Research Article

Gas Hydrates Accumulations on the South Shetland Continental Margin: New Detection Possibilities

V. D. Solovyov, V. G. Bakhmutov, I. N. Korchagin, S. P. Levashov, N. A. Yakymchuk, and D. N. Bozhezha

1 Department of Seismometry and Physical Properties of the Earth, Institute of Geophysics of National Academy of Science of Ukraine, Palladin Avenue 32, 03680 Kyiv, Ukraine
2 Department of Geomagnetism, Institute of Geophysics of National Academy of Science of Ukraine, Palladin Avenue 32, 03680 Kyiv, Ukraine
3 Department of Geothermy and Modern Geodynamics, Institute of Geophysics of National Academy of Science of Ukraine, Palladin Avenue 32, 03680 Kyiv, Ukraine
4 Institute of the Applied Problems of Ecology, Geophysics and Geochemistry, Laborator Street 1, 03133 Kyiv, Ukraine

Correspondence should be addressed to V. D. Solovyov, valera@igph.kiev.ua

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The results of investigations in 2006–2010 for hydrocarbon 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 to the special technology of satellite data processing and interpretation using. These results confirm the high gas hydrates potential of the West Antarctica 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 improving their efficiency for different geological and geophysical problems solving.

1. Introduction

Previous studies have revealed the real possibilities of new mobile geophysical technologies using for hydrocarbon (HC) accumulations prospecting [1–6]. One of this 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 stratigraphic (geologic) model beneath a sounding site. The first publications about this technology as a whole had appeared in Russian (in 2001), in English—in 2003 [1, 2]. The basic physical principles that underlie the method of VERS probing described in English in the patent nos. 7227362, 7248052 (USA, 2007). On the basis of this patent in the United States was elaborated the power imaging (PI) geophysical prospecting method to aid in the exploration for hydrocarbons. PI technology is used to confirm the thickness and depth of expected hydrocarbon zones and provides a means for the direct detection of hydrocarbons [7].

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 showed the working capacity and economic efficiency of the FSPEF-VERS technology [1–6]. 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. The FSPEF-VERS technology has passed approbation on more than 55 known oil and gas fields. The “deposit” type
anomalies were fixed by the FSPEF survey on all oil and gas fields. The anomalous polarized layers (APL) of “oil” and “gas” type were chosen by VERS soundings in cross-section within the mapped anomalies. The “deposit” type anomalies were mapped also by FSPEF method within 70 perspective structures and separate areas from the 97 examined.

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. New (nonclassical) methods of geophysical research focused on direct search for specific physical substances with a characteristic set of properties: oil, gas, gas hydrates, water, various minerals, and rocks. The first method of satellite data interpretation is connected with electromagnetic fields structure of definite substance studying [8, 9].

“Spatial-frequency electromagnetic fields structure of any substance is determined by the chemical composition and spatial structure of molecules or the crystal lattice of the substance. A large number of homogeneous matters will create a collective characteristic of the substance in the electromagnetic field radiation power which is proportional to the substance concentration in a given direction. We can assume that the linear-polarized wave with a given frequency response carries information about the structure of the substance and is not absorbed by the medium, and the wave intensity does not decrease with distance. The homogeneous substance at any depth would create a field as if the substance was on the surface. It turned out that the characteristic electromagnetic wave of a large quantity of oil and gas is fixed in a certain way in satellite images. In most cases the technology of the quantum-optical satellite imagery filtration allows to identify the boundaries of oil and gas projected fields anywhere in the world and to record the density of stocks distribution” [5]. There are also the method of the distance-controlled discovery of HC deposits [6] and InfoScan technology, which is based on processing of analog photo material [9]. Accuracy of object location detecting directly depends on the scale of the investigated photograph.

This original satellite data processing technology may be integrated also with the traditionally used methods of HC accumulations and gas hydrates prospecting as well as with nonclassical geophysical technologies.

2. Some Results of Proposed Technologies Practical Using

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

2.1. Continental Margin of Antarctica. First approbation of these special methods was realized for the area situated not far from the Ukrainian Antarctic station (UAS) “Academic Vernadsky” (Figure 1).

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.

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 [4]. 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 (Figure 2).

We applied the special method of satellite data processing and used only reconnaissance character which was carried out on the investigated sites (Figure 3).
2.2. Experiments on Gas Hydrate and Oil Fields. Traditional energy sources deficiency arouses scientific and practical interest to nontraditional sources and the gas hydrates deposits. 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, 11].

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 [10].

The satellite data processing for the Messoyakh gas hydrates deposits area (Figure 4) was carried out to verify the correctness of these parameters determined 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.

2.3. Pechora Sea Arctic Region of Russia. Six deposits are discovered on the Pechora Sea offshore: 4 oilfields (Prira-zlomnoye, Varandey-More, Medynskoye-More 2, and Dol-ginskoye), 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 south from Medynskoye-More 2 field (Figure 5).

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, falls almost into the anomalous zone center. Nevertheless, the anomaly maximum is shifted slightly to the north-west of the project well point (Figure 6). 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 scaled 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 was carried out in this region. 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 (Figure 6).

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 of Earth.

2.4. Gulf of Mexico. 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 [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 (Figures 7 and 8).

The relative values of reservoir pressure were determined within most of the anomalies also. 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. The relative value of reservoir pressure has been defined equal to 6; that is, the pressure in the wells is highest in comparison with those at other surveyed sites. In principle, this high values may be used to indicate the higher probability of commercial fluid inflow receiving. But too high expenses and risks that are related to 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 (Figure 8). The same values of gas hydrates parameters, as in the Antarctic region and Messoyakh field, have been used satellite for data processing in this area. 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 northwestern part of district (Figure 7) with low layer pressure and anomaly of “gas-hydrate deposits” type with the higher intensity of anomalous response. Such combination of anomalous areas promotes technological risks during drilling works in this place to a great extent.

On April 20, 2010 an explosion and fire racked the “Deepwater Horizon,” a drilling platform operating in the Gulf of Mexico, in Mississippi Canyon. It may be assumed that the explosion of giant bubble of methane was one of the reasons of the “Deepwater Horizon” platform destruction.
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” [11]. This part of continental margin is limited by two fracture zones, Shackleton (NE) and Hero (SW), the South-Shetland trench in a southeast and South Scotia Ridge in the East. The region of the triple junction between the Shackleton Fracture Zone, the South Shetland trench, and the South Scotia Ridge is an area where the BSR-zones are the strongest [12–14].

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’s continental and oceanic structures and are the result of active breaking which is connected with regional rifting processes [13, 15]. 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 [10–12], 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 (Figure 10).

The contours of identified anomalous zones (Figure 10) are superimposed on the bottom topography map and the scheme of seismic profiles [12–14]. 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. It was rather unexpected because the thickness of the free-gas zone was estimated on average to be about 50 m, with local increases of as much as 400 m but variable average concentration [13, 14].

Possibly, free gas between the BSR and the Base of Gas Reflector accumulates in amounts that are insufficient for detection by this satellite method.

4. Conclusions

The results of the FSPEF-VERS technology obtained during the Ukrainian Antarctic expeditions have confirmed high efficiency of the separate methods of technology for different geological-geophysical problems decision.

(1) The “deposit” type anomaly was mapped by FSPEF survey in the Antarctic margin structure, 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) Investigations have demonstrated high efficiency of the VERS method using for studying of the Earth’s crust and upper mantle deep structure.

(3) First approbation of satellite special data processing and interpretation original technology was conducted on the known hydrocarbon fields and gas hydrates occurrences. This technology may be integrated also with the traditionally used methods of HC accumulations and gas hydrates prospecting as well as with nonclassical geophysical technologies. Our practical experiments testify that integration of satellite data processing and materials of FSPEF-VERS methods enable improving their efficiency for different geological and geophysical problems solving. Obtained results confirm the high HC and gas hydrates potential of Antarctic Peninsula region.

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