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NEW CRUSTAL MODELS OF DRAKE PASSAGE AND THE HYDROCARBON RESERVOIR SEARCHING IN THE ANTARCTIC PENINSULA CONTINENTAL MARGIN STRUCTURES (BY THE 17th UKRAINIAN ANTARCTIC EXPEDITION RESULTS)

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During the 17th Ukrainian Antarctic Expedition (UAE, 2012) new geophysical data for the West Antarctica bottom structures were obtained. The geophysical investigations included the geoelectric methods of forming a short-pulsed electromagnetic field (FSPEF), vertical electric-resonance sounding (VERS) and the special method of remote sensing (RS) satellite data processing and interpretation. These methods were used for the crustal structure studying and the hydrocarbon accumulations searching in continental margin bottom structures. Detailed geoelectric sections (with depth up to 24km) were constructed for Drake Passage, Scotia Sea and Bransfield Strait tectonic structures as a result of these seasonal works. There are presented some crustal boundaries between stratigraphically heterogeneous layers and deep depth discontinuities. The occurrence of complex fault zones near the coast of South America and the Antarctic Peninsula are showing. Some specific geoelectric boundaries below the Moho presence and the occurrence of possible deep high-temperature zones of rocks may reflect the heterogeneity of Passage bottom structures and available processes of tectonic and magmatic activity with the local areas of modern rifting.
Some anomalies of "oil deposit" type with total area of about 900 km^2 and three new anomalous zones of the "deposit of gas hydrates" type were mapped in the UAS "Academician Vernadsky" area. These data support the assumption of the possible existence new oil and gas area in this part of the West Antarctica. The parameters of two anomalous zones of the "deposit of gas hydrates" type with total thickness of 100 - 500m were determined at the continental slope of the South Shetland Islands. The presence of a number of "satellite" anomalous zones beyond the identified anomalies within the BSR-zones shows that gas hydrate reserves of this area are higher than previously calculated.
New detailed data for local gas hydrate accumulations confirm the high potential perspectives of this part of the South Shetland margin and allow attributing it to one of the most promising areas of the Antarctic region.
Keywords: West Antarctica, South-Shetland Trench, hydrocarbons, gas hydrates, remote studies, geoelectric methods.

Новые модели строения земной коры пролива Дрейка и результаты поисков скоплений углеводородов в структурах континентальной окраины Антарктического полуострова (по материалам 17-й УАЭ).

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Реферат. Представлены результаты геоэлектрических исследований глубинного строения земной коры (до 24 км) пролива Дрейка, а также новые данные об углеводородном потенциале структур материковой окраины Антарктического полуострова, полученные во время сезонных работ 17-й УАЭ (март 2012 г.). Морские геоэлектрические методы СКИП и ВЭРЗ применялись в комплексе с новой технологией обработки и дешифрирования спутниковых данных дистанционного зондирования Земли, что позволило провести «прямые» поиски углеводородов в рамках «вещественной» парадигмы интерпретации геофизических данных.

Показано, что распределение глубинных геоэлектрических границ и крупных неоднородностей разрезов может отражать масштабные нелинейные процессы преобразования первичной коры пролива Дрейка и западной части моря Скоша в ходе геодинамической эволюции региона.
По материалам ВЭРЗ в районе УАС Академик Вернадский определены параметры аномальных пластов и их положение в разрезе для четырёх аномалий типа «залежь нефти». Общая площадь аномалий, выявленных ранее по спутниковым данным, составляет около 900 км^2. В результате проведенных работ в районе УАС Академик Вернадский (восточнее о. Анверс) впервые обнаружены три аномальные зоны типа «залежь газогидратов». По данным ВЭРЗ, небольшие скопления газогидратов залегают на глубине 1000–1040 м в виде пластов переменной (от 4 м до 20 м) мощности и длиной до 4,5 км. Для двух известных аномалий типа «залежь газогидратов», приуроченных к материковому склону Южно-Шетландских островов, были определены параметры аномально поляризованных пластов газогидратов мощностью от 100 до 500 м, залегающих на глубине от 2500 до 5000 м при глубинах дна от 2000 до 4000 м.
Показано, что потенциальные запасы газогидратов в районе Южных Шетландских островов значительно превышают подсчитанные ранее. Это позволяет относить изученный участок к одному из перспективных мест скоплений газогидратов в Антарктике.

Нові моделі будови земної кори протоки Дрейка і результати пошуків скупчень вуглеводнів у структурах континентальної окраїни Антарктичного півострова (за матеріалами 17-ї УАЕ). І.М. Корчагін, В.Д. Соловйов, В.Г. Бахмутов, С.П. Левашов, М.А. Якимчук, Д.М. Божежа

Реферат. Представлено нові результати геоелектричних досліджень глибинної будови земної кори (до 24 км) протоки Дрейка, а також нові дані про вуглеводневий потенціал структур материкової окраїни Антарктичного півострова, отримані під час проведення сезонних робіт 17-ї УАЕ (березень 2012 р.). Морські геоелектричні методи СКІП і ВЕРЗ застосовувалися в комплексі з новою технологією обробки і дешифрування супутникових даних дистанційного зондування Землі, що дозволило провести «прямі» пошуки вуглеводнів у рамках «речової» парадигми інтерпретації геофізичних даних. Показано, що розподіл глибинних геоелектричних горизонтів і неоднорідностей розрізів може відображати масштабні нелінійні процеси геодинамічної еволюції структур дна протоки Дрейка і західної частини моря Скоша в ході перетворення фрагментів первинної кори регіону. За матеріалами ВЕРЗ у районі УАС Академік Вернадський визначено параметри аномальних пластів та їх положення в розрізі для чотирьох аномалій типу «поклад нафти». Загальна площа цих аномалій, виявлених раніше за супутниковими даними, становить близько 900 км^2. У районі УАС Академік Вернадський (на схід від о. Анверс) вперше виявлено три аномальні зони типу «поклад газогідратів». За даними ВЕРЗ, невеликі скупчення газогідратів залягають на глибині 1000–1040 м у вигляді пластів змінної (від 4 м до 20 м) потужності з довжиною до 4,5 км. Для двох відомих аномалій типу «поклад газогідратів» на материковому схилі Південно-Шетландських островів визначено параметри аномально поляризованих пластів газогідратів потужністю від 100 до 500 м, що залягають на глибині від 2500 до 5000 м при глибинах дна від 2000 до 4000 м. Показано, що потенційні запаси газогідратів у районі Південних Шетландських островів значно перевищують підраховані раніше. Це дозволяє відносити досліджену ділянку до одного з перспективних районів скупчень газогідратів Антарктики.

1. Introduction

The geological and geophysical studies of West Antarctica crustal structure refer to the basic purposes of the Antarctic research program (2011-2020 years) of the National Antarctic Scientific Center (NASC) of Ukraine. Particular attention in this program must be given to study of the Ukrainian Antarctic Station (UAS) Academician Vernadsky region. The researches of the continental margin structures that are perspective for the mineral resources are of a great interest too. Such studies can be carrying out during the Antarctic seasonal expeditions of the NASC of Ukraine [2, 7-11, 15, 16].

Ukrainian Antarctic expeditions acquired new geoelectric data for some bottom structures of Drake Passage, Scotia Sea and Antarctic Peninsula margin. These data provide new insights into crustal structure of some segments of Drake Passage, Scotia Sea and continental margins down to depth of 24-32 km. Obtained crustal inhomogeneities could be connected with magmatic processes and Drake Passage evolution stages. These original results make it possible to supplement with new details of the geodynamic formation and evolution picture.

New results of geoelectric and distant methods using to confirm the thickness and depth of mapped hydrocarbon zones are also described.

2. Geoelectric and the remote sensing special data proceeding technologies

Employed in 17th UAE field methods combined the "short-impulse electromagnetic field formation" (FSPEF), "vertical electric-resonance sounding" (VERS) technologies and frequency-resonance method of the remote sensing (RS) special data processing and interpretation [7, 8, 11, 15].

The FSPEF and VERS technologies are based on medium geoelectric parameters in pulsed transient fields and the spectral features of the Earths' quasi-stationary electric field over hydrocarbon (HC) accumulation studying because there is a direct relationship between the resonating frequencies of waves and the depths to the various geologic boundaries. **The VERS technology** is based on processes which polarize naturally-occurring electric fields at the surface of Earth. The polarised fields are analysed for their spectral characteristics. This technology can be used to confirm the thickness and depth of expected hydrocarbon zones [8, 11]. It has excellent depth resolution, no environmental impact and minimum acquisition costs.

These technologies allow operatively: 1) assess the oil-and-gas prospect of investigated areas with method of the RS-data processing using; 2) reveal and map the "deposit" type anomalies, which may be connected with the HC accumulations; 3) define the bedding depths and anomalous polarized layer of "oil", "gas" types thickness.

The "deposit" type anomalies (DTA) were mapped by FSPEF method within more than 75% of investigated structures and areas. 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 indicates a high probability of HC-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.

Now we use both technologies for deep horizons structural imaging and for the "direct" detection of hydrocarbons.

Express-technology of HC accumulations "direct" prospecting with geoelectric methods (FSPEF-VERS) was developed by experiments on many known oil and gas fields within the largest gas-and-condensate fields [8, 11, 15].

RS-technology is based on the satellite special data processing and interpretation with resonance frequencies of the electromagnetic field data for each type of hydrocarbons' compounds using. Special processing and analysis of space data obtained from remote sensing satellites (Landsat-7, etc.) within the study area can allocate the local sites for detailed works by FSPEF and VERS (or other geophysical) field methods. The anomalous zone of "deposit" type in many cases correlates with detected FSPEF – anomalies (DTA). Experiments show that there is a real opportunity not only to map the "hydrocarbon deposit" anomalies, but also to recognize the mean reservoir pressure values within these anomalies. Obtained data may be used to locate the most promising areas.

This original satellite data processing technology may be integrated with the traditionally used methods of HC accumulations and gas hydrates prospecting too. Thus, there are new possibilities of detection and mapping (in a first approximation) of the of the "hydrocarbon accumulation" type anomalous zones for large and medium hydrocarbon deposits. These possibilities are confirmed by the interpretation results for various oil-and gas-bearing provinces of the world [7, 8, 15].

3. Obtained results

Marine researches with FSPEF-VERS technology were fulfilled during three seasonal works of the UAE and obtained data were partially published [7–10, 15].

The geophysical investigations in 17th UAE included the geoelectric technologies FSPEF - VERS and the special technology of remote sensing (RS) satellite data processing and interpretation.

During the 17th UAE geoelectric measurements were carried out along profiles with the total length of 3955 km. These measurements made in the area of UAS "Academician Vernadsky", near the South Shetland and the Falkland Islands, in the Bransfield Strait and Drake Passage (Fig. 1) (Fig. 1-15 see the color paste between pages 26&27).

The geophysical survey consists of: 1. FSPEF- survey along profiles with total length of 2768 km; 2. deep VERS-survey (87 points) along 4 regional profiles with total length of 2424km; 3. geoelectric survey (480km) in the "search for oil anomalies" regime and VERS-sounding (57 points) in areas of identified anomalies such as "oil accumulation" in the UAS Academician Vernadsky region; 4. geoelectric survey on 2 profiles (80 points) in the "hydrate anomaly searching" regime near Anvers Island; 5. VERS-sounding (33 points) in areas of identified anomalies of the "deposit of gas hydrates" type near the South Shetland Islands.

Below we present some results of geoelectric data interpretation for Drake Passage and Antarctic Peninsula continental margin bottom structures.

3.1. Deep structure and the geoelectric sections of Drake Passage tectonic belt

Drake Passage and some areas of the Antarctic Peninsula continental margin are relatively accessible part of the West Antarctic Region for geological and geophysical studies of the deep structure, evolution and tectonic activity. In recent years, the amount of geophysical data along profiles in Drake Passage and Scotia Sea has increased substantially, which allows to summarize and differentiate the crustal characteristics of this region.

The processes in Drake Passage play a key role in understanding the stages of the geodynamic development and evolution of a vast region between the continents of South America and Antarctica. Geological interpretation of geophysical data is complicated considerably because there are only isolated ocean drilling data and limited geology information about Drake Passage basement rocks. There is a lack of the Moho spatial distribution data too. The obtained crustal thickness values for separate structures vary greatly. 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 tectonic of Gondwana margin and a younger one is associated with the Oligocene extensional tectonic phase of the Western Scotia Sea development [3].

Assumptions of researchers about other processes of bottom structures tectonic development of this region are quite proved. Formation and geodynamic evolution of the heterogeneous bottom structures of Drake Passage and Scotia Sea are considered to be caused by the processes of the South American and Antarctic lithosphere plates development [3, 4].

There is also another view that Drake Passage - Scotia Sea tectonic belt consists of the South America - Antarctica continental bridge large fragments [14]. This contradiction can be resolved only if there will be a sufficient amount of data about the Moho spatial distribution, as well as information about the structures presence (or absence) with transitional crust and mantle inhomogeneities in this region. Therefore, the new independent data attracting, including geoelectric survey materials, is of a great importance for the tectonics and geodynamics analysis of this region.

New geoelectric model of the deep crustal structure along the profile 1-1a (across Drake Passage) was built according the VERS deep soundings (46 points) data during the seasonal work of 17th UAE obtained (fig. 1).

The profile with total length about 1250 km crosses the structures of the continental margin of South America, Shackleton Fracture Zone, rift zone fragments of the West Scotia Ridge and the South Shetland Trench structure near the South Shetland Islands (Fig. 2).

The Earth's crust section (profile 1-1a) describes the crustal structure of Drake Passage central part to a depth of 24 km. Such depth allows identifying the specific facilities within the continental and oceanic crust boundaries and shows the complex nature of fault zones and mantle heterogeneities of Passage.

In the central part of the Drake Passage the lengthily horizon break (about 150 km) with the oceanic crust thinning of up to 6 km is recorded (Fig. 2). This place may be a channel for high temperature rocks of the upper mantle as it can be constructed by the VERS-data. The influence of rifting processes on the deep boundaries formation is extreme at sites located near the intersection of the Shackleton Fracture Zone with the Scotia Ridge western segments. There are the Moho-depth variations from 6-8 km to 11-12 km. Main deep geoelectric boundaries position in a model (Fig. 2) suggests a fundamentally different structures distribution of these crustal and mantle inhomogeneities which formed continental and oceanic crust complexes of rocks. So clearly expressed West Scotia Ridge rift topography reflects the current stage of large-scale conversion processes of the Drake Passage crust and upper mantle, identified by geoelectric data also.

Some specific geoelectric boundaries below the Moho and high-temperatures areas of upper mantle rocks may reflect the heterogeneity of structures and possible tectono-magmatic activity and rifting processes in bottom structures of the Passage. Schematic section of the Earth's crust (Fig. 2) confirms the basic patterns of deep inhomogeneities distribution by the results of previous (2006) geoelectric studies revealed [9].

There are certain differences of deep cuts obtained in expeditions in 2006 and 2012. Thus, the M2 border relief by VERS-data (2012) has more contrasting character than it was determined early by previous VERS-data (2006) and by seismic data about Moho distribution in Drake Passage.

This map clearly identified areas with M2-border rise up to 2-3 km from its mean value in the bottom structures. The most expressive M2-reductions (Moho uphill) are confined to distinct relief topography of the West Scotia Ridge rift segments and Shackleton Fracture Zone. Perhaps, the anomalous variations of the boundary position are connected with the existence of upper mantle high temperature zones which were embedded to crustal layers at 9–12 km depth (Fig. 2, 3).

3.2. Geoelectric survey at the South-Shetland Trench tectonic system

Profile 1-1a in its south-eastern part crossed the boundary of oceanic and continental crust in the South Shetland Trench. This trench extends along the South Shetland Islands in the form of a narrow bottom depression with depth up to 4600 m in the south-western part and up to 5200 m in its north-eastern part. This trench with the South Shetland Islands, Bransfield Strait rift and the Antarctic Peninsula structures are often treated as a single interconnected tectonic system. The nature of trench is not clearly established, therefore, the new geoelectric depth' section model of is interesting to studying the tectonics of this part of the continental margin of the Antarctic Peninsula.

Seismic profile DSS-17 with total length of about 300 km had been worked out in 1987 [11, 12]. Moho depth varies along this profile from 10 km for the oceanic crust beneath the Drake Passage and the South Shetland Trench to 40 km beneath the Antarctic Peninsula. Part of the profile of 1-1a in a larger scale (Fig. 4) exactly corresponds to the seismic profile DSS-17 location. This allows more objectively compare deep section obtained by DSS (profile DSS-17) method and VERS deep soundings (Profile 2, Fig. 4) data.

It should be noted that the model presented (Fig. 4) differs significantly from the seismic profile (DSS-17) section in oceanic and continental parts. In the oceanic part of profile the geoelectric crustal model contains (at 18-20 km depth) an added horizon with thickness of 1-3 km, which indicating the presence of the mantle heterogeneities in deep section. The mantle heterogeneities in the oceanic part of seismic profile were not allocated. In the transition ocean-continent zone the geoelectric section showed a significant dive of the continuous border M2 (Moho) from 11 km (Drake Passage) to 18 km (South Shetland Islands). The upper mantle rocks (at 18-22 km depth) underlie the crust of the tectonic' belt structures from Drake Passage to the Bransfield Strait. An additionally high temperature zone of upper mantle rocks is marked at a depth of 19-24 km (Fig. 4). These mantle rocks are located under the South Shetland Islands too, that may indicates the existence and movements of an active asthenolith in this tectonic zone. The most significant models (seismic and geoelectric) differences are marked for South Shetland

Islands, where the crustal thickness value by seismic data (DSS-17) reaches 28-35 km. The deepest geoelectric boundary of the continental crust model does not fall below 19 km. Such large variation in the deepest boundary position is obtained for the Bransfield Strait too, where the seismic thickness of the crust is more than 30 km [4, 5]. The deepest geoelectric boundary of the continental crust does not fall below 16 km there. According the VERS-data the border contact of oceanic and continental crust rocks passes through a large sloping fault and ends at 17-18 km depth (Fig. 4).

Most researchers share the view about the subduction nature of the South Shetland trench, that resulting from the process of the Phoenix Plate dipping beneath the continental lithosphere of the Antarctic Peninsula margin. It is considered that the seismic profile DSS-17 strongly supports its subduction nature [4, 5].

There is also an alternative explanation for the mechanism of formation of the continental margin structures [1, 14].

Assumed that the development of the trench' axis may be associated with normal faults and does not require the subduction mechanism. A significant increase in the depth of the Moho, which is characteristic for different types of continental margins, is not a proof of the of the active subduction process in this area. The compared deep sections were obtained in other places of the transition zone from the oceanic crust of the Drake Passage to the continental crust of the South Shetland Islands. [2, 10].

The deep geoelectric section (Fig. 4) by some parameters (total crustal thickness and layers distribution) generally resembles the seismic section across the Drake Passage, South Shetland Islands and Bransfield Strait (Fig. 5). Layer 1 of the continental crust rocks (Fig. 4) corresponds to the thick (up to 2 km) sedimentary layer with V = 1.8–4.0 km/s of the seismic section; layer 2 – rocks with V = 5.1–6.0 km/s; layers 3 and 4 with their total power (more than 10 km) are close to the seismic horizon with V = 6.6–6.7 km/s (Fig. 5). Differences of the crustal thickness values (based on these data) are less than one kilometer to the Drake Passage and Bransfield and about 4 km to the South Shetland Islands. The obtained VERS-data (Fig. 3, 4) do not confirm the presence of a clearly expressed subduction at the continental margin of the South Shetland Islands. They indicating the important role of thrust and vertical movements in the South Shetland Trench formation. Such conclusions have been made for other segments of the South Shetland Islands, previously intersected by VERS-profiles [1, 10].

4. Geoelectric experiments on Oil and Gas Hydrate Fields

4.1. Continental Margin structures near the "Academician Vernadsky" UAS

Oil and gas deposits may be associated with large zones of tectonic fractures on the continental margin of Antarctica as there are all necessary conditions for generating and inorganic HC-synthesis. First approbation of our special technologies was realized for the area not far from the Ukrainian Antarctic Station (UAS) "Academician Vernadsky" situated [1, 2, 9]. Marine researches with FSPEF-VERS technology were used for the hydrocarbon accumulations prospecting near Anvers Island where one "deposit" type anomaly (DTA) zone was mapped by VERS sounding in depth interval up to 3500 m.

We applied the RS-data processing and interpretation for hydrocarbons' compounds in this area (Fig. 6). The accuracy and details of the anomalous objects mapping may be increased substantially if the concentration of points will be raised.

Now we have some new results of geophysical survey with marine geoelectric FSPEF and VERS technologies in area where anomalous zones of "oil deposit" type were discovered (fig.7). There is a unique possibility to compare the predicted and real distribution of anomalous zones of "oil deposit" type on the shelf of the Antarctic Peninsula in the vicinity of the "Academician Vernadsky" UAS (fig. 6, 7)

The depth of the producing formations such as "oil deposit" (with thickness from 40 to 100 m) ranges from 400 to 3300 m. The largest and the most powerful layers within the Oil-1 anomaly lie at the depth of 1600-1800 m. Detailed work by VERS method showed that two anomalies (Oil-2 and Oil-4) disintegrated into the separate anomalies, each of them was characterized by a set of productive layers at 600-3200 m depth (Fig. 7, 8).

The maximum reservoir pressure value varies from 20 to 33 MPa within the large area (Oil-1, Oil-2 and Oil-2a) and does not exceed 16 MPa for the anomalous zones Oil-3, Oil-4 and Oil-4a (Fig. 7, 8). Preliminary estimates of separate layers length, their section position and the effective area of anomalous zones, as well as reservoir pressure values within identified anomalies show their sufficiently attractive. This confirms the assumption about the possible existence of a new promising oil and gas area in this part of the Antarctic shelf.

4.2. Gas hydrate reservoir mapping

4.2.1. Gas hydrate reservoir mapping near the Academician Vernadsky UAS

Gas hydrates may be a potential future energy resource [12, 13, 17]. During the 17th UAE seasonal works (Fig. 9, 10) geoelectric survey was carried out along two profiles in the "hydrate anomalies searching" regime near Anvers Island. The anomalous zones ("gas hydrate reservoir" type) to East of Anvers Island (Gh-1, Gh-2) were studied by VERS-technology.

The gas hydrates accumulation Gh-1, Gh-2 were formed at a depth of 1000-1040 m as a layer with variable (4-20 m) thickness and length of 4.0-4.5 km (Fig. 10). These anomalous zones are founded in the Strait, where the bottom depth is about 200 m. We do not know any another information about the gas hydrates findings or their searching in this area. Added anomalous zone of the "accumulation of gas hydrates" type (Gh-2) was founded in this area too. This anomaly is similar to anomaly Gh-2. The VERS-soundings are not carried out here, therefore, the layer' parameters are not defined. Estimated hydrate reserves (with an average concentration of 6.3% [6, 17]) for these small anomalies do not exceed $3,0 \times 10^6 m^3$ of methane (at standard temperature and pressure).

4.2.2. Gas hydrates reservoir mapping on the South Shetland continental margin (SSCM)

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 SSCM show that Bottom Simulating Reflectors (BSR-s) are widespread in the area, implying large volumes of gas hydrates [6, 12, 13, 17]. The BSR follows a thermobaric surface and usually marks the base of a gas hydrate layer below which there is free gas. Gas hydrates may be present even in places without BSR identified zones. It is possible to consider that numerous deep tectonic fractures assist to formation the natural gas migration ways towards the surface, creating the necessary conditions for stable BSR-zones appearance.

According to the calculations [13, 17], the total amount of gas hydrates and free gas in the areas of mapped BSR-zones (with small and large amplitudes) in this area of the SSCM is about $1,68\text{-}2,8 \times 10^{12} m^3$.

Satellite RS-data for BSR-zones localities near the South Shetland Islands were interpreted and new anomalous zones of "gas hydrate reservoir" type were discovered (Fig. 9). These results indicate that the anomalous zones are located near the Shackleton Fracture Zone (eastern region) and at a considerable distance away from it (57° - 59°W).

During the seasonal works on this part of SSCM new geoelectric data (33 VERS-points) were obtained. The parameters of two anomalously polarized layers with thickness from 100 to 500 m at a depth from 2500 to 5000 m were determined (Fig. 12).

BSR-zones, partially separated by a series of major and minor faulting are allocated at a depth of 2300-3200 m on the seismic section 197213 (Fig. 13). In the western part of this profile data show a BSR-zone dive. It's in a good agreement with the position of gas hydrates in the anomalous zone Gh-1 (Fig. 12). Seismic profile 197214 [12, 13, 17] in the most eastern part of area passes through the anomalous zone which crosses the entire slope of the South Shetland Trench. BSR-zone is distinguished clearly at a depth of about 500 m below the bottom, including the central part of the slope that is impaired by the fracture zones [13]. Thus, the presence of gas hydrates was mapped with RS-data using (Fig. 7) and confirmed with detection of the BSR-zones by seismic data. VERS-data were obtained only for two RS-anomalous zones where BSR-zones had been found too [13, 17]. A comparison of data by the different methods obtained shows that the polarized layers depth of the "gas hydrates deposit" type in the Gh-1 area and the seismic BSR-zone position are almost the same (Fig. 11-13).

The possible gas hydrate seismic velocity variations (Fig. 14A) are consistent with the concentration variations (Fig. 14B). The RS-anomaly of "gas hydrates deposit" type (Fig. 11) in the eastern part of the area (near the intersection of seismic lines 19207, 19209 and profile KSL93-7) corresponds to the position of increased (Fig. 14A) velocity anomaly (about 600 m/s) and gas hydrates high volume concentration (about 8%) value (Fig. 14B).

As it's shown, the possible gas hydrate thickness may reaches 300-500 m along the profile (Fig. 15).

The presence of some "satellite" RS-anomalous zones (Fig. 9), beyond the identified BSR-zones [12, 13–15, 17] shows that the actual reserves of gas hydrates and free gas may exceed the previously total amount calculations. This study area may be including to one of the most promising gas hydrate accumulations in Antarctica.

5. Conclusions

1. New results of the FSPEF-VERS technologies using have confirmed their high efficiency and mobility for different geological-geophysical problems decision such as the Earth's crust deep structure study and the hydrocarbon accumulation prospecting.

2. The geoelectric models of Drake Passage structures have given the new evidences of possible basification processes with mantle substance uplifting and displacement. The short-lived local rifting has a real value in forming and evolution processes of Drake Passage and Scotia Sea crustal structures.

3. Four "hydrocarbon deposit" type anomalies were detected on Antarctic margin in the region of UAS "Academic Vernadsky" due to the RS-data processing and interpretation using. Some anomalous parameters of polarized layers were chosen by VERS sounding within these anomalies. These data confirm the assumption about the possible existence of the new oil and gas area in this part of the Antarctic continental margin.

4. New data from direct and indirect geophysical measurements may help to increase our understanding on the occurance and distribution of gas hydrate accumulations beneath the ocean bottom on the South Shetland margin.

5. The presence of a number of satellite RS-anomalous zones beyond the seismic BSR-zones shows that an actual gas hydrates and free gas accumulations on the SSCM are much higher than previously calculated. These data allow including the study area to one of the most promising areas of gas hydrate accumulations of the continental margin of Antarctica.

6. Practical experiments in the Antarctic region testify that integration of RS-data processing and FSPEF-VERS data may be used for the hydrocarbon accumulation prospecting in the remote regions of Antarctic and Arctic areas.

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