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Geology and Petroleum Potential of the Gulf of Mexico, Cuba

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Abstract

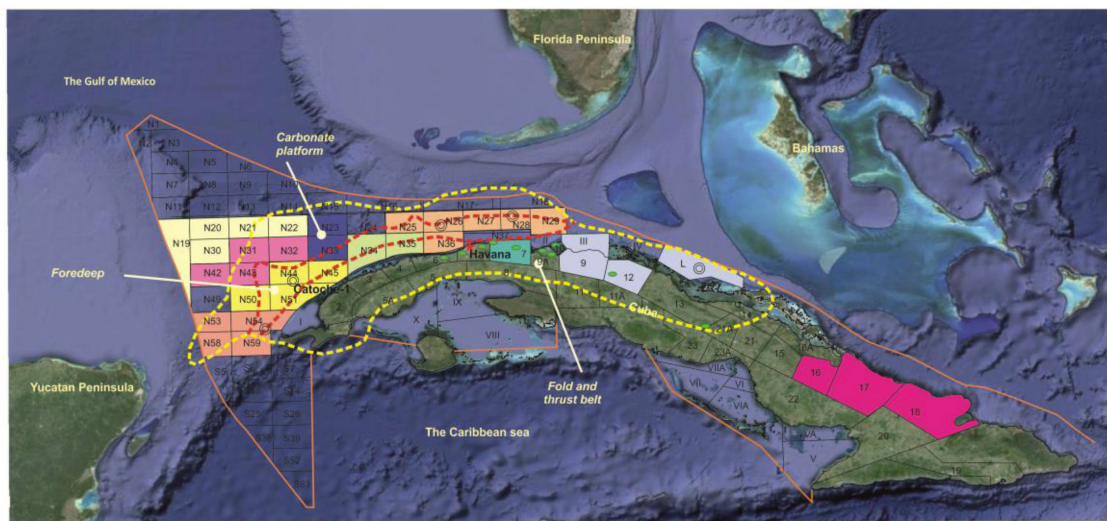
Oil-and-gas potential of Cuba is ascertained by discoveries among which there are the most large-scale deposits, such as Boca de Jaruco and Varadero fields of heavy oils. Currently the petroleum and petroleum products needs of the island state are satisfied by own sources by less than a half. Prospects of the hydrocarbon resource base development are connected with the adjacent water area of the Gulf of Mexico where foreign companies have been granted license blocks for geological study and further development since 2001. Two Russian companies - JSC Gazprom Neft and OJSC Zarubezhneft among others took part in the development of the Cuban part of the Gulf of Mexico. Since 2004 5 oil wells have been drilled by various companies in deep water of the exclusive economic zone of Cuba. Commercial oil-and-gas bearing prospects have been established in neither of them for both geological and technological reasons. However, only a small part of the water area has been covered by drilling and the productivity of the drill core has been tested at the depth of Cretaceous sediments only. In our opinion, oil-and-gas bearing prospects of the exclusive economic zone of the Republic of Cuba in the Gulf of Mexico remain undervalued and the mentioned water area needs additional geological exploration. Planning of exploration work in this poorly explored region shall be carried out systematically and it shall be based on the results of the regional scientific research.

Introduction

Overseas exploration projects are one of the priority directions of the hydrocarbon resource base development for JSC Gazprom Neft According to the adopted “Strategy 100-70-40” by 2020 production in foreign countries shall equal 10% of total production. Currently, Gazprom Neft executes a number of projects in Serbia, Iraq, Kurdistan Autonomous Region of Iraq and Venezuela. Since 2010 the Company participated in the project with Malaysian company Petronas on evaluation of the oil-and-gas bearing prospects of 4 areas in the exclusive economic zone of Cuba. In the well Catoche-1 drilled in 2012 presence of hydrocarbons was found but nocommercial field was found. It should be noted that it was the first experience of JSC Gazprom Neft participation in an international project with drilling of a well in deep water. Despite the fact that both companies have left the Cuban project there remains a need to analyze the steps which were taken and assess them critically. Such analysis allows to take into account

Table 1—Assessment of the Jurassic-Cretaceous hydrocarbon system of the North-Cuban oil and gas bearing basin (USGS, 2010)

Oil and gas bearing region	Oil, mmt	Gas, bcm	Condensate, mmt	Total for oil and gas bearing region
Of the fold and thrust belt	67	16	5	88
Of the foredeep	439	216	97	752
Carbonate platform	120	45	22	187
Total for phase condition	626	277	124	1027



Users of subsurface resources: 1 – CNPC; 2 – Petrovietnam; 3 – PDVSA; 4 – Petronas/ Gazpromneft; 5 – ONGC; 6 – Repsol; 7 – Zarubezhneft; 8 – Sherritt; 9 – Sonangol; 10 – well; 11 – the border of oil and gas bearing region.

Figure 1—The location of the license blocks with the participation of the State fire supervision and the project well Catoche-1 on the shelf of Cuba

different circumstances in the future that influenced the outcome of the project and implement new projects like this with much greater success.

Assessment of the resource potential of the hydrocarbons

According to the assessment of the U.S. Geological Service oil and gas bearing potential of the North-Cuban oil and gas basin is just over 1 billion toe. According to the average probabilistic assessment recoverable oil resources are estimated at 626 mmt, gas - 277 bcm, condensate - 124 mmt (table 1). In addition to the above, according to Cuban specialists oil and gas potential of Cuba is about 3 billion toe. (<http://www.benzol.ru/news/newsone.php?id=184001>)

USGS specialists distinguish one Jurassic-Cretaceous hydrocarbon system within which resources are estimated for the areas of the fold and thrust belt, the foredeep and the carbonate platform (Fig. 1). Borders of the HC system are justified by the fact that within these limits migration of hydrocarbons from catagenetic mature clay-carbonate Jurassic and, possibly, Cretaceous source rocks is possible (Schenk, 2008, 2010). The area of the foredeep is estimated as the most hydrocarbon-rich, and drilling of most of the marine deep wells was concentrated in it.

The state of geological and geophysical exploration on land and in the sea

Cuba has been a territory with known oil and gas reserves since the end of the XIX century. The first field was discovered in 1881. Currently there are 28 fields, geological reserves of oil in each of them are from a few millions up to a billion barrels (J. Schenk, 2008)

The largest fields Boca de Jaruco and Varaderos with initial geological reserves of more than 100 mmt (about 1 billion barrels) each are characterized by a complex block structure, a significant degree of depletion and a low product quality of the extracted products. Thus, the density of oil at the field of Varadero is $0.96\text{--}1\text{ g/cm}^3$ ($9^{\circ}\text{--}16^{\circ}\text{API}$) heaving up to upper horizons, oil recovery factor is 0.07-0.12, sulfur content exceeds 2%. Collectors are distinguished by lateral instability but permeability in them can be up to 5-6 Darcy due to karstic phenomena which are rather characteristic of Cuba.

Currently Cuba meets about a half of its oil needs basing on its own hydrocarbon resources extracting about 3.5 mmt of oil a year. Shortage of oil is covered by supplies from Venezuela. There are prospects of resource base expansion on the shelf and especially in the deep-water area of the Gulf of Mexico, where the discovery of large and giant hydrocarbon fields is possible.

The first fields were discovered on the Cuban sea shelf in shallow water in 1990. They are confined to the marine extension of oil and gas bearing area by characteristic fold and thrust structure. The fields are small in reserves and crude oil in them is characterized by high density and high content of sulfur. More encouraging results were obtained at the end of 2004 near the Northern coast of the island in Santa Crustal Norte district, 60 km from Havana, where a new field of high-quality oil with the reserves of at least 100 million barrels was discovered (14 mmt). (<http://www.mineral.ru/News/16055.html>)

Persistent attempts to discover hydrocarbon fields in the deep water in the Cuban part of the Gulf of Mexico have not stopped for the last 10 years. On the initiative of the Cuban authorities, 59 license blocks for oil exploration with average area of 2000 km^2 and an average water depth of 2000 meters were allocated in the waters area in 2001, foreign companies received access to a part of them (Fig. 1). In 2004, Spanish company Repsol drilled the well of Yamagua-1 in the deep water within the block 27 (depth of the water column – 1,631 m, bottom hole – 3,410 m) located in 100 km to the east of Havana. The well did not discover commercially productive hydrocarbons although showings of oil were found in three section intervals. In the subsequent analysis the lack of hydrocarbon deposits on the structure of Yamagua-1 was explained by insufficient capacity of the sealing horizon and its significant fracturing due to proximity to the zone of thrust deformations of the island of Cuba.

In may 2012 the same company Repsol with its partners Statoil (Norway), and ONGC (India) announced that the drilled deep water well Jaguey-1 (block 26) turned out to be “dry”. The bore hole of the well reached the depth of 6,096 m.

Attempts to find hydrocarbons on the Cuban shelf by Petronas together with JSC Gazprom Neft (the well of Catoche-1) and later by Venezuelan company PDVSA (the well of San Antonio) ended approximately with the same results.

OJSC Zarubezhneft performed drilling of a prospecting well L-1 on the block L in 2013. However, the construction of the well failed to be completed on time. In the process of well drilling complex mountain and geological conditions and high intensity of drilling fluids absorption were identified the total amount of which exceeded the similar levels in the drilled wells on the shelf in the region by 10-30 times. Following this OJSC Zarubezhneft together with Cubapetroleo decided to change the program of well construction by division of it into 2 stages. The second stage of geological exploration works on block L was planned to start in 2014. (Oil without borders, 2013)

Experience of Gazprom Neft: the project of Catoche

In May-August 2012 with the participation of JSC Gazprom Neft Catoche-1 well was drilled in the exclusive economic zone of Cuba (operator - Petronas). The share of JSC Gazprom Neft in the project for geological study of the north-western part of water area of Cuba (blocks 44, 45, 50, 51 with the total area

of more than 7 thousand km²) in partnership with Malaysian Petronas was 30%. In geological respect the blocks were confined to the prospective oil and gas bearing region of the foredeep of North-Cuban oil and gas bearing basin.

Preliminary the regional and detailed 2D seismic survey was carried out within the blocks 44, 45, 50, 51 which helped to prepare more than ten potential objects for exploratory drilling in potentially productive Jurassic-Paleogene deposits of presumably carbonate composition.

The well of Catoche-1 was set at the object of N1 which is the largest potential trap closed on all sides and it causes the least geological risks. The major search object was assumed to be in carbonate deposits of lower Cretaceous. The objects of the second stage which could be opened by the well were timed to the upper Jurassic and lower Eocene.

Drilling of the well of Catoche-1 was performed using the semi-submersible drilling rig “Scarabeo 9” (the platform of the 6th generation with an installed derrick of RamRig/DualActivity/type). The borehole of the well from the rotary table reached the bottom chalk at the mark of 4,666 m at the water depth of more than 2 kilometres.

Presence of positive structure and convergence of forecasted and actual markings of the main reflecting horizons were confirmed by drilling. In turn, carbonate saturated collector was not found in the sediments of the Eocene and Cretaceous. Oil indications in the sludge (smell, glow under UV rays) were found in terrigenous rocks of Cretaceous and Eocene which are constituents of layers with the thickness, as a rule, of a little more than 1 meter. It should be stated that these results of drilling quite logically fit in the well-known data on regional Geology of the North of Cuba. In addition, the well did not confirm the expected lack of upper Cretaceous rocks in the column and this fact also fits into the overall regional concept.

So summarizing the results of drilling of the well of Catoche-1 it should be stated that the following facts **were confirmed**:

- presence of closed positive structure;
- position of the marks of the basic geological boundaries;
- predominantly carbonate section.

The following facts were not confirmed:

- lithology and the type of collector;
- absence of the upper Cretaceous deposits;
- commercial oil and gas content.

In our opinion, numerous geological and technological uncertainties led to the unsuccessful outcome of the exploration, at that, some of them could have been resolved prior to drilling with the help of:

- 3D seismic survey;
- engineering survey of the seabed;
- study of the project on the basis of regional analysis.

Hydrocarbon bearing prospects: a new geological model of sub-thrust complex

As the analysis of the results of exploration works in the water area of the Gulf of Mexico near Cuba shows, currently the drilling exploration of this area does not allow to make conclusions about reasonable prospects of oil and gas bearing potential and especially to give up on it. The presence of only 5 wells which uncovered only Cretaceous sediments at maximum bears the evidence of insufficient volumes of exploration work in this promising region.

The new concept of geological development of the region proposed by geologists of JSC Gazprom Neft is based on the fact that the vertical and lateral southward migration of hydrocarbons can be more

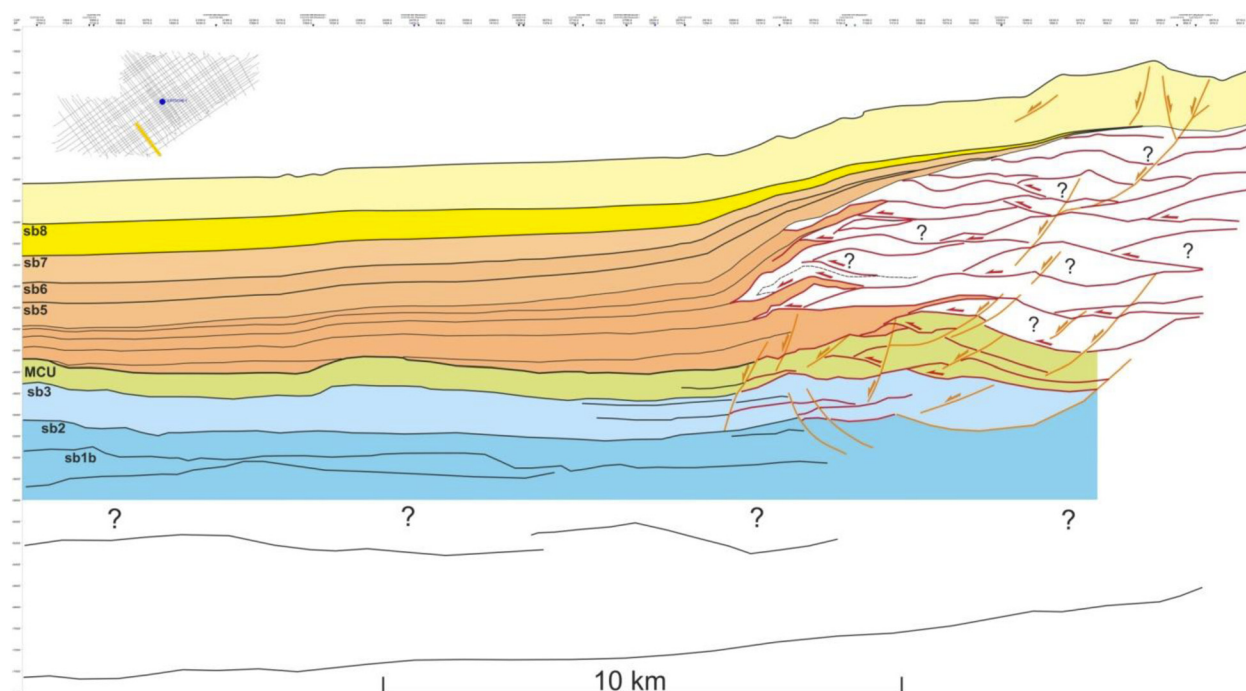


Figure 2—Interpreted fragment of profile 16, illustrating the internal structure of the junction area of the offshore extension of the fold-and-thrust belt of Cuba and of the foredeep (Orange shows young discharges of NW(?) fall, acting as possible ways of hydrocarbon migration)

intensive in comparison with the previous models. The reason for this is breakdowns (slip detachments) formed by tension in the area of the Northern front of the Cuban thrust-fold belt. In particular, the main deposits of oil on land such as the largest field of Varadero can be associated with the above-mentioned migration routes, some light hydrocarbons are lost (Fig. 2).

Detailed geological and structural interpretation of a fragment of the seismic profile No. 16 (Fig. 2) in general confirmed the fold-thrust structure of the frontal structures of the Cuban region at the junction with the foredeep. Here, in the southern part of the profile numerous gentle thrust scales (duplexes) with flat and ramp geometry were found. Separate thrust scales have the size of (up to 5) km in diameter. At that, the horizontal displacement amplitude along these faults may achieve the first or even tens(?) of kilometers. Judging by the natural decrease of intensity of deformation towards the bottom horizons basal detachment (a series of detachments?) should be approximately near the border of Jurassic and Cretaceous.

Along with this in generally expected fact a number of unknown or previously under-marked regularities of the structure were revealed (Mossakovsky, 1978, Puscharovsky, 1987). For example, it became apparent that most of the interpreted surfaces of detachment are characterized by the direction of fall along the continental slope in the direction from the fold belt to the foredeep. This suggests a significant role of gravitational forces in their formation by analogy with numerous gravitational fold-discontinuous structures found in many continental slopes of the World Ocean (gravity-driven fold belts).

It is also noteworthy that in many cases the juncture area of the Cuban fold belt and of the foredeep on the level of development of the lower Eocene-Paleocene(?) has a characteristic geometry of push in slips which is quite typical for the frontal zones of many fold belts of the world. Basing on the available temporal reference of seismic horizons it is obvious that the most intensive processes of overthrust faulting took place after the Cretaceous period and continued up to the initial Eocene period. This time interval, in general, is synchronous with the time of the main orogeny of Cuba and, apparently, we should talk about paragenetical signs of deformation on the land and the Northern water areas of Cuba.

Basing on the essential time similarity of the deformation symptoms of compression in Cuba and in its Northern part of the water area, it can be assumed that the gravitational structures on the continental

slope could occur as a result of the collapse and slide down the slope of the front parts moving in the Northern direction of collision thrusts. That is, the front thrusts of the Cuban region in the explored segment have apparently tectonic-gravitational nature.

Over the whole range of the sedimentary section (JURA-Pliocene/Quaternary) a series of young (modern?) discharges SW(?) of the fall with small amplitudes of displacement - up to the first tens, more rarely - hundreds of meters was also marked. It is obvious that young discharges pointed by us could serve as the migration routes of hydrocarbons up the slope (which was not taken into account by the USGS model) - towards the fields located along the Northern coast of Cuba.

In general, we want to note that the presented block diagram can be worked out further in more detail which will lead to a significant complication of the internal structure of individual thrust-fold scales. Accordingly, it becomes evident that the potential objects in the south (Cuba region) part of Petronas license blocks are complex fault-fold antiforms crucially similar to the known deposits of Cuba: Varadero, Boca de Jaruco, etc. However, for the water areas there is an acute question of the age of rocks forming separate thrust slips. Basing on the above mentioned column it is not clear that the fold-and-thrust scales developed here in the upper part are formed by upper Jurassic-Neocomian carbonates which are productive in the north of Cuba. It is likely that these scales can be formed by younger - Paleocene-economiceenergy deposits, hydrocarbon bearing prospects of which in this part of the area are not quite clear. However, by analogy with low Eocene thin sand interlayers (1-2 m) opened by the well of Catoche-1 they can show relatively good reservoir properties.

Conclusions

Thus, the exclusive economic zone of Cuba is a promising oil and gas bearing water area. Drilling of 5 wells in the deep water has not led to the opening of industrial deposits of hydrocarbons but it allowed to study the geological structure of the region to some extent. The Project fulfilled with the participation of JSC Gazprom Neft can not be univocally considered as unsuccessful. It allowed the Company to increase the competence, to try its hand in a new field of production, to implement exploration project in an unexplored basin. The suggested new concept for oil and gas exploration in Cuban waters is a key idea to continue geological prospecting works in this promising region.

References

- A.A. Mossakowsky, H.F. Albear Top structure of the Western and North Cuba and the history of its formation in view of olistostrome and molasse studying// *Geotectonics*. 1978. No. 3. P. 100–117.
- Oil without borders (Neft bez granits)/ Corporate publication of OJSC Zarubezhneft*, № 1.- 2013. - p.11 (http://www.nestro.ru/media/filer_public/2d/5f/2d5f5f4b-a988-46e7-835d-90a705ea01c5/journal_zn_001_june.pdf)
- Explanatory note for the Geological map of Cuba, scale 1:250 000. Executive Editor Y.M. Pushcharovsky Authors: Y.M. Pushcharovsky, A.A. Mossakovsky, G.E. Nekrasov, S.D. Sokolov, F. Formel, L. Penialver *Geological Institute of the Academy of Sciences of USSR*, Institute of Geology and Paleontology of the Academy of Sciences of Cuba. 1989.
- Pszczolkowski A. Cretaceous sediments and paleogeography in the western part of the Cuban miogeosyncline // *ActaGeologicaPolonica*. 1982. V. 32, No. 1-2. P. 135–159.
- Schenk, C.J. *Jurassic-Cretaceous Composite Total Petroleum System and Geologic Assessment of Oil and Gas Resources of the North Cuba Basin*, Cuba. U.S. Geological Survey, Reston, Virginia: 2008.
- Schenk, C.J., 2010, *Geologic assessment of undiscovered oil and gas resources of the North Cuba Basin*, Cuba: U.S. Geological Survey Open-File Report 2010–1029, 1 sheet.
- <http://www.benzol.ru/news/newsone.php?id=184001>
- <http://www.mineral.ru/News/16055.html>