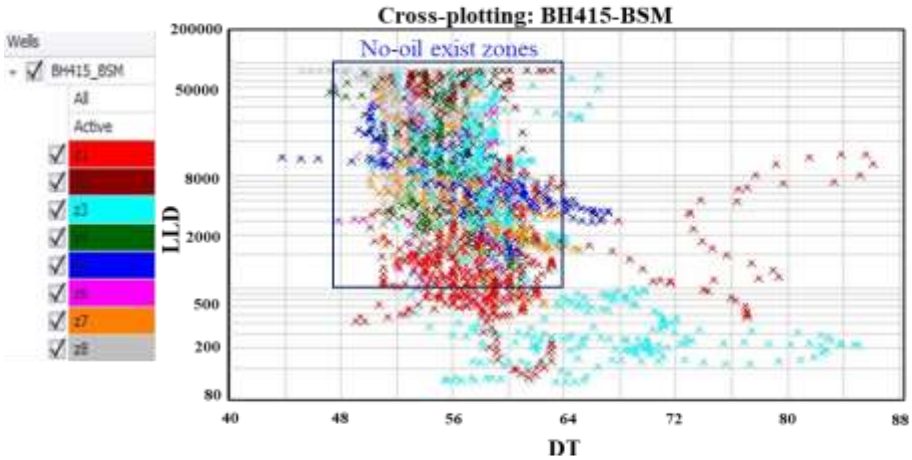

Fig. 8. Results of cross-plotting DT–LLD analysis of BH415 well in Bach Ho Field

Рис. 8. Результаты перекрестного анализа DT–LLD скважины BH415 на месторождении Бах-Хо

Based on the findings, it can be stated with certainty that the use of the cross-plotting technique can contribute to distinguishing the zones with and without the presence of oil reservoirs in the basement rock similar to oil wells where they have mainly lithological compositions of granite and granodiorite rocks.

Specifically, based on the cross-plotting RHOB–DT can distinguish the granite rock from the granite-granodiorite group in the BH415-BSM, BH809-BSM and BH905-BSM wells of Bach Ho Field (Fig. 9).

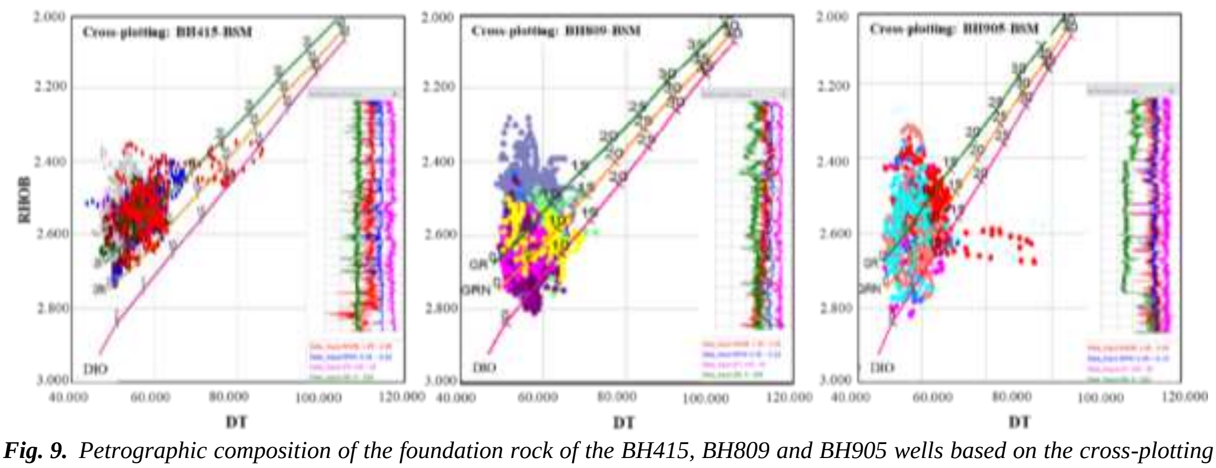

Fig. 9. Petrographic composition of the foundation rock of the BH415, BH809 and BH905 wells based on the cross-plotting analysis

Рис. 9. Петрографический состав породы фундамента скважин BH415, BH809 и BH905 на основе анализа перекрестных графиков

The well-logging interpretation results based on the cross-plotting technique are relatively consistent with the formation microimages as well as with the mined actual data from the wells. So, the determining of cross-plotting value ranges of DT–NPHI and RHOB–NPHI from the BH415-BSM well, then apply for the BH809-BSM and BH905-BSM wells obtained good results with correlation coefficients and divergence at BH415-BSM, BH809-BSM and BH905-BSM wells varied from 0,070 to 0,976 and from 0,019 to 0,710, 0,700 to 0,976 and 0,013 to 0,376, and 0,661 to 0,998 and 0,011 to 0,222, respectively (Table).

Table. *Correlation between theoretical and measured curves of BH415-BSM, BH809-BSM and BH905-BSM wells belonging to the Bach Ho Field in the Cuu Long Basin*

Таблица. *Корреляция между теоретическими и измеренными кривыми скважин BH415-BSM, BH809-BSM и BH905-BSM, принадлежащих месторождению Бах Хо в бассейне Куу Лонг*

Curve type Тип кривой	BH415-BSM		BH809-BSM		BH915-BSM	
	Divergence Отклонение	Correlation Соответствие	Divergence Отклонение	Correlation Соответствие	Divergence Отклонение	Correlation Соответствие
DT/ДТ	0,052	0,700	0,035	0,732	0,046	0,661
GR/ГР	0,710	0,756	0,023	0,983	0,016	0,998
NPHI/НПХИ	0,019	0,863	0,376	0,936	0,222	0,902
RHOB/РОБ	0,019	0,976	0,013	0,887	0,011	0,886

Conclusions

The study focused on the apply of cross-plotting technique for analysing the raw well-logging data of three wells – BH415-SBM, BH809-SBM and BH905-SBM, belonging to Bach Ho field in the Cuu Long Basin, Vietnam to identify the potential oil reservoirs. The obtained results are cataloged as bellows:

Granite in the analyzed zones responds to the value ranges encompassing 0,000–0,100 for NPHI and 46–64 for DT and 2,375–2,750 for RHOB corresponding to no-oil existing zones while the value ranges deviating from the above-mentioned value ranges are recorded as the oil existence zones.

Oil exist zones are identified by applying the cross-plotting technique based on well-logging data and the resistivity ratio method. The results indicated that most of the oil-exist zones are located within the granite fractures.

In general, efficient extraction of information from raw well-logging data through cross-plotting technique does not only allow classifying bedrock in the study area but also enables the initial assessment of oil reservoirs.

The cross-plotting technique effectively contributes to initial assessment of the potential positions of the oil reservoirs in the Bach Ho field. In addition, the application of the cross-plotting approach will contribute to enhancing the predictability of oil and gas in the reservoirs as well as supporting the size determination of oil reservoirs in other oil fields.

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ВЫЯВЛЕНИЕ ГЕОЛОГИЧЕСКИХ ОСОБЕННОСТЕЙ МЕСТОРОЖДЕНИЯ БАХ ХО ПО ДАННЫМ ГИС

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В исследовании применялся метод кроссплоттинга, основанный на необработанных данных каротажа скважины для выявления возможной корреляции между данными гамма-каротажа и каротажа скважины, включая нейтронную пористость, время звукового переходного процесса и объемную плотность в трех скважинах (BH-433, BH-809 и BH-905) месторождения Бах Хо в бассейне Куу Лонг, Вьетнам. Для развертывания этого исследования данные ГИС были интегрированы в микроизображения пласта и нейтро, скорость звука и плотность фундамента в изученных позициях коллектора. Результаты показали, что гранит в исследованных зонах отвечает двум диапазонам плотных значений (зоны отсутствия нефти) нейтро (0,000–0,100) и скорость звука (46–64), а также нейтро (0,000–0,100) и плотность (2,375–2,750), в то время как диапазоны значений, которые отклоняются от 0,000–0,100, 46–64 и 2,375–2,750, соответственно, для нейтро, скорость звука и плотность, тесно связаны с зонами хорошей проницаемости и пористости (зонами нефтеносности). Основываясь на результатах, можно подтвердить, что анализ кросс-плотов внес положительный вклад в первоначальную оценку потенциальных диапазонов нефтяных коллекторов на месторождении Бах Хо. Применение метода кроссплоттинга будет способствовать повышению предсказуемости нефти и газа в пластах.

Ключевые слова:
месторождение Баххо, бассейн Куулонг, кроссплоттинг, плотность, каротаж.

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