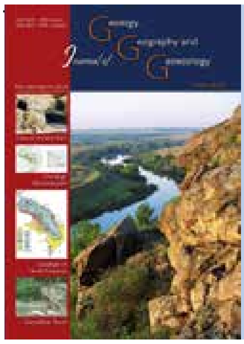

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Assessment of the relationship of reservoir properties of hydrocarbon fields in the Lower Kura depression (Kursengi and Southern Kursengi areas)

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Abstract. The article is devoted to the analysis of the geological-petrophysical properties of the Kursengi and Southern Kursengi fields of the Lower Kura depression with a view to clarify the changes in the physical properties (carbonate content, permeability, porosity) of rocks with depth. Promising sediments and horizons of deposits are also considered based on a detailed analysis of numerous rock samples. Oil and gas bearing objects are especially distinguished by area, as well as possible oil and gas bearing blocks. The main purpose of these studies is to unravel changes in carbonate, porosity and permeability of rocks with depth based on core samples taken from drilled wells in the study area and to identify the factors causing these changes. To do this, using the obtained well data, the dependences of changes in depth of porosity, permeability and carbonate were compiled. As known, with increasing depth, rocks experience compaction. With the depth of changes in porosity, the rocks do not show any regularity, i. e. at some depths, an increase in the porosity of rocks is observed, and at some depths, a decrease, and this occurs in an abrupt manner. In our sections, the critical depths of porosity decrease are observed from 500 m to 1600 m, and the critical depth of porosity increase from 1600 m to 2950 m. In other words, the porosity of reservoirs, with a general gradual decrease in depth, begins to sharply decrease from a depth of 3200 m. In the study of core materials, it was found that the rocks are characterized by good reservoir properties. However, in many of the studied samples, the porosity of the rocks varies within a wide range of 12.8–27.8 %, and the permeability ranges from 0.001x10–15m^2 to 120x10–15m^2. Changes in petrophysical values are observed in both study areas. The reason for the change in petrophysical values in a wide range at the objects of study is associated with the lithological heterogeneity of the complexes and the occurrence depth of the reservoir.

Key words: petrophysical characteristics, porosity, permeability, carbonate content, sandiness, reservoir, thickness.

Оцінка взаємозв›язку колекторських властивостей нафтових родовищ Нижньокурінської западини (площі Кюрсангя та південна Кюрсангя)

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Анотація. Стаття присвячена аналізу геолого-петрофізичних властивостей родовищ Кюрсанги та південної Кюрсанги Нижньокурінської западини з метою з'ясування змін фізичних властивостей (карбонатність, проникність, пористість) порід із глибиною. Також розглядаються перспективні відкладення, горизонти родовищ виходячи з детального аналізу численних зразків порід. Особливо виділяються нафтогазоносні об'єкти на площах, і навіть можливі нафтогазоносні блоки. Основна мета даних досліджень – простежити зміни карбонатності, пористості та проникності гірських порід із глибиною на основі зразків керна, взятих із пробурених свердловин на досліджуваній площі та виявити фактори, що викликають ці зміни. Для цього за отриманими свердловинними даними були складені залежності зміни по глибині пористості, проникності та карбонатності. Як відомо, із зростанням глибини породи зазнають ущільнення. З глибиною зміни пористості породи виявляють якусь закономірність, тобто. на деяких глибинах спостерігається збільшення пористості порід, а на деяких – зменшення, причому це відбувається стрибкоподібно. На наших розрізах критичні глибини зменшення пористості спостерігається від 500 м до 1600 м, а критичні глибина збільшення пористості від 1600 м до 2950 м. Інакше кажучи, пористість колекторів при загальному поступовому зниженні по глибині з глибини 3200 м починає різко зменшуватися. При дослідженні кернових матеріалів встановлено, що породи характеризуються добрими колекторськими властивостями. Проте, у багатьох досліджених зразках пористість порід змінюється у межах 12,8–27,8 %, а проникність коливається від 0,001х10–15m^2 до 120х10–15m^2. Зміни петрофізичних значень спостерігаються у обох районах дослідження. Причина зміни петрофізичних значень у широкому діапазоні на об'єктах дослідження пов'язана з літологічною неоднорідністю комплексів та глибиною залягання колекторів.

Ключові слова: петрофізичні характеристики, пористість, проникність, карбонатність, піщанистість, поклад, потужність.

Introduction

The Kursengi oil and gas condensate field is located in the southeastern Shirvan region, 23 km southeast of the Shirvan region. The field covers the low part of Azerbaijan, with a height below 19–20 m above sea level. The central part of the field is complicated by the Kursangi mud volcano (Alizade, et al., 1966; Shikhlinsky, 1967).

In the geological structure of the fields, deposits of the productive series (PS), Akcagil, Apsheron, Baku stages, including modern and old Khazar deposits are widespread. When analyzing the emissions of a mud volcano, it was found that there are also Oligocene-Miocene and Upper Cretaceous deposits in the section of the field (Fig. 1).

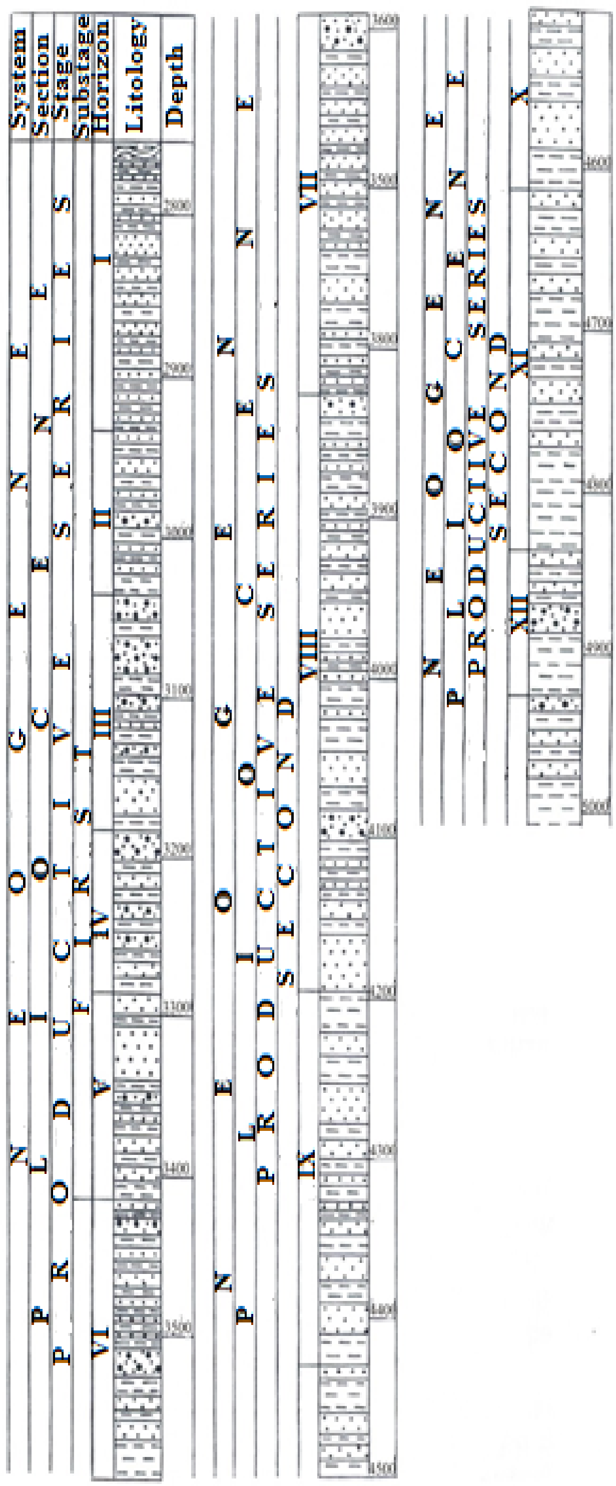

Fig. 1. Generalized geological section of the Kursengi field

The deposits of the productive series were opened up to the XVI horizon with deep drilling wells; the thickness of the PS is 2300 m. According to the core composition, these deposits are represented by alternating sands and clays of grey, brown-grey and greenish-grey colours. The upper part of the PS is characterized by high sand content (40–55%). The horizons below XI horizon are marked by low sandiness, what is more the sand content decreases to 15–20%. According to the sections of the wells No: 80, 87, 72, the total thickness of PS is 3800 m.

Sediments of the Akcagil stage are represented by alternating dark grey clays and greyish brown sands with fine carbonate grains. The shaliness of the section is higher here and reaches 75–80%. The thickness of the deposits varies from 95 m to 120 m.

Deposits of the upper Absheron substage are up to 450 m thick and are represented by clays with interlayers of sands and sandstones. The thickness of the deposits of the middle Absheron substage is 670 m and lithologically is represented by alternating sands, sandstones and clays. The sediments also contain layers of volcanic ash. Deposits of the lower Absheron substage are represented by greyish dark fatty clays with thin interlayers of limestones, brownish sands and sandstones. The thickness of the deposits is 520 m.

The deposits of the Baku stage, with 145 m thickness, are represented by grey and brown carbonate dense clays with rare sand interlayers.

Loams, sandy loams, mud volcano breccias, sands, sandstones and yellowish and greyish-brownish coloured clays represent the modern and old Khazar deposits. The thickness of the deposits is 550 m.

Tectonically, the Kursengi and Southern Kursengi uplifts are located in the southeast part of Shirvan city, between the Kelameddin-Bandovan and Kurovdag-Neftchala anticlinal zones (Fig.2).

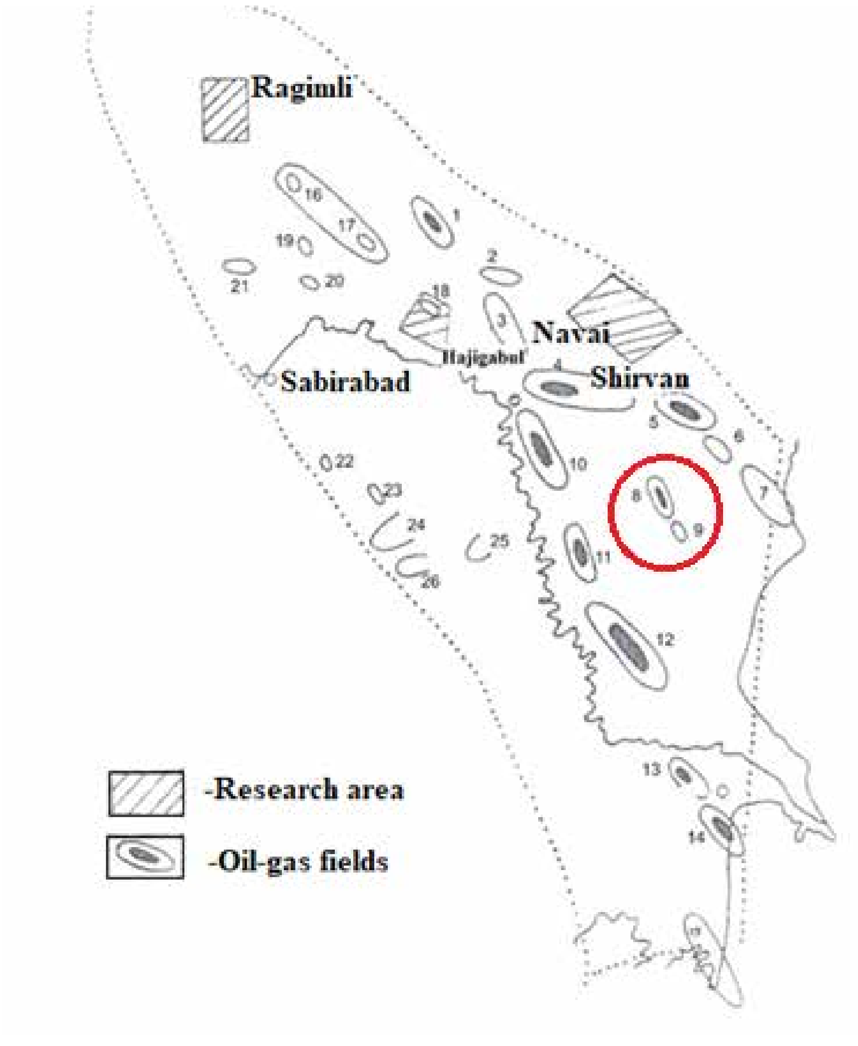

Fig. 2. Local uplifts in the Lower Kura depression

1 – Kalamaddin; 2 – Creater Harami; 3 – Lesser Harami; 4 – Mishovdag; 5 – Kalmas; 6 – Hidirli; 7 – Agzibir-Bandovan; 8 – Kursangi; 9 – S.Kursangi; 10 – Kurovdag; 11 – Garabagli; 12 – Babazanan-Durovdag; 13 – Killi; 14 – Neftchala; 15 – Kizilagac; 16 – N.Padar; 17 – S.Padar; 18 – Kurtasi; 19 – W.Garasu; 20 – Govlar; 21 – Arabgubali; 22 – Azadkend; 23 – Nesimkend; 24 – Azadkend; 25 – Muganli; 26 – Serhanbeyli.

Kursengi and Southern Kursengi are submerged uplifts and morphologically they are not exposed on the Earth's surface, but the presence of a mud volcano of the same name here testifies to these uplifts (Fig. 3).

The Southern Kursengi uplift is located southeastward of the Kursengi brachyanticline (second undulation). Moreover, when the Kursengi field was discovered in 1961, the Southern Kursengi area was considered as the far-out southeastern pericline of the main field, where 4–5 wells were drilled, without any positive results.

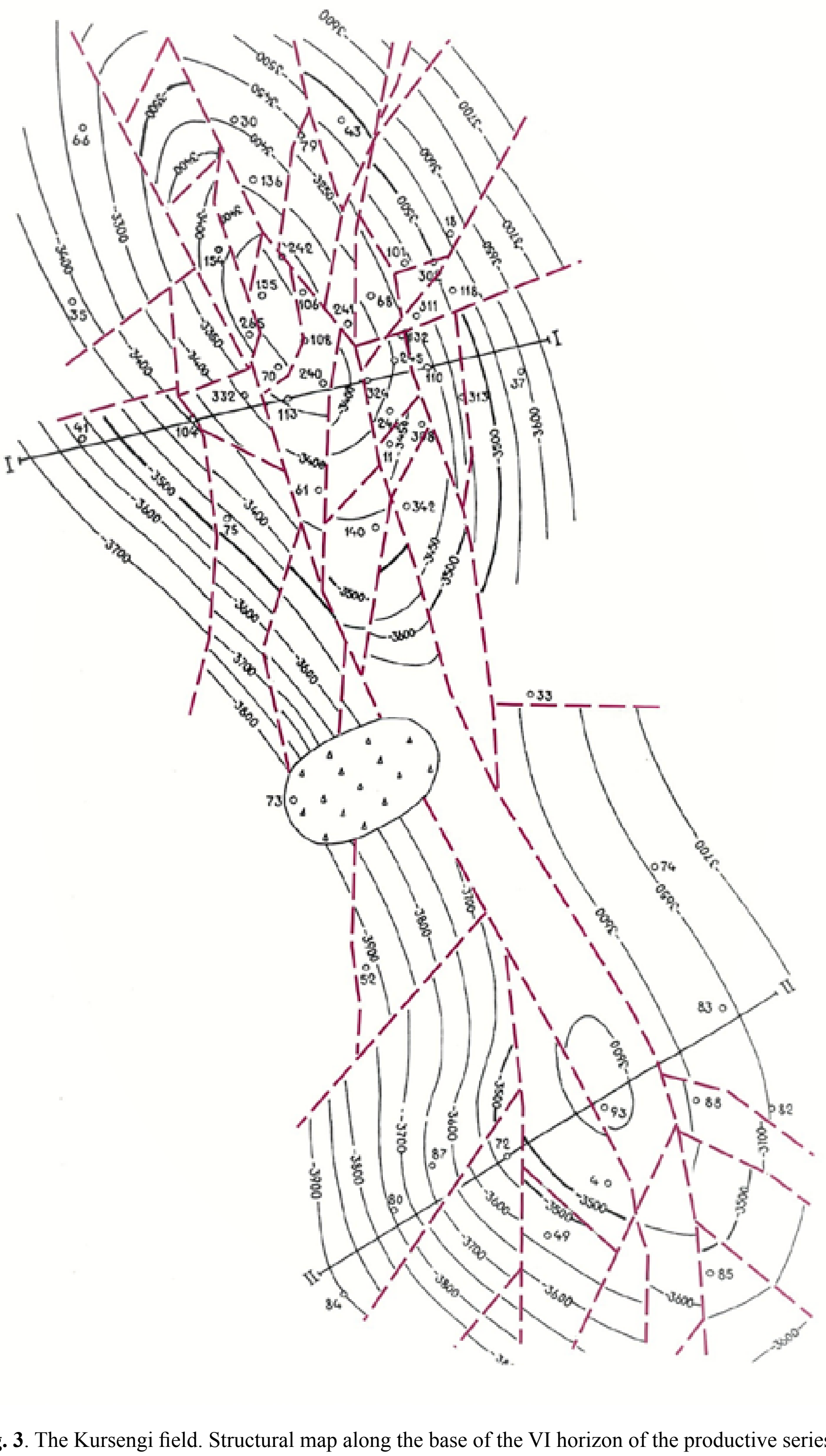

Fig. 3. The Kursengi field. Structural map along the base of the VI horizon of the productive series

Naturally, in order to prepare the field for development, it was necessary to concentrate drilling operations in the Kursengi field. However, in 1966-1969 based on minimal seismic data and conducted paleotectonic studies, the existence of the Southern Kursengi structure was confirmed. Seismic works, which carried out in 1968–1969, confirmed the existence of this structure, but well No. 84 drilled here in 1973 has opened the oil-bearing of this field (XIII horizon). The Southern Kursengi uplift is 6 km long and 4 km wide, the dip angle of the limps varies from 10^0 to 120^0 in the southwest part of area and from 8^0 to 100^0 in the northeast one.

Both uplifts are complicated by two parallel faults that can be traced along the long axis, as well as numerous transverse faults. Along the longitudinal faults, the central blocks fell out in the form of grabens with an amplitude of 80–150 m (Fig.3, 4) (Shikhlinsky, 1967).

The amplitudes of transverse and radial faults vary from 70 to 200 m and play an important role in the distribution of oil and gas in the field. The Kursengi mud volcano is associated with both longitudinal and transverse faults.

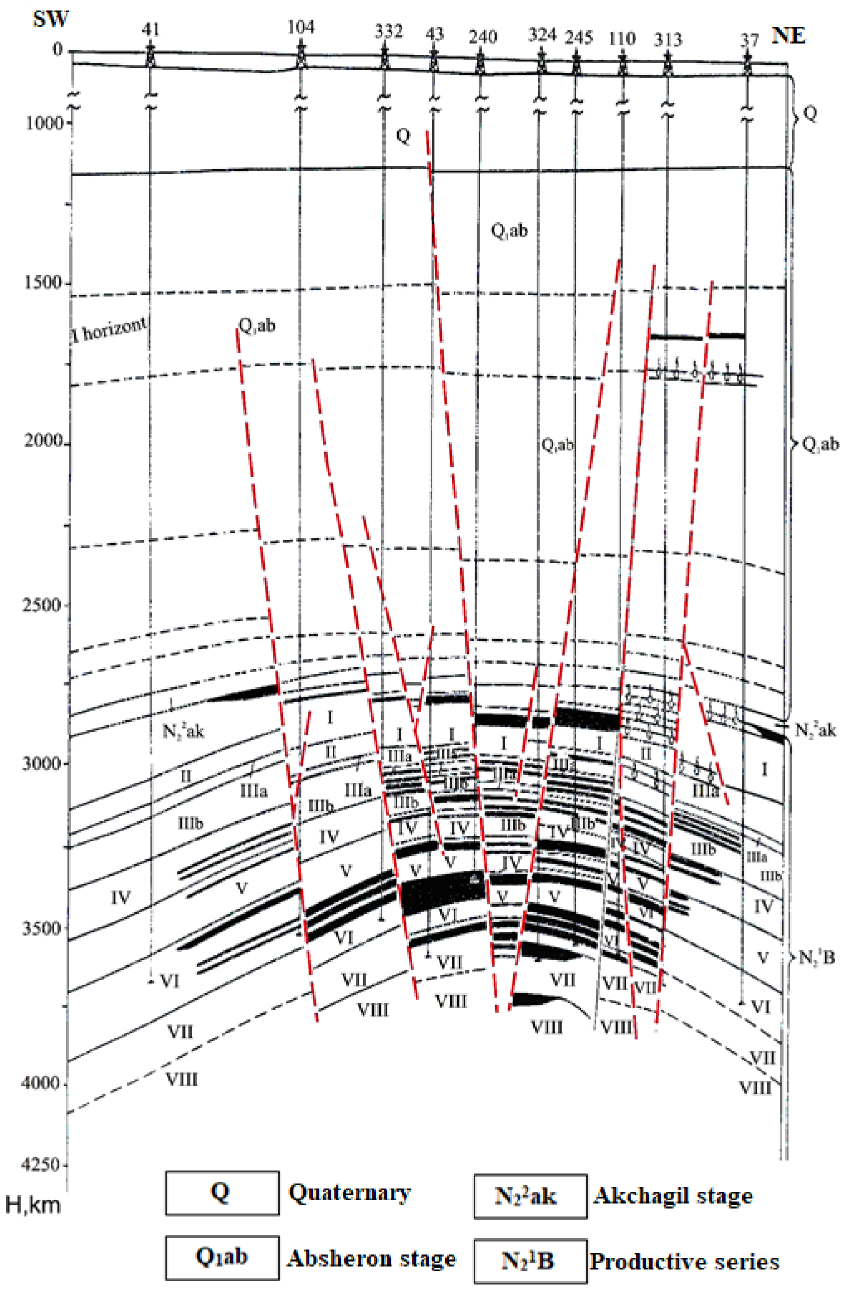

Fig. 4. The Kursengi field. Geological profile along the line I–I

The prospects of the Kursengi field became known in 1961. Exploration well No. 8 drilled on the crestal part of the structure was stuck-off at a depth of 3047 meters, and on the sidelines of the "oil bath" for unfreezing the drill pipes, a gusher occurred in the well. Subsequent geological exploration works determined the oil and gas bearing of the lower horizons of the productive series up to the XII horizon, as well as the deposits of lower and middle of the Absheron stage. In general, six sandy horizons in the upper part of the productive series were found to be oil and gas bearing. The rest horizons of the PS (including XII horizon) in some blocks are oil and gas bearing. The highest oil and gas saturation is observed in the near-crestal part of the central blocks. In the near-limps blocks, these horizons are weakly oil and gas bearing or completely "empty". Among the 25 tectonic blocks identified in the area, hydrocarbon accumulations were found only in 15 blocks. The deposits present here are mainly associated with tectonic screened and domed traps (Fig. 4, 5).

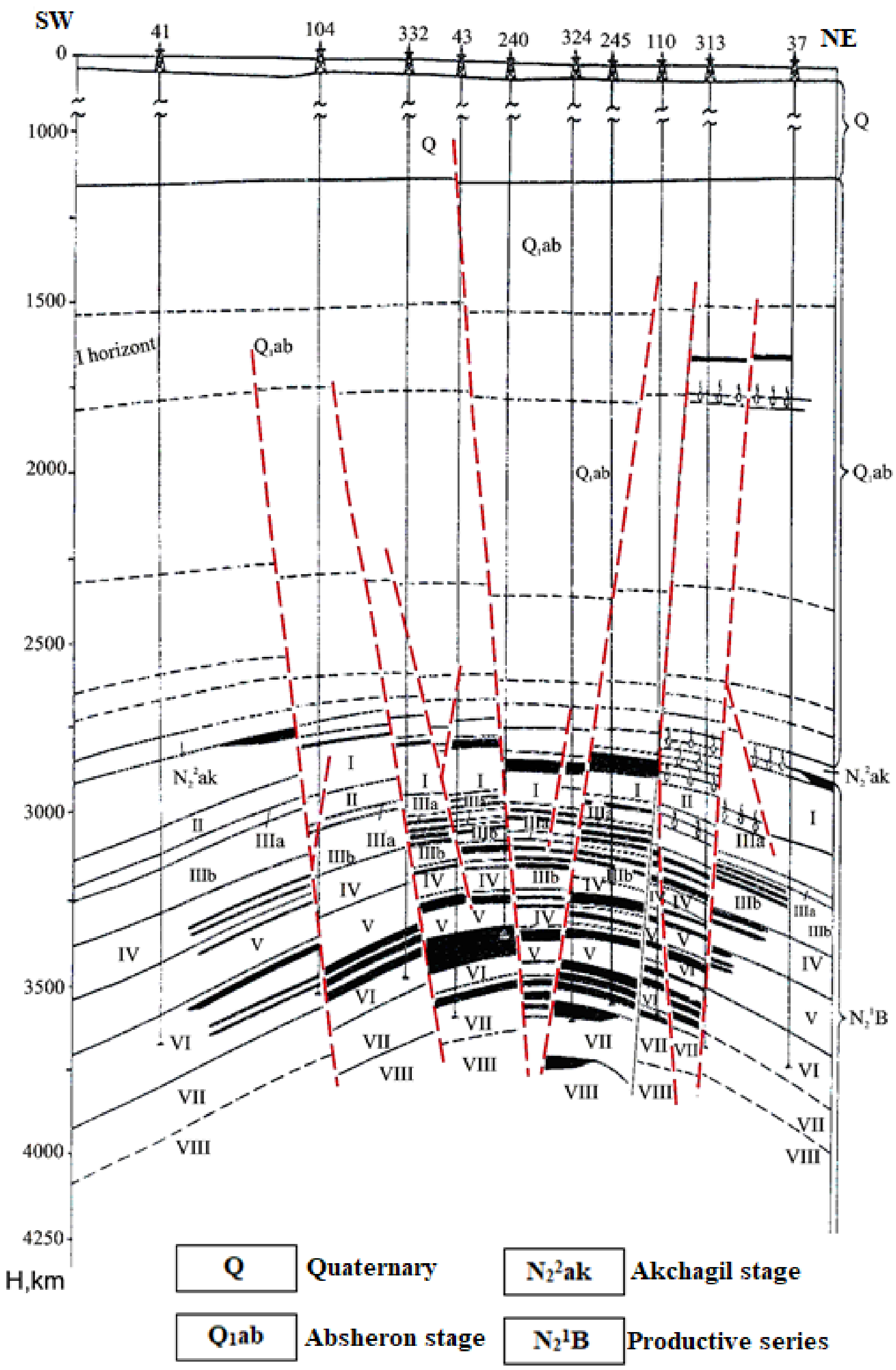

Fig. 5. The Southern Kursengi field. Geological profile along the line II-II

Despite the fact that the geological structure of the Kursengi and Southern Kursengi fields are very similar, the oil and gas horizons differ in oil and gas saturation. Thus, the productive oil-bearing horizons at the Kursengi field are mainly associated with the upper horizons of the deposits of the productive series, and at the Southern Kursengi field, productivity is noted in the lower horizons (III–XII).

Gas inflows were also obtained in some of the near-crestal blocks of the field from horizons I and III. Moreover, the largest oil inflows were recorded in horizons I, III, V and VI, with a flow rate in the range of 57–310 tons/day. Gas production amounted to 98–433 thousand m^3/day. The oil of the field is mostly heavy – 0.900–0.930 g/sm^3.

Materials and methods

The main purpose of these studies is to unravel changes in carbonate content, porosity and permeability of rocks with depth based on core samples taken from drilled wells in the study area and to identify the factors causing these changes. To do this, using the obtained well data, the dependences of changes in depth of porosity, permeability and carbonate were compiled.

As known, with increasing depth, rocks experience compaction. With the depth of changes in porosity, the rocks do not show any regularity, i. e. at some depths, an increase in the porosity of rocks is observed, and at some depths, a decrease, and this occurs in an abrupt manner. In our sections, the critical depths of porosity decrease are observed from 500 m to 1600 m, and the critical depth of porosity increases from 1600 m to 2950 m. In other words, the porosity of reservoirs, with a general gradual decrease in depth, begins to sharply decrease from a depth of 3200 m.

As can be seen from the graph, the porosity and permeability of the rocks is lower at depths where the carbonate values are higher compared to other depths. However, at a depth of 3100 m, this regularity is violated. With a high carbonate content in the rocks (19.2 %), the permeability is $120x10^{-15}$ m^2. The change in the permeability of rocks at some depths is probably associated with the manifestation of derivative fractures at these depths.

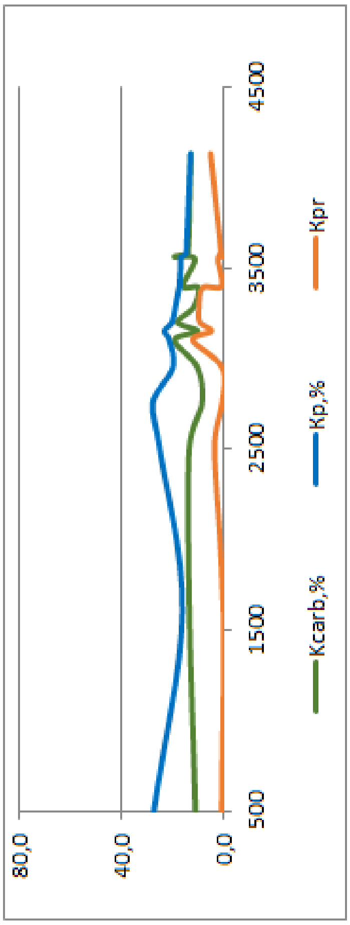

Fig. 6. Changes in the values of porosity, permeability and carbonate content of rocks with depth

The high content of carbonates in sediments reduces the permeability of the rocks and negatively affects their porosity.

As can be seen from the graph, the carbonate content of the rocks is uneven in depth. At certain depths, an increase, at some a decrease, in the carbonate content of rocks is observed, and at a certain depth the increase in carbonate content occurs abruptly. In this case, the sandstones reduce their poroperm properties in relation to the previous interval of relative stabilization of reservoir properties to the marked depth, i. e. each time the rocks take on a new qualitative state. The critical depths, where the carbonate content of the rocks sharply increases, correspond to the interval of 3100–3560 m.

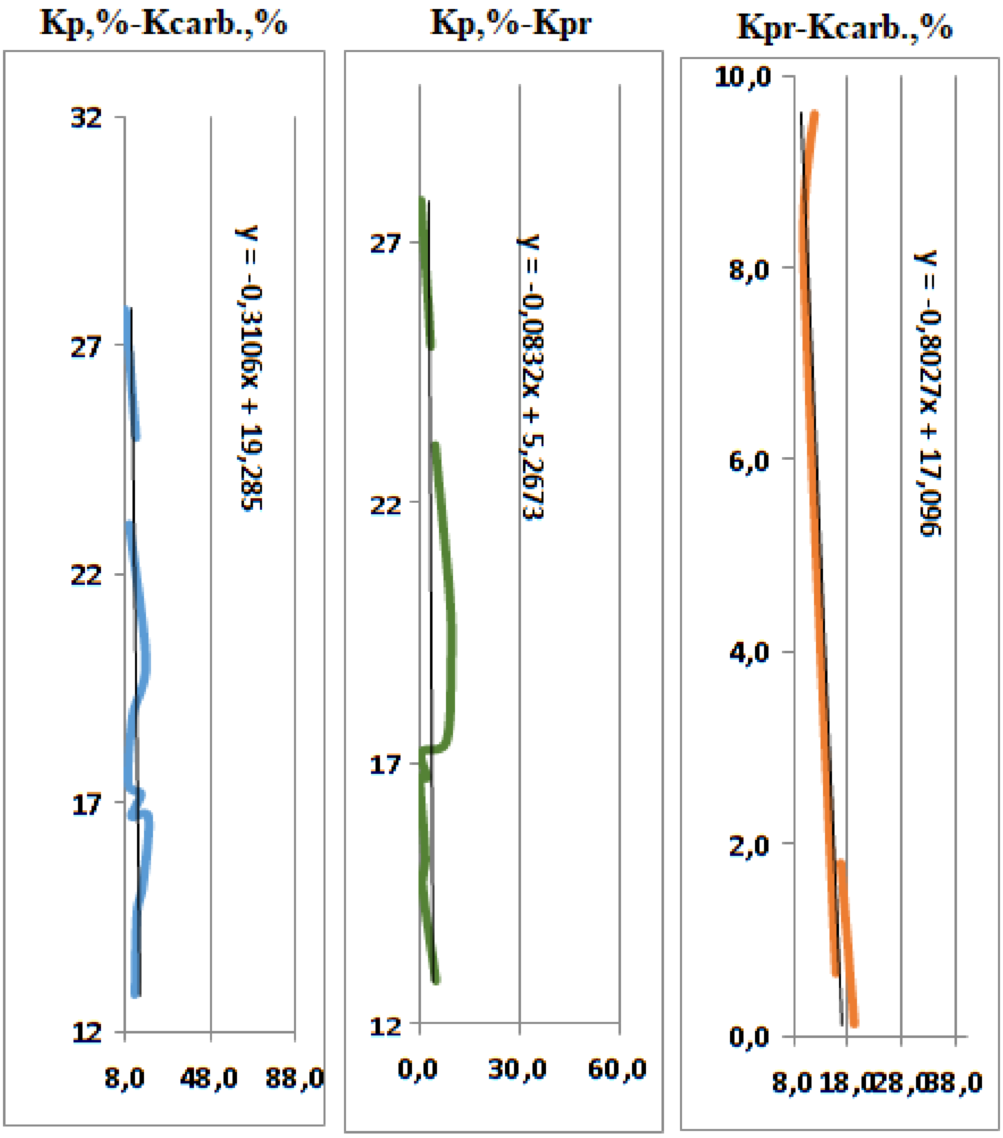

Fig. 7. Relationship between the values of porosity, permeability and carbonate content of rocks

Considering the above, it was of interest to clarify the degree of interdependence of the studied parameters and the nature of their variability along the depth of the section. For this purpose, we analyzed the depth variations of paired bonds K_p,% – K_{carb},%, K_p,% – K_{pr} and K_{pr}-K_{carb},%. The results of the performed analysis are shown in Figure 7. As follows from the compiled dependencies, the dependence between permeability coefficient of rocks ($K_{pr.}$) and carbonate content (Kcarb.) are most consistent and monotonic. Correlation relationship between $K_{pr.}$ and $K_{carb.}$ it has the opposite nature of the dependence and is described by the equation $K_{pr.} = -0.802 * K_{carb.} + 17.09$.

A more complex nature of the dependence, with the presence of areas of stick-slip variations and inversions of values (breaks), is observed between the porosity coefficient (K_p) and carbonate content ($K_{carb.}$). Critical areas of the section with sharp variations in values can also be distinguished here. A similar, stick-slip nature of the dependence is observed for the pair dependence of Kp and Kpr, which indicates a stable effect of carbonate content on the poroperm properties of oil-containing reservoirs.

Table 1. Critical depths and corresponding values of petrophysical parameters of reservoir rocks

Critical depth, m	Permeability, 10^{-15} m^2	Porosity, %	Carbonate content,%
2500	35	25,0	13,4
3150	48	23,1	10,2
3280	96	18,9	11,8
3390	82	17,4	9,8
3560	10	16,7	19,2

Conclusions

According to the studies, the PS deposits in the study area are lithologically composed of alternating sands, sandstones, silts and siltstones with thick layers of clay. Changes in petrophysical values are observed in both study areas. The reason for the change in petrophysical values in a wide range at the objects of study is associated with the lithological heterogeneity of the complexes and the reservoir depth.

From the constructed dependences of the values of porosity, carbonate content and permeability of reservoirs, it follows that at certain (critical) depths, there are stick-slip variations in reservoir properties with depth. The study of reservoir features of the region shows that, in particular, at some critical depths, there is a decrease in porosity, but a simultaneous increase in permeability, which may indicate the presence of derivative fractures and an improvement in reservoir properties of oil-bearing horizons.

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