Известия Уральского государственного горного университета. 2019. Вып. 3(55). С. 90-97

Технические науки
Engineering sciences

УДК 550.83 https://doi.org/10.21440/2307-2091-2019-3-90-97

Study of genesis of productive series based on integrated well data (in case of Pirallahi field)

Kifayat Aladdin KERIMOVA*,
Reyhanxanim Yashar GANIYEVA**

Azerbaijan State Oil and Industry University, Baku, Azerbaijan

Relevance. It is known that over than 90 % of oil produced in Azerbaijan is extracted from the South Caspian Basin. The South Caspian basin is one of the largest deeply buried basins. Sedimentation process here is characterized by high rate as 25 km for 150–170 mln years (0.6–0.7 km/mln years). For the last years due to wider scope of exploration works in the South Caspian basin and evaluation of its hydrocarbon perspectives the study of genesis of Productive Series gain more interest.
Purpose of work. The purpose of the work is to study genesis of sediments and sedimentation environment on the basis of quantitative and qualitative interpretation of logging curves, make correlation of facies in various wells and perform comparative analysis.
Research methodology. Applying "Quantitative and qualitative models of log facies" on the basis of well logging data the analysis of lithology, facies and genesis of sedimentary rocks in Pirallahi structure have been done and results were derived. Within the framework of the study by use of Neuralog software based on LL, SP, GL, NGL and other log types the data have been transformed into the LAS format, then the permeability, porosity, oil and gas saturation, bulk clay coefficient alteration models have been designed by use of Petrel software.
Conclusions. Study of sedimentation environment constantly draws the interest of geoscientists due to the direct dependence of structure and identification of oil and gas traps on sedimentation environment. This paper deals with study of genesis of Productive Series deposits based on quantitative and qualitative analysis of logging curves. The study target is Kirmaky suite across Pirallahi field of Absheron oil-gas bearing region.

Keywords: facies analysis, log facies, genesis, flow, bar, coastal plain.

Relevance

In Azerbaijan more than 90 % of oil is produced from fields of the South Caspian basin. The South Caspian basin is one of the basins subsided to the large depths.

Sedimentation process here is characterized by high rate and reaches approximately 25 km per 150–170 million years (0.6–0.7 km/mln years). Characteristic features of the South Caspian basin involves compression of its sedimentation components and overpressure in some areas [1]. The major role in the III period sedimentation played fluvial-deltaic, avandeltaic sediments, turbidites and contourites accumulated mainly in river deltas, faults and paleogeographic plains [2–5].

In general, the morphology of negative relief (river-channels, channel, cliffs) where sediments are accumulated depends mostly on dip angle, sediments thickness, climate, tectonic features, etc. [6]. Reservoirs generated at various time periods and in changing environment vary in time depending on morphology of negative releif (river, river-bed, cliff). Thus, fluvial-deltaic system is not constant through a definite stratigraphic unit. The problem consists in generation of facies alteration and unconformity surfaces in fluvial systems [7].

Purpose of work

In this respect, the study of sedimentation environment and genesis of sedimentation process is always in the sphere of interest of petroleum geoscientists. For the last years the lithological traps are also studied along with structural and stratigraphic traps.

This study is devoted to analysis of genesis and environment of sedimentation process done through quantitative and qualitative interpretation of logging curves.

The study target is Kirmaky suite in sections of conditionally numbered wells X1, X2, X3, X4 and X5 in Pirallahi area.

Productive Series (PS) deposits of Absheron oil-gas bearing region consist mostly of alternation of sandstone, sandstone clay, aleurolites, argilltes and clay layers and have vast hydrocarbon reserves. It is known that Productive Series in Pirallahi field consists of alternation of sand, sandstone, aleurite and clay. Its maximum thickness is 1380 m. Due to erosion of upper part of PS, it is mainly represented by lower part (Gala, Post-Kirmaky, Kirmaky, Upper-Kirmaky sand, Upper-Kirmaky clay suites). Of these the oil presence is identified in Post- Kirmaky, Kirmaky and partially in Gala series (in the south Pirallahi fault) [8].

According to results of geophysical studies covering Kirmaky suite of PS in Pirallahi area the study of genesis of PS deposits drives attention from the point of view of hydrocarbon presence.

It is known that several factors influencing the form of logging curves must be taken into account while facies interpretation. These include granulometric composition, porosity, clay content, brine water, drilling mud composition, borehole diamater, etc. In this respect, analysis of spontaneous polarization and GL (Gamma Log) curves for evaluation of sedimentation are not clear [9, 10].

* kifageo.com@rambler.ru
https://orcid.org/0000-0001-8753-8791
**qeniyevsamir89@gmail.com
https://orcid.org/0000-0003-2808-3760

Research methodology

Well logging techniques applying jointly with quantitative evaluations, well logging curves, effective porosity of layers, curves of variation of bulk clay versus depth allow to derive more accurate lithological composition, as well as genesis and sedimentation environment of deposits. In distinction to other techniques this method is based on accurate values of oil-field geophysical parameters while analysis of lithological characteristics of rocks [11].

Due to this, comparative analysis of lithological features of rocks in Kirmaky suite (Productive Series) by use of "quantitative and qualitative models of log facies" allowed to derive their genesis and the results is expounded in this paper [12, 13].

The Table shows effective porosity and bulk clay in reservoir layers defined by use of log diagrams across studied sections.

Based on Table the bulk clay and effective porosity versus depth histograms has been drawn and genesis of sediments has been studied by the display forms of these histograms. By display form of these histograms the conditional well N1 section in Binagadi field is characterized for genetic origin of rocks as the following (Fig.1).

It can be seen from Fig. 1 that rocks of Kirmaky suite in conditional X4 well section in Pirallahi field consists of alluvial and deltaic sediments which are characterized by gradual replacement of near-coastal marine facies by flow-originated facies in upward direction. Flow-originated facies are overlaid by thin bar facies, replaced again by flow facies. Near-coastal marine facies are observed at 459–467 m depth interval. These facies are again replaced by flow-bar originated facies.[14, 15]

Similar analysis has been done for sections of conditionally numbered wells X1, X2, X3 and X5 of Pirallahi field.

It can be seen from the Fig. 2 that Kirmaky suite rocks studied in conditional X1 well consist of alluvial and deltaic deposits with upward gradual replacement of bar-originated facies by coastal plain facies. Coastal plain facies are also overlaid by flow and bar-originated facies. At 775–625 m depth interval the coastal plain facies are alternating with flow-originated facies. From 625 m depths the bar-originated, coastal plain facies are observed.

Fig. 2 displays correlation of similar facies of Kirmaky suite in sections of conditionally numbered wells X1, X2, X3 and X5 of Pirallahi field. It can be seen from the figure that flow and bar orginated, as well as coastal plain facies are traced along well X5 section. However, it must be noted that coastal marine facies are observed only in two various intervals of X4 well section. These features of sedimentation process can be related to sea level regression and transgression.

Evaluation of effective porosity and bulk clay variation in rocks versus depth according to integrated interpretation of log diagrams acquired for well sections of Pirallahi field.

Оценка эффективной пористости и вариации глины в горных породах в зависимости от глубины согласно интегрированной интерпретации каротажных диаграмм, полученных для скважинных участков месторождения Пираллахи.

Number	Top	Foot	Porosity	Clay
1	555.6	559.0	0.225	0.075
2	559.7	561.9	0.224	0.173
3	565.3	566.5	0.222	0.186
4	567.0	568.2	0.192	0.268
5	568.9	570.5	0.209	0.277
6	572.8	574.1	0.185	0.354
7	577.2	581.7	0.167	0.353
8	590.2	591.3	0.199	0.324
9	596.0	597.2	0.189	0.328
10	606.2	607.5	0.164	0.309
11	608.6	611.1	0.182	0.286
12	613.7	617.1	0.163	0.352
13	619.9	621.1	0.177	0.355
14	624.9	629.6	0.159	0.353
15	634.9	639.1	0.194	0.221
16	643.3	645.4	0.201	0.358
17	646.4	648.4	0.217	0.224
18	649.6	651.9	0.181	0.357
19	652.9	657.8	0.158	0.350
20	663.2	667.7	0.154	0.359
21	670.7	673.0	0.159	0.355
22	676.1	676.9	0.206	0.352
23	680.5	685.0	0.168	0.350
24	697.0	699.7	0.167	0.349
25	702.2	704.7	0.184	0.188
26	706.9	709.1	0.203	0.169
27	710.4	713.2	0.169	0.354
28	718.5	720.4	0.207	0.295
29	721.8	723.2	0.175	0.350
30	725.7	727.0	0.204	0.317
31	734.5	736.0	0.191	0.353
32	737.2	738.5	0.198	0.336
33	748.6	749.8	0.229	0.294
34	751.1	754.0	0.177	0.351
35	756.4	759.3	0.160	0.349
36	765.0	766.5	0.172	0.319

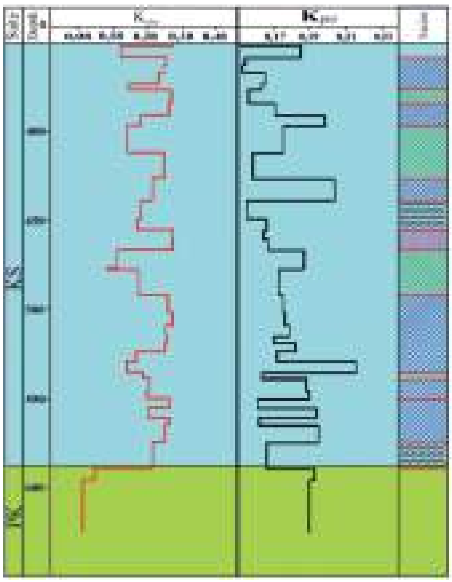

Figure 1. Analysis of lithological characteristics of rocks attributed to Kirmaky suite (KS) of Productive Serie (PS) studied in conditional X1 well section in Pirallahi field. K_{clay} – clayiness coefficient; K_{por} – porosity coefficient.

Рисунок 1. Анализ литологических характеристик пород, относящихся к Кирмаки свите (КС) продуктивной толщи (ПТ), изученной в условном разрезе скважины X1 месторождения Пираллахи. K_{clay} – коэффициент глинистости; $K_{пор}$ – коэффициент пористости.

The study also covered analysis of sedimentation environment by GL curves with further correlation (Fig. 2). Comparative analysis of Fig. 2 and Fig. 3 by use of quantitative analysis allowed to group sediments as flow-originated, bar and coastal facies. Based on features of GL curves these groups have been further divided into sub-groups of facies.

For conditionally numbered X1 well Upper-Kirmaky sand suite involves mainly bar-originated facies. Gala suite facies are featured as the following: 525–575 m depth involves bar-originated facies, 575–625 m depth interval consists of coastal plain and bar originated facies, 675–725 m depth interval involves bar-coastal-flow facies, 725–775 m depth interval consists of alternation of bar-flow-coastal-bar facies.

Facies variation in section of conditionally numbered well X2 is observed only is Gala series: 400–450 m interval consists of alternation of bar-flow-bar facies, 450–500 m – bar-coastal marine-flow facies, 500–550 m depth interval – flow originated facies.

Similar to X2 the section of conditionally numbered well X3 is interpreted only for Gala suite. 450–500 m depth interval involves bar facies, 500–600 m depths interval involves alternation of bar and flow originated facies, 600–650 m depth interval the coastal-bar-flow originated facies and 650–700 m depth interval bar-flow originated facies are observed.

Gala suite has been analysed for conditionally numbered X4 well. The interpretation sequence is as the following: 300–400 m depth interval is characterised by alternation of flow-bar facies, 400–450 m depth interval consists of bar-flow originated-coastal facies, 450–500 m depth interval consists of coastal – bar, at 500–600 m depth interval the flow originated facies are dominating.

Sedimentation environment of Gala and Post-Kirmaky suites has been analysed for section of conditionally numbered X5 well. Facies vary as the following: 450–500 m involves bar-originated facies, 500–600 m depth interval is featured by the dominance of flow originated facies and we may observe the alternation of coastal plain and bar facies also. At 600–700 m depth interval of Gala suite the alternation of bar facies is observed. In Post-Kirmaky suite and at 750 m depth interval the coastal plain facies were identified.

Bulk clay and effective porosity are dynamic parameters of reservoirs. These two parameters are depends on some factors. There are intensive and dynamic relation between these parameters. Fig. 4 shows the correlation relation between bulk clay and effective porosity for any 1st well sections of Pirallahi field on studied KS suite.

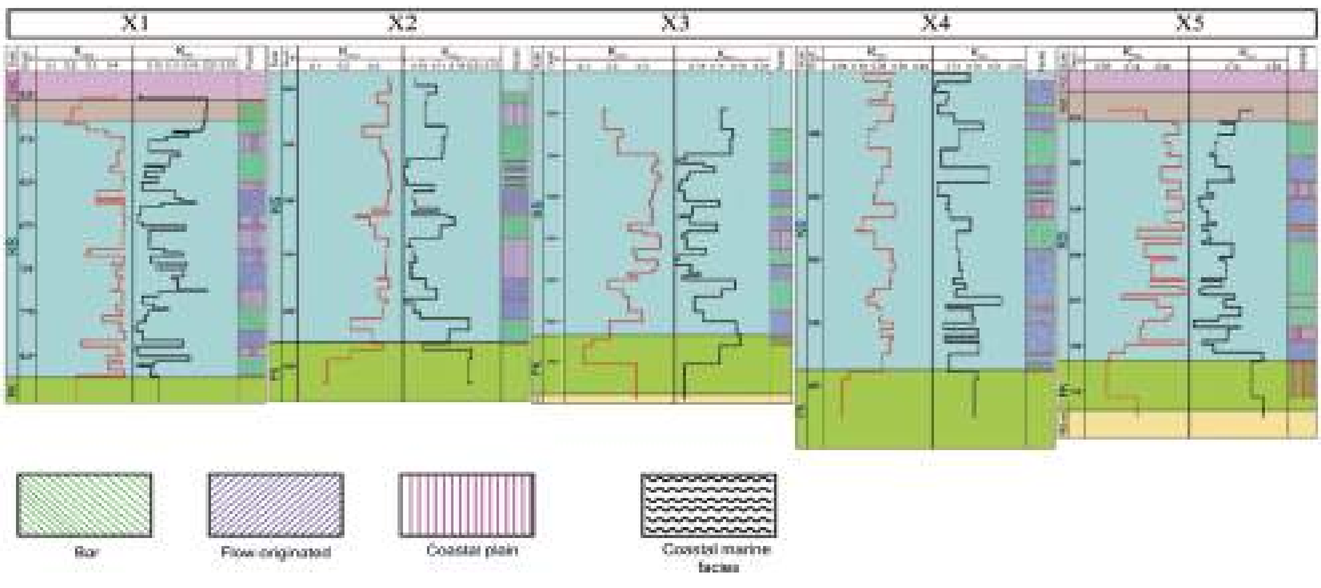

Figure 2. Lithlogy and facies of Kirmaky suite (KS) rocks of Productive Series (PS) studied based on well data from Pirallahi field. K_{clay} – clayiness coefficient; K_{por} – porosity coefficient; PK – Post-Kirmaky; KUS – Kirmaky Upper Sand; KUC – Kirmaky Upper Clay.

Рис. 2. Литология и фации пород кирмакской свиты (КС) продуктивной серии (ПС), изученных на основе данных скважин с месторождения Пираллахи. K_{clay} – коэффициент глинистости; $K_{пор}$ – коэффициент пористости; ПК – Пост-Кирмаки; КВП – Кирмаки Верхний Песок; КВГ – Кирмаки Верхняя Глина.

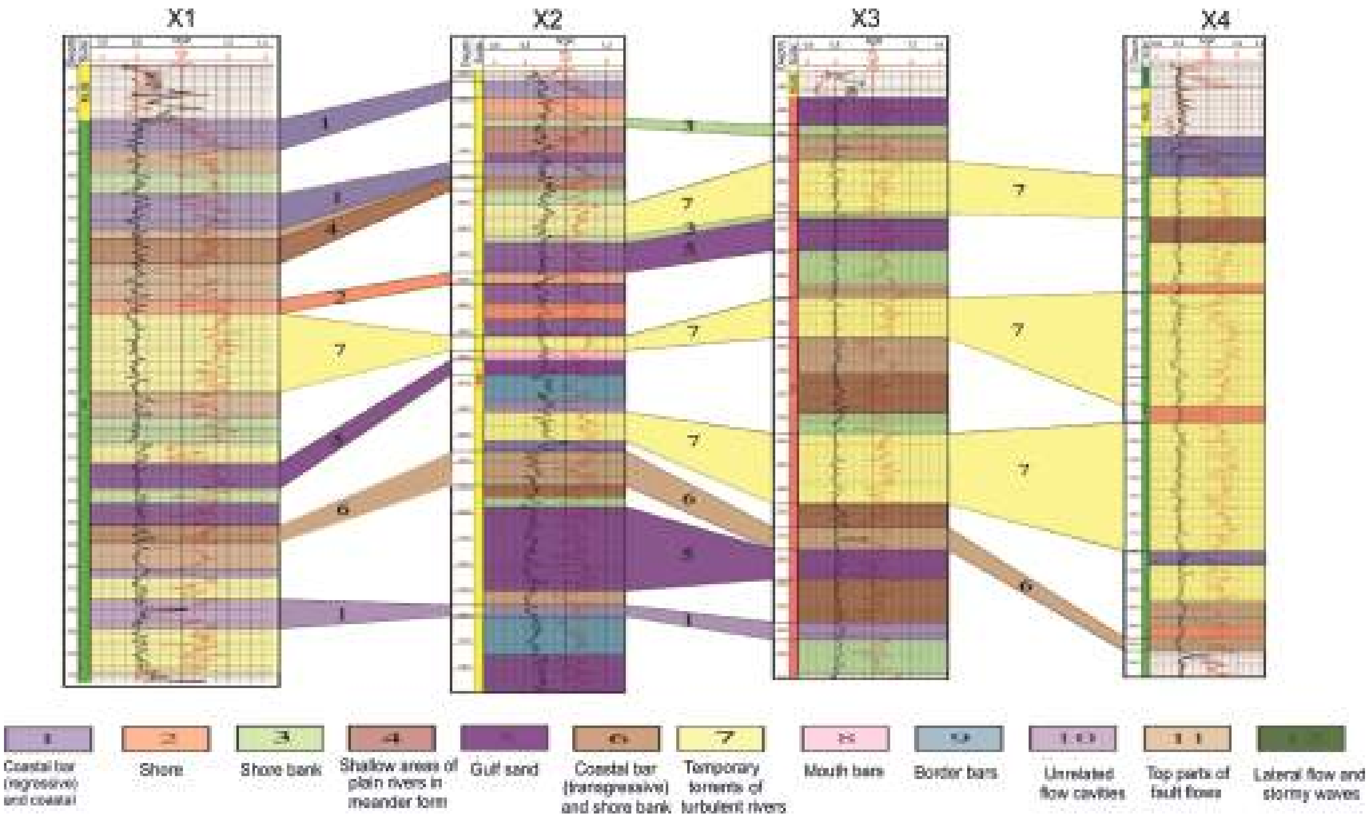

Figure 3. Analysis and tracing of facies based on qualitative interpretation of data acquired from well sections of Pirallahi field. K_{clay} – clayiness coefficient; K_{por} – porosity coefficient.
Рисунок 3. Анализ и отслеживание фаций на основе качественной интерпретации данных, полученных из скважинных участков месторождения Пираллахи. K_{clay} – коэффициент глинистости; $K_{пор}$ – коэффициент пористости.

It can be seen from dependence graph that regression equation $K_{por} = -2{,}537\ K_{clay} + 0{,}7689$ characterized between bulk clay and effective porosity with high correletion coefficient (r = 0,716) is getting. This correletion relation is also significancy for dividing litotypes of cross-section. As can be seen from the figure that litotype with 35,9 % of bulk clay has 15,4 % of porosity, the effective porosity of the lithotype with a bulk clay of 7.5 % was estimated at 22.5 %.

Integrated well logging data acquired in five wells in the study area have been processed by use of Neuralog software and data acquired by LL, SP, GL, NGL and other log diagrams have been transformed into LAS format. Then by use of Petrel software package the permeability (Fig. 5), porosity (Fig. 6), oil-gas saturation (Fig. 7), bulk clay (Fig. 8) models have been designed applying appropriate formula. It can be seen from Fig. 5 that the scale is logarithmic and permeability varies within 10–100 mD range.

Fig. 6 displays porosity characteristics in various wells. The lowest porosity value is within 2–10 %, while the highest value is within 22–34 % range.

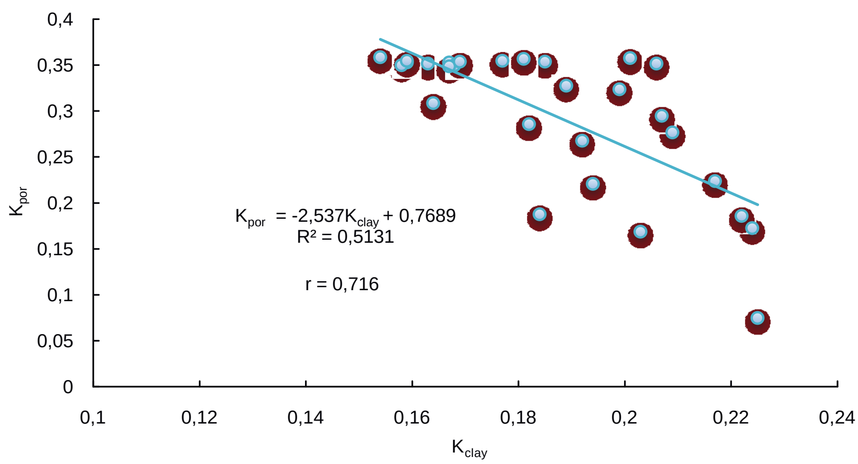

Figure 4. Correlation relation between bulk clay and effective porosity for any 1st well sections of Pirallahi field.
Рисунок 4. Соотношение корреляции между глиной и эффективной пористостью для любых участков 1-й скважины месторождения Пираллахи.

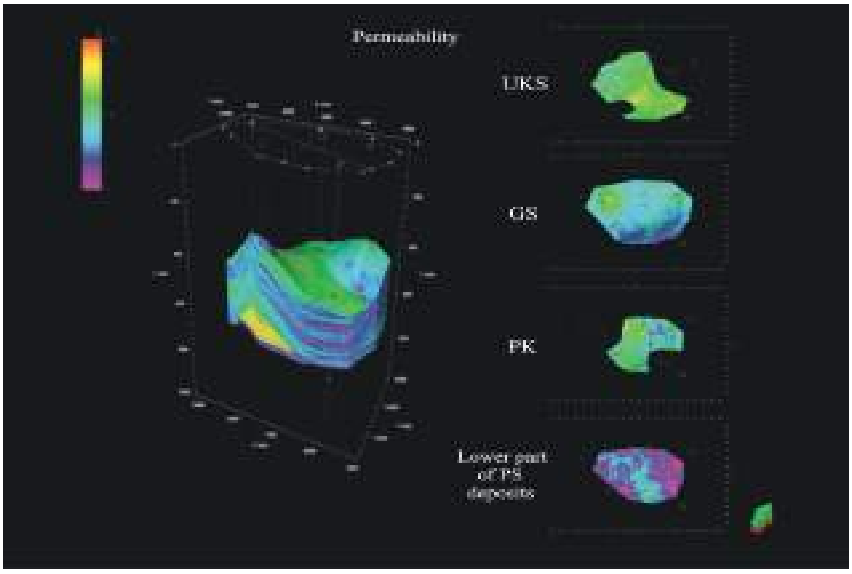

Figure 5. Permeability model of Upper-Kirmaky sand (UKS), Gala suite (GS), Post-Kirmaky (PK) and Lower part of PS deposits.
Рисунок 5. Модель проницаемости верхне-кирмакских песков (UKS), Гала-свиты (GS), Пост-Кирмаки (PK) и нижней части месторождений ПС.

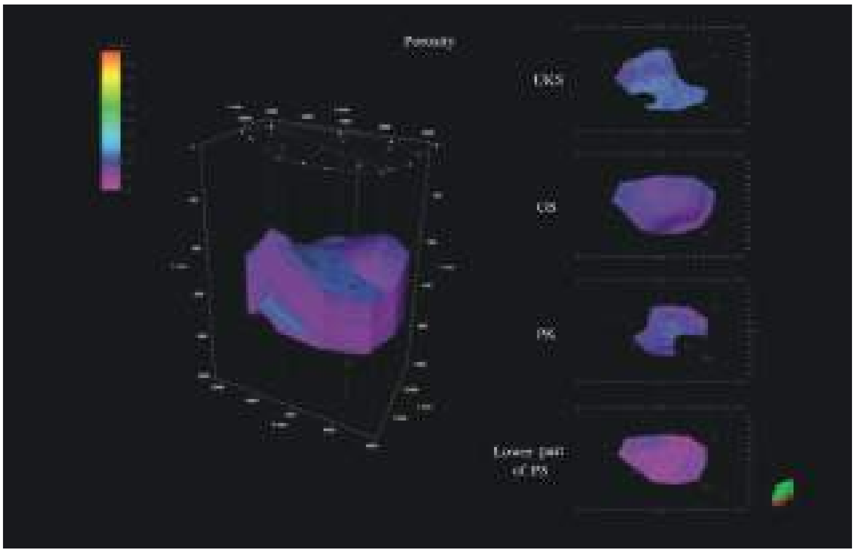

Figure 6. Porosity model of Upper-Kirmaky sand (UKS), Gala suite (GS), Post-Kirmaky (PK) and lower part of PS deposits.
Рисунок 6. Модель пористости верхне-кирмакского песка (UKS), Гала-свиты (GS), Пост-Кирмаки (PK) и нижней части месторождений ПС

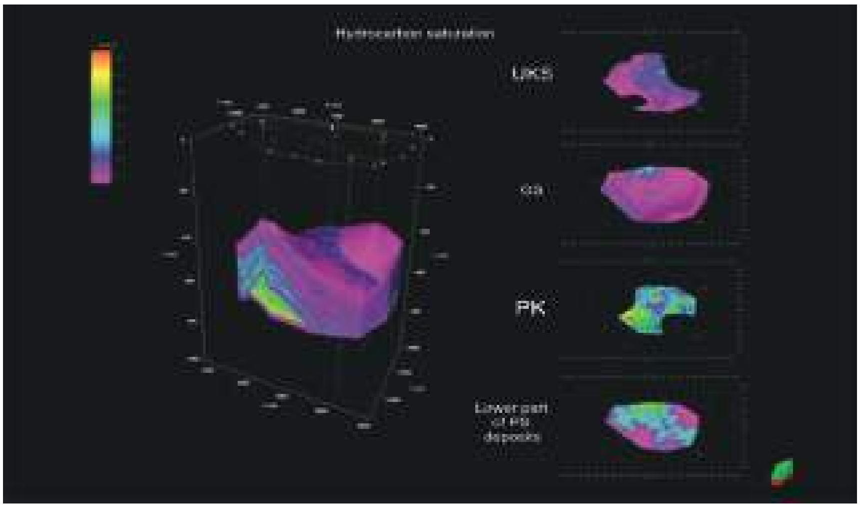

Figure 7. Hydrocarbon saturation model of Upper-Kirmaky sand (UKS), Gala suite (GS), Post-Kirmaky (PK) and lower part of PS deposits.
Рисунок 7. Модель насыщения углеводородами верхнекирмакского песка (UKS), Гала свиты (GS), Пост-Кирмаки (PK) и нижней части месторождений

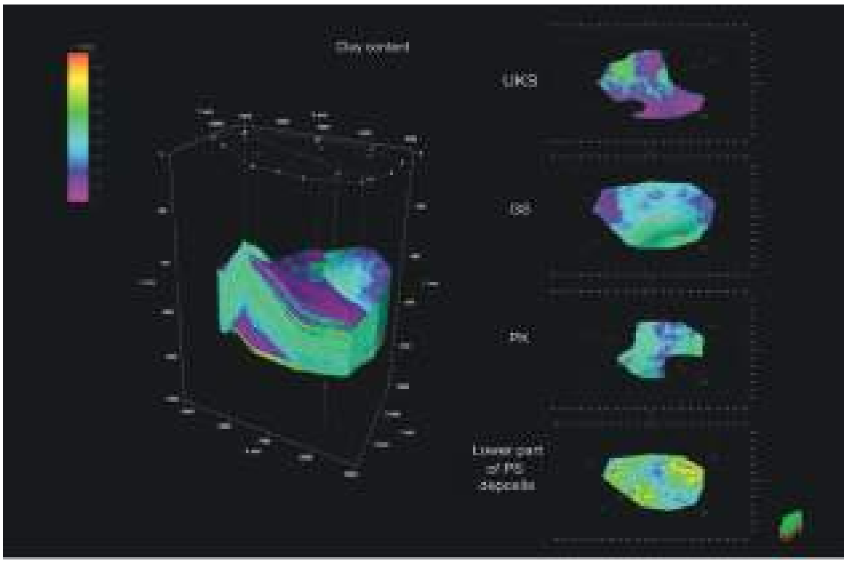

Figure 8. Clay content model of Upper-Kirmaky sand (UKS), Gala suite (GS), Post-Kirmaky (PK) and lower part of PS deposits.
Рисунок 8. Модель содержания глины в верхне-кирмакском песке (UKS), Гала-свите (GS), Пост-Кирмаки (PK) и нижней части месторождений ПС.

Fig. 7 depicts one of the most important characteristics of reservoir rocks as oil-gas saturation. The lowest oil-gas saturation values vary within 10%-20% ranges while the highest value vary within 60–70 % ranges.

Fig. 8 is designed on the basis of calculated quantity-clay, negatively impacting reservoir rocks. The highest clay coefficient varies within 0.35–0.48 and the lowest value varies within 0.07–0.18 range.

Conclusions

1. Based on well log data the quantitative and qualitative analysis has been done, sedimentation environment were evaluated, correlation diagrams have been drawn for facies variation across wells with further comparative analysis.

a) Based on quantitative analysis of X1, X2, X3, X4, X5 wells it is possible to trace bar-originated facies in the upper part of the diagram. Futher down the bar-originated facies are replaced by flow-originated and coastal facies. However, coastal marine facies are rare along well section.

б) Interpretation done on the basis of qualitative analysis of X1, X2, X3, X4 wells displays good correlation. Thus, temporary flows of speedily flowing rivers are dominating. Facies of coastal, offshore bar, shallow parts of plain rivers in a meander form and some other types are met here. Regressive flows (bars) are observed at lower borders and partially at upper borders. At the lower borders transgression is replaced by regression.

2. Porosity, permeability, clay, oil-gas saturation modeling results have been analyzed by use of Neurolog and Petrel software packages. It has been derived that permeability varies within 10–100 mD, the lowest value of porosity varies within 2–10 % ranges while the highest value varies within 22–34 %, the lowest value of oil-gas saturation varies within 10–20 %, the highest value varies within 60–70 %, the highest value of clay content varies as 35–48 % while the lowest value varies within 7–18 % ranges.

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The article was received on July 09, 2019

УДК 550.83 https://doi.org/10.21440/2307-2091-2019-3-90-97

Изучение генезиса продуктивных толщ по интегрированным данным скважин (на месторождении Пираллахи)

Кифаят Аладдин КЕРИМОВА*
Рейханксаним Яшар ГАНИЕВА**

Азербайджанский государственный университет нефти и промышленности, Баку, Азербайджан

Актуальность. Известно, что более 90% добываемой в Азербайджане нефти добывается из Южно-Каспийского бассейна. Южно-Каспийский бассейн является одним из крупнейших глубоко залегающих бассейнов. Процесс седиментации здесь характеризуется высокой скоростью - 25 км в течение 150–170 млн лет (0,6–0,7 км / млн лет). В последние годы в связи с увеличением масштабов геологоразведочных работ в Южно-Каспийском бассейне и оценкой перспектив его углеводородов изучение генезиса продуктивных толщ вызывает интерес.
Цель работы. Целью работы является изучение генезиса отложений и осадконакопления на основе количественной и качественной интерпретации кривых каротажа, корреляции фаций в различных скважинах и проведения сравнительного анализа.
Метод исследования. Используя «Количественные и качественные модели каротажных фаций» на основе данных каротажа скважин, был проведен анализ литологии, фаций и генезиса осадочных пород в структуре Пираллахи и получены результаты. В рамках исследования с использованием программного обеспечения Neuralog, основанного на LL, SP, GL, NGL и других типах каротажа, данные были преобразованы в формат LAS, затем были разработаны модели проницаемости, пористости, нефтегазонасыщенности, изменения коэффициента объемной глины с использованием программного обеспечения Petrel.
Заключение. Изучение среды седиментации постоянно вызывает интерес геологов из-за прямой зависимости структуры и идентификации нефтегазовых ловушек от среды седиментации. Данная статья посвящена изучению генезиса месторождений продуктивной толщи на основе количественного и качественного анализа кривых каротажа. Целью исследования является свита Кирмаки на месторождении Пираллахи Апшеронского нефтегазоносного района.

Ключевые слова: фациальный анализ, каротажная фация, генезис, добыча, жила, береговая равнина.

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Статья поступила в редакцию 09 июля 2019 г.

* ✉kifageo.com@rambler.ru
https://orcid.org/0000-0001-8753-8791
**qeniyevsamir89@gmail.com
https://orcid.org/0000-0003-2808-3760