ANAS Transactions Earth Sciences 2 / 2023

http://www.journalesgia.com

AQUIFER ACTIVITY MODEL IN HYDROCARBON FIELDS (SOUTH CASPIAN BASIN AS A CASE STUDY)

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Keywords: *aquifer, field, formation, field modeling, hydrodynamics, formation pressure, fluid*

Summary. The SCB (South Caspian Basin) is considered one of the world's unique in terms of hydrocarbon reserves. At present, the hydrocarbon potential of the basin has attracted foreign companies to conduct large-scale research here. As a result of these surveys, 120 structures were discovered in the Azerbaijani part of the SCB, of which 21 structures were identified as oil and gas and 17 fields are being developed.

The main purpose of the study is to analize the hydrodynamic activity characteristics of the basin, to improve field models, to develop efficient development scenarios, to more accurately forecast the reserves and resources of the field and, as a result, to develop a modeling of the aquifer basin of the South Caspian Basin. The hydrodynamic activity model of the basin is especially important in the modeling of oil and gas and gascondensate fields. While modeling the hydrocarbon-water contact and the movement mechanism (Fetkovich, Carter Tracy, inactive), for the improvment an effective field development plan, it is necessary to clarify pressure, direction of movement, etc., which is possible only as a result of the compilation and analysis of the basin activity model. The advantage of the study is that the used data from oil and gas fields related to the surrounding basins, and the volumes of gas produced from the basin were calculated in reservoir conditions. In this regard, the research is of great theoretical and practical importance.

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Introduction

In general, the South Caspian Basin is divided into three parts according to its geological, structural-tectonic, lithological-stratigraphic and orohydrographic features, which are the Absheron, the Baku archipelagos and the Deep Caspian.12 of the developed fields are located in the Absheron and 5 in the Baku archipelagos. The depth of the sea in the basin is up to 1000 m. The main object of exploitation in the basin is the Productive Seria (PS) sediments, the thickness of which varies between 2800-4000 m. Most of the developed fields operate in active water flooding, gas cap and dissolved gas regimes. At the same time, in some fields (the Neft Dashlari, shallow water Guneshli, the Azeri-Chirag-Guneshli, etc.) development was carried out by injection. At present, the oil recovery factor in the SCB has reached 0.23 and the gas recovery factor has reached 0.22 (Abasov et al., 1997; Salmanov et al., 2021; Нариманов, 1998; Велиева, 1997).

Investigative methods

As a result of large-scale seismic and exploration drilling in the basin, the structural and tectonic form of the area was studied and three-dimensional structural models were created (Fig.1). The three-dimensional model also shows that the depth in the Absheron archipelago is shallower than in other areas due to the top and bottom of the PS (1500-3000 m according to Pereriv series - PrS). The south-western part of the Baku archipelago is also more hypsometrically shallower (2000-3000 m according to PrS). It should be noted that this factor has made it relevant to conduct large-scale exploration work in these areas. The deeper areas of the PS are the central parts of the SCB (5000-7000 m according to the PrS).

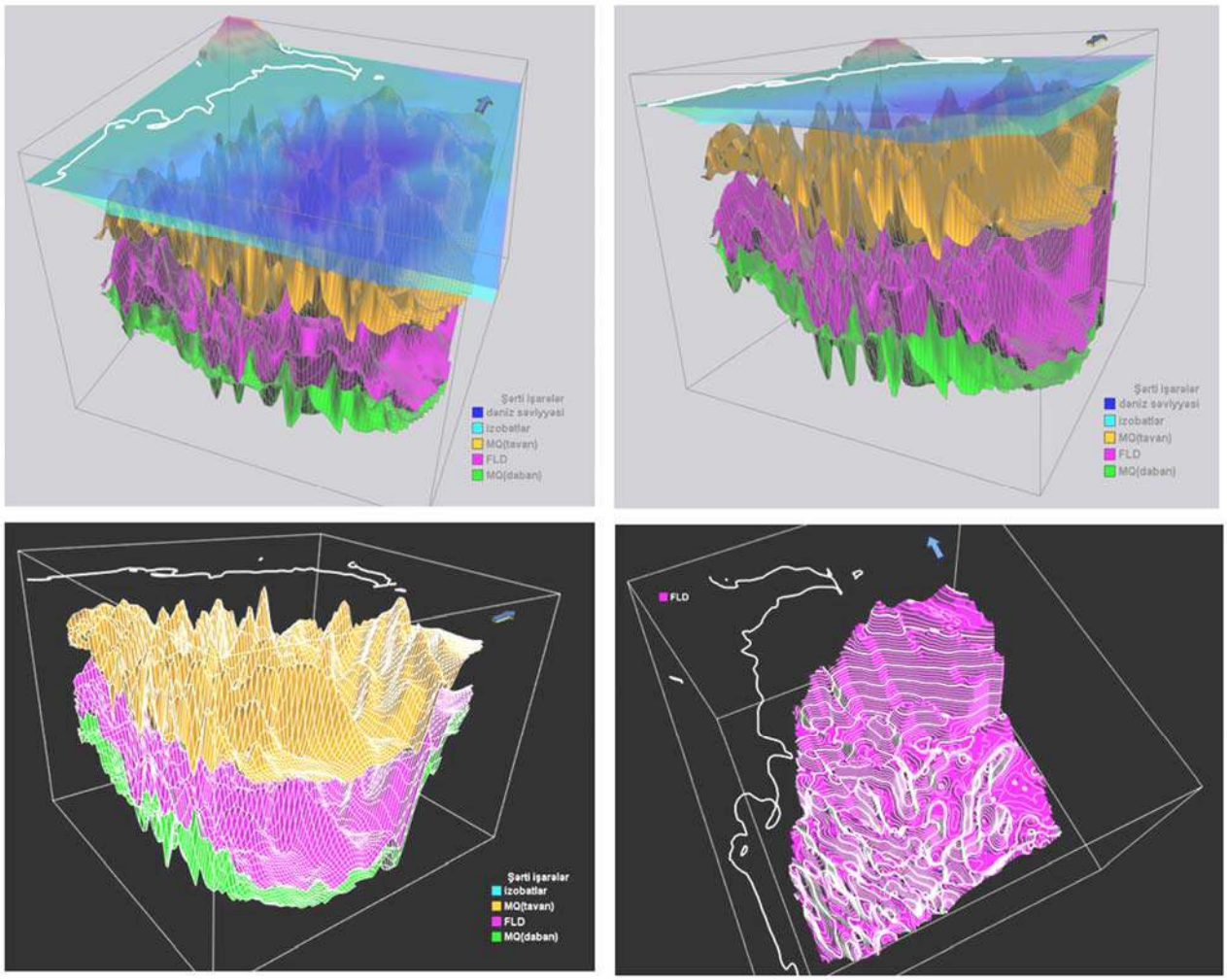


Fig. 1. 3D structural-tectonic models of the SCB

Due to the characteristics of the individual structures in the SCB, the main complex structures are located in the Absheron archipelago. The Absheron uplift zone is more geologically complex. In the north-western part of uplift zone, the top of the PS is almost eroded. The thickness of the PS towards the center of the SCB is also increasing. It requires deeper exploration and drilling in the area.

The developed three-dimensional structural-tectonic model of the South Caspian Basin made it possible to study these tectonic features in more detail. The model fully reflects the structural and tectonic structure of the top and bottom of PS sediments. The uplifts and structures located in the Azerbaijani sector of the Caspian Sea were analyzed in the general case, and then analyzed on regions (the Absheron Archipelago, the Baku Archipelago and the deep Caspian region). These models are very important in the classification of structures, basin modeling, and the compilation of regional tectonic maps (Salmanov et al., 2021; Салманов и др., 2019; Rahimov et al., 2019; Ahmadov, Veliyev, 2019; Шыхова, 2018; Искендеров и др., 2017). From this point of view it would be correct to consider the model currently compiled as a single three-dimensional structural-tectonic model for the South Caspian Depression. It is necessary to collect, systematize and analyze the following geological data to develop a basin activity model:

– Seismic exploration and prospecting drilling work on stratigraphic units (main horizons);

– Lithofacial features of the basin;

– Accumulated fluid volumes on deposits and horizons – regional drainage maps;

– Formation pressure on the field (initial and current).

The hydrodynamic activity model of the basin was compiled on the basis of the mentioned geological data with the following sequence of processes (Fig. 2).

The following calculation method was used to calculate the produced geological and field data brought to the stratum conditions and produced fluids (oil, water, gas) in the reservoir conditions:

$$Q_{total} = (Q_{osc} / \rho_o + Q_{water} + V_{girc}) - V_{iw}$$

where, Q_{total} – volume of the accumulated total fluid, m^3;

Q_{osc} – quantity of oil is measured under standart conditions, ton;

ρ_o – density of oil and condensate, kg/m^3;

Q_{water} – volume of the produced water, m^3;

V_{girc} – volume of gas produced in reservoir conditions, m^3;

V_{iw} – volume of the injected water into the formation, m^3.

The initial formation pressure in the unexplored areas of the basin was predicted on the basis of depth dependence graphs (Fig. 3).

Based on these graphs, the first formation pressure in the unexplored areas of the basin at the corresponding horizons were calculated and maps of the field distribution of the first averaged pressures derived by interpolation were compiled (Fig. 4). It can be seen from all the maps that the main hydrodynamic impact on the developed deposits of the basin is associated with deep areas of the southern Caspian. The forces of motion created by such high pressure make it possible to predict the source and direction of activity. But the main mechanisms of movement of the water basin, its velocity, directions can be determined as a result of other studies (Ворошилов, 2001; Ahmadov, 2013).

In Fig. 5 regional drainage maps of the basin on the horizons were compiled. As noted, to increase the accuracy level of drainage maps, the accumulated fluid volumes were calculated in reservoir conditions (Fig. 5).

The research work shows that the main movement of the water basin is directed towards the areas that are drained. An analytical approach has been applied to calculate the current formation pressure depending on the fluid volumes produced to investigate the dynamics of water flow. To determine the dependence of the volume of fluid extracted in the basin on the current formation pressure, first of all, the condition was accepted that the water basin is inactive, and the corresponding drop in reservoir pressure per volume of extracted fluid in 1 million m^3 was calculated (Fig. 6).

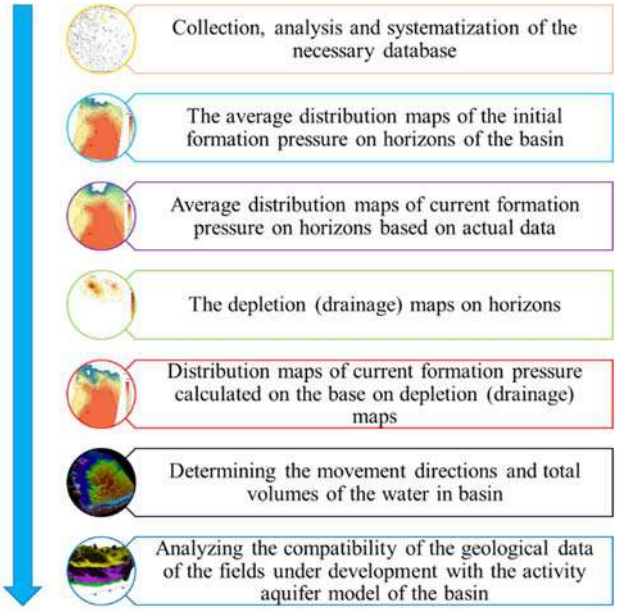


Fig. 2. Scheme of the creation model of hydrodynamic activity of the basin

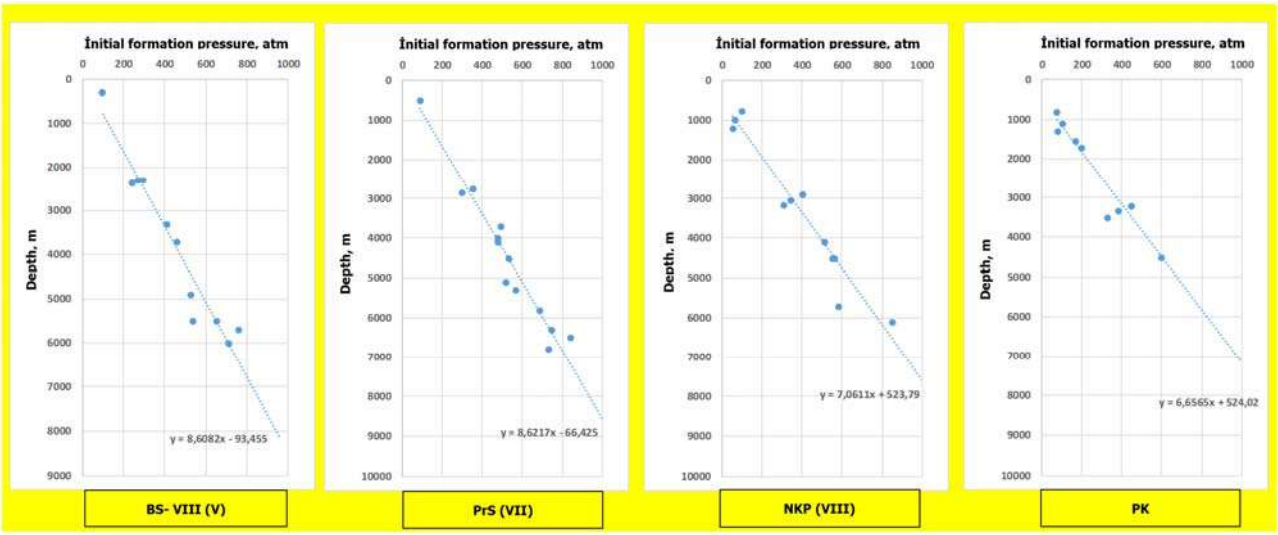


Fig. 3. Graphs of depth dependence of the initial formation pressure

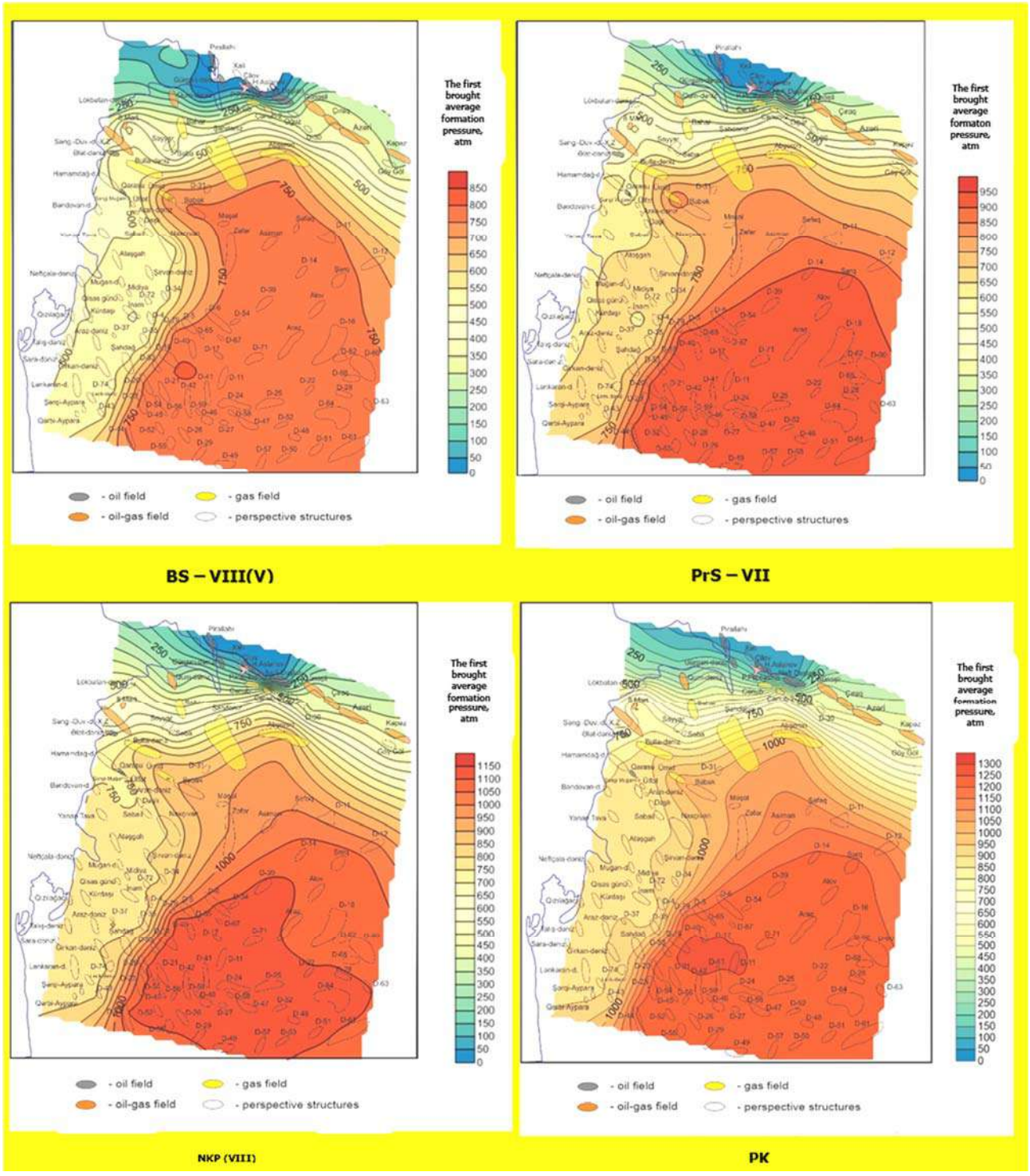


Fig. 4. Maps of the pressure distribution of the initial formation along the horizons

As we know, in accordance with the volume of fluid produced in the deposits, the pressure of the formation should also fall. This pressure drop should change according to a straight-line graph defined in the dependency graphs. But the scatter charts show that in most fields the decline formation pressure, which depends on the volume of produced fluid, is very low. The reason for this can only be due to the movement of the water basin and partial retention of reservoir pressure due to natural forces. For the case of inactivity of the basin the current formation pressure in the fields was calculated by the method:

$$k = (P_{initial}-P_{current}) / Q_{total}$$

where, k – is the pressure drop coefficient of the layer corresponding to the volume of the produced fluid in 1 mln m^3;

$P_{initial}$ – is the initial formation pressure, atm

$P_{current}$ – is the current formation pressure, atm

Q_{total} – is the volume of total fluid extracted from that field.

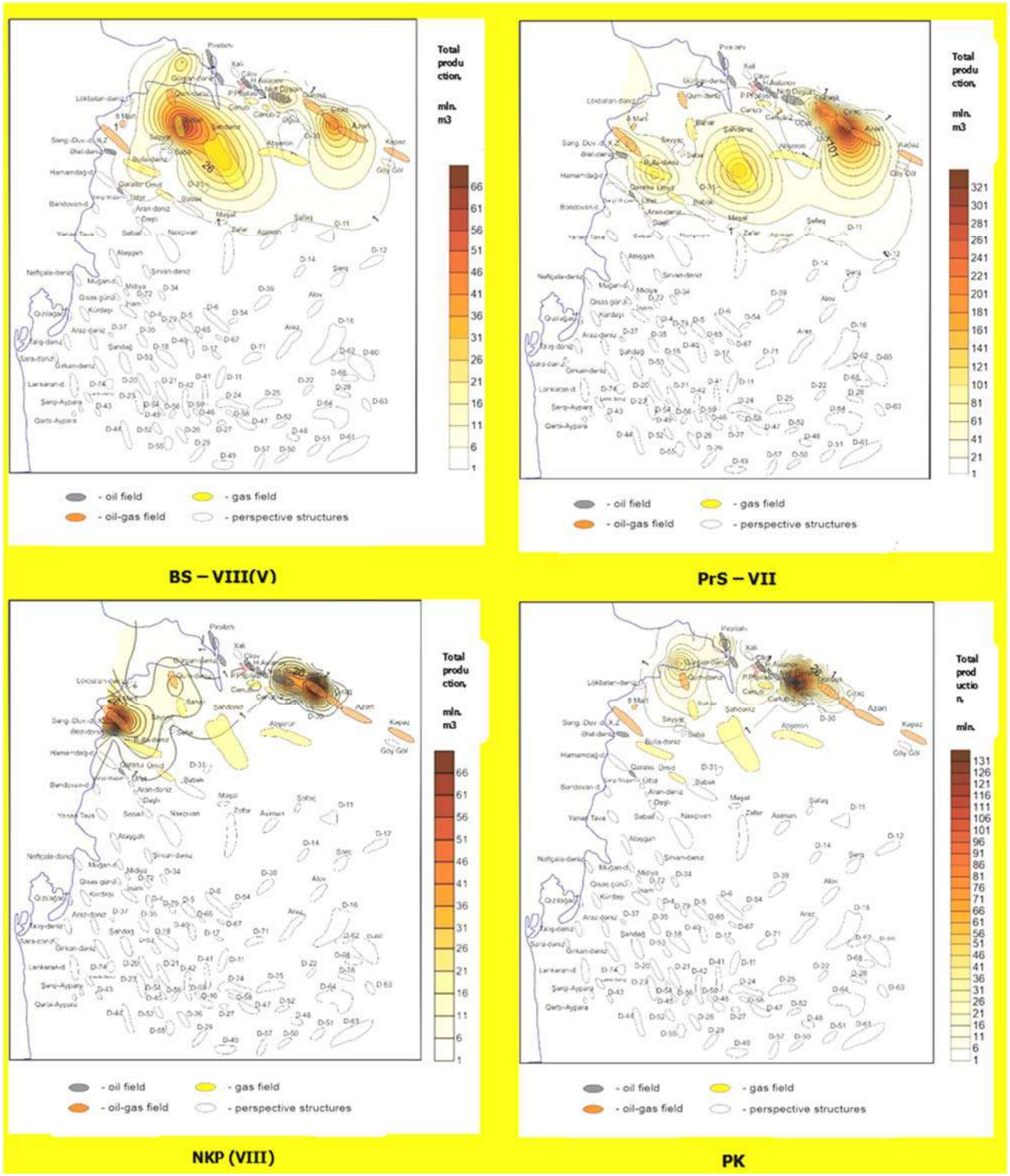


Fig. 5. Total fluid maps collected on horizons (regional drainage maps)

If we calculate the current layer pressure ("how much should it be") using the corresponding formation pressure drop trend to the output fluid volume of 1 million m^3, then we get the following mathematical expression:

$$P_{curr.calc} = P_{initial} - k_{trend} \cdot Q_{total}$$

where, $P_{curr.calc}$ – is the calculated current formation pressure, atm;

$P_{initial}$ – is the initial formation pressure, atm;

k_{trend} – is the coefficient calculated by the method of the trend of the formation pressure drop corresponding to the volume of the produced fluid in 1 million m^3;

Q_{total} – is the volume of total fluid extracted from that field.

Thus, the distribution maps of the calculated current pressure of the formation are compiled (Fig.7).

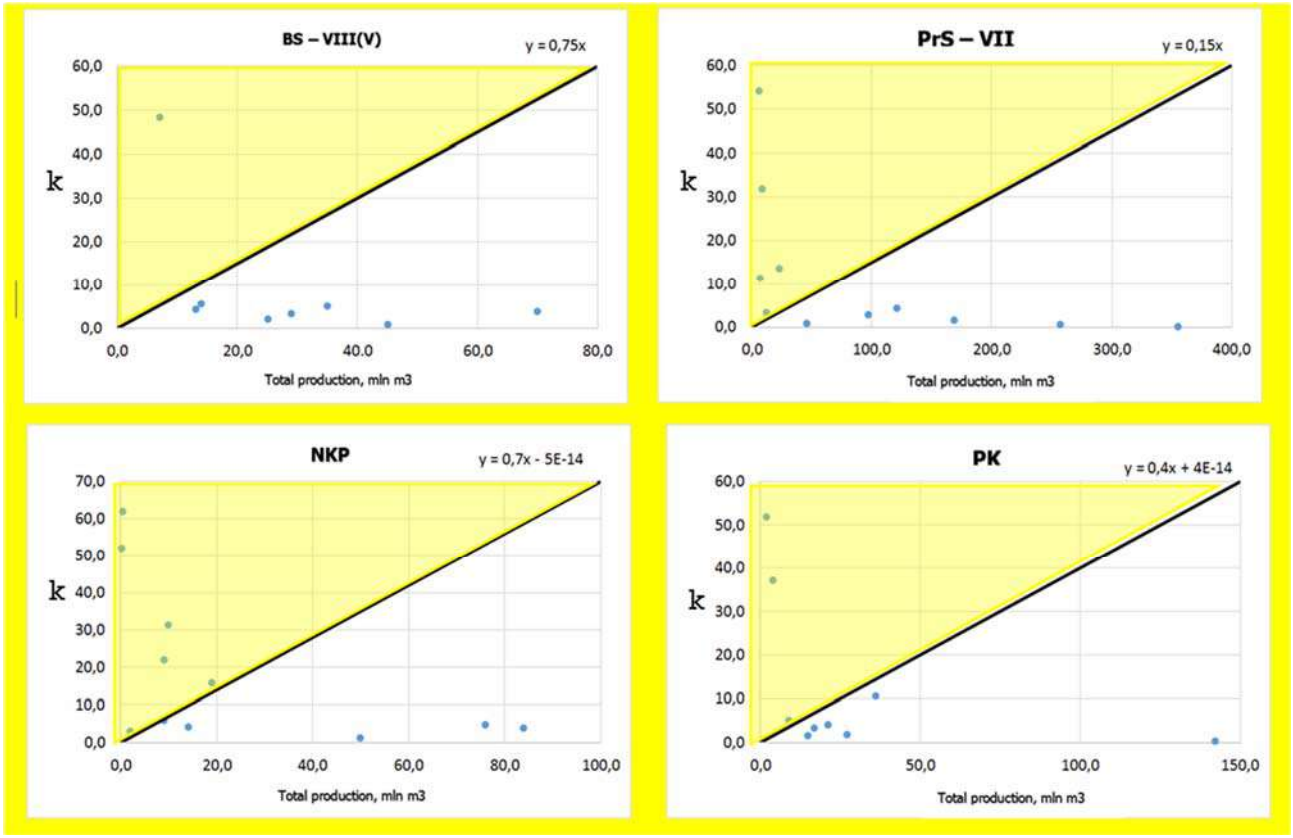


Fig. 6. Graphs of the corresponding drop in formation pressure to the volume of the extracted fluid of 1 million m^3 on the horizons

Determination of the hydrodynamic activity of the water basin (direction of movement, velocity, mechanism, etc.) for the study, a joint analysis of the current pressure maps of the layer (Fig. 8) was carried out compiled on the basis of actual measured data, cumulative maps of the remote fluid (regional drainage maps) and corresponding calculated maps of the current pressure of the remote fluid layer.

Thus, in the VIII horizon of the Balakhani formation (BS) in the direction of the Bahar, Gum-Deniz, Neft Dashlari, Azeri-Chirag-Guneshli deposits, the current formation pressure should have been less than 50 atm. But the formation pressure was partially maintained (200-250 atm in the ACG field). The analysis of regional drainage and average distribution maps of actual current formation pressure shows that the main direction of the water basin on the VIII horizon of the Balakhani reservoir moved in the direction of the Neft Dashlari, Azeri-Chirag-Guneshli, Bahar and Gum-Deniz deposits, and about 110-170 million m^3 of water moved in these directions.

This movement (dynamics) on the PrS is higher. Thus, about 500-570 million m^3 of water were put into motion in the direction of the Neft Dashlari, Azeri-Chirag-Guneshli, Bahar, Shah Deniz and dry fields located on the Absheron.

The results are characterized more differently in the lower part of the PS. The water basin of the Upper Kirmaki sandstone (NKP) and Lower Kirmaki (PK) formation is more passive than the upper part of the PS. Thus, the water basin of the NKP reservoir moved mainly in the direction of the Neft Dashlari, shallow water fields of the Guneshli, Gum Deniz and Sangachal-Duvanny-Khara-Zira, and about 110-150 million m^3 of water moved in these directions. According to the PK layer, the water basin moved in the direction of the Palchig Pilpilesi, Neft Dashlari and shallow water Guneshli fields, and about 150-180 million m^3 of water moved in these directions.

Results and Discussion

In order to determine the reliability of the results of large-scale research work, the obtained results were subjected to comparative analysis with field-geological and operational indicators of hydrocarbon deposits under development in the basin. Thus, the oil and water boundaries at the Guneshli field are actively irrigated mainly from the southern wing. In the upper part of the PS at the AChG fields (VIII, IX, X horizons of the Balakhani layer and PrS), although active irrigation was carried out from the northern wing, but the southern wing was irrigated faster, and the water-oil boundaries moved more actively. The main development horizons of the southern wing at the Sangachal-Duvanny-Khara-Zira, Alat-Deniz, Bulla-Deniz and Umid fields are water-saturated. In addition, the eastern periclinal of the Bulla-Sea field is irrigated faster.

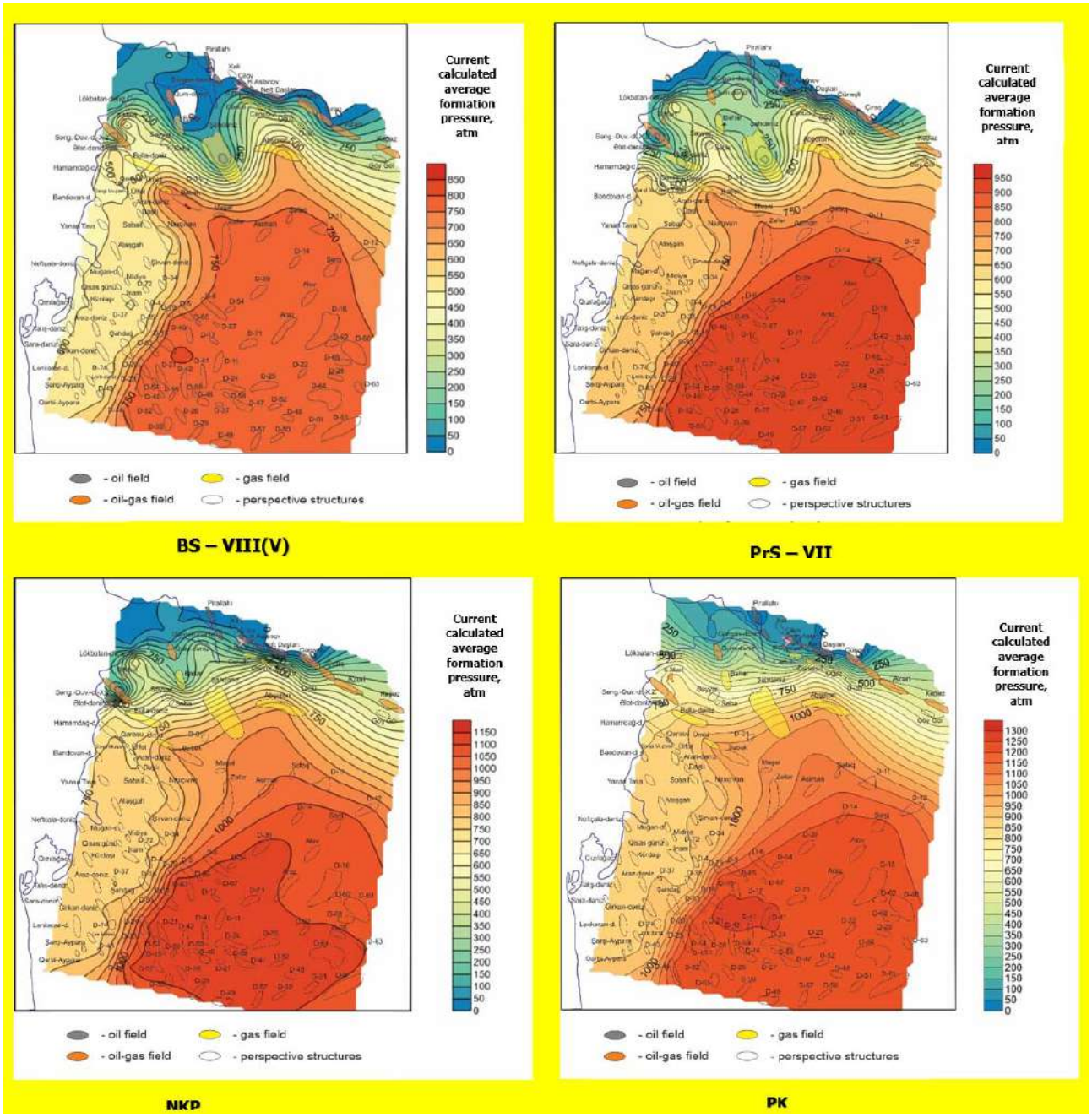


Fig. 7. Maps of current average formation pressure calculated on horizons

At the Absheron field, based on the analysis of attribute maps compiled along the VIII horizon and the PrS of the Balakhani layer, there is a shift of hydrocarbon boundaries to the north and a saturation of hydrocarbons in the southern wing of the field. The analysis of hydrodynamic conditions at the marked fields also confirms the results of the research work, that is, the hydrodynamic activity of the water basin in the SCB from the northeast to the northwest.

Conclusions and Recomendations

Based on the conducted large-scale research work and comparative analysis of the compiled two-dimensional model of hydrodynamic activity of the SCB water basin, the following results were obtained and useful suggestions were given:

– Actual historical indicators of field development and analysis of the aquafer show that in the upper horizons of the PS and PrS, the aquafer is more active than in the southern one, about 700-900 million m^3 of water moved along these horizons in this direction.

– In the lower horizons of the PT (except the Gala layers), it is less active than in the upper horizons. This is due to the fact that the lower horizons of the PS are involved in development on small areas. About 300-400 million m^3 of water moved from south to north along the lower horizons of the PS.

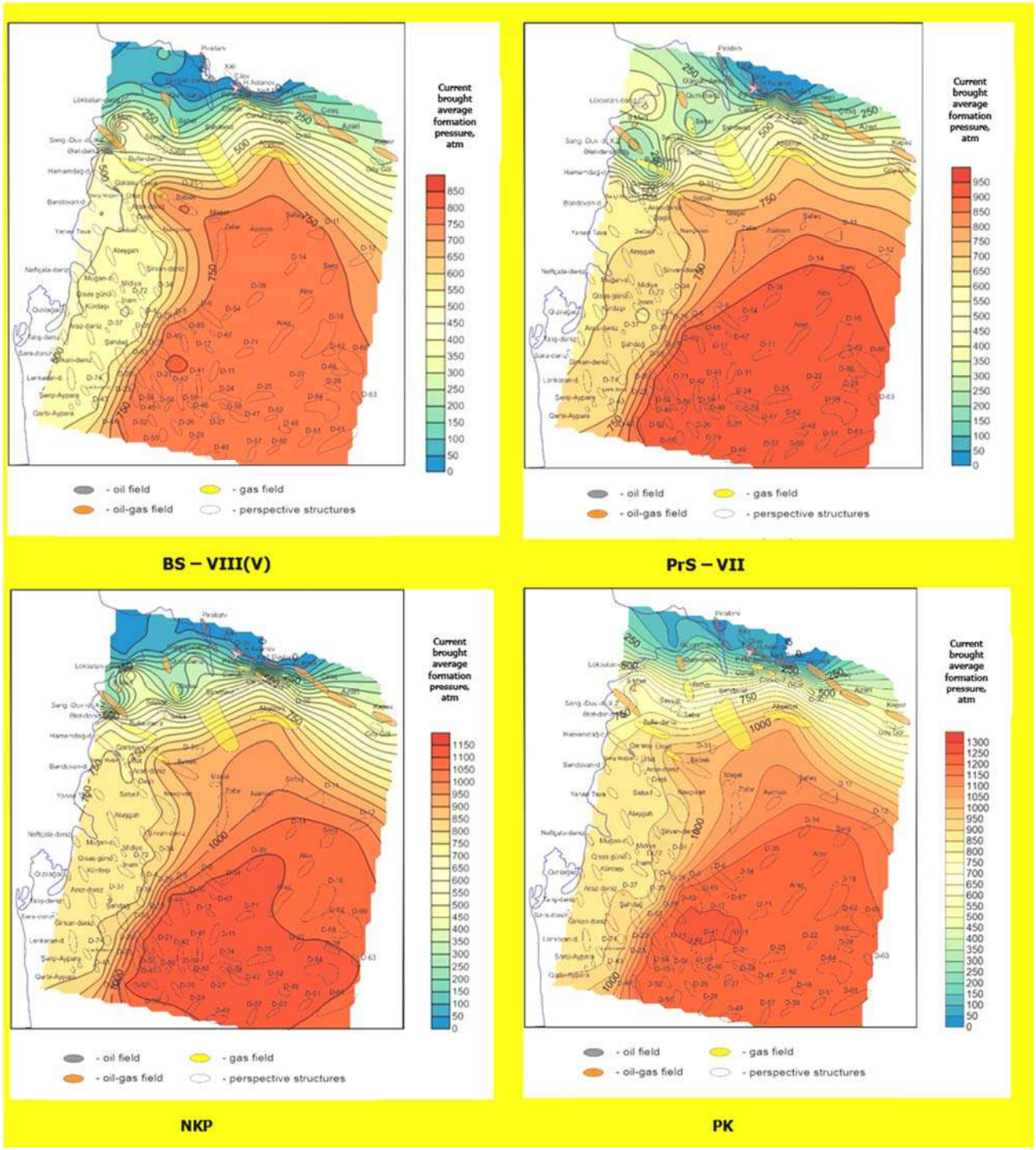


Fig. 8. Maps of actual current average formation pressure on horizons

– The basin activity model provides serious assistance in ensuring the efficiency of field development, deployment of a network of wells, design and proper conduct of water treatment, accurate compilation of a hydrodynamic model of deposits, forecasting resources, forecasting pressure in the basin.

– Research should be expanded, in particular, the lithophase model should be developed more precisely.

– An adequate reservoir model of the hydrodynamic activity should also be compiled for the Kura basin.

– The results obtained should be transferred from the 2D model to the 3D model, which will ensure the work of the current and historical model of the movement of the reservoir.

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МОДЕЛИРОВАНИЕ ГИДРОДИНАМИЧЕСКОЙ АКТИВНОСТИ БАССЕЙНА НА УГЛЕВОДОРОДНЫХ МЕСТОРОЖДЕНИЯХ (НА ПРИМЕРЕ ЮЖНО-КАСПИЙСКОЙ ВПАДИНЫ)

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Резюме. Исследование проводилось на примере одного из крупнейших бассейнов по запасам углеводородов в Азербайджане – Южно-Каспийского бассейна.

Южно-Каспийский бассейн считается одним из уникальных бассейнов мира по запасам углеводородов. В этом бассейне проведены масштабные геолого-геофизические исследования и геологоразведочные работы. В настоящее время углеводородный потенциал бассейна привлек иностранные компании для проведения здесь масштабных исследований. В результате этих изысканий в Азербайджанской части Южно-Каспийского бассейна обнаружено 120 структур, из них 21 структура определена как нефтегазовая и 17 месторождений разрабатываются.

Основная цель исследования – проанализировать характеристики гидродинамической активности бассейна, усовершенствовать модели месторождения, разработать эффективные сценарии разработки, более точно прогнозировать запасы и ресурсы месторождения и, как следствие, разработать рабочую гидродинамическую модель аквифера. Модель гидродинамической активности бассейна особенно важна при моделировании нефтяных и газоконденсатных месторождений. При моде-

лировании водо-углеводородных контактов и механизма движения (Феткович, Картер Трейси, неактивный) для уточнения эффективного плана разработки месторождения учитываются давление, скорость, направление движения и т.д. аквифера. Следует пояснить, что это возможно только в результате разработки и анализа гидродинамической модели активности бассейна. Преимущество исследования заключается в том, что здесь использовались данные о нефтяных и газовых месторождениях, относящихся к окружающим бассейнам, а объемы добытого газа рассчитывались в условиях пласта. С этой точки зрения данная исследовательская работа имеет важное теоретическое и практическое значение.

Ключевые слова: *аквифер, месторождение, свита, моделирование месторождений, гидродинамика, пластовое давление*

KARBOHİDROGEN YATAQLARINDA SU HÖVZƏSİNİN HİDRODİNAMİK AKTİVLİK MODELİ (CƏNUBİ XƏZƏR ÇÖKƏKLİYİNİN TİMSALINDA)

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[3]SOCAR, Azərbaycan
AZ1021, Bakı, Q.Əliyev prospekti, 121

Xülasə. Tədqiqat işi karbohidrogen ehtiyatlarının həcminə görə Azərbaycanın ən böyük neftli-qazlı hövzəsinin – Cənubi Xəzər Çökəkliyinin timsalında yerinə yetirilmişdir. Cənubi Xəzər Çökəkliyi dünyada karbohidrogen ehtiyatlarının həcminə görə unikal hövzələrdən biri hesab edilir. Bu hövzədə irimiqyaslı geoloji-geofiziki tədqiqatlar, axtarış-kəşfiyyat işləri aparılmışdır. Hazırda hövzənin karbohidrogen potensialı xarici şirkətləri burada böyük həcmdə tədqiqat işləri aparmaq üçün cəlb etmişdir. Bu tədqiqatlar nəticəsində Cənubi Xəzər Çökəkliyinin Azərbaycan hissəsində 120 struktur aşkar edilmişdir ki, bunlardan da 21 strukturun neft-qazlılığı müəyyənləşdirilmiş və 17 yataq işlənməyə cəlb edilmişdir. Tədqiqatın əsas məqsədi hövzənin hidrodinamik aktivlik xüsusiyyətlərinin tədqiqi, yataqların modellərinin təkmilləşdirilməsi, səmərəli işlənmə ssenarilərinin tərtibi, sahənin ehtiyat və resurslarının daha dəqiq proqnozlaşdırılması və nəticədə Cənubi Xəzər Çökəkliyinin su hövzəsinin işlək aktivlik modelinin tərtib olunmasıdır. Hövzənin hidrodinamik aktivlik modeli xüsusilə, neft-qaz və qaz-kondensat yataqlarının modelləşdirilməsində mühüm əhəmiyyət kəsb edir. Yataqların səmərəli işlənmə planının tərtibi üçün karbohidrogen-su hüdudları və hərəkət mexanizimi (Fetkoviç, Karter Treysi, non-aktiv) modelləşdirilərkən su hövzəsinin təzyiqi, hərəkət sürəti, hərəkət istiqamətləri və s. dəqiqləşdirilməlidir ki, bu da yalnız hövzənin aktivlik modelinin tərtibi və təhlili nəticəsində mümkün olur. Tədqiqatın üstünlüyü ondan ibarətdir ki, burada ətraf hövzələrə aid olan neft və qaz yataqlarının məlumatlarından istifadə edilmiş və hövzədən çıxarılan qaz həcmləri lay şəraitində hesablanmışdır. Bu baxımdan qeyd olunan tədqiqat işinin mühüm nəzəri-təcrübi əhəmiyyəti vardır.

Açar sözlər: *su hövzəsi, yataq, lay, yataqların modelləşdirilməsi, hidrodinamika, lay təzyiqi, fluid*