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ВИВЧЕННЯ КАРТУВАЛЬНИХ ОЗНАК ПЕРЕДУМОВ ФОРМУВАННЯ РОДОВИЩ ВУГЛЕВОДНІВ НА КОНТИНЕНТАЛЬНОМУ СХИЛІ ЗАХІДНОЧОРНОМОРСЬКОЇ ЗАПАДИНИ

STUDY OF MAPPING FEATURES OF PRECONDITIONS FOR FORMATION OF HYDROCARBON DEPOSITS ON THE CONTINENTAL SLOPE OF THE WESTERN BLACK SEA BASIN

(Матеріал друкується мовою оригіналу)

Наведено результати вперше виконаних на континентальному схилі Західночорноморської западини комплексних структурно-термо-атмогеохімічних досліджень (СТАГД).

Об'єктом досліджень у цій зоні була Британська площа на ділянці виявлених сейсморозвідкою структур – Британська-1 та Британська-2. Окреме завдання полягало в проведенні аналогічних досліджень (11 станцій) на ділянках активного прояву "газових факелів" (площа Схилова) на континентальному схилі.

За геоструктурним аналізом, палеогеоморфологічними та гідролого-гідрогеологічними особливостями, структурно-неотектонічним дешифруванням космознімків, атмогеохімічною зйомкою придонного шару води (за радоном, торієм, гелієм, вуглекислим газом, воднем і вільними вуглеводнями), термічними та атмогеохімічними дослідженнями донних відкладів виокремлено перспективні ділянки нафтогазоносності.

Охарактеризовано морфоструктурні, тектонічні, стратиграфічні особливості структури континентального схилу. З'ясовано, що в цьому регіоні поширені потенційно нафтогазоносні відклади, які генетично подібні до продуктивних мезокайнозойських стратонів північно-західного шельфу та інших регіонів Кримсько-Кавказької області.

Підтверджено, що з'ясування закономірностей просторового розподілу термометричних та атмогеохімічних аномалій придонної води континентального схилу Чорного моря є важливою критеріальною ознакою нафтогазоносності та флюїдопроникності.

Отримані результати засвідчують доцільність застосування СТАГД для локального прогнозування перспективних об'єктів на початкових стадіях пошукових робіт, раціонального розміщення свердловин під час пошуку, розвідки та видобування вуглеводнів.

Ключові слова: Чорне море, континентальний схил, Західночорноморська западина, тектоніка, стратиграфія, літологія, донні відклади, атмогеохімія, термометрія, нафтогазоносність.

The integral thermo-atmogeochimical structural investigations (TAGSI) have been carried out at the continental slope of the Western Black Sea Depression for the first time. The technique of TAGSI as non-traditional and cost-effective exploration technology is originally developed at Institute of Geological Sciences. It consists of phased geo-structural researches and analysis of fault tectonics, morphological analysis and neotectonic interpretation of space images, thermal and atmo-geochemical surveying, lab measurements and processing of the data acquired to build thematic map using GIS technologies. Field data acquisition stage includes thermometric, emanation and gas surveying (Rn/Tn, He, CO₂, H₂, free hydrocarbons) in petroleum-prone onshore areas and bottom sediments (up to 2 m below the surface) thermometry, Rn-metering and measurements of gas content in the near-bottom layer offshore.

To conduct the surveying there was developed a special instrument with some modifications designed to work onshore and offshore respectively. This technology is tested in different regions of Ukraine over known oil and gas fields.

The results of TAGSI are considered in the paper. The geostructural analysis, interpretation of space images, atmogeochimical survey of the near-bottom water layer (radon, helium, carbon dioxide, hydrogen, free hydrocarbons), thermic and lithogeochimical examination of bottom sediments enable to outline the petroleum-promising areas. Morphological, structural, tectonic, stratigraphic features of the continental slope's structure are characterized. It has been found that potential petroleum-bearing structures occur in the region, which are genetically similar to the productive Mesozoic and Cenozoic strata of the northwestern shelf and other areas of the Crimean – Caucasian Region. The results of the carried out studies show that it is purposeful to use TAGSI for local forecast of promising targets at the early search stages, for rational location of drillholes, prospecting and recovery of hydrocarbons.

Keywords: Black Sea, continental slope, Western Black Sea basin, tectonics, stratigraphy, lithology, bottom sediments, atmospheric chemistry, thermometry, oil and gas.

Significant hydrocarbon resources are associated to the continental slope and deep-water depression of the Black Sea. Experts evaluate them as over 346 mln t in oil equivalent. Such high promises are quite natural, accounting that over 93 % of all recovered reserves of oil, gas, and condensate belong to the continental slopes of Eurasia [8]. So, in the Bengal Bay, Caspian, Mediterranean, Northern, Barents, and other seas, a rich petroleum presence is in the Phanerozoic terrigenous and carbonate sediments, especially in the Cretaceous and Cenozoic formations which lithological and stratigraphic properties are similar to those of the sedimentary complex of the Black Sea.

Today, petroleum prospecting in the Black Sea's aquatories is carried out mainly at the shallow shelf areas. A topical problem is an evaluation of the local structures at the continental slope and deep part of the Western Black Sea Depression that demands new methodological and methodical approaches.

The study of the continental slope is rather specific that is caused first of all by the depth (down to 2,000 m) and absence of a regional model of geological structure. It is related to the problem of interpretation of available seismic data and absence of drillholes in the deep-water part. It significantly complicates an analysis of structural features and fault-block tectonics for a determination of the most probable discharge network for fluid-gas flows.

In this connection, it was decided to determine possibilities for applying the newly developed methods of integral thermo-atmogeochimical structural investigations (TAGSI) for a forecast of hydrocarbon-promising areas and structures at the deep-water part of the Western Black Sea Depression (fig. 1).

The British Area (at the seismically proven structures British-1 and British-2) was our study target in this zone. An individual task was to carry out analogous investigations (11 stations) on locations with active "gas torch" signs [17] (Slope Area) at the continental slope.

Applying the TAGSI technique, for the first time mapping works were made that shown the necessity of detailed geological

study of this region for hydrocarbons (HCs). The TAGSI technique was created in the Institute of Geological Sciences, NAS of Ukraine, as a development of ideas on non-traditional near-surface methods for recognition of fluid concentrations [2–6, et al.]. It was used at search for HCs both at the land and sea.

This technique supposes stage-by-stage structural, thermometric and atmogeochimical investigations following the scheme: 1) geostructural study and analysis of fault-block (disjunctive) tectonics to determine the most probable ways for discharging fluid-gas flows; 2) structural-neotectonic interpretation of space images for localization of active neotectonic dislocations – recent zones of potential higher permeability; 3) thermometric and atmogeochimical survey; 4) lab chromatographic examination of collected samples; 5) processing of obtained data and creation of cartographic schemes.

The integrated field works include thermometry of subground layer, emanation survey (radon/thoron); sampling of subground air for determination of contents of helium, carbon dioxide, hydrogen, free HCs; thermometry of the subground layer, near-bottom water layer and bottom sediments, radon measurements, determination of the gas constituent content in the near-bottom water layer (radon, helium, hydrogen, carbon dioxide, free HCs). The TAGSI technique has been tested at the known Ukrainian oil and gas fields (both land and marine) and used to evaluate productivity of over 50 promising areas in the Dnieper-Donets Depression, Fore-Carpathian Trough, Volyn-Podillia. In the Ukrainian aquatories, we used this technique in the Azov Sea, at the northwestern and near-Kerch shelves of the Black Sea [2, 4]. To evaluate "standard" thermal and atmogeochimical parameters of productive structures and blocks, we investigate marine fields Morske-1, Eastern Kazantip, Odessa, Bezimenne etc. The results of these investigations enable to reveal such the characteristic features of HC accumulations:

1) accumulations are related to geodynamically inactive microblocks of poor fluid permeability, which are suitable for occurrence of HC traps. In the near-surface atmogeochimical fields they manifest as areas of predominantly background concentrations of radon, carbon dioxide, hydrogen, helium surrounded by their local maximums;

2) over the productive blocks, weakly intensive (diffusive) aureoles of methane and ethane occur framed on their periphery by local maximums and anomalies of heavier HCs of the methane group;

3) higher temperature parameters of bottom sediments and near-bottom water layer over HC accumulations.

The obtained standard features were used to evaluate HC promises of a number of problematic areas, which productivity till now is not proven with drilling (Western Biriutcha, Meotian, Subotina etc) [3, 4].

Increasing operation depths demand to improve methods and technology of samples. For this purpose, series of samplers-degasers was been designed and produced. Those enabled to integrate temporally measurements of temperature and radon concentrations in the near-bottom water layer and bottom sediments, analysis of gas components and lithological samples (fig. 2).

Analyzing preconditions of the petroleum presence, data on the geomorphic, geological, structural-tectonic features of the region are involved.

One of the ways of TAGSI applying is studies of the mud volcanism and gas hydrates, that correspond to the fault zone, which forms the continental slope of the Western and Eastern Black Sea Depressions, as well as to deep faults, positive structures, deep discharge of fresh waters, paleodeltas etc.

Fig. 1. Location of TAGSI sites at the continental slope of the Western Black Sea Depression

I – continental slope canyons of various ranks [11]; 2 – points of atmogeochimical and thermometric investigations; 3 – temporal section line; 4 – fields of intensive gas emanations; 5 – petroleum-promising structures; 6 – isobaths. Areas of investigations: I – Slope, II – British

Fig. 2. Equipment for thermo-atmogeochemical investigations in aquatories

The gas hydrate zones in the deep-water depression related to abyssal fluids from the bowels and located above positive structures at various structural levels of the Mesozoic-Cenozoic sedimentary formations and older sequences. In the Black Sea, the Sorokina Depression and deep-water hollows of the Western and Eastern Black Sea Depression are considered as the most promised on gas hydrates. A certain zonation is observed in gas shows in the Black Sea: on the periphery, in the joint zone of the shelf and continental slope, gas torches occur, and in the central (deep-water) part gases are constituents of gas hydrates.

As for today, enough data are available to confirm the relations between gas emanations and gas accumulations in the Earth's crust. Direct correlation exists between the number of gas shows and reserves of individual petroleum-bearing provinces. So, over 70 % of oil and gas fields of the Southern Caspian Sea (giants are amongst them) are accompanied by numerous gas shows. Both the Black Sea and Southern Caspian Basin have similar schemes of the geological history and tectonic events that resulted in the formation of depression with avalanche sedimentation of terrigenous matter. It also is a criterion of hydrocarbon promises. At the continental slope of the Western Black Sea Depression, numerous mud volcanoes occur, which are associated with the Maikopian clays. In fact, all known gas torches at the shelf and in the Western Black Sea depression are related to the weaken zones (faults, in part), and methane is of mainly abyssal origin. Faults of various ranks are transportation channels for it [18]. Therefore, these evidences are somewhat corresponding to the notion that the continental slope with its thick sedimentary cover is a large promising petroleum-bearing region.

It should be noted that recovery of gas hydrates as well as prospecting and development of hydrocarbon accumulations at the continental slope and deep-water depression is a problem of the future especially due to the absence of adequate drilling equipment for large depths. But just now the petroleum potential should be clarified through mapping of oil-gas and gas hydrate targets and evaluation of their promises using both geophysical and low-cost methods. TAGSI should be at the top of them.

Another way is applying TAGSI to obtain recommendations about search of fluid-permeable zones at the continental slope and in deep-water depressions. For this purpose, hydrodynamic types of hydrocarbon fields are mapped that can be linked with channels of pre-rivers and canyons, which in fact cross all continental slope of the eastern and western Black Sea depressions. This forecast methods is not mastered good enough yet but searches of fields in hydrogeological basins along tectonic dislocations, in blocks between them, in river valleys (including pre-rivers), canyons or closely to them in cross points of these morphostructures are very prospective accounting that a large part of fields (e. g., in Western Siberia, Urals Region) belongs just to the hydrodynamic type. In this aspect, the continental slope of the Western Black Sea Depression accounting its complicated structure can be a demonstration range for the development of various techniques with the aim to find the criteria for HCs forecast.

The recent continental slope where TAGSI was carried out was formed by global, horizontal and vertical tectonic movements. Significant

inclinations are characteristic of its, and they increase eastward. The inclination angles increase in parallel to the reducing thickness and completeness of the Mesozoic-Cenozoic sedimentary sections at the part of northwestern Black Sea shelf adjacent to the slope.

The continental slope of the Black Sea is the transitional zone between the shelf and abyssal depression. It is a surface between the brow and slope base at the margin of its joint with flattened surface of the hollow bed (fig. 1).

The boundary of the slope base in most clearly observed in the relief at the depths of 1,500–1,700 m, and at the depths of 2,000–2,100 it gradually passes into deep-water hollow. It should be noted that deep-water hollows in the western part are traced at the depths of 1,300–1,700 m, and in western part they occur at the depths of 2,000–2,100 m. The continental slope in its general shape is similar to the outline of the Western Black Sea Depression.

Large erosional cuttings-in are typical for the continental slope [9, 11]. They dissect the whole slope surface from the upper brow to the base. Canyons have V-like shape, their width vary between 150–2,500 m, and depth is 400–500 (sometimes 1,000) m. The flanks are symmetrical that is caused by lateral erosion. Intensity of lateral erosion varies depending on inclinations and geological structure. The longitudinal profiles of the canyons clearly show their step nature that reflects geological events in the region in corresponding geological epochs.

The morphostructural plan of the continental slope is significantly governed by the regional fault zones, which are caused by tectonic processes. The canyons of paleo-Danube, paleo-Dniester, paleo-Dnieper, paleo-Kalantchak correspond to these faults. The erosional and denudational activity of the canyons resulted in the appearance of large submarine erosional amphitheatres near the brow of the continental slope. The eroded complexes of sediments form large in thickness and volume sites. They are marginal abyssal fans forming the transitional zone from the continental slope to the deep-water hollows. They create peculiar ramparts, hillocks, submarine ridges, and imposed fans that were formed by suspension flows. The fan thickness is several kilometers. The Danubian fan is the most distinctive morphostructure in the northwestern part of

the Black Sea. It is a large accumulative body. The principal morphological elements are slip terraces in the lower part of the slope and submarine canyons formed by suspension flows. The surfaces of slopes and flanks of the canyons are modeled by submarine (drainage and plane) and suspension currents. The fan developed in the Mesozoic-Cenozoic and even in the Quaternary time in some stages in the process of direct advance of the Danube's foredelta and submarine erosion of the continental slope brow bench. Large slides significantly influenced the dynamics of suspension flow. Large areas of low-hillock relief and cone-like sopkas (nipple-like hills) were found. In the base of the continental slope, carbonate formations were recognized that are probably related to the methane smokers. Characteristic forms of the relief are appropriated to zones of active gas emanation and mud volcanism shows [17].

A comparative analysis of the complicated recent morphology and pre-Quaternary one shows that the neotectonic movements are inherited, and disjunctive structure of the shelf, continental slope and abyssal depression were crucial in the distribution of thicknesses and facies both in the Quaternary sediments and in the whole sedimentary cover of the depression (fig. 3).

By CDP (common deep point) seismic data, "a paleocontinental slope" is mapped at the recent continental slope. It manifests on the seismic sections as a wide (12–13 km) zone of subparallel tectonic dislocations. Along them, the pre-Cretaceous discordance surface dips step-by-step southward from 2,000–4,000 m to 6,500–7,500 m with average inclination 20–35°. At the south, the zone is bounded by large-amplitude Northern Euxinian Flank Chop of the Cretaceous-Cenozoic age that has "listric kinematics" with displacement surface flattening towards the Western Black Sea Rift [10].

Using CDP seismic data, a chain of structures was mapped in the band of the paleocontinental slope (Omar, Barova, Lagoon, Pluto, Sand etc.) as well as studied by us structures British-1 and British-2. This wide (8–20 km) zone of local structures is referred as the Lomonosov Ridge, or submarine massif.

It reflects in a complicated pattern of seismic record that is interpreted ambiguously. The dragged there samples of bottom sediments are various by age and lithology rocks including magmatites from acid to ultrabasic composition that is typical for near-suture melange. From these features, the Lomonosov Ridge is interpreted as a suture tectonic zone (may be, the eastern prolongation of the

Petcheniaga-Kamena Suture) – a fragment of the active Mesian paleocontinental margin in the allochthon. For the upper parts of sections in the near-flank zone, gravitational-tectonic dislocations are typical, with development of olistostromes, tectonic sheets and scales. Proceeding from the notion about suture nature of the continental slope in the abyssal Western Black Sea Depression, one can conclude that this region has high prospects.

Accordingly to seismic-stratigraphic model of region, over the Paleozoic fundament the rift Triassic and Cretaceous sediments occur that is covered by the Cenozoic sequence. The principal petroleum-bearing sedimentary formations of the Western Black Sea Depression and adjacent shelf are represented by the Paleocene-Eocene (up to 3 km thick), Oligocene-Miocene (3–5 km), Pliocene (up to 1,2 km), and Quaternary (1–3 km) sediments. Respectively, they are three sedimentation megacomplexes: Paleogene, Miocene, and Pliocene-Quaternary. They have a rather complicated structure, and during their existence they passed through numerous reformations of tectonic plans, inheritance of imposed structures and inversion movements. Heteromorphic formational complexes of various ranks are discriminated that have a clear cyclic structure and form lateral series standard for marine basins – shelf, continental slope and abyssal. The following sedimentation complexes are recognized: terrigenous (turbidites, stratified flysch-like sequences with asymmetric rhythms); carbonate (organogenic-detrital limestone sequence); flint (flint-siderite-limy-clayey sequence) that are appropriated to all sedimentary complexes. An analysis of stratigraphic structure shows that at the northern continental slope of the Western Black Sea Depression the thicknesses and completeness of the Cenozoic sediments decrease, especially there where inclination of the slopes increase. In its western part, where the slope is composed by the thick sequence of the Anthropogene Danubian delta, beneath the latter, all Paleogene and Neogene strata occur though of small thickness. Narrow zones of washed out Miocene Maikopian and Paleocene-Eocene sediments occur at the bends of the slope. The Pliocene-Quaternary sediments cover brows of the old slope almost without changing thickness. The main feature of this model is a presence of overthrusts, which formed in some stages since the Oligocene. The pre-Meotian time was the most active – Otian orogenesis phase at the Late Sarmatian – Meotian boundary (9 Ma) that was clearly identified at the Caucasus and also manifested in

Fig. 3. Temporal section of the northwestern shelf of the Black Sea [12]

the Caspian region trough significantly increased volcanic activity. Accounting the complicated patterns of seismic records, reflecting horizons can be traced only over short distances; they are not dynamically steady and of different vectors. That is why various variants of seismic stratification are possible for reflecting horizons in this region.

As the seismostratigraphic analysis shows, the sedimentary sequence of the continental slope consists of a number of seismic complexes, which join various formations of different age that decreases the resolving power of this method at evaluating promises. An efficient forecast of petroleum presence demands a detailed geological-stratigraphic model. We developed a detailed stratigraphic model for the northwestern shelf that together with comparative analysis of geological data (paleontological, stratigraphic, paleoecological etc.) obtained in special trips enabled to conclude that the same strata were recognized at the continental slope and shelf, in part in the Paleogene – Neogene (fig. 3). The Paleocene, Eocene, Oligocene, Miocene formations have flyschoid features similar to those in the shelf drillholes and productive Paleogene-Neogene sections of the Kerch-Taman region, Caucasus, Carpathians.

Paleontological, paleoecological, lithogenetic interpretation of the bed rocks shows that just in the dawn of the Paleogene the northern part of the Black Sea Depression was characterized by increased depth of sedimentation that went in the geosyncline conditions. With certain level of reliability, it is possible to consider about existence of the continental slope since the Paleocene as well as in the Oligocene and Neogene-Quaternary time. The so long history of the continental slope is proved also by seismic stratigraphic data. In the joint zone of the Crimean Megaanticlinorium and Black Sea Depression, thicknesses smoothly decrease to the slope; one observes the gradual uplift of all layers in the same direction (more for older layers), their gradual pinching out, shifts of erosion zones (absence of sediments from older to younger upward the slope). The inherited nature of cyclic marine sedimentogenesis is traced through the Cenozoic.

The Pliocene-Quaternary stage, especially recent sedimentation, has factors of the sedimentational environment and types of formational complexes similar to those of the Paleogene and Neogene. In the facial structure of the Black Sea Horizon (Holocene), we observe recent analogs of those systems, which have signs of the past, e. g. potentially oil and gas source formations (sapropelic, carbonate-terrigenous complexes). Recent sedimentogenesis at the continental slope of the Black Sea is an active analog of the Paleogene facial systems, in part, the Oligocene domanik-like complex that is able to be a model for reconstruction of sedimentogenesis during the Mesozoic and Cenozoic.

The principal role in the formation of local structures, migration and distribution of HCs belongs to the tectonic factor. But, as an analysis of the Mesozoic and Cenozoic section shows, the lithological-stratigraphic factor is also important in clarification of forming conditions for stratiform and paleogeomorphologic traps. All hydrocarbon fields of the northwestern shelf are clearly stratigraphically linked to the corresponding horizons. Hydrocarbon accumulations are accustomed to corresponding strata: Belokamenkian and Katchian – to the Paleocene; Simferopolian and Kumian – to the Eocene; Molotchanian and Kerleutian – to the Oligocene; Bathysiphonian, Sarmatian, Meotian, Kimmerian-Kuyalnikian – to the Miocene and Pleistocene. The reservoir rocks and petroleum accumulations in the Mesozoic and Cenozoic sediments related to siderite-siltstone-sandy terrigenous and limestone complexes that are often created by turbidite flows and form deep-water fans. All these formational complexes are spread at the continental slope and in abyssal depression [9]. It is proved by their identification in the bed rocks.

Therefore, lithological-stratigraphic conditions of oil-and-gas accumulation exist at the continental slope that concern to tectonic, morphostructural factors and are signs of high hydrocarbon promises of the continental slope.

An important criterion of the petroleum presence and fluid permeability that is an important constituent of the TAGSI system complex is the clarification of regularities in the spatial distribution of thermometric and atmogeochemical anomalies of near-bottom water at the Black Sea continental slope.

Studies of the distribution of dissolved hydrocarbon gases (HCG) concentrations in sea waters and accompanying atmogeochemical anomalies is amongst top-priority tasks of petroleum geology [1, 14]. The results of long-year studies in the Caspian, Okhotsk, and Baltic seas demonstrate that near-bottom water layer (1–4 m) is the most informative target of marine search geochemical investigations. In the near-surface portion of bottom sediments, HCG anomalies are less sharp. Already at the first stages of marine investigations, HCG anomalies in the near-bottom water layer and bottom sediments were considered as possible indicators of petroleum genesis spots in the World Ocean [7].

Large investigations on the distribution of HCG were carried out in the Black Sea aquatory [1, 13, 17, et al.]. It enabled to elicit most general regularities in the distribution of gas concentrations and to determine principal criteria of regional forecasts in various sea aquatories about for planning of search and prospecting of HCs. It was recognized that the whole mass of anaerobic water is a giant HCG anomaly. The Black Sea's waters beneath depths of 120–150 m contain anomalous concentrations of methane that are two-three orders of magnitude higher than background ones and gradually increase as the sea deepens. In bottom sediments of the Black Sea, anomalous methane concentrations are caused by gas hydrates and occur at the continental slope. In the end of 1980s, marine and submarine investigations discovered mass jet methane emissions and abyssal mud volcanoes. Despite specifics of the Black Sea as a miomectic-type basin, the distribution of HCG in its bottom sediments is generally analogous to general regularities of the World Ocean [1 and others].

Main difficulties in gas-geochemical investigations of HCG distribution in deep-water zones are caused by that fact that local anomalies are hardly outlined there due to high methane saturation of the near-bottom waters. Recognition of local anomalies at continental slopes is complicated by common for the whole Black Sea Basin “marginal effect” of mass gas emanations – their relations to the peripheries of depressions in the Black Sea along the base and brow in the shape of numerous jets and mud volcanoes. The use of bottom sediments for geological and geochemical studies is also problematic because methane-saturated gas hydrates occur in them in significant amounts.

These difficulties are complemented by similar compositions of higher gas flows despite their multifarious manifestation forms. The main component of gas-saturated mixture is methane (up to 80–99 vol. %) that is known to be of different nature. Different notions exist about its genesis in each specific case of anomalous flows because the integrated approach to studies of gas-anomalous natural phenomena is absent, and different understanding of fluid-generating processes exist.

The majority of modern studies of fluid signs has specifically geochemical specialization and is aimed to chemistry of gas outflows in the Black Sea [17]. These parameters of discharge targets of fluid flows are complemented by gas-biochemical signs [1]. In part, a high biological activity of the marine environment is found over submarine mud volcanoes that is an additional criterion for their mapping.

The studied by us British area has the structural position rather different from the areas of antecedent works. It is situated at the northern flank of the Western Black Sea Deep-Water Depression [10]. In the recent structural plan, this part of the Black Sea's bottom corresponds to the continental slope zone at the depths of 860–1,210 m that is complicated by a system of subparallel V-like canyons, 150–2,500 m width, 400–500 m (sometimes 1,000 m) in depth.

Structures British-1 and British-2 were found with CDP seismics. On a structural map on reflecting horizon IV (base of the Lower Cretaceous) they are outlined as spatially close subparallel anticlines of NE-E strike (dimensions 11x1,5 i 4x1,2 km respectively). Two domes complicate the larger British-1 structure. These anticlines are divided and bounded on the north and south by disjunctive dislocations of accorded strikes. The structures structure British-1 and British-2 in cross sections corresponds to individual benches of the continental slope complicating it and forming its characteristic reversal-step structure that is caused by listric dynamics of block movements.

Using TAGSI technique, we made integrated works at the British area including geostructural analysis, interpretation of space images, atmogeochemical survey of the near-bottom water layer (radon, helium, carbon dioxide, hydrogen, and free HCs), thermometric and lithogeochemical examination of bottom sediments. Both British structures were crossed by three submeridional profiles through their apical parts (fig. 1). Distances between profiles were 7–8 km, between stations 1–1,5 km. The profiles and observation stations were preciously located using personal GPS personal navigator. In some points lithological sampling of bottom sediments was carried out.

The results of our works at the British areas enable to affirm (fig. 4):

1. The temperature field is described by small drops in the range of 9,2–8,65 °C. All in all, temperature parameters of the near-bottom layer decrease as the sea bottom dips. This regularity is disturbed at the distances of the profiles that cross the apical parts of the structures British-1 and British-2. In these parts, the decline of temperature parameters discontinues and they settle at 9,0–9,1 °C with increasing up to 9,2 °C in the most dip parts of the sea.

2. Radon is determined at all observation stations. Its minimum content in the near-bottom water layer is 0,11, maximum 2,31, background 1,16 Bq/l. The main peculiarity in the radon spatial distribution is sharp variability of its concentrations from one station to another that is typical for areas of small-block tectonics and caused by fault zones of deep discharge of subsurface waters. Generally, the radon content increases as the sea bottom dips. Stations with minimum radon content in water samples gravitate to the southern flank of the British-1 structure that is disturbed by concordantly striking tectonic dislocation and coincide with anomalous temperature peaks. The good correlation exists between radon anomalies and points of anomalous hydrogen concentrations that also proves higher abyssal permeability of seismically recognized tectonic dislocations.

3. On gas survey evidences, the near-bottom water layer (excluding rare samples) is distinguished by high hydrocarbon saturation of gases. The main component of dissolved gases is methane that overall has abnormally high concentrations in the margins of $10\text{--}200 \cdot 10^{-2}$ vol. %. The background values reach $153,1 \cdot 10^{-2}$ vol. % and four orders of magnitude exceed background and maximum ones at the known shelf fields, in particular, at the largest Odessa field. Good correlation exists between carbon dioxide and methane distribution. Anomalous values of carbon dioxide have been found in 11 points. The background value is 7,06 vol. %, maximum reaches 12,5 vol. %.

Besides methane, anomalies of its homologues and ethylene occur in the near-bottom water samples in far lower concentrations.

Fig. 4. Location of promising areas on TAGSI data

Structural elements on seismic evidences: 1 – disjunctive dislocations, 2 – isohypses of IV reflecting horizon (base of the Lower Cretaceous); structural elements on space images interpretation data: lineaments – 3 – regional, 4 – local; annular structures – 5 – regional, 6 – local; 7 – TAGSI points, 8 – TAGSI profiles and their number; 9 – promising areas for further search and evaluation on TAGSI data. Cx – Slope area. Local structure: Bp-1 – British-1, Bp-2 – British-2

Ethane prevails amongst methane homologues. This gas has been found in eight points; the background value is $396 \cdot 10^{-6}$ vol. %, maximum – up to $1,110 \cdot 10^{-6}$ vol. %. The background and maximum ethane concentrations that were found in the samples of the near-bottom water layer from the British area is order of magnitude higher than those of the Odessa field. Another recognized methane homologues are: propane (four points, background $0,35 \cdot 10^{-6}$ vol. %, maximum $44,6 \cdot 10^{-6}$ vol. %) and isobutane (two points, background $0,22 \cdot 10^{-6}$ vol. %, maximum $5,04 \cdot 10^{-6}$ vol. %). Concentrations of these methane homologues at the British area conform to those of the Odessa field. Our studies and results of numerous other investigations prove that that the presence of methane homologues in the samples from near-bottom water layer (butane especially) indicate a probable migration of HCs from abyssal sources – potential accumulations of oil and gas. Besides HCs of the methane series, ethylene (background $0,33 \cdot 10^{-6}$ vol. %, maximum $54,9 \cdot 10^{-6}$ vol. %) and propylene (back-

ground $4,83 \cdot 10^{-6}$ vol. %, maximum $35 \cdot 10^{-6}$ vol. %) have been measured in four points in the near-bottom water layer. Their concentrations are almost order of magnitude lower than those at the Odessa field. Their presence, as Russian scientists suppose, evidences biodegradation of oil.

Spatially, all revealed anomalies of methane and ethylene homologues coincide with western boundary parts of the British-1 and British-2 structures. The results of our previous marine investigations in shelf zones show that anomalies of heavy HCs of the methane series and olefines are located, as a rule, around contours of known fields.

Therefore, the distribution regularity of gas constituent and temperature fields that we have revealed, the presence of these HCs in dissolved gases of the near-bottom water layer and bottom sediments can indicate the presence of their accumulations in the continental slope sediments. Accordingly the empiric experience, evaluated by us concentrations of isobutane and n-butane, in particular, predominating of the former over the latter, it is possible to suppose the prevailing gas genesis of potential accumulations of HCs.

Studies with TAGSI technique with more dense net of stations will enable to outline promising areas of hydrocarbon genesis and accumulation.

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