Abstract. The results of investigations in 2006-2010 for oil, gas and gas hydrates on the Antarctic Peninsula continental margin are given. In 2004 and 2006, the marine geoelectric researches by methods of forming a short-pulsed electromagnetic field (FSPEF) and vertical electric-resonance sounding (VERS) had been conducted in this region. The "deposit" type anomaly was mapped by FSPEF survey, and anomalous polarized layers of "hydrocarbon deposit" type were chosen by VERS sounding within this anomaly on Antarctic margin in the region of UAS "Academician Vernadsky". Anomalous zones of “gas hydrate deposit” type were detected on the South Shetland margin due the special technology of satellite data processing and interpretation using. These results confirm the high gas hydrates potential of the West Antarctic region. Some practical results of the experimental approbation of these original technologies for the “direct” prospecting and exploration of hydrocarbon (HC) and gas hydrates accumulations in different oil and gas bearing basins of Russia and Gulf of Mexico are proposed. The integration of satellite data processing and materials of FSPEF-VERS methods enable to improve their efficiency for different geological and geophysical problems solving.

Keywords: Antarctic margin, gas hydrates, hydrocarbon deposits, geoelectric methods, satellite data, direct prospecting

1. Introduction

Previous studies have revealed the real possibilities of new mobile geophysical technologies using for hydrocarbon (HC) accumulations prospecting [1-5].

One of these technologies, method of forming a short-pulsed electromagnetic field (FSPEF) and vertical electric-resonance sounding (VERS) makes possible the efficient and accurate determination of a geologic model beneath a sounding site. Field observations carried out with portable measurement systems «Gema» and VERS that with a software interface connected to a GPS-receiver and field computer. The “deposit” type anomalies (DTA) were mapped by FSPEF method within 70 perspective struc-
tures and separate areas from the 97 examined. The anomalous polarized layers (APL) of "oil" and "gas" type were chosen by VERS soundings in cross-section within the mapped anomalies. It was also shown that the APL indicate a high probability of hydrocarbon deposits presence, but this probability beyond is very low. The geoelectric researches on some oil-and-gas fields allow finding out new perspective sites and horizons and may be used for operative prospects estimation of the deep productive horizons. Express-technology of "direct" prospecting of the HC accumulations by geoelectric methods (FSPEF-VERS) was developed by experiments on the known oil and gas fields within the largest gas-and-condensate fields of Ukraine and once again shown the working capacity and economic efficiency of this technology. The “deposit” type anomalies (DTA) were fixed by the FSPEF survey on all oil and gas fields. The application of this technology (in areal version) allows significant reducing the search area and selects the most promising areas for the production of detailed geological and geophysical studies.

The second used technology for mobile HC accumulation prospecting is based on the satellite special data processing and interpretation and on the selection and processing of the resonance frequencies of the electromagnetic field data for each type of hydrocarbons’ compounds [3, 4, 6].

Special processing and analysis of space data obtained from remote sensing satellites (Landsat-7, etc.) can allocate within the study area the most promising local sites that require a detailed statement of work by field methods FSPEF and VERS (or other geophysical methods). This original satellite data processing technology may be integrated also with the traditionally used methods of HC accumulations and gas hydrates prospecting. There is already considerable experience of such remote prospecting within vast territories, as well as positive integration results of satellite data processing and interpretation of FSPEF - VERS technology.

Traditional and experimental approaches to treatment and interpretation of remote sensing data open up new possibilities of prompt detection and mapping (in a first approximation) of the anomalous zones of the "oil deposit" and (or) "deposit of gas" for large and medium hydrocarbon deposits especially. These capabilities are confirmed by the results of such interpretation for many fields in various oil-and gas-bearing provinces of the world [3 - 5]. It should be noted that this method may be used to detect and map the local anomalous objects (size 100-300m) with the interpretation of large-scale (1:10 000 and larger) conditioned satellite data [7].

Important for the detection of small size and low-contrast hydrocarbon deposits by the interpretation of satellite data is the fact that the anomalous zone of "deposit" type in many cases correlates with detected FSPEF – anomalies (DTA). As the experience of the research, there is a real opportunity not only to map the "deposits" anomalies of hydrocarbons, but also recognize the likely values of the mean reservoir pressure within the delineated anomalies. This is of particular importance to obtain a prelimi-
inary assessment of the actual fluid flow for each of the selected anomalies and the allocation of sites with the reservoir pressure elevated mean values within which the likelihood of commercial flows of hydrocarbons significantly increases. Obtained data on the distribution of relative average values of reservoir pressure within the limits of “deposit” anomaly can not only assess the extent of any necessary additional geophysical work (and drilling too), but also to locate the most promising areas.

2. Some Results of Proposed Technologies Practical Using on Gas and Oil Fields.

The first successful approbation of this technology was conducted on the known hydrocarbon fields and gas hydrates occurrences.

2.1. Antarctic Peninsula Continental Margin

First approbation of these special methods was realized for the area situated not far from the Ukrainian Antarctic Station (UAS) "Academic Vernadsky" (Fig. 1).

Fig. 1a. The scheme of the ship motion and region location of the FSPEF-VERS – profiles in 11-th UAE (2006):
1 – sounding profile through Drake Passage;
2 – UAS "Academician Vernadsky" (Galindez Island);
3 – Scheckleton Fracture Zone

Fig. 1b. Generalized map of Antarctic Peninsula continental margin:
1 – location of UAS "Academician Vernadsky" (Galindez Island);
2 – location of the geoelectric anomalous zone of the “hydrocarbon deposit” type
The HC-potential experience has shown that oil and gas deposits may be associated with large zones of tectonic fractures and rift structures of the continental margin of Antarctica. There are necessary conditions to generate and for the inorganic synthesis of HC of different types. The HC formation may be connected with the presence of subglacial drainage network which helps the crustal fluids and gases to move in Antarctic continental shelf direction [8].

Fig. 2. The VERS sounding data over geoelectric anomalous zone of the “hydrocarbon deposit” type in the Antarctic Peninsula region:
1 – sounding points (125-132);
2 – anomalous polarized layers of “hydrocarbon deposit” type;
3 – tectonic fracture zone

Marine researches with FSPEF-VERS technology were fulfilled during the seasonal works of the Ukrainian Antarctic expeditions (UAE) with the aim of studying the crustal structure of Drake Passage and Bransfield Strait down to depth of > 30 km [5].
This method was also used for the hydrocarbon accumulations prospecting on the Antarctic Peninsula continental margin near Anvers Island. One "deposit" type anomaly (DTA) zone was mapped by VERS sounding in depth interval up to 3500 m (Fig. 2).

We applied the special method of satellite data processing and used only reconnaissance character was carried out on the investigated sites (Fig. 3).

Fig. 3. Map of anomalous zones of "oil deposit" type in the Antarctic region (relative coordinates, area of the "Academician Vernadsky"), allocated by the satellite data special processing and interpretation results:

1 – the anomalous response intensity scale;
2 – points of the anomalous response values;
3 – predicted tectonic fractures;
4 – points of "deposit" type anomalies registration by marine geoelectric methods FSPEF and VERS

It means that a number of small and possibly medium-sized objects (fields) could be omitted. However, during the larger scale data processing they can be identified and mapped. The points of anomalous response values determination are shown on figure. The accuracy and detail of the anomalous objects mapping can be increased substantially when the concentration of points will be raised.
2.2. Fields of Pechora Sea, Arctic Region of Russia.

As practical examples of the use of this technique presents the results of the interpretation of geoelectrical anomalies and anomalous zones found in the Arctic region of Russia. Shelf of the Pechora Sea is one of the most promising oil and gas areas of the Arctic shelf of Russia. The deposits in this region are structurally confined to the anticlines, complicating further swells of the Timan-Pechora province to the Arctic shelf. Six deposits are discovered on the Pechora Sea offshore: four oilfields (Prirazlomnoye, Varandey-More, Medynskoye-More 2, and Dolginskoye), North-Gulyaevskoe oil, gas, and gas-condensate field and Pomorskoye gas-condensate field. Oil pools are installed on the Medynskoye-More 2 field in the upper and lower Devonian and Silurian sediments. The area of Medynskaya-More 1 structure is located to south from Medynskoye-More 2 field (Fig. 4).

Fig. 4. Sketch-map of the structures and oilfields location in Pechora Sea (Arctic, Russia)

The satellite data for this structure area were processed and interpreted. Large-scale anomalous zone of "hydrocarbon reservoir" type of high intensity was identified and mapped within the structure contours. The borehole, projected according to seismic and other geological and geophysical data, fall almost into the anomalous zone center. Nevertheless, the anomaly maximum is shifted slightly to the north-west of the project well point (Fig. 5). Four small anomalous zones of low intensity and different scale were mapped to the east from anomalous zone over the Medynskaya-More 1 structure. The area of these anomalies location can be recommended for detailed study by other geophysical methods.
Two anomalous zones of small area were identified also to the west of the Medynskaya-More 1 structure, and another – to the north. A large-scale anomalous zone of high intensity was fixed in the north-eastern part of the satellite data processing and interpretation area.

This anomaly is even more large-scale than anomalous zone over the Medynskaya-More 1 structure. This area deserves high priority when the further exploration carrying out in this region.

Fig. 5. Sketch-map of anomalous zones of “hydro-carbon deposit” type (DTA) in the “Medynskaya-More 1” structure region:
1 – scale of anomalous response intensity; 2 – points of anomalous response determination; 2 – location of projected well on the “Medynskaya-More 1” structure; 4 – prognostic areas of oil-saturation maximum; 5 – tectonic fracture zones
It is possible to suggest the fracture zones presence within the investigated site on the satellite data processing results. The possible fractures positions are also shown (Fig. 5).

The received results indicate that the special technology of satellite data processing and interpretation may be applied for hydrocarbon accumulations prospecting and exploration in the Arctic and Antarctic regions.

2.3. The License Blocks Fields (shelf of Venezuela)

The position of license blocks Urumaco I, Urumaco II, Cardon III, Cardon IV on the shelf of Venezuela [9] is shown (Fig. 6). Remote sensing data in the licensed blocks are in good agreement with the results of drilling and allow saying the following:

1. Major gas condensate field was revealed by three wells within the Cardon IV Block. It is located in a zone of major anomalies such as "gas deposit." In the southern part of this anomalous zone detected as an anomaly of the "oil deposit" of smaller size.

Fig. 6. Map of anomalous zones of "hydrocarbon pool" type in the vicinity of the licensed blocks Urumaco I, Urumaco II, Cardon III, Cardon IV (Gulf of Venezuela, Venezuela's shelf) based on the processing and interpretation of satellite data:

1 – the scale of the anomalous response; 2 – the anomalous zones of the "gas deposit" type; 3 – the anomalous zones of "gas + oil deposit" type; 4 – tectonic disturbances by satellite data
In the eastern part of the block detected two anomalous zones such as "gas deposit" type of small size. Presence within them of zones with relatively high values of reservoir pressure indicates the appropriateness of their range of prospecting and drilling.

2. On the site Urumaco I was found two small area anomalies such as "gas deposit" type. Anomaly in the left corner of the block is not of practical interest, since it is characterized by relatively low values of the anomalous response. Within the block Urumaco II were revealed three relatively small anomalous zones such as "gas deposit". Of the greatest interest is the Western, the largest in size anomaly.

3. There is a real doubt on the advisability of further exploratory work within the block Urumaco I by the results obtained. Detailed analysis of these materials and their comparison with the available geological and geophysical data can also help in the decision to conduct further exploratory work within the block Urumaco II or no.

2.4. Gas Crater in Darwaz (Turkmenistan)

Gas crater ("Gates of Hell") is a width of about 60 m and a depth of 20 m structure in the center of the Karakum desert (Fig. 7). It formed in the process of geological prospecting in 1971 when drilling rig collapsed crater. It was decided to burn the gas located in the voids, but it stays on for 40 years. Not far from the burning crater there are two similar failure of similar origin. The gas pressure is much weaker there. The processing of satellite data within the treated area founded two anomalous zones of "gas reservoir" type with areas of high values of average reservoir pressure (Fig. 7). The crater is located in the central anomalous zone in the path of high reservoir pressures. Within this anomaly the anomalous zone of "oil pool" type is delineated.

The second anomalous zone is adjacent to the southern boundary of the site survey and is not traced completely to the south. An additional and independent data received showed that the crater is located in the mid-size gas fields, where it is in the process of its destruction due to leaks in tires. The presence of anomalous zones with high reservoir pressure values indicates that industrial (commercial) gas flows can be obtained from this area. The presence of the second (southern) anomalous zone indicates the possibility of additional anomalous zones of "gas deposit" and "oil deposit" types in this area detecting. Therefore this region may be considered as a promising area for search operations on oil and gas.
3. Some Results of Proposed Technologies Practical Using on Gas Hydrate Fields

3.1. The Messoyakh field (Russia)

Traditional energy sources deficiency arouses scientific and practical interest to non-traditional sources, the gas hydrates deposits including. Gas hydrates are solid compounds of the gas molecules and water that exist under certain values of pressure and temperature. The Messoyakh field in Russia was the first deposit with gas hydrate concentrations. It is located in the north-eastern part of Western Siberia and was discovered in 1967 [10].

The deposits of natural gas and gas hydrates are installed there in dome trap of Cenomanian productive stratum (Dolgan formation) at 800 - 900 m depth. There are several hypotheses of Dolgan deposits structure. By one of them the gas hydrate deposits are located in the structure roof, and the gas reservoir is underlain by water at the structure base (http://www.neftegaz.ru/science/view/433).
Fig. 8. Map of hydrocarbon accumulations zones, produced on the satellite data processing results for the "Messoyakh" gas-hydrate deposit area (Western Siberia, Russia):

1 – zone of gas-hydrate deposits; 2 – zone of gas deposits; 3 – zone of oil deposits; 4 – points of the anomalous responses registration from gas-hydrate deposits

The satellite data processing for the Messoyakh gas hydrates deposits area (Fig. 8) was carried out to verify the correctness of these parameters determining in order to find the anomalous zones of "gas hydrates deposit" type in the Antarctic region.

The anomalous zones of "gas hydrates deposit" type were discovered and mapped only within two hydrocarbons deposits, and with the parameters of satellite data processing and interpretation, as in the Antarctic region. The anomalous zones of "gas hydrates deposit" and "gas deposit" types have been discovered and mapped with the satellite data processing in the southern part, and anomalous zones of "gas deposit" and "oil deposit" types – in the northern part of the surveying area.

3.2. Gulf of Mexico Fields

This technology was used for the hydrocarbon deposits detection and possible risk determination of oil production at one of the Gulf of Mexico (GOM) local areas [10, 11].

The intensive anomaly of "oil deposit" type has been isolated and mapped by the results of satellite data processing in the area of emergency drilling platform in the Gulf of Mexico (Fig. 9, 10).
Also the relative values of reservoir pressure were determined within most of the anomalies. The dependence of the values of the anomalous response from the reservoir pressure for gas has been installed by experimental measurements earlier. The scale of relative values of the pressure in the range from 0 to 6 has been formed by these data using.

Fig. 9. Map of the "oil deposit" type anomalies in the area of the “Deepwater Horizon” drilling platform in the GOM, based on the satellite data processing results:
1– scale of the reservoir pressure relative values;
2– points of the anomalous response registration; 3– emergency platform location;
4– relative values of reservoir pressure in the anomalous zone

The relative value of reservoir pressure has been defined equal to 6, i.e. the pressure in the wells is highest in comparison with those at other surveyed sites. In principle, this high values may use to indicate the higher probability of commercial fluid inflow receiving. But too high expenses and risks that related with gas hydrates production are reasons for terms transfer of these resources future mastering. Satellite data from this region were also processed for the gas hydrates deposits detection and mapping (Fig. 10). The results of satellite data processing showed that the “Deepwater Horizon”, an emergency drilling platform had been situated in the center of "oil deposit" type anomaly with high intensity values of reservoir pressure and in the anomalous zone of “gas-hydrate deposits” type with relative high intensity values of the response too.

Such combination of anomalous areas promotes technological risks during drilling works in this place to a great extent. There are also another "oil deposit" type anomaly in north-eastern part of area (Fig. 9) with low layer pressure and anomaly of “gas-hydrate deposits” type with the higher intensity of anomalous response.

Such combination of parameters specifies on relatively small potential of this deposit and promoted level of danger at his possible early development. These data also
show the wide occurrences of the anomalous zones of “gas-hydrate deposits” type with relative high intensity values of the response.

On April 20, 2010 an explosion and fire racked the “Deepwater Horizon”, a drilling platform operating in Mississippi Canyon of GOM. It may be assumed that the explosion of giant bubble of methane was one of the reasons of the «Deepwater Horizon» platform destruction.

![Map of anomalies of “gas-hydrate deposits” type in the area of the “Deepwater Horizon” drilling platform in the Gulf of Mexico:](image)

1 – scale of intensity values of the anomalous response;  
2 – points of the anomalous response registration; 3 – platform location;  
4 – relative values of the reservoir pressure in the anomalous zone; 5 – contours of the anomalous zone of "oil pool" type, based on satellite data

The results of searching and mapping of hydrocarbon and gas hydrates accumulations in different regions show the necessity of this technology application especially on the early stages of researches when appears the possibility not only to detect the, perspective on the different types of minerals areas but also to estimate possible risks during their future industrial development.

3.3. Gas hydrate Reservoir on the South Shetland Continental Margin (SSCM) Finding

In some parts of the Antarctic Peninsula margin there are available all necessary thermo-baric conditions for gas hydrates existence and their deposits formation that is proved by their distribution and concentration detection and mapping on South Shetland continental margin. The multi-channel seismic data acquired on the South Shetland
margin show that Bottom Simulating Reflectors (BSR-s) are widespread in the area, implying large volumes of gas hydrates [12-14].

According to sights of many researchers, this area represents “two distinct and superimposed tectonic regimes: an older regime is related to Mesozoic-Middle Cenozoic subduction-related tectonism of Gondwana margin; a younger one is associated with a mainly extensional tectonic phase, and related to the Oligocene development of the Western Scotia Sea [15]. This part of continental margin is limited by two fracture zones, Scheckleton(NE) and Hero(SW), the South-Shetland trench [16] in a southeast and South Scotia Ridge in the East (Fig. 11).

Assumptions of researchers about other processes of bottom structures tectonic development of this region are quite proved. Geodynamic features of this region may be defined also as complex interaction of different age continental and oceanic structures and are the result of active breaking which connected with regional rifting processes.

Fig. 11. Interpreted geoelectric cross-section of the crust and upper mantle along the profile through Drake Passage and the South Shetland Trench (SST) (Location of profile (A-B) shown in Fig. 1):

1 – complex of volcanic and crystalline rocks;
2 – rocks of crust–mantle transition layer; 3 – upper mantle;
4 – Moho boundary; 5 – VERS points;
6 – fracture zones. AP - Antarctic Peninsula

The BSR is mostly confined to this sector of the margin. It is possible to consider that numerous deep tectonic fractures assist to formation of natural gas migration ways towards the surface, creating the necessary conditions for stable BSR-zones appearance.
Satellite data over the BSR zones extension area, identified by seismic studies [12-14] have been processed and interpreted. The various processing parameters were analyzed for revealing and mapping the anomalous zone of "gas hydrates deposit" type within the surveying area.

The contours of identified anomalous zones (Fig. 12) are superimposed on the bottom topography map and the scheme of seismic profiles. In general, the revealed and mapped anomalous zones of "gas hydrates deposit" type correlate satisfactory with BSR zones defined by seismic data. The anomalous zones of "gas deposit" and "oil deposit" types were not detected within the surveyed sites.

Fig. 12. Map of the anomalous zones of "gas hydrates deposits" type, produced by the special satellite data processing results (Antarctic Peninsula region):
1 – anomalous responses intensity scale; 2 – points of the anomalous response values;
3 – BSR zones defined by seismic data

Conclusions

The results of the FSPEF-VERS technology obtained during the Ukrainian Antarctic expeditions have once again confirmed the high efficiency and mobility of this method.

1. The "deposit" type anomaly was mapped by FSPEF survey in the Antarctic margin structures and the anomalous polarized layers of "hydrocarbon deposit" type were chosen by VERS sounding within this anomaly. This indicates the possibility of the FSPEF-VERS technology using for hydrocarbon accumulation prospecting.

2. First approbation of satellite special data processing and interpretation original technology was conducted on the known hydrocarbon fields and gas hydrates occurrences. The interpretation of regional satellite data can detect and map abnormal areas of the "oil pool", "gas accumulation and (or) "gas hydrate” reservoir, due to a distinct
medium and large deposits. Anomalous objects of small size (100 - 300 m) may be detected and mapped by processing the satellite data of a larger scale (1:10 000 and larger) and permissions. This technology may be integrated also with the traditionally used methods of HC accumulations and gas hydrates prospecting as well as with non-classical geophysical technologies. Our practical experiments testify that integration of satellite data processing and materials of FSPEF-VERS methods enable to increase their efficiency for different geological and geophysical problems solving.

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