EARTH SCIENCES
RESEARCH JOURNAL

Earth Sci. Res. J. Vol. 21, No. 4 (December, 2017): 169-174

UNIVERSIDAD NACIONAL DE COLOMBIA

GEOLOGY OF OIL AND GAS

Formation of Oil and Gas Reservoirs in the Great Depths of the South Caspian Depression

Gahraman Nariman Ogly Gahramanov
State Oil Company of Azerbaijan Republic gahraman@inbox.ru

ABSTRACT

The aim of this article is the identification and characterization of complex factors acting simultaneously on forming large sized reservoirs in the deep South Caspian Basin, as well as the development of a model based on a combination of synchronous natural processes of the formation of hydrocarbon deposits. The article analyses reasons for high layer pressures in the hydrocarbon fields of the South Caspian Depression (SCD), impacting factors. The tectonic factor and density-barometric model can become the main criterion for selection of priority projects for exploration and site selection for drilling wells. Obtained results allow conducting effective studies of the exploration and development of oil and gas condensate fields in the SCD area.

Keywords: folding genesis; hydrocarbon deposits; neo-tectonic activity; horizontal compressive strain; vertical forces.

Formación de Depósitos de Petróleo y Gas en las Profundidades al Sur de la Depresión Cáspica

RESUMEN

El objetivo de este artículo es la identificación y caracterización de los complejos factores que actúan en la formación de depósitos de gran tamaño en lo profundo de la cuenca al sur del Mar Caspio, al igual que el desarrollo de un modelo de formación de depósitos de hidrocarburos basado en la combinación de procesos naturales sincrónicos. Este artículo analiza las causas de la presión de las capas altas en los campos de hidrocarburos ubicados al sur de la depresión cáspica y sus factores de impacto. Además, se propone el componente tectónico y el modelo de densidad barométrico como los criterios más importantes para la selección de proyectos prioritarios de exploración y la escogencia de lugares para perforación de pozos. Los resultados obtenidos permiten realizar estudios de exploración y desarrollo en los campos de petróleo y gas condensado en el sur de la depresión cáspica.

Palabras clave: formación de plegamientos, depósito de hidrocarburos; actividad neotectónica; esfuerzo horizontal de compresión; fuerzas verticales.

Record
Manuscript received: 13/04/2017
Accepted for publication: 25/08/2017

How to cite item
Gahraman Gahramanov, O.N.(2017). Formation of oil and gas reservoirs in deep water areas of the South Caspian Depression. Earth Sciences Research Journal, 21(4). 169-174
doi:http://dx.doi.org/10.15446/esrj.v21n4.64008

ISSN 1794-6190 e-ISSN 2339-3459
http://dx.doi.org/10.15446/esrj.v21n4.64008

Introduction

The SCD is the most deep-sunk sedimentary basin in the world and occupies the entire southern deep-water part of the Caspian Sea and its adjoining Kur and Western-Turkmen Depressions in the west and east, respectively. The SCD is the most deep-sunk sedimentary basin in the world and occupies the entire southern deep-water part of the Caspian Sea and its adjoining Kur and Western-Turkmen Depressions in the west and east, respectively. It is a unique geological structure in the Earth's crust in terms of sedimentation conditions, thickness and rate of deposition, history of geotectonic development, oil and gas formation, oil and gas accumulation and depth of their deposition, reserves, volumes, and geological structure of reservoirs. The SCD is a relic of the Large Caucasian South Caspian Back-Arc Marginal Sea, which emerged in the Middle Jurassic period and differs from deep-water basins in inland and marginal seas of the world: the SCD has the thinnest (6-8 km) consolidated oceanic crust and the thickest sedimentary cover (25-30 km). The thickness of Pliocene-Quaternary sediments is 10-12 km. At that, the thickness of the main oil and gas -pay red rocks horizons of the Pliocene – is 7-8 km. The SCD was formed in the Arabian-Eurasian collision zone. It is surrounded by the mountain ranges of the Greater Caucasus, Kopet Dag, Talysh, and Elbors (Mamedov, 2008; Aliyev, 2005; Eybatov, 2010).

Effective exploitation of hydrocarbon (HC) resources in the SCD requires a development of a new scientific bases and methodological solutions of relevant tasks.

The creation of theoretical models of these SCD deposit formations is an unprecedented and complicated task. At present, hydrodynamic modeling methods for hydrocarbon deposits, computer and programming technologies are being developed rapidly, which allows designing detailed numeric hydrodynamic models with account for the most factors that affect the development of deposits. In particular, this approach is described in detail in by J. Hunt (2013). This allows using in the output data for mathematical modeling the entire source material that is accumulated at oil fields by the documentation of the state of development by wells and the deposit in general. However, one should not forget that a numerical geological model is the basis for the detailed hydrodynamic model (Mstislavskaya et al., 2005; Zhang, 2012; Carvalho, 2013)

Shaymardanov et al. (2003) and Abasov et al. (2007) established that the most productive structures (deposits) at great depths are formed in favorable conditions of earlier- generated and preserved hydrocarbon gases, i.e. where gas did not escape through cap rocks or they were not destroyed by mud volcanoes or other geological processes. Preservation of HC at great depths is also facilitated by "sealed" deposits and lithological traps (Bochever et al., 1972). Under these conditions, HC preservation is determined by a weakened draining-out of formed gas during oil destruction due to significant deceleration of its diffusion.

Theory and practice showed that the probability of finding "sealed" deposits and high-capacity lithological traps is low (Kartsev et al, 1992; Gurbanov et al., 2014). The creation of comprehensive geological three-dimensional filtration models, based on the combination of their preconditioning natural simultaneous processes (Norman, 2001), is a promising area of theoretical and applied geology that allows taking a big step towards the solution of this problem. Intensive HC generation due to the existence of a powerful deep source is a geochemical prerequisite of HC deposit formation (Abasov, 2008).

Another question of interest: can folded structures of the sedimentary basin, which appeared in the SCD, or poor folds be further developed by means of internal force impact in the HC deposit itself? At that, the creation of a theoretical model of formation of such deposits is a complicated task. The difficulties are determined by a wide range of geological conditions and the lack of relevant information (Popkov et al, 2014). Limited data on these underground processes in HC deposits, located in the SCD (Kazmin et al., 2011), allow designing only a conceptual model of HC reservoir formation (Baak, 2010), based on the natural peculiarities of oil and gas deposits at great depths. The conditions of the tectonic development of the SCD and its subsidence primarily in the Neogene-Quaternary period determined the accumulation of a thick flysch formation and the accumulation of large oil and gas deposits thereon (Gurbanov et al., 2014). Interdisciplinary modelling shows that subsidence and sedimentation in the SCD resulted from thermal subsidence following Jurassic rifting and further enhanced subsidence due to sedimentation during in the Neogene-Quaternary (Alizadeh et al., 2017). Based on advanced analytical methods, hydrocarbons of the Lower Pliocene Productive Series (the main reservoir) are of epigenetic origin (Feyzullaev et al., 2015). They have been formed due to subvertical impulsive migration from the Oligocene-Miocene sediments. Two main phases of oil migration produced commercial accumulation in the Productive Series.

The following questions arise:

1. Which factors preconditioned the accumulation of such thick hydrocarbon-bearing sedimentary layers and which forces played the main role in the formation of large oil and gas deposits?
2. Why are deposits with satisfactory reservoir properties (RP) encountered at such great depths in the SCD area? This should not happen at such depths.

The purpose of this study is to determine and characterize the complex of simultaneously acting factors of the formation of large reservoirs at great depths of the SCD, and the development of a model, based on the combination of their preconditioning natural simultaneous processes.

Method

Kuliyev et al. (1998) shows that there are several variants of the mechanism of formation of folds by means of "internal" factors of the sedimentary basin. In the present paper, these results were taken as the theoretical aspects of the proposed concept. Under certain conditions, abnormally high reservoir pressures (AHRP) are formed and, consequently, sediments are compacted. This process mostly occurs in the central, the most submerged parts of the sedimentary basin, mostly comprised of clay rocks. Rock compaction primarily depends on the effective pressure (P_{ef}) (Kuliyev et al., 1998):

$$P_{ef} = P_{rc} - cP_{por} \tag{1}$$

where (P_{rc}) is the pressure of the overlying sedimentary rocks, (P_{por}) is the pressure of fluids that saturate rocks (pore pressures); c is the load coefficient that varies from 0 to 1. The studies conducted in this area, showed that rock porosity can be determined by the following formula

$$K_p^{(P_{ef})} = K_p^{(o)} e^{-\beta P_{ef}} \tag{2}$$

where $K_p^{(P_{ef})}$, $K_p^{(o)}$, is the rock porosity under Pef pressure and without compacting pressure, respectively, β is the irreversible compaction coefficient. Taking into account the fact that porosity is related to density by formula

$$\gamma_p = \gamma_m - \alpha K_p^{(P_{ef})} \tag{3}$$

where γ_m s the matrix density, is the proportionality coefficient, formula (3), taking into account (1), can be written as

$$\gamma_p = \gamma_m - \alpha K_p^{(o)} e^{\beta(P_{rc} - cP_{por})} \tag{4}$$

From formulas (1) and (4) it follows that under other various conditions, marginal areas of basins will be characterized by the greatest level of effective pressure and rock density (Kuliev et al., 1998). In the central parts, where pore pressures are close to geostatic ones, effective pressure will be significantly lower and can even theoretically be close to zero (Mamedov, 2008; Kuliyev et al., 1998). Consequently, such discrepancies in the levels of compacting load directly affect rock density, in particular: rock density in the horizontal section reduces from the periphery to the center of the basin.

Results

The location of oil and gas and anticlinal structures of the South Caspian megadepression, which gives an idea of the location of major hydrocarbon deposits in the study region is presented in the Fig. 1.

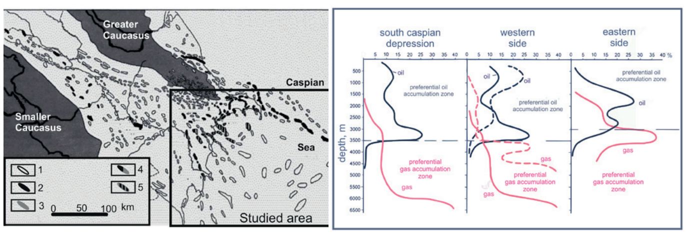

Figure 1. Left: Location of the petroleum and anticlinal structures of the South Caspian megadepression. 1 - anticlinal structures; Fields: 2 - oil, 3 - gas, 4 - oil and gas, 5 - oil and condensate.

Due to specific geological, geochemical, pressure, and temperature conditions of HC accumulation in traps and its preservation in deposits at great depths, excessive reservoir pressure is a crucial factor. It is determined by the size of the reservoir, the presence of AHRP beyond its boundaries, and the difference in fluid density. The formation of larger and thicker structures is investigated as a process of accumulation, self-organization, and self-preservation of natural oil and gas reservoirs at great depths. This allows for a new approach to the problem of folding and formation of large fields on a local scale in the SCD itself.

The formation of anticlinal traps is known to be accompanied by an almost simultaneous development of the sedimentary basin itself. The theoretical substantiation and adequate modeling of values, the direction and nature of the effect of Pef, Prc, and Phyd (hydrostatical pressure) factors, and the possibility of gas-dynamic and geodynamic pressure effect are the determinants of the scale and form that implement structural changes. In the anticlinal structures of a gas condensate field, especially with low HC density, in this phase, pressure, which corresponds to the far-wing parts of the structure can be transferred to its crest without significant changes. This zone is characterized by excessive reservoir pressure. The considered mechanism of formation and reformation of gas condensate fields up to large sizes due to excessive pressure in the elevated structure parts of the SCD provides a more reasonable explanation of their vertical and horizontal zonation.

In the authors' opinion, the preservation of large HC accumulations in the SCD deposits can be governed, primarily, by two reasons. The first one is the type and size of traps, with anticlinal structure and deposit thickness being of great importance. The second one is the intensive generation of gas due to catagenetic destruction of organic matter (OM) under the elevated pressure and temperature conditions and influx of gaseous fluids into traps.

It is worth noting that the scale of oil catagenetic transformation is affected by both its genetic peculiarities, i.e. the initial HC content of oil, and the pressure and temperature conditions, required for the change of the HC phase structure. Therefore, liquid HCs, which have the greatest resistance to thermal action, are located at great depths. At present, the initial level of reservoir pressure decreased significantly in the gas condensate fields of many regions. Due to the development of gas condensate fields, the reduction of reservoir pressure could affect the changes of HC phase structure in these fields to the liquid phase, since under favorable temperature conditions, the level of reservoir pressures is important during this process.

The decisive factor of great depths is the capacity and reservoir properties (RP) of rocks. The temperature conditions in the SCD are favorable for the preservation of HC. The temperature reaches 120°C at 6 km depth (Guliyev et al., 2011). Therefore, the main factor that deteriorates the RP of rocks with depth is pressure, i.e. increased rock pressure (Yusifzade, 1985, 2013). In the authors' opinion, the preservation of large HC accumulations in the South Caspian Depression deposits can be determined by two reasons. HC-containing reservoirs, in the thick elevated anticlinal structures, have a relatively increased reservoir pressure due to the growth of excessive pressure. The growth of excessive pressure in the elevated part of an anticlinal structure is caused by the difference in the density of deposit water and gas. It increases with temperature growth. The reservoir pressure in the contour, where the relative depth increases, in thick structures in gas fields, is almost transferred to the crest of the deposit. The deposition depth in the crest of the anticlinal structure decreases significantly compared to the wings. Reducing the effective pressure level facilitates the deceleration of rock compaction, sometimes even decompaction. This helps preserve or even slightly reduce the primary capacity and reservoir properties of rocks. In reducing the negative impact of rock pressure on the horizon and preserving RP, high reservoir pressure in the crest of a depressed structure during simultaneous HC accumulation facilitates the loss of stability of the considered environment, the growth of the anticlinal structure itself and, subsequently, the continuation of HC accumulation in this trap, which ultimately forms large reservoirs. The most important criterion for the estimation of oil and gas basins' prospect is the volume of sediment accumulation and the frequency of discovery of large and giant oil and gas fields (Aliyev, 2007). The SCD volume of sediment accumulation is estimated to be ca. 3.25 million km3. The thickness of the sediment complex is 25 km. The complex consists of a thick stratum of sediments of primarily terrigenous and carbonate content from the Jurassic to the Quaternary period. Most oil and gas (gas condensate) deposits, discovered in the pay horizon of Azerbaijan are limited to the "Absheron facies", formed by deltaic deposits of the Paleo-Volga (Aliyev, 2007). The sediment accumulation of compacted sand and clay, alongside a mass of diatoms, high temperatures in the depression zone (Absheron-Balkhan depression) and the counter count of high-temperature fluids, created ideal conditions for oil and gas accumulation (Abasov et al., 2007). Since the 1970s, a number of promising oil and gas condensate fields have been discovered in the Absheron Archipelago of the Azerbaijan sector of the Caspian Sea. These include such large fields as Azeri-Chyrag-Guneshlil, Shah Deniz, large structures of Kyapaz, Umid, Safar-Mashal, Nakhchivan, and others. The main deposits of hydrocarbons (over 70%) in abovementioned fields are concentrated in the "Pereriv" suite and the X layer of the pay horizon (Yusifzade, 1985). The geological structure of the area is formed mostly by Pliocene-Quaternary sediments with a thickness of 3700-4000 m. On the regional scale a certain growth in reservoir pressures is observed, where the anomaly coefficient reaches 1.05-1.07 on average. On the local scale, i.e. within HC deposits, the level of reservoir pressures can exceed the hydrostatic pressure significantly. At that, the anomaly coefficient can go up to 1.7 and more.

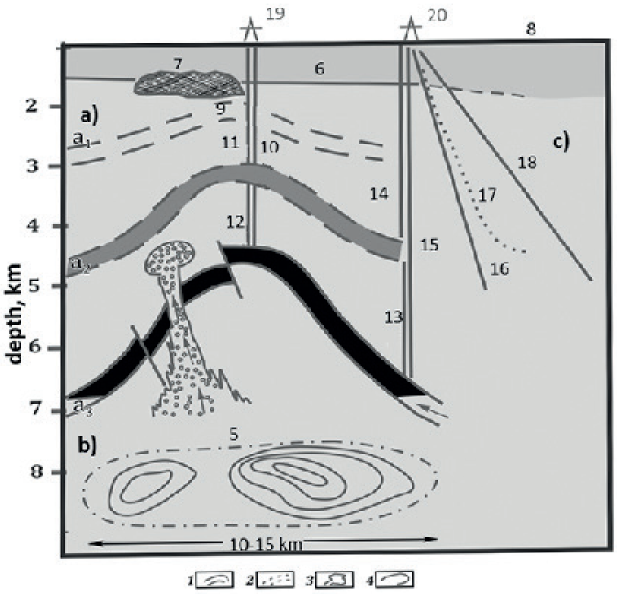

Figure 2. Schematic cartoon that explains the distribution mechanism of pressures (P_{rc}, P_{por}, P_{ef}) in the mentioned fields that created excessive pressure in the crest of the anticlinal structure, which causes structure growth (a1, a2, a3) with increase of deposition depth.
a) density-baric model;
b) discovered and assumed structure;
c) diagram of the hydrostatic, geostatic, and reservoir pressures.
1 – current position of the structure; 2 – structure at the early stage of development; 3 – mud volcano; 4 – assumed structure; 5 - gas-dynamic system; 6 - sea bottom; 7 - smooth bank; 8 - sea level; 9 - water and gravity system; 10 - Decompaction zone; 11, 14 - Pef – 38 MPa; 12, 13 - Ppor – 70 MPa; 15 - Compaction zone; 16 - 0,1 MPa/m; 17 - Prv (excessive pressure) in well No. 1; 18 - 0,24 MPa/m; 19 - well No. 1; 20 - well No. 2.

The following question arises can folded structures of the sedimentary basin in the SCD, or poor folds be further developed by means of internal force impact in the HC deposit itself notwithstanding the external force impacts, in particular, tectonic forces? The reason for the emergence of intrabasin linear structures (there are seven such lines in the Absheron Archipelago and four in the Baku Archipelago) is the horizontal compressive strain, which causes folding in the sedimentary cover in the SCD and subducting in the consolidated crust. Another question arises: can folded structures of a sedimentary complex be formed by internal force impact of the basin itself? During sedimentation, horizontal gradients of effective pressure and density are formed in the basin, which are directed from the center to the periphery. i.e. the basin, essentially, generates internal compressive horizontal forces, independent on the external forces effect. The magnitude of such strain can be sufficient for the development of folds. The probability of folding in this region is high. The period of origination and youth of the sediment basin are inherent in all basins. Therefore, the described mechanism is typical of all basins, irrespective of their geological age. Both lithological and geotectonic reconstruction should consider the possibility of folding due to the internal forces of the sediment cross-section (Kuliyev et al., 1998; Babayev et al., 2014). A similar process occurred in the pay horizon (PH) of the SCD, since in the deep-lying horizons, there is a high probability of favorable conditions for the formation of HC in cases of deposition at depths of less than 2.5-4.5 km. The constructed profile for the determination of the influence of effective pressure shows changes in the sizes of the structure with the increase of the deposition depth of the pay horizon and the distribution of Pef, Prc, and Ppor strains (Figure 2). In the anticlinal structures of gas condensate fields, especially in the conditions of low HC density, the pressure that corresponds to the far wings of the structure also affects its crest without significant changes. Thus, such zones are characterized by excessive reservoir pressure.

Due to excessive pressure in the elevated parts of the structure in the SCD, distribution of vertical forces in the deposit area provides for a more substantiated explanation of the mechanism of formation and reformation of gas condensate fields up to large sizes (Kuliyev, 1998). Estimations of excessive pressures for various thicknesses and depths of gas condensate deposits were carried out in order to determine the regularities of the changes in excessive pressure and the gradients of reservoir pressure with depth (Table 1).

Table 1. Information on the distribution of primary geological reserves of gas with depth at the western edge.

Gas condensate depth, m	HC-fluid density in reservoir conditions, kg/m³	Deposit thickness, m.			
		500 P_{ex} MPa in structure crest	1000 P_{ex} MPa in structure crest	1500 P_{ex} MPa in structure crest	2000 P_{ex} MPa in structure crest
3000	0.242	3.79	7.58	11.37	15.6
4000	0.283	3.58	7.17	10.75	14.3
5000	0.298	3.50	7.02	10.53	14.0
6000	0.312	3.44	6.88	10.32	13.8
7000	0.322	3.34	6.67	10.02	13.4

Figure 3 presents charts of changes in the anomaly of reservoir pressures with depth, depending on deposit thickness, which shows how important the thickness of gas condensate deposits for the formation of large fields and the conditions of preservation of deposits (reservoirs) at great depths. In the crest and far wings of the structure, Pef values differ significantly and increase with the growth of the structure and, consequently, the preservation of reservoir properties occurs primarily in the elevated parts of the structure. The local maximum Pef in the elevated part of the structure creates the difference in anomalies both horizontally and vertically. The ΔPef gradient, which affects the long period even at small values, affects the formation (growth) of the anticlinal structure.

Thus, other thing being equal, the greatest levels of rock pressure and density will be characteristic of the marginal and aquifer zones of the deposit. In the central parts, the effective pressure will be significantly lower. In the crest of the structure, due to a relatively small deposition depth, rock pressure will be the lowest, while internal pressure will be the highest.

It is also expedient to examine the mechanism of emergence of horizontal compressive strains in a quick subsidence regime (Figure 4). In a submerging basin, other mechanisms of formation of horizontal compressive strains are possible. Assume that within the abovementioned geological situation, i.e. due to substance differentiation, the values of forming horizontal compressive strains are insignificant.

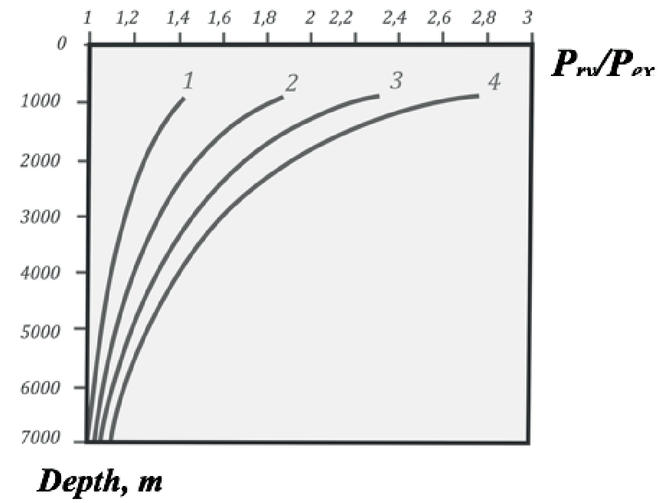

Figure 3. Gas condensate deposits. Changes in excessive pressure (Prv/Pex) with depth, depending on the deposit thickness of 1, 2, 3, 4 – 500, 1000, 1500, 2000 m, respectively.

After a certain geological time, the magnitude of such horizontal strains can be sufficient for the process of elastic instability of the competent bed (Kuliyev et al., 1998). Next, it is expedient to investigate the mechanism of formation of SCD structures during the emergence of vertical forces. The studied structures differ from other folds in the studied region in relatively large sizes and mostly isometric dislocation. These structural features confirm the dominance of normal vertical forces in their formation. A very important peculiarity of the folding process is the possibility of the growth of folds together with sedimentation.

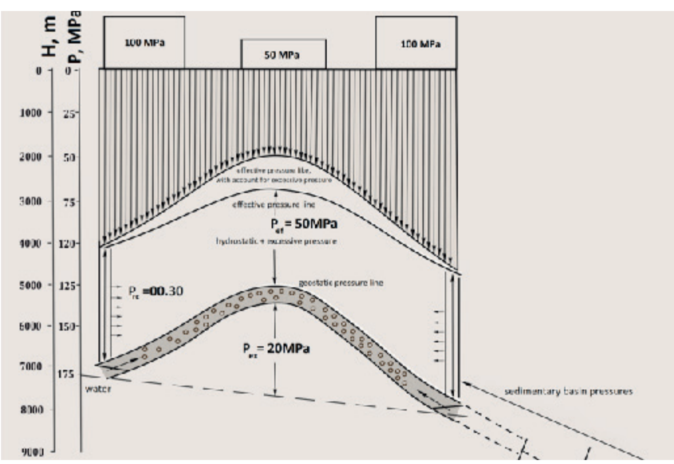

Figure 4. The schematic cartoon of structural elevation under the effect of forces. It is considered geostatic, hydrostatic, effective, and excessive pressure, with account for sedimentary basin pressures. Sedimentary basin pressure is only explained by influence of sedimentary cover. More preferential mechanism is the combination of loading the edges of the basin and large horizontal compressive forces due to the syn - compressional bending associated with subduction of the SCD (Abdulaev et al., 2015).

This process should result in the natural change of thicknesses and facies of individual stratums. Their thickness should mostly be reduced in the crests of anticlines and increased in the most depressed parts. The facies in the crests of the anticlinal syngenetic horizon should include several coarse sediment fractions, while in the depressions they should be thinner. The sediments will not "die out" with depth, while the dying out of deformations can occur in the upper intervals. In certain cases, epigenetic deposits can occur at great depths. For example, due to intensive subsidence of PH deposits in the SCD, the structures of the Absheron Peninsula were subjected to strong effect of folding. Consequently, the crests of the lower and upper structures of the PH often do not coincide, sometimes shifting over large distances.

Discussion

In general, the formation of large reservoirs at great depths of the SCD is determined by the effect of a set of simultaneous factors, the most important of which, in the authors' opinion, are:

1. The presence of excessive pressure determined by the HC deposit thickness, which height changes depending on the deposit thickness and depth, and HC density. For example, at a depth of 7 km and a deposit thickness of 2000 m, excessive pressure is 14-15 MPa.

2. The presence of anomalously high reservoir pressures in PH, which increase significantly with hypsometric depth. For example, in the study region of the SCD, at a depth of 7 km, AHRP level can reach relatively high levels, since in marine fields at a depth of 6-6.5 km, the Prv/Phyd value varies from 1.3 to 1.7.

3. Under intensive subsidence of the SCD due to the effect of avalanche sedimentation and flow, the thickness of the PH and its depth created appropriate pressure and temperature conditions at great depths of the SCD, where HC migrated from the area with high reservoir pressures to the area with low reservoir pressures.

In the conditions of intensive submersion of the SCD because of the effect of abovementioned forces, depositional structures are formed and grew, which created large reservoirs. HC migrated from the area of higher initial gradients of reservoir pressure (depressed zones) to areas of low gradients (the most elevated zone). Traps, filled to the hinges ended up an enclosed on all sides by high potential zones, where the process of HC migration and accumulation continued, which required a growth of the gas-containing capacity of traps at great depths under high reservoir pressures. At that, high potential zones grew under the effect of abovementioned forces, creating a range of high strains across the entire PH section above the structure.

Consequently, the mechanism of formation of large reservoirs in the PH at great depths of the SCD is determined by a simultaneous effect of a set of factors and the presence of conditions, related to the peculiarities of the geological structure of the depths. The peculiarities are lithofacial change in the sediments of the PH and its intermittent structure along the section, which are characterized by the presence of reservoirs or interconnected reservoirs that form a single hydrodynamic system, on the one hand, and a powerful cap of clay strata with continuous migration of HC under pressure gradients from submerged zones and their accumulation and self-preservation in traps, on the other hand. From this, it follows that at such great depths, small deposits cannot exist. Favorable conditions for the natural preservation of reservoir properties are created only in large and thick deposits.

The suggested density-structure-fluid theory of formation of large fields in the SCD can be used for both explored fields and for explorations in this region, with a view to modelling above mentioned fields. The suggested theory can increase the probability of discovering oil and gas fields during explorations of regions, located in similar geological conditions. At that, the main factor that resists the negative effect of rock pressure on the RP of rocks at great depths is the reservoir pressure.

Thus, the main factor that resists the negative impact of rock pressure on RP of rocks at great depths is the reservoir pressure, which is directly dependent on its size. Under these conditions, HC-containing reservoirs in the thick elevated anticlinal structures have a relatively increased reservoir pressure due to the growth of excessive pressure.

The growth of excessive pressure in the elevated part of an anticlinal structure is caused by the difference in the density of deposit water and gas. The excessive pressure increases with temperature growth and the reservoir pressure in the contour, where the relative depth increases, in thick structures in gas fields, is almost transferred to the crest of the deposit. In addition, the deposition depth in the crest of the anticlinal structure decreases significantly compared to the wings. (Other sources exist, which facilitate the reduction of rock pressure towards the crest). Reducing the effective pressure level facilitates the deceleration of rock compaction, sometimes even decompaction. This, in turn, helps to preserve or even slightly reduce the primary capacity and reservoir properties of rocks (perhaps, form fractures).

Thus, continuous accumulation of HC in traps, growth of anticlinal structure sizes, especially the increase in the thickness of the structure, deceleration of rock compaction, especially in the elevated part of the structure are interconnected. These facilitate the preservation of large HC clusters at great depths of the SCD, which is an important scientific substantiation of hydrocarbon extraction processes and ensures enrichment of scientific knowledge with the possibility of their direct use for the solution of practical problems.

Conclusions

The result of the study is the compilation of a list and characteristics of the set of simultaneously acting factors invoked in forming reservoirs at great depths in the SCD. They are the presence of excessive pressure; the presence of abnormally high reservoir pressure in pay horizons, the thickness and occurrence depth of which created respective pressure and temperature conditions at great depths of the SCD, as well as developing a model based on the combination of their preconditioning natural simultaneous processes. This paper suggests the possibility of development of autonomous folding due to the formation of internal pressures in the HC field (deposit) itself which the author called the structure-fluid theory of large-amplitude structure formation in the SCD. The density-baric model reflects one of the most important physical, geological, and industrial characteristics of reservoirs. Consequently, the tectonic factor and its density-baric model can be the main criterion of the primary objects for exploration, the optimal choice of primary programs for drilling, and for the placement of exploratory and industrial wells. This model allows distinguishing potentially dangerous areas for drilling wells at the beginning of the field exploitation.

To conclude, it should be noted that both studied types of folding with differences in their formation mechanism, could have correlations that are more complex. In the authors' opinion, folds of the singular large structures can be relatively simple. Noted regularities in the distribution of facies and thicknesses of deposits that form the studied large folds, are convincing proof of the leading role of vertical forces in their formation.

References

Abasov, L. G., Kondryushkin, M.T., Aliyarov, Yu.M., Krutykh & R.Yu. (2007). *Study and prediction of parameters of complex natural oil and gas reservoirs of the South Caspian Depression.* Baku, Azerbaijan: Azerbaijan Oil&Gas.

Abasov, M. T., Kondrushkin, Yu.M., Aliyarov, R.Yu. & Krutykh, L.G. (2007). Steep methodical approach to the study and forecasting of parameters of natural oil and gas reservoirs of the South Caspian basin. *Oil and Gas Geology,* 2(1), 27-33.

Abdullaev, N.A., Kadirov, F. & Guliev, I.S. (2015). Subsidence history and basin-fill evolution in the South Caspian Basin from geophysical mapping, flexural backstripping, forward lithospheric modelling and gravity modelling. In: Brunet, M.-F., McCann, T. & Sobel T (eds) (2015). *Geological Evolution of Central Asian Basins and the Western Tien Shan Range,* 427 Geological Society, London, Special Publications 175-196. DOI: https://doi.org/10.1144/SP427.5.

Aliyev, A.I (2005). *All about oil.* Baku, Azerbaijan: Azerbaijan Oil&Gas..

Aliyev, A. I. (2007). South Caspian Depression: its location among the large and giant oil and gas basins, conditions of formation and preservation of oil and gas deposits, hydrocarbon resource estimation. *Azarbayan Neft Tyasyarrtsvaty*, 6(1), 15–23.

Baak, C. G. C. van (2010). *Glacio-Marine transgressions of the Early and Middle Pleistocene Caspian Basin, Azerbaijan.* MSc thesis, Paleomagnetic Laboratory 'Fort Hoofddijk', Utrecht University, Faculty of Geosciences.

Babayev, M.S., Sultanov, L.A., Ganbarov, Sh. & Aliyev, T.A. (2014). On the results of petrophysical studies productive strata deposits Baku archipelago areas of oil and gas. *Proceedings of the higher technical educational institutions of Azerbaijan,* 2(1), 7-12.

Bochever, A. K. & Oradovskaya, F.M. (1972). *Hydrogeological substantiation of the protection of underground water and water intakes from pollution. Moscow,* Russia: Nedra

Carvalho, I. D. S., Mendes, J.C. & Costa, T. (2013). The role of fracturing and mineralogical alteration of basement gneiss in the oil exhsudation in the Sousa Basin (Lower Cretaceous). *Northeastern Brazil. Journal of South American Earth Sciences,* 47(1), 47– 54.

Eybatov, T.M. (2010). Caspian seal (Pusa Caspica Gmel.) - endemic of Caspian. *News of the Azerbaijan National Academy of Sciences, Geosciences,* 4(1), 151-169.

Feyzullayev, A.A., Tagiyev, M.F. & Lerche, I. (2015). On the origin of hydrocarbons in the main Lower Pliocene reservoirs of the South Caspian Basin, Azerbaijan. *Energy Exploration & Exploitation,* 33 (1): 1–14.

Guliyev, E. Aliyeva, D. Huseynov, A. Feyzullayev & P. Mamedov (2011). Hydrocarbon Potential of Ultra Deep Deposits in the South Caspian Basin. Search and Discovery Article #10312.

Gurbanov, V.S., Sultanov, L.A. & Abbasov, G.G. (2014). The lithological and petrographic and reservoir properties of Meso-Cenozoic deposits of the Pre-Caspian-Guba petroleum district. *Geophysical news in Azerbaijan,* 3-4(1), 10-13.

Hunt, J. (2013). *Oil and gas geochemistry and geology.* Moscow, Russia: Book on Demand.

Kartsev, V. P. Vagin, A.A. & Shugrin, S.B. (1992). *Oil and gas hydrogeology.* Moscow, Russia: Nedra.

Kazmin, V.G. & Verzhbitskii, E.V. (2011). Age and origin of the South Caspian Basin. *Oceanology,* 51(1), 131–140.

Kuliev, G.G., Djevanshir, R.D., Kasimova, S.M. & Kulieva, G.Z. (1998). Folding caused by inner stresses effect in sedimentary basins. *Proceedings of Azerbaijan Academy of Sciences. The Sciences of Earth,* 2, 97–102.

Mamedov, P.Z. (2008). The reasons for the rapid subsidence of the earth's crust in the South Caspian Basin. *Azerbaijan oll industry,* 1(1), 8-20.

Mstislavskaya, V. & Filippov, L. (2005). *Oil and gas geology and exploration. Moscow,* Russia: TsentrLitNefteGaz.

Norman, J. H. (2001). *Nontechnical Guide Petroleum Geology, Exploration, and Production.* Tulsa, Oklahoma: PennWell.

Popkov, V. I., Zatsepina, S. V. & Mironova, E. A. (2014). Reactive-Diffusive Geo-dynamics of Porous Media, Analytics of Navier-Stokes Equation. *IV Int. Conf. Euro-Asian Community of Scientists. Modern concepts of scientific studies, Moscow, Russia, September,* 58-61.

Shaymardanov, V. G., Voronin, M.M., Orentlikherman, D.V., Mikhaylin & E.I. (2003). On the conduction of works in accordance with the ARWaL (Acoustic Rehabilitation of Wells and Layers) technology at extracting wells of 'Pokachevneftegaz' Territorial Industrial Enterprise. *Intensification of oil and gas extraction: Papers of the International Technological Symposium,* August, 301–308.

Yusifzade, Kh. B. (1985). Geological model of formation of deep structures in the SCD (problems and estimations). *Azerbaijan Oil Ind.,* 9(1), 23–45.

Yusifzade, Kh. B. (2013). Application of modern technologies in the field of exploration and production of oil and gas fields in *Azerbaijan. Azərbaycan Neft Təsərrüfat,* 7-8(1), 3-13.

Zhang, L. (2012). North Ustyurt Basin Structure Evolution and Basic Petroleum Geological Characteristics. *Inner Mongolia Petrochemical,* 3(1), 133-134.