OIL AND GAS GEOLOGY

Application of method of heat vision generalization for the estimation of terms of accumulation of hydrocarbons in the Western desert of Egypt

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The article presents results of an innovative technologies application – the thermal imaging generalization method for environments assessing that make possible the accumulation of hydrocarbon in the Western Desert of Egypt. This method was first applied in the cumulative desert in new modification, which applies not only the field of thermal radiation, but also an indicator of relative water saturation. It gives an opportunity to confirm and specify the discovered contours of oil and gas deposits and similar to them to discover some new, which are predicted for the first time.

For a few last years for the estimation of oil and gas bearing of certain areas and territories innovative technology more and more applied is a method of heat vision generalization, based on method of digital algorithmic transformation of initial heat vision images into digital volumed model of the field of caloradiance. It is more known according to publications [1-4] as a method of heat vision generalization, or method of heat vision generalization of Mukhamediarov (HVHM) - after the surname of one of its main developers of R. D. Mukhamediarov, doctor of technical sciences, professor, general director and main designer of “Aero-Space Instrument Making Institute” CJSC [5]. V. R. Tumanov worked out the criteria of searches of hydrocarbon raw material with this method. [3]. A term "method of heat vision generalization"(HVG) is used in our article, as exactly under such name it was applied during implementation of works within the limits of the licensed block of “Naftogaz of Ukraine” National Joint-Stock Company Alam El-Shawish East in the Western desert of Arabic Republic of Egypt.

Works on estimation of terms of accumulation of hydrocarbons with the help of method of HVG within the limits of the licensed block of Alam El - Shawish East were decided to be conducted at finishing stage of geological survey works. As a rule, such works are conducted on the regional stage. Cost of works by the method of HVG for one linear kilometre of profile or one square kilometer of area more than in 10-20 times less than the cost of reconnaissance for seismic researches in 2D and 3D respectively. That is why works according to method of HVG shall be conducted before setting of reconnaissance for seismic works in order to concentrate the last exactly on the objects educed by it with favourable terms for the accumulation of hydrocarbon raw material and due to it to reduce the cost of geological survey works. In the moment of decision-making in relation to application of method of HVG on territory of block of Alam El - Shawish East on 80% of its area (north and south parts) were conducted reconnaissance for seismic works in 3D and in total about 20 searching and reconnaissance mining holes were bored. An exception was made only for southern-eastern part of area (about 200 km2), for which by then for reasons not depending on the Company the permission for realization of seismic and reconnaissance researches in 3D and boring drilling of oil and gas searching mining holes in its limits was not received. Taking it into account, setting of works by

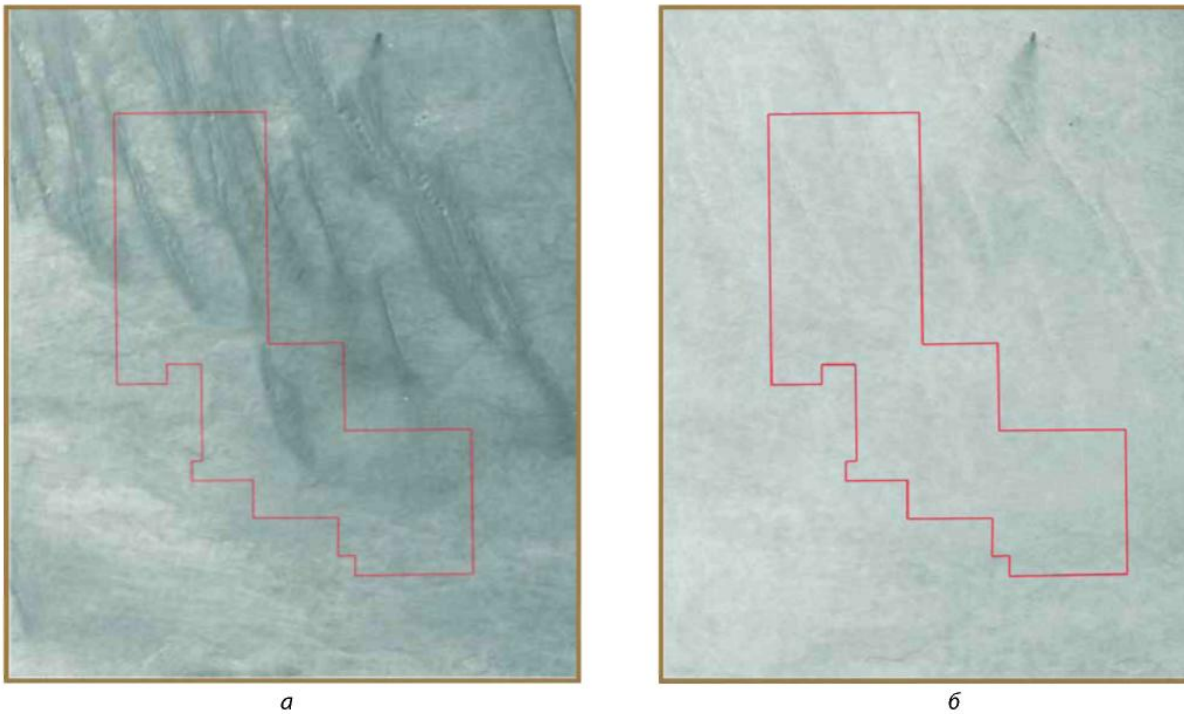
the method of HVG on all territory of block of Alam El - Shawish had to deside following tasks:

firstly, to get the prognosis of oil and gas bearing for north and south parts of the licensed block for further use during determination of location and sequences of gobbing and boring drilling of searching and reconnaissance mining holes, and also for determination of borders of the ground mountain taking;

secondly, during the decision of previous task to evaluate efficiency and authenticity of method on the basis of comparison of its results got on the basis of minimum initial information, with the results of reconnaissance for seismic researches in 3D and boring drilling of oil and gas searching and exploration mining holes;

thirdly, to get the prognosis of oil and gas bearing for southern-eastern part of area of block of Alam El - Shawish East, being based on appraised efficiency and authenticity of method according to the results of application in northern and southern parts.

It is important to note that for the estimation of terms of accumulation of hydrocarbons by means of method of HVG within the limits of the licensed block of Alam El Shawish East new modification developed by V. R. Tumanov, which uses not only the field of caloradiance, but also index of relative water saturation, was applied.



а *б*

Figure 1. Initial images on the ground of digitalized space pictures from satellite Landsat 7: *а* – average geometric value of summer and winter values in infra-red diapason; *б* – visualized correlation of summer values to winter ones. Intensity of tone reflects relative water saturation in surface layer

Essence of method of heat vision generalization is in consequent averaging of the digitised infra-red image that gives an opportunity to trace thermal heterogeneities and borders between them from a terrene on a depth step by step. Id est in the process of realization of method the formalized selection, smoothing or filtration of image in accordance with the set algorithms and formal criteria, determined as generalization, is performed.

Heat vision space pictures represent the radiation temperature related to the thermodynamics temperature by dependence [6]:

$$T_p = \sqrt[4]{\varepsilon} \cdot T_т, \qquad (1)$$

where Tp is a radiation temperature; ε - radiate ability of surface; Tт is a thermodynamics temperature.

A radiate ability for every concrete substance is the function of wave-length and temperature, it equals unit for black "body" and can be infinitely small for an "absolutely white" body. If ε equals 1, then molecular and radiation temperatures are equal. Values ε for mountain breeds are estimated by values of about 0,95-0,65. That is why the map of radiation temperatures always will differ from the map of molecular temperatures from a heterogeneous radiate ability of substances, even if molecular temperature of superficial layer is homogeneous one.

Calculated by layer-by-layer generalization volume models of field of caloradiance in the bowels of the earth are hardly concerted with the polyzonal image of terrene, satisfy an idea about dissipative structures in unstable power open system and well contact with the models got by means of other geophysical and geological methods.

In a geological aspect HGV method had the following task: to educe the structure of heterogeneities of the field of heat radiation and classify this heterogeneities by form, by correlation with structural layers- before- Cambrian basis, paleozoic, jurassic, three Cretaceous ones (Berias-low-Apt, up-Apt-Cognac, Santon-Maastricht), two Cainozoic (Paleozen-middle-Eozen and Miozen) and also and by the floors of geohydrology, by directions of vectors of heat radiation and by the credible mechanisms of heat mass transition (conductus or convective).

Initial data for implementation of works by the method of HGV were space pictures of earth surface (winter and summer) in infra- red range of waves of 8-12 mcm and in a visible range. The selection of space pictures was carried out taking into account such requirements:

maximal resolution;

approximately the same daypart of different hour surveys, it is desirable near to morning sunset;

maximally contrasting seasons: one stage - in the middle of summer, other - in maximally cold time of winter.

On the initial stage initial data for interpretation a stratum cut and four teaching sentinels and erected seismic profiles were used. In further to them also attached areport about the results of trials on the miningholes completed by the boring drilling by then. On the basis of these erections from a 21 mining hole table of correlations after the roofs of structures and their powers, that was used for attachment of their heterogenies and borders between them, that were distinguished during works, was made.

The use of contrast of summer thermal streams in relation to winter became a result protracted search of more sensible parameter for the method of HVG. Sharply this problem appeared also in connection with that on initial stage of works interpretation of trial vertical cuts of the field of caloradiance for 4th seismic profiles in the block of Alam El - Shawish East showed non-satisfactory results, though up to this time during works such difficulties did not arise up in other climatic zones. Through large homogeneity of surface field of caloradiance picture upon the stream on the depths of about 3 kilometres and deeper, that are of interest, turned to be lack of details, non-informative.

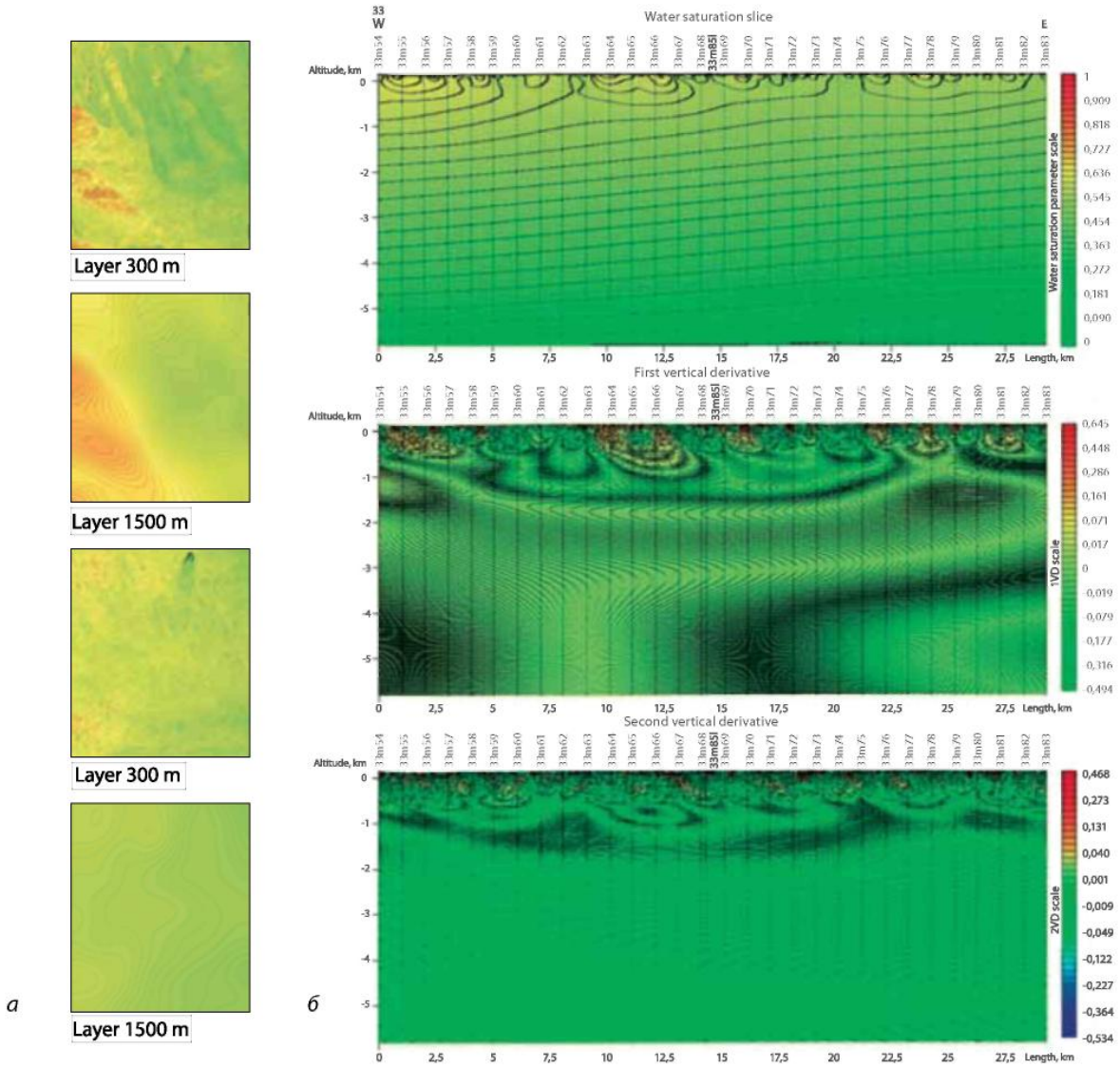


Рис. 2. Щільності потоку теплового випромінювання (*а* - верхні два фрагменти) та показник відносної водонасиченості (*а* - нижні два фрагменти) для глибин 300 і 1500 м. Вертикальні розрізи показника відносної водонасиченості (*б*) та відповідно зверху вниз його перша і друга похідні

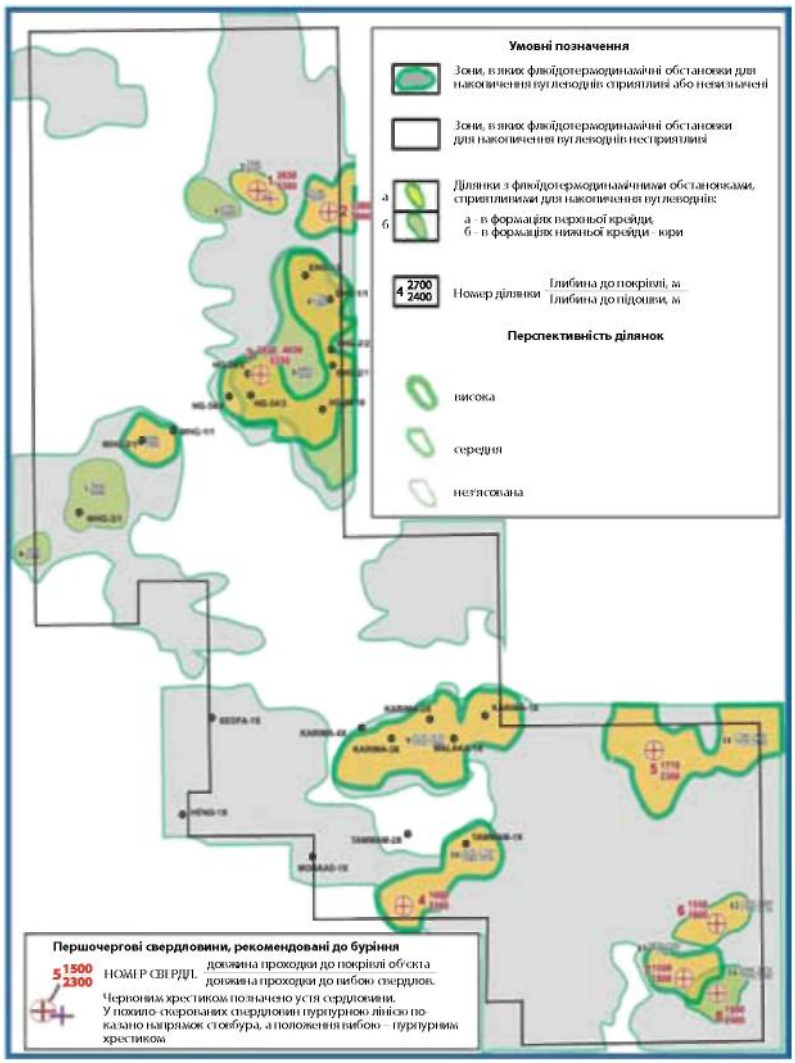


Figure. 3. Map of forecasts and recommendations

According to a formula (1) a radiation temperature stream depends on a radiate ability of surface of objects and on a thermodynamics temperature. Radiate ability of surface of soils in summer and in winter in the conditions of the Western desert of Egypt are practically identical (for lack of snow in winter). It gives an opportunity to consider that the contrast of summer and winter emission of thermal streams and contrast of summer temperatures with winter ones are numerally equal. Due to it we exclude the factor of radiate ability of surface of objects from further consideration as a constant value.

On the basis of generalization of data in relation to the heat-conducting of layer oils, waters and mountain breeds [7] it was determined that the higher is their heat absorption capacity, the less they are heated in summer and cooled down in winter. The dependence of temperature-contrast caused by heat-conducting, temperature-conducting, thermal inertia under conditions of conductive heat mass transfer has the similar character. Herewith the analysis of mutual influences of the above-stated indices on temperature contrast showed that under conditions when the factor of heat conduction is leveled and the factor of heat capacity goes out on the first plan, the factor of water saturation is manifested in the most brightly way.

The first results of use of parameter of relative water saturation showed the completely satisfying result: oil and gas bearing intervals and the number of delicate peculiarities were manifested on cuts, and it gives opportunity to evaluate oil and gas bearing. So the new modification using not only the thermal radiation field, but also the index of relative water saturation, was used in conditions of Western desert of Egypt for the first time. The reference data for new modification of exhaust gas temperature method were the average geometric mean

of summer and winter values in infra-red diapason and visualized correlation of summer values with winter ones, which intensity of tone reflects relative water saturation in surface layer (figure 1).

In the process of realization of exhaust gas temperature method – successive digital algorithmic smoothing (filtration) of digitalized infra-red image thermal heterogeneities and borders between them from the surface to the depths, where further smoothing is unreasonable, are traced gradually, which is the evidence of reaching of the marginal depth of the method, which in its turn is determined by resolution of the reference pictures.

During program-mathematical and topical processing of space pictures the number of logic procedures (operations) was implemented.

1. Calculation of density of stream of calorific radiation and the index of relative water saturation. Calculation of this parameters are performed on cuts with minimal initial step on the depth of 60 meters and in case of necessity with multiple gradual increase of a depth. Examples of such calculations are stated on figure 2 a.

2. Construction of the system of vertical cuts of caloradiance and digital field of index of relative water saturation. During realization of this operation we also determined first and second derivatives of the marked parameters according to the set grid and additionally through the set seismic cuts (figure 2 b).

3. Calculation of depth heat model of density of thermal stream and formal classification of thermal radiation field according to such elements as positive and negative linear heat streams, geothermal stems and apical apical parts of positive geothermal anomalies, geothermal hills, terrace, saddleback, pit.

Interpretation of vertical cuts of heat radiation field and digital field of the index of relative water saturation and their first and second derivatives are performed at first for each of these cuts, and then their results are reconciled to one cut.

5. Construction of multi-layered schemes of thermodynamics, that generalize volume data according to the maps of isolines of the density of heat radiation and its horizontal gradients, with elements of geologic interpretation according to the series of cuts in intervals of depths with consideration of the location of main structural and geothermal complexes.

6. Emphasizing and analysis of situations being conformed with models of thermal and fluid dynamic sceneries, development of geothermal criteria and forecasting of the traps of hydrocarbons, and also the additional characteristics according to the index of relative water saturation. Ranging of geothermal criteria performed according to their importance according to [3], is not stated in the article in details.

Criteria of the index of relative water saturation were analyzed in the following consequence:

Availability of the angle ascending streams of the increased water saturation in the interval of few hundred meters over the forecasted or defined object with favorable conditions for accumulation and storage of hydrocarbon raw material;

Availability of vectors of dryness reaching to a depth in lateral limitations of objects;

Weak manifestations of ascending vectors of dryness directly in the objects and over them (are not differentiated on big depths).

7. Construction of the map of forecasts and recommendations with ranging of thermal and fluid dynamic situations according to oil and gas perspective (stated on figure 3).

In the process of performance of works with the help of exhaust gas temperature the scheme of modern geo dynamics on the ground of decipher of space images in visible diapason and three-dimensional digital models of density of fluence of caloradiance and field of index of relative water saturation were received. These models for demonstrativeness and practical use in complex with other geologic and geophysical data are transformed into rather broad list of the effective illustrative materials: maps of different parameters and their vertical cuts, schemes of thermal dynamics and namely the map of forecasts and recommendations.

On figure: Two forecasted productive levels, the upper one (AR – "G") is defined by brightly yellow color, the second one is defined by pale yellow color. The contours of the revealed deposits are defined by dark-violet color, mine allotments are defined by color dotted lines.

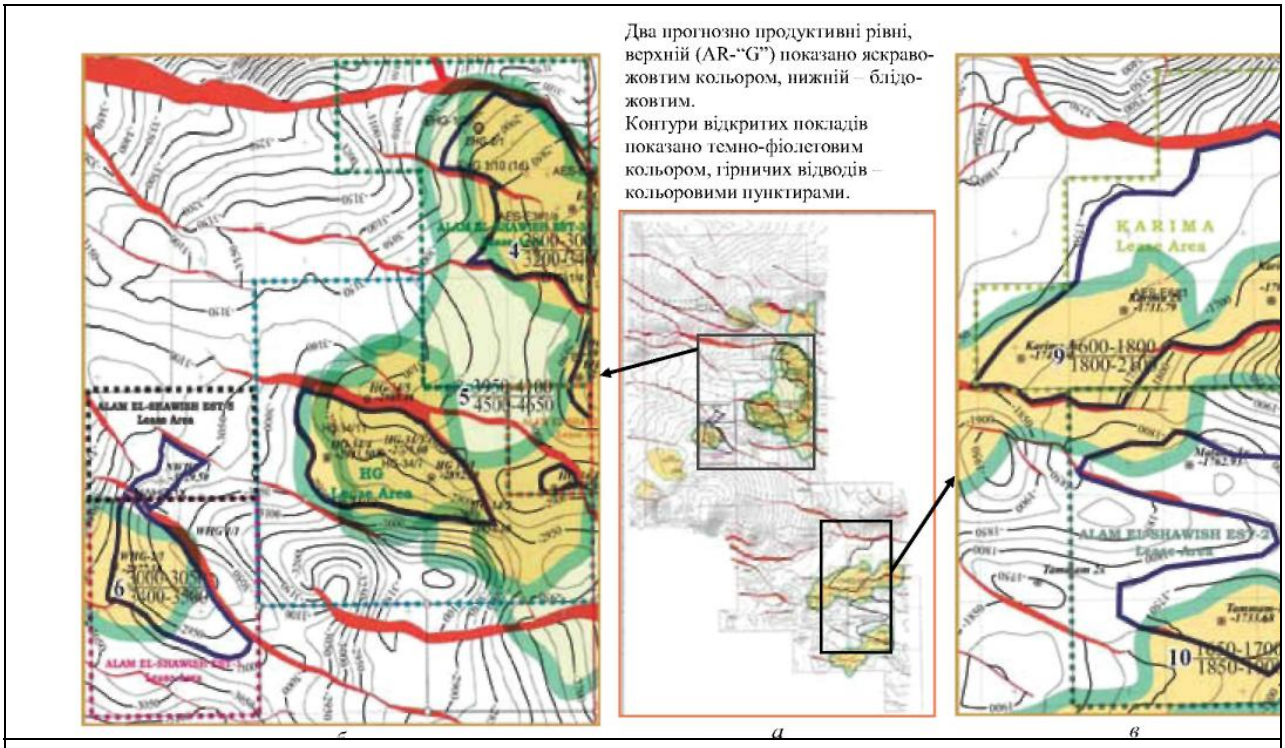


Figure. 4. Comparison of the fragments of Map of revealed deposits (*a*) with contours of forecasted objects within the borders of Northern (b) and Southern (c) parts of Alam El-Shawish East

These illustrative materials can be used for analysis of geologic prerequisites during determination of location of loading and order of drilling of search and development mining holes. The most significant and important one in the stated list of illustrative materials is the map of forecasts and recommendations (figure 3), which without overestimation can be considered the main gaining of the performed works. On the map of forecasts and recommendations the areas corresponding to objects with high, average and not defined fluid and thermodynamic sceneries advantageous for accumulation of hydrocarbon deposits. During comparison of forecast areas with high level of such sceneries of this map with the map of the results of works constructed in the Company according to complex data of 3D seismic reconnaissance, and drilling of 28 mining holes (see figure 3) it was found out that almost all of them correspond to open deposits within the borders of Northern and Southern parts of Alam El-Shawish East block. Upon this it is necessary to state the following concerning check of provability of the forecasts: for "dry" mining holes (9 units) coincidence of forecasts and results of trials is complete;

For effective mining holes (20 units) – coincidence for 19 of them. The exception is only one difference connected with за NWHg-1 with deposits of oil of 0,07 millions of tons and area of the deposit of about 1 km^2 on the depths of 3266,3–3279,5 m. These data can be accepted as

the threshold of determination of oil and gas objects of the depths of over 3 km (0,07 millions of tons, area is less 1 km^2);

Concerning the depths of bedding of objects being forecasted there is a complete provability with consideration of the fact that exactness of forecasts made with the help of exhaust gas temperature method can not exceed 60 m taking into account size of pixel on space photo.

More detailed comparison of fragments of the map with revealed deposits with counters of forecasted objects within the borders of northern and southern parts of Alam El-Shawish East block are showed on figure 4. The forecasted objects of oil and gas bearing emphasized within the borders of mine allotments Alam El-Shawish East-3 Lease Area and HG Lease Area are of particular interest. Two levels of oil and gas bearing are forecasted here with the help of exhaust gas temperature method. The first level are the formations Bahariya –Abu Rawash «C». Is object is shown on fragment of figure 4 b with bright yellow color and defined with number 4, its roof is located in interval of depths of 2800–3000 m, and the bottom is on the depths of 3200–3400 m. It is expected that on the lower level there are watered horizons determined also according the results of drilling, and deeper the new not revealed level of oil and gas bearing is forecasted. On fragment of figure 4 b it is showed by pale yellow color and defined by number 5 with the roof in interval of depths 2950–4100 m and bottom 4500–4650 m. It is not excepted that its effectiveness shall be evaluated even higher than the one received from Bahariya – Abu Rawash «C» formation, because the contours of this object in its major part seize the contours of object 4. In northern part of block forecasts according to depth coincided with revealed deposits within the limits of stated exactness. Difference in ranges of forecast deposits is connected with already mentioned exactness of method, and also with receipt of principally new additional information, that expands the counter of oil and gas bearing and in such way can increase the evaluated resources of revealed deposits. On other hand, as the reconnaissance of revealed deposits was not completed, contours of their oil and gas bearing can not be considered finally determined. It is even more true for contours of deposits located within the borders of mine allotments Karima Lease Area and Alam El-Shawish East-2 Lease Area (see figure 4 c). Thus, contour of oil and gas bearing in northern part of Karima deposit was constructed according to the data of seismic reconnaissance and was not proved by the results of drilling as of today. Also on the ground of seismic data the contours of oil and gas bearing of mine allotment Alam El-Shawish East-2 Lease Area, within the limits of which from mine hole Malaka-1 during the trials a small influx of gas was received, and mine hole Tammam-1x gave rather high influxes of oil and gas, were constructed. The land plot on southern east and south from mine hole Malaka-1x, like the plot located on southern east from mine hole Tammam-1x, according to the data of gas exhaust temperature method are referred to the area with fluid and dynamic sceneries unfavorable for accumulation of hydrocarbons.

According to the results of works performed by exhaust gas temperature method 40% of area are of northern and southern parts of license block Alam El-Shawish East were rejected as prospectless, which was also proved by "dry" mine holes. In addition, the Company refused from 25 % of the area in 25 % in utmost southern and western part of southern plot of license block as prospectless according to the results of performed analysis of geologic structure on the ground of 3D researches performed within its limits. Thus, total area rejected as prospectless one is about 65%. Having the results of forecasting of conditions of accumulation of hydrocarbons with the help of exhausting gas method before performance of seismic 3D researches their volume should be 35–40 % from actually performed ones. It can be the evidence of efficiency of the method.

Comparison of the results of exhaust gas temperature method of oil and gas prospective objects with the data of drilling of oil and gas search and reconnaissance mine holes within the border of northern and southern license block Alam El-Shawish East demonstrated that almost all effective mine holes are located within the borders of forecast plots with high level of sceneries favorable for accumulation of hydrocarbons. Such conclusion about provability of

exhaust gas temperature gives opportunity to say that it turned to be verifiable and effective in conditions of Eastern desert of Egypt.

According to the forecast of oil and gas bearing for southern and eastern part of the area of license block Alam El-Shawish East received with the help of exhaust gas method two plots highly prospective for accumulation and storage of hydrocarbons located on northern and southern east of this part of the block are emphasized. The total area of these plots does not exceed the third part of the above-stated part of block, and their location coincide with built structures according to the results of 2D seismic reconnaissance researches performed in the middle 80s of last century. This fact by itself is the evidence of efficiency of exhaust gas temperature method. Within the limits of this area two search mine holes were drilled in the last century. First of them, Agnes-1 mine hole, which revealed on the spent the deposits of up part of middle Jurassic period, was drilled in 1970 року. However it is located beyond the contour of southern and eastern object and at the result of trials it turned to be "dry", which is also the evidence of efficiency of exhaust gas temperature method. Other mine hole - Hf-36/4, was drilled in 1992 up to the depth of 2106 m and met on the spent deposits of Bahariya formation. Mine hole is located on southern end of northern and eastern object and in its time it was not tried, which requires the reconsideration of available data of this mine hole.

So the use of new modification of exhaust gas temperature method that uses not only heat radiation field, but also the index of relative water saturation, within the limits of license block Alam El Shawish East, gave opportunity to prove and specify already revealed contours of oil and gas deposits and to reveal new ones forecasted at first on the analogy with them.

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News

On participation of Ukrainian delegation in Polish and Ukrainian gas conference

On April, 1, 2013 in Warsaw (Poland) by initiative of Polish Ukraininian Club of journalists under patronage of chairman of the Polish-Ukrainian economic chamber Jacek Pekhota and vice-prime Minister of Ukraine Yurii Boika Polish and Ukrainian gas conference was held under participation of deputy head of the board V. P. Chuprun, director of Department on gas and oil extraction O. Yu. Zeikan and deputy head of Department of oil and gas extraction V. V. Hladun on behalf of "Naftogaz of Ukraine" National Joint-Stock Company.

Conference consisted of three sessions: "Integration of Ukrainian gas sector with European Union", "Terminals for receipt of liquefied gas in Poland and Ukraine – diversification of directions, supplies and suppliers of LNG», «Slate gas: experience of Poland and Ukraine".

In his speech V. P. Chuprun outlined the number of issues concerning the state and prospects of development of oil and gas complex of Ukraine in the context of general European energy safety. Namely:

In relation to strategic meaning of Ukrainian gas and transport system connected with gas and transport systems of neighboring European countries and integrated into common European gas network for European Union;

Role of underground gas storages of Ukraine that give opportunity to create reserves of natural gas for Ukraine and for countries of Western and Central Europe;

Modernization of gas transport system of Ukraine, which is the important priority for European Union, Ukraine and international financial organizations;

Current state of reorganization of "Naftogaz of Ukraine" National Joint-Stock Company in context of annexation of Ukraine to the Contract on Foundation of Energetic Society and necessity of adaptation of legislation of Ukraine to legislation of European Union in sphere of energetic;

Diversification of sources and routes of supply of gas to Ukraine.

During discussion "Slate gas: experience of Poland and Ukraine" the question concerning approximate data concerning deposits of slate gas in Poland and Ukraine and the results of researches performed in this directions. Taking into account mutual interest the parties agreed to continue exchange of experience in sphere of reconnaissance and development of slate gas deposits.