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About Relations between Natural Gas and Oil in Connection with Forecast of Their Reserves in Azerbaijan

A. A. Feizullaev [SC]

Institute of Geology and Geophysics of National Academy of Sciences of Azerbaijan, Baku, Azerbaijan

Abstract: Azerbaijan is one of the oldest oil and gas provinces, where more than 2 bln tons of oil have been extracted over more than a century. At present, the oil production is declining and mainly determined by production from the Azeri-Chirag-Guneshli offshore block (AChG). Compared to oil, the opportunities for further growing natural gas reserves and production are very promising. For the latest years, a number of large gas condensate fields have been discovered in the deep-water part of South Caspian Sea, such as Shakh-Deniz, Apsheron, Umid. There are a number of prospects that have not yet been drilled in this part of the sea basin. The paper assesses their prospectivity, substantiates the priority exploration targets and, on the basis of the statistical analysis of the quantitative gas/oil ratio data for many other Azerbaijanian and world basins, an attempt is made to assess the reserves in the prospects. The total recoverable oil reserves in Azerbaijan are estimated at 3.5 bln tons, of which slightly above 2 bln tons have already been extracted. Based on the statistically estimated ratio between the volumes of gas and oil in various basins of the world, including Azerbaijan, the total possible natural gas reserves in Azerbaijan are estimated at about 4 trillion m^3. This is in agreement with the other available estimates. Of this volume of natural gas, 0.85 trillion m^3 has already been extracted, and the approved geological reserves are estimated at 2.55 trillion m^3. Almost 83% of the extracted natural gas belonged to offshore fields. This trend will continue in the future, and, moreover, will be strengthened due to large volumes of gas condensate accumulations in the deep-water part of the basin. In this part of the basin, the most attractive prospects are Mashal, Shafag, and Israfil Huseynov, total reserves of which are expected at 0.6 trillion m^3 of natural gas.

Keywords: sedimentary basin, gas, oil, fields, extraction, ratio, reserves, Azerbaijan

О соотношении природного газа и нефти в связи с прогнозом их запасов в Азербайджане

А. А Фейзуллаев [SC]

Институт геологии и геофизики Национальной Академии Наук Азербайджана, г. Баку, Азербайджан

Аннотация: Азербайджан является одной из старейших нефтегазоносных провинций, где за более чем вековой период из недр добыто более 2 млрд т нефти. В настоящее время добыча нефти идет на спад и в основном определяется добычей из морского блока Азери – Чираг – Гюнешли. В сравнении с нефтью перспективы дальнейшего прироста запасов и добычи газа очень высокие. В последние годы в глубоководной части Южного Каспия выявлен ряд крупных газоконденсатных месторождений, таких как Шах-Дениз, Апшерон, Умид. В этой части бассейна имеется ряд еще не разбуренных структур. В связи с этим в статье оценены их перспективы, обоснованы первоочередные поисковые объекты и на основании выполненного статистического анализа количественного соотношения газа и нефти по данным различных бассейнов/стран мира, а также Азербайджана предпринята попытка оценить запасы в них газа. Суммарные извлекаемые запасы нефти в Азербайджане оцениваются в 3,5 млрд т, из которых извлечено чуть более 2 млрд т. Исходя из статистически выявленного соотношения между объемами газа и нефти в различных бассейнах (странах) мира, включая и Азербайджан, прогнозная оценка суммарных запасов газа в Азербайджане составляет около 4 трлн m^3. Это в целом согласуется с существующими оценками. Из этого объема газа уже добыто 0,85 трлн m^3, а утвержденные перспективные запасы газа оцениваются в 2,55 трлн m^3. Почти 83 % газа добыто из морских месторождений. Эта тенденция в будущем не только сохранится, но и будет увеличиваться благодаря введению в разработку крупных газоконденсатных скоплений в глубоководной части бассейна. В этой части бассейна к наиболее перспективным могут быть отнесены структуры Машал, Шафаг и Исрафил Гусейнов, суммарные запасы в которых прогнозируются в 0,6 трлн m^3 газа.

Introduction

South Caspian Basin (SCB) of Azerbaijan, located within the Alpine-Himalayan tectonic belt, is a typical intermount basin. Recent structure of the basin is controlled by the ongoing collision of the Arabian and European (Russian) plates.

Recent geological and geophysical studies have revealed some features being characteristic of subduction regimes at the northern boundary of the SCB [1]. The main structural element of this zone is the Apsheron-Pribalkhan uplift zone, located immediately above the frontal part of the subduction zone. The studies showed the most favorable conditions for generation of hydrocarbons

(HC) were in place here [2]. The largest oil and gas accumulations of the SKB continental and offshore parts (Apsheron Peninsula and Apsheron Archipelago) are confined to this sub-latitudinal belt, from which more than 1.5 bln oil have been extracted (about 75% of total oil produced in Azerbaijan) (Fig. 1).

In the early exploration stages within the SKB, in its continental part, oil fields were mainly discovered; therefore Azerbaijan was referred to as an oil province. This was for both objective and subjective reasons.
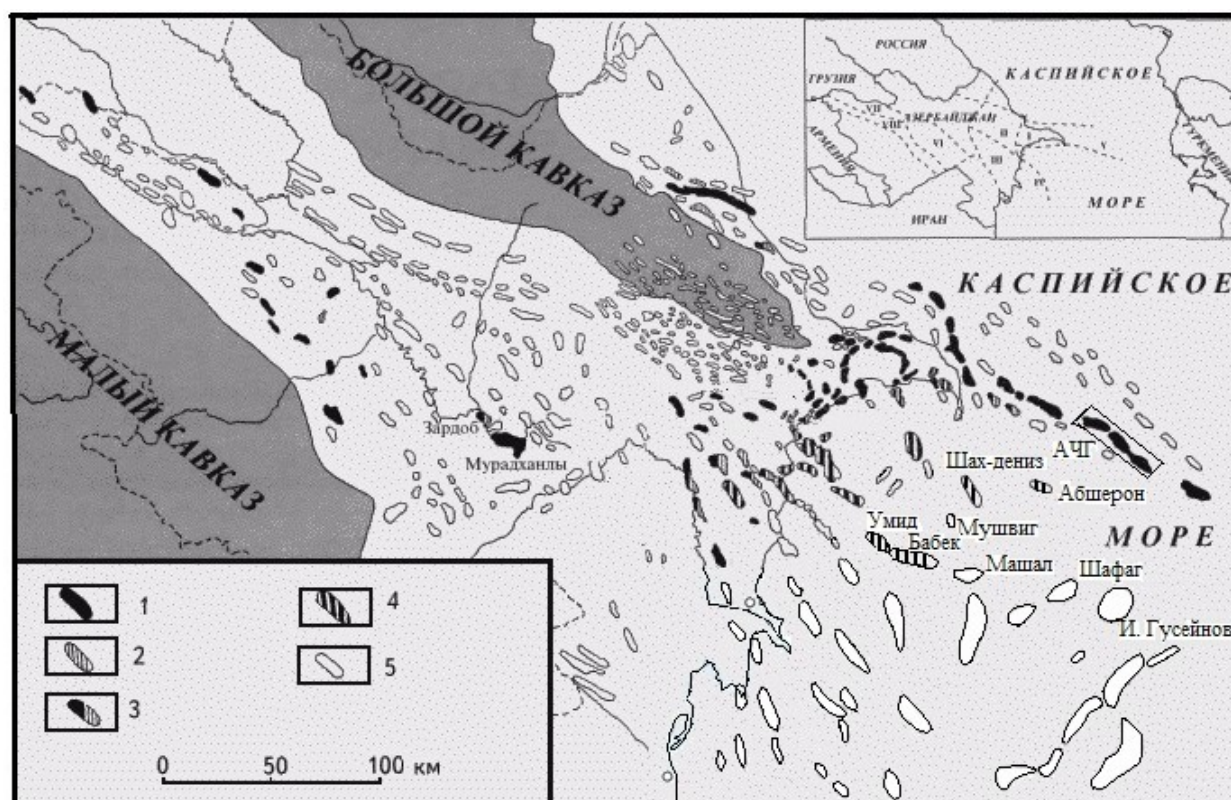

Fig. 1. Oil and gas potential of Azerbaijan:
1–4 – hydrocarbon deposits; *1* – oil; *2* – gas; *3* – gas and oil;
4 – gas condensate; *5* – prospects (exploration targets)

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The objective reason comprises three main factors: 1) the presence of vertical zoning of oil and gas formation; 2) phase redistribution of hydrocarbons in the section caused by the processes of their subvertical-lateral movement; 3) unfavorable preservation conditions and significant losses of the gas component of hydrocarbons in shallow fields subject to intensive degassing. This explains the absence of gas fields in the upper diagenetic gas formation zone. This is typical for almost all sedimentary basins located in mobile tectonic belts. More than 90% of these gases have been lost in this belt. Commercial accumulations of biochemical methane are known only in Italy (in turbidite sediments of the Po river basin) and in Western Siberia, where these gases have been preserved due to the permafrost layer playing the role of a seal.

The subjective reason is connected with the lack of data on the zone oil-and-gas potential and the phase state of hydrocarbons (HC) in the deep-water part of the basin at the initial stage of exploration.

However, the results of further prospecting and exploration, as well as widespread introduction of modern geological and geochemical methods for studying organic matter (OM), oil and gas served as the basis for changing ideas about the phase relationship of hydrocarbon resources in the SKB. This was facilitated by:

- discovery of a number of large gas condensate fields, such as Shah Deniz, Apsheron, Umid, with reserves ranging from several hundred bln to more than a trillion cubic meters in the deep-seated part of the SKB;

- identification of qualitative characteristics of the OM of the parent Oligocene-Miocene rocks capable of generating, along with oil, significant volumes of gaseous hydrocarbons (about 70% of the total generation);

- widespread development of mud volcanoes in the SKB, which permanently carry large volumes of gases to the surface during periods of both gryphon activity and paroxysm.

By now, Azerbaijan has turned from an oil supplier only into a major supplier of natural gas to foreign markets. The peak of oil production in Azerbaijan was recorded in 2010 at 51 million t. Then, up to now, natural decline in the oil production takes place. Further increasing the HC reserves is expected in connection with discovery of mainly gas condensate fields in the central, deep-seated part of the basin [3]. In this regard, the issue of predicting gas reserves in the SKB is of exceptional interest.

Research Methods

To date, in the world, there are a huge number of classifications of oil and gas reserves and resources. In fact, each oil-producing country has its own classification, but there are also generally recognized world classifications and methods for estimating oil and gas reserves, which are used in many countries [4].

Depending on the exploration maturity and availability of the necessary data, different approaches and methods for estimating hydrocarbon resources and reserves are used:

Analogy method. It is based on the assumption that the reservoir under consideration is comparable with the analogous reservoir in terms of poroperm properties and fluid properties, which determine the volumes of ultimate recoverable reserves.

Volumetric method. It is based on using data on reservoir poroperm properties and fluid properties for estimation of initial geological reserves and then determining their recoverable part for a specific development project. This method is used in early exploration stages.

Material balance method. It is based on analyzing a reservoir pressure changes while extracting HC from it. This method is applied in the intermediate exploration stages.

Performance analysis method. It is based on the analysis of the rate of extraction and phase composition of the extracted HCs depending on the time and the amount of accumulated extraction as the reservoir is depleted. The method is applied at the end of the field's life, when most of the oil and gas has already been extracted, and the field's production rate is declining.

Of the above methods, the volumetric one is the most commonly used.

This study provides an assessment of the possible recoverable natural gas reserves in Azerbaijan based on statistical analysis of the ratio of proven reserves and production of natural gas and oil in 30 countries. In addition, the results of statistical analysis of the primary values of gas/oil ratio (GOR, the ratio of gas and oil production volumes) in Azerbaijani gas field for 54 continental and offshore fields (754 data points in total) are used.

Although this statistical method cannot claim universality, it may well be applied in the conditions of Azerbaijan. This is due to the fact that one of the parameters (oil reserves) is quite reasonable and predictable in comparison with another parameter (gas reserves). In the future, there are no convincing prerequisites for discovery of new commercial oil reserves, and further prospects for increasing hydrocarbon reserves in Azerbaijan are connected with discovery of exclusively gas (gas condensate) fields in the SKB deep-water part.

Research Findings

Existing estimates of recoverable oil reserves in SKB

The first well in Azerbaijan with a depth of 21 m was drilled for oil production in 1846 at the Bibiheybat area near Baku, and in 2017 the total amount of oil production in Azerbaijan exceeded 2 bln tons. The first bln t of oil was extracted for 125 years (by 1971), whereas the second one, for 46 years.

Current estimates of recoverable oil reserves in Azerbaijan are shown in Table 1.

As follows from the table, total recoverable oil reserves in Azerbaijan are estimated at 3-4 bln tons. However, when determining the fairest value of the total oil reserves, a number of facts must be taken into account. Firstly, for more than a century of exploitation, slightly above 2 bln tons oil have been extracted from more than 70 fields. Secondly, at present, almost all oil fields in the region are at late stage of development and highly depleted, with the only exception of the Azeri-Chirag-Guneshli (AChG) mega-block, where oil reserves are predicted to be between 511 and 923 million tons [9]. Considering that this block provides 91–93% of the country's oil [9, 10], the possible, not yet discovered oil/gas condensate reserves in Azerbaijan as a whole can be assumed to be about 1.5 bln tons.

Table 1

Current estimates of oil reserves in Azerbaijan

Recoverable oil reserves, bln tons	Source
4.1	[5]
4.05	[6]
4.04	[7]
3	[8]
2 + 1.2* = 3.2**	[9]

*including estimated AChG oil reserves
**author's estimate (produced + possible reserves)

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According to Khoshbakht Yusifzade, first vice-president of the State Oil Company of Azerbaijan (SOCAR), in Azerbaijan, the updated recoverable oil and gas condensate reserves are estimated at 1.5 bln tons [11], and taking into account the already extracted 2 bln tons of oil/gas condensate, the total initially available reserves are estimated at 3.5 bln t.

Thus, the volume of the initially available recoverable oil reserves in Azerbaijan at 3.5 bln tons can be taken as the most reasonable.

About relations between natural gas and oil volumes

Analysis of data for different basins (countries). Fig. 2 presents a histogram of proved gas to oil reserves ratio distribution for 30 countries, drawn up based on BP data [12] (excluding countries with large gas resources).
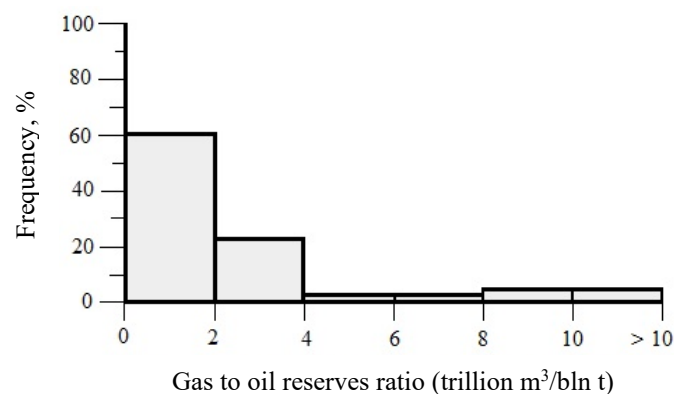
According to the presented histogram, in slightly more than 60% of cases, the ratio do not exceed 2 trillion m^3 of gas per 1 bln tons of oil, and the average ratio is about 1.2 trillion m^3 of gas per 1 bln tons of oil.

The analysis of the gas to oil production ratio calculated based on the 2016 data for 35 countries [13] is illustrated in Fig. 3, which presents the histogram of the ratio distribution. The average value of the ratio is 1.1 bln m^3/1 million tons (1.1 trillion m^3/1 bln tons).

Analysis of GOR data for the SKB fields. Compilation and analysis of GOR data for fields in Azerbaijan based large statistically significant data array showed its values ranging 2.5–80,000.0 m^3/t (1,457 m^3/t on average). Histogram of GOR values distribution is shown in Fig. 4.

Fig. 2. Histogram of proved gas to oil reserves ratio distribution (2014 [12]) in 30 countries
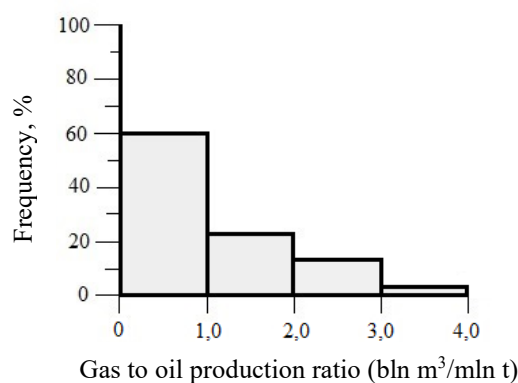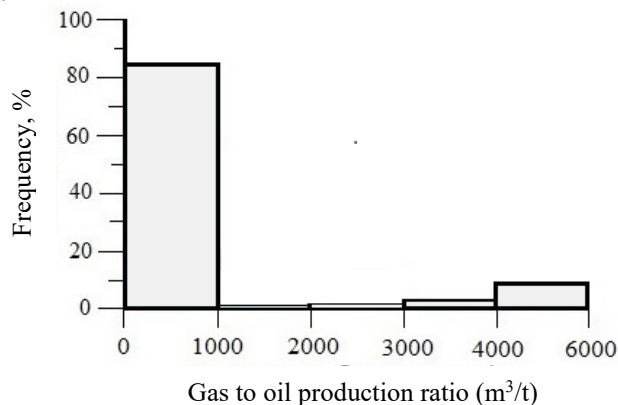

Fig. 3. Histogram of gas to oil production ratio distribution (2016) in 35 countries

Fig. 4. Histogram of GOR distribution for the fields of Azerbaijan

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The revealed interval of the GOR values variations is typical for both oil and oil-gas, and gas condensate fields [14–16]. In this regard, GOR can serve as a criterion for assessing the phase state of hydrocarbon accumulations and the patterns of its spacial changes.

In the SKB, GOR increases from the side parts towards the deep-water part (Fig. 5). This is in good agreement with changing the HC phase state in this direction, which is manifested by successive change from oil fields to oil-and-gas and gas condensate ones.

High gas saturation of liquid hydrocarbons in the offshore part of the basin provides their relatively lower density (less than 880 kg/m^3) in comparison with the continental fields (Fig. 6).

According to the exploration findings, the central deep-water part of the basin is exclusively gas-bearing, with gas condensate and no oil. Under the temperature and pressure conditions in this part of the basin, in addition to gas condensate, also light, so-called "volatile" oils can be found.

Estimation of possible gas reserves in Azerbaijan. All estimations of the possible gas reserves in the SKB based on the ratio of gas and oil (for the proved reserves and the produced volumes of gas and oil in various countries, as well as the GOR values for the SKB fields) were carried out on the basis of the accepted value of the total recoverable oil reserves in Azerbaijan of 3.5 bln tons.

Taking into account the average value of the proved gas to oil reserves ratio calculated based on the data of 30 countries, the possible gas reserves in Azerbaijan can be estimated as follows: 3.5 bln tons of oil × 1.2 trillion m^3/bln tons = 4.2 trillion m^3. This is graphically presented in Fig. 7.

Taking into account the average value of the gas to oil production ratio (1.1 trillion m^3/bln tons) in 2016 calculated based on the data of 35 countries, the possible gas reserves in Azerbaijan can be estimated as follows: 3.5 bln tons of oil × 1.1 trillion m^3/bln tons = 3.9 trillion m^3.

The value of possible gas reserves, estimated taking into account the average GOR of 1,082 m^3/t, estimated for 54 fields in Azerbaijan, is 3.5 × 1,082 = 3.8 trillion m^3.
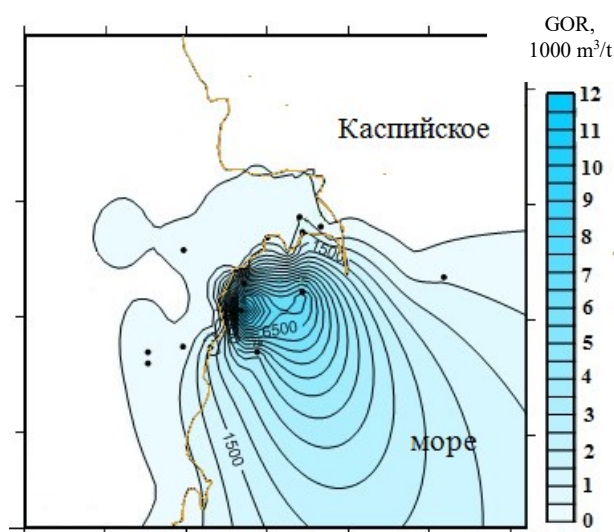

Fig. 5. Distribution of the average GOR values in the productive strata (Lower Pliocene) over the area (to exclude the influence of the preservation conditions on the average values, the data for depths below 2 km only were used)
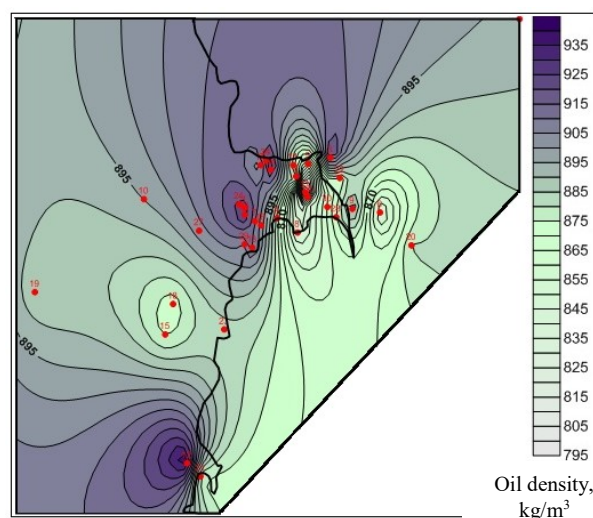

Fig. 6. Spatial regularities of liquid hydrocarbon density variations in the SCB
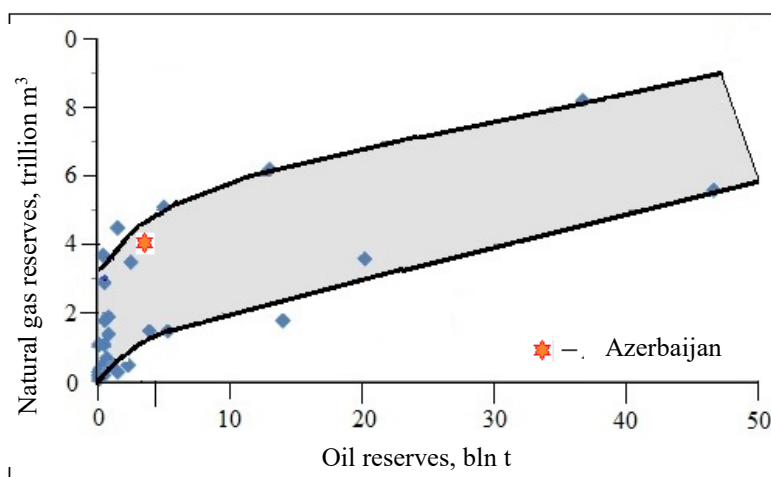
**Fig. 7. Relationship between proved oil and gas reserves
in various countries and predictive estimate for Azerbaijan**

Thus, total recoverable gas reserves in Azerbaijan, estimated based on three different indicators of the gas to oil ratio, can be accepted at about 4 trillion m³, including the already extracted 0.85 trillion m³ of gas [17].

According to the existing official estimates, in Azerbaijan, possible not yet extracted gas reserves are estimated at 2.55 trillion m³ [11, 6]. These reserves mainly belong to such already discovered fields as Shakh Deniz, Umid, Apsheron, the AChG block and the Babek prospect. Proved gas reserves for these fields amount to 1.2, 0.2; 0.35; 0.35, and 0.4 trillion m³, respectively (a total of 2.5 trillion m³) [10].

Thus, the official estimate does not take into account the prospects of discovering new gas condensate accumulations in the SKB deep-water part. The volume of the unaccounted possible gas reserves, according to our estimations, may be about 0.6 trillion m³: 4 trillion m³ (the estimated total reserves) – 0.85 trillion m³ (the already extracted volume) – 2.55 trillion m³ (the approved proved gas reserves) = **0.6 trillion m³**.

Such a volume of natural gas, depending on the size of the structure, can correspond to gas reserves of some two or three prospects. Based on the modern tectonic-geophysical model of the oil-and-gas potential of the South Caspian Basin (SCB) [2], most likely, Mushvig, Mashal, Shafag, and Israfil Huseynov structures can be among such prospects (see Fig. 1). However, it should be noted that although the Mushvig structure is the most promising, it is most likely to be classified as unprofitable due to its small dimensions.

Conclusion

Total recoverable oil reserves in Azerbaijan are estimated at 3.5 bln tons, of which slightly above 2 bln tons have been extracted. Based on the statistically estimated ratio between the volumes of gas and oil in various basins of the world, including Azerbaijan, the predictive estimate of the total natural gas reserves in Azerbaijan was estimated at about 4 trillion m³. This is in agreement with the other available estimates. Of this volume of natural gas, 0.85 trillion m³ has already been extracted; the approved geological reserves are estimated at 2.55 trillion m³.

Almost 83% of the extracted natural gas came from offshore fields. This trend will continue in the future, and will be even strengthened due to large volumes of gas condensate accumulations in the deep-water part of the basin. In this part of the basin, the most attractive prospects are Mashal, Shafag, and Israfil Huseynov, total reserves of which are expected at 0.6 trillion m³ of natural gas.

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References

1. Kadirov F., Floyd M., Alizadeh A., Guliev I., Reilinger R., Kuleli S., King R., Nafi Toksoz M. Kinematics of the eastern Caucasus near Baku, Azerbaijan. *Nat. Hazards*. 2012;(3):1-10.

2. Feyzullayev A. A., Kadirov F. A., Kadyrov A. G. Tectono-Geophysical Model of the Southern Caspian in the Context of the Presence of Oil and Gas. *Physics of the Solid Earth*. 2016;52(6):913-923.

3. Feyzullayev A. A. Generation and phase state of hydrocarbons at great depths. In: *1st International Conference "Ultra deep hydrocarbon potential: future energy resources – reality and prediction"*. June, Baku, Azerbaijan. 2012. P. 32-34.

4. Rasheed R., Kulkarni A. Reserve Estimation Using Volumetric Method. *International Research Journal of Engineering and Technology*. 2016;3(10):1225-1229.

5. How much oil and gas in the Caspian? Biznesinfo.az. URL: http://www.biznesinfo.org/observer/dossier/params/ln/ru/article/94442/ (In Russ.)

6. The volume of oil and gas reserves of Azerbaijan has been announced. *Gazeta Respublika = Newspaper Respublika*. URL: http://www.vesti.az/ekonomika/ob_yavlen-ob_em-neftegazovykh-zapasov-azerbajdzhana-351182 (In Russ.)

7. Guseynov E. *Oil reserves in Azerbaijan amount to 15 bln barrels*. 2007. URL: http://www.day.az/news/economy/95649.html [In Russ.]

8. Dikarev A. Strategy of Continental Shelf Energy Resources Development. *Politiya*. 2010;(1):60-73. (In Russ.)

9. Tyurin A. Status of oil and gas exploration in the Azerbaijani sector of Caspian Sea. URL: http://www.kavkazoved.info/news/2015/03/25/ (In Russ.)

10. Israfilbayova S. Azerbaijan reduces oil, natural gas production. *AZERNEWS*. 23 January 2018. URL: https://www.azernews.az/oil_and_gas/125939.html.

11. State Oil Company of Azerbaijan disclosed oil and gas reserves in the country. *Praym = Prime*. URL: https://news.rambler.ru/business/38820646 (In Russ.)

12. *BP Statistical Review of World Energy*. June 2014. 45 p.

13. *BP Statistical Review of World Energy*. June 2017. 66th edition. 49 p.

14. Shurupov S. V., Belousova A. S. Estimation of associated petroleum gas resources in oil production in Russia. *Gazokhimiya = Gasgeochemistry*. 2010. P. 70–74. (In Russ.}

15. Kaiser M. J. and Yunke Yu. Gulf Coast economic limits-1: Economic limits estimated for US Gulf Coastal fields. *Oil and Gas Journal*. 2010;108(20):47–54.

16. Maclay D. M., Shepard N. K., Zeringue B. A. *Estimated Oil and Gas Reserves Gulf of Mexico*. OCS Report BOEM 2013-01160. U.S. Department of the Interior Bureau of Ocean Energy Management Gulf of Mexico OCS Region. New Orleans; July 2013. 23 p.

17. *Illik hesabat. SOCAR*. Baku, Azerbaijan; 2017. 200 p.

Библиографический список

1. Kadirov F., Floyd M., Alizadeh A., Guliev I., Reilinger R., Kuleli S., King R., Nafi Toksoz M. Kinematics of the eastern Caucasus near Baku, Azerbaijan. *Nat. Hazards*. 2012;(3):1-10.

2. Feyzullayev A. A., Kadirov F. A., Kadyrov A. G. Tectono-Geophysical Model of the Southern Caspian in the Context of the Presence of Oil and Gas. *Physics of the Solid Earth*. 2016;52(6):913-923.

3. Feyzullayev A. A. Generation and phase state of hydrocarbons at great depths. In: *1st International Conference "Ultra deep hydrocarbon potential: future energy resources – reality and prediction"*. June, Baku, Azerbaijan. 2012. P. 32-34.

4. Rasheed R., Kulkarni A. Reserve Estimation Using Volumetric Method. *International Research Journal of Engineering and Technology*. 2016;3(10):1225-1229.

5. Сколько нефти и газа на Каспии? Biznesinfo.az. URL: http://www.biznesinfo.org/observer/dossier/params/ln/ru/article/94442/

6. Объявлен объем нефтегазовых запасов Азербайджана. *Gazeta Respublika = Newspaper Respublika*. URL: http://www.vesti.az/ekonomika/ob_yavlen-ob_em-neftegazovykh-zapasov-azerbajdzhana-351182

7. Гусейнов Е. Запасы нефти в Азербайджане составляют 15 миллиардов баррелей. URL: http://www.day.az/news/economy/95649.html

8. Дикарев А. Стратегия освоения энергетических ресурсов шельфа Мирового океана. *Politiya = Politiya*. 2010;(1):60-73.

9. Тюрин А. Состояние работ на нефть и газ в Азербайджанском секторе Каспия. URL: http://www.kavkazoved.info/news/2015/03/25/

10. Israfilbayova S. Azerbaijan reduces oil, natural gas production. *AZERNEWS*. 23 January 2018. URL: https://www.azernews.az/oil_and_gas/125939.html

11. Госнефтекомпания Азербайджана обнародовала запасы нефти и газа в стране. *Praym = Prime*. URL: https://news.rambler.ru/business/38820646

12. *BP Statistical Review of World Energy*. June 2014. 45 p.

13. *BP Statistical Review of World Energy*. June 2017. 66th edition. 49 p.

14. Шурупов С. В., Белоусова А. С. Оценка ресурса попутного нефтяного газа при добыче нефти в России. *Газохимия*. 2010. Январь-февраль. P. 70–74.

15. Kaiser M. J. and Yunke Yu. Gulf Coast economic limits-1: Economic limits estimated for US Gulf Coastal fields. *Oil and Gas Journal*. 2010;108(20):47–54.

16. Maclay D. M., Shepard N. K., Zeringue B. A. *Estimated Oil and Gas Reserves Gulf of Mexico*. OCS Report BOEM 2013-01160. U.S. Department of the Interior Bureau of Ocean Energy Management Gulf of Mexico OCS Region. New Orleans; July 2013. 23 p.

17. *Illik hesabat. SOCAR*. Baku, Azerbaijan; 2017. 200 p.