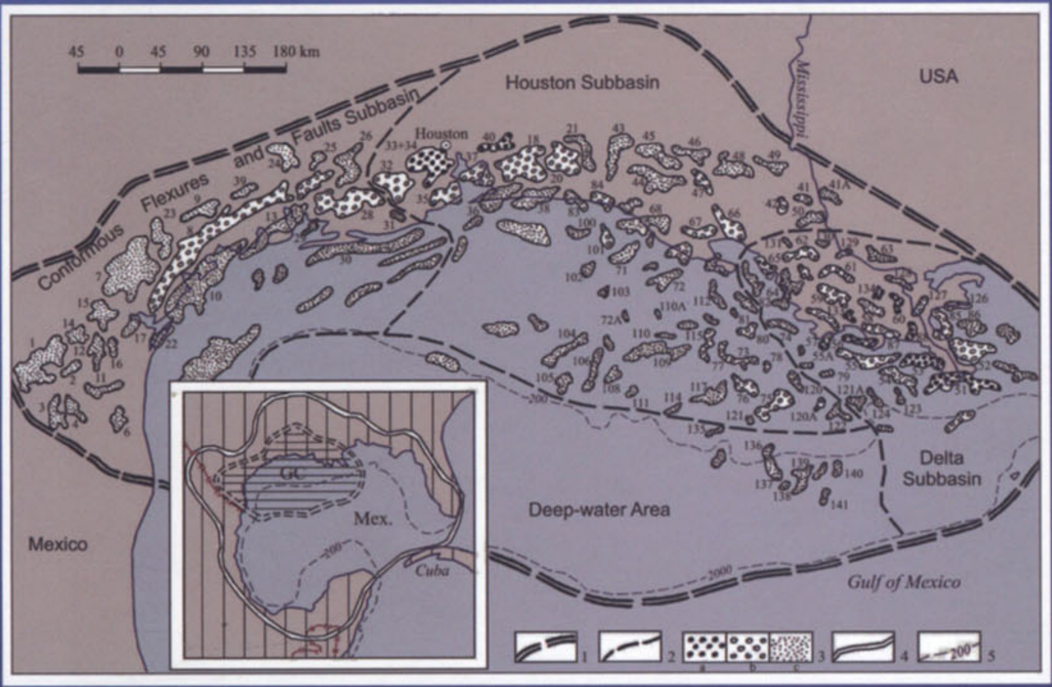
Petroleum Accumulation Zones on Continental Margins



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Abbreviations and Symbols

AHFP	Abnormal formation pressure
BCM	Billion of cubic meters
BT	Billion of tons
MCMD	Thousand cubic meters per day
MCM, MMCM	Thousand cubic meters, million cubic meters
TCM	Trillion of cubic meters
MMY	Million years
MT, MMT	Thousand tons; million tons
P_{sat}	Saturation pressure
P_{res}	Formation pressure
P_{sat}/P_{res}	Baric saturation coefficient
$\delta^{13}C$	Oil carbon isotope composition, ‰
$\delta^{13}C_1$	Gas methane carbon isotope composition, ‰
iC_6/nC_6	*i*-butane/*n*-butane ratio in gas
R°	Vitrinite reflectance

Contents

Dedicated To

Dr. Henry Chuang,
Chairman of Willie International
Holdings Limited (Hong Kong, China)
for his commitment to the education
and advancement
of the Petroleum Industry

and

Dr. Chengyu Fu
for his important contributions
to the World Petroleum Industry
and World Economy

INTRODUCTION

At high degree of scrutiny of the basic oil- and gas-bearing provinces of Russia, of particular importance is the development of the continental shelf where more than a third of undeveloped hydrocarbon resources are located.

Any further development of subaquatic oil and gas resources is impossible without the involvement of the new scientific techniques.

Initial discoveries and evaluation of the oil- and gas-accumulation zones in the World Ocean have already begun. Highly important at this stage are the development of scientific grounds for the zonal forecast in the offshore areas and the creation of a representative databank.

That is exactly what this book is all about. Its main subject, an oil- and gas-accumulation zones, requires some introductory notes.

The appearance of a spatially variable zonal HC-sphere structure in the course of the depositional basin evolution is unavoidable as the formation of hydrocarbons. Gubkin (1953) presented two major elements within the oil and gas basins, oil-collecting areas and oil-gas-accumulation zones. As the major petrogeological element, oil-gas-accumulation zones were discussed by I. O. Brod and Eremenko (1953), Khain (1954), Bakirov (1959), Uspenskaya (1972), Zolotov, Lebedev and Samsonov (1987), Perrodon (1991), Nesterov (1992) and many others. This concept took root, in particular, in the form of play analysis as a means for a detailed evaluation of the oil and gas potential on land and offshore. We consider the zonal oil and gas accumulation as an imminent property of oil and gas basins and the best example of the self-organization in these systems.

Zones are an element of the non-uniform spatial macro-structure, which have arisen from a carboniferous matter that was previously uniformly distributed in the source rocks before catagenesis, emigration and hydrocarbon accumulation within traps. It makes it logical to define and identify the zones through the result of these processes as intrinsic natural groupings of the genetically and spatially associated fields. The zones are bounded by the areas where the fields are not present or are located at a significant distance away. Such a conceptual under-standing and identification of the zones is the only way that provides for applying the parameters and patterns of the formation and distribution of such objects in petroleum geology.

Oil and gas basins are open evolutionary geologic systems. As such, they are characterized by asymmetry in the mass distribution of phase-detached hydrocarbon matter. That asymmetry is implemented through drastically non-uniformly distributed Hydrocarbon resource size and concentration within zonal accumulations range substantially. It especially illustrates probabilistic, stochastic nature of the oil and gas accumulation processes. These processes are non-linear. It is clearly manifested in the spatial distribution of oil- and gas-accumulation zones near the most stable oil-gas zones within the oil-gas basins, which frequently assumes a dissipative nature. At the same time, concentration of the richest zones near the most stable oil-gas-generation nodes (within traps of the first-second echelon) is an example of self-organizing system. Another evidence of the self-organizing nature of basin petroleum systems is a phase separation of the hydrocarbons in the basinal subsurface clearly detected on the zonal level. It is a result of a complex nonlinear nature of the time-stretched hydrocarbon migration, formation, reformation and preservation.

As a result, even at small volume accumulating in macro-accumulations of hydrocarbons (2–3 %, rarely 4–7 %, according to A.E. Kontorovich) non-uniform structure of their distribution and zones of concentration of oil and gas are an integral part of the naphtide basins. Through their resource parameters, pictures of the spatial distribution and phase separation of the hydrocarbons, the HC zonal groupings characterize complex, nonlinear processes of the oil- and gas-basin formation as self-evolving petroleum systems. Therefore, the oil- and gas-accumulation zone is a sovereign, genetically caused link of the hierarchical chain, province – basin – oil-gas-area – zone – field. This link is closely associated with the rank of preceding and succeeding oil-gas-accumulation objects.

The book is structured in line with the aforementioned positions. Oil-gas-accumulation zones are deemed to be a relatively independent category of the petroleum-geologic objects together with the provinces and areas. Their properties encompass the structure, spatial grouping, size, size distribution within the oil-gas-basin, resources, and possibly even the hydrocarbon phase state. These properties are controlled not only by the local but also regional factors, up to the evolutionary nature of the continental margins. Their characteristics and the analysis are established according to the data on country basins and provinces on various types of continental margins and accompanied by data on the major oil and gas fields in the allocated zones of oil-gas-accumulation.

The following issues are elucidated in the six chapters of the book: the status of the zonal forecast problem and its place in the conduct of exploration on the continental shelf; conditions of oil and gas occurrence and resources of the marine oil and gas basins over the passive and active continental margins, and their oil and gas-accumulation zones. Special sections are devoted to the formation, distribution, and phase separation patterns of the oil- and gas-accumulation zones and to the field size estimation criteria within them.

The book sheds light on the issues of the detailed zonal forecast for the potential of the continental margins, and first of all their submerged areas. For the best studied areas of the Russia's continental shelf, meeting the zonal forecast standards, the objects of prime development (accounting for the value of expected discoveries, separately for oil and gas) are separated and proved for the first time.

CHAPTER 1

METHODOLOGICAL SUPPORT OF THE ZONAL FORECASTING

Chapter 1 deals in-brief with some issues of the methodological support for the zonal forecasting. These issues include its status as applied to the shelf environment and certain methodological solutions used in the identification and study of proved oil- and gas-accumulation zones in mature oil and gas basins.

1.1. Zonal oil and gas potential forecast in an offshore environment

Numerous publications based on many years of the industry experience in detailed forecasting of hydrocarbon accumulations onland show that the zonal forecasting leaves a lot to be desired.

The issue is even more acute offshore. Most of the oil- and gas-accumulation zones there belong to transitional regions between the continents and oceans with their appropriate geologic signatures, particular evolution rhythm and patterns of oil and gas occurrence (Gramberg, 1998; Popovich and Kravchenko, 1995; and Khain, 1985).

Petroleum geology-associated uniqueness of most aquatory areas dictates the need in ever more substantiated methodology of regional forecasting. At the same time it turns out that some base positions and very important elements of earlier proposed techniques are ambiguous and difficult to apply under rigid conditions of detailed petroleum potential forecast over the aquatory areas. Thus, it appears reasonable to review three methodological aspects of the zonal forecasting. They include a definition and major principles in the identification of oil- and gas-accumulation zones; component analysis in the zonal forecasting; and possible ways to estimate the phase state of hydrocarbons in the subsurface.

Table 1 includes some existing definitions of the oil- and gas-accumulation zones. A smaller portion of these definitions (by Khain, Bakirov, Uspenskaya) are structured around the major, naphtide feature of the zones, i. e., hydrocarbon fields, rather than based on geologic elements and factors enclosing these fields and supposedly controlling their formation. Most definitions use other indications as definitive. Under those definitions, oil- and gas-accumulation zones, despite their belonging to the realm of petroleum geology objects, are without merit identified not in connection with their oil and gas occurrences, but rather based on diverse characteristics that are difficult, sometimes impossible, to associate with these oil and gas occurrences. They may include structural, lithologic, hydrogeologic features, etc. This approach causes natural errors in the identification of zonal targets and makes it more difficult to conduct comparative analysis of the zones and come up with the universal positions of a detailed forecast.

Main requirements to the content of the concept and identification criteria of the oil- and gas-accumulation zones have been published (Trofimuk et al., 1982). They assume the uniqueness in the zone identification, specificity of the used reference parameters, and the composition of the component elements.

These requirements are satisfied in the definition we propose here: an oil- and gas-accumulation zone is a natural elementary agglomeration of the associated and size- different fields. This agglomeration is bounded by the areas of their absence or significant distance from one another with a decrease toward the zone boundary of the resource density and the vertical range of occurrence.

Table 1

Some definitions of the oil- and gas-accumulation zones

Definition of oil- and gas-accumulation zone	Author	Year
Major structural elements that groups of oil and gas accumulations (composing fields) are regularly associated with. The grouping of traps within an oil- and gas-accumulation zone may be caused by anticlines affecting a large oil and gas-bearing element, by pinch-outs or stratigraphic unconformity over the oil-gas-bearing sequences.	I.O. Brod N. A. Eremenko	1953
Groups of fields associated through the commonality of oil-gas-bearing formations and similarity in mode of occurrence as well as through their connection with large structural or exostructural units.	V. E. Khain	1954
Association (conglomeration) of adjacent and geologically similar oil and gas deposits connected with certain and in general unified group of genetically associated traps.	A. A. Bakirov	1959, 1985
Certain large geologic structure of regional significance (swells, anticlines, etc.) with which are associated, also regionally, oil and gas fields connected with similar local structures or zones of regional stratigraphic unconformity and lithofacies changes.	M. F. Mirchink	1963

Table 1 (continued)

Definition of oil- and gas-accumulation zone	Author	Year
Group of similar oil and gas fields regularly associated with certain structural, paleotectonic or paleogeographic element and characterized by common oil and gas-bearing formations and similar conditions of the field formation.	N. Yu. Uspenskaya	1972
Population of adjacent structural forms that include or are capable of including oil and/or gas accumulations and that have common mechanism and timing of formation.	I. V. Vysotsky, K. Beka	1976
Geologic structures of any origin and of mostly second-order of magnitude, segregated within a certain structural plan and controlling the population of similar oil and gas fields and accumulations.	M. F. Mirchink et al.	1976
Segregated part of the sediment cover containing oil and gas accumulations and identified by the following features: similar reservoir rock age and lithology (belonging to the same formations); small number of trap types; similarity in the chemical composition of hydrocarbons.	G. Gess, C. Bois	1976
Part of earth's crust within its structurally segregated element and providing by its genesis and structure the commonality of its contained oil and/or gas fields.	V. B. Olenin	1977
Oil- and gas-accumulation zone or areal is a group of known and potential fields whose formation and distribution within the area and in the section are associated with a regional unit (structural or depositional-denudational) that regularly forms and/or is activated at a certain stage of basin evolution.	E. V. Kucheruk E. R. Alieva	1985
Naphtoid accumulation zone is a zone of adjacent naphtide (oil, condensate, gas, natural bitumens) fields formed as a result of hydrocarbon fluid accumulation from single similarly directed migration flow/flows.	M. K. Kalinko	1985
A system of traps localized within an oil-gas basin (most often in an oil-gas complex) with the common HC accumulation mechanism. They form in the areas of primary and secondary non-uniformities of the sealed reservoir systems and fluids whose physical state is conducive to the HC accumulation.	A. N. Zolotov B. A. Lebedev V. V. Samsonov	1987

Table 1 (continued)

Definition of oil- and gas-accumulation zone	Author	Year
Part of the sediment cover that is relatively wholesome structurally (a II – order high, a structural nose, an uplifted monocline fault-block) within which the sediment volume may be 600 to 5,000 km^3; its exposure relative to the HC gene-generation zones allows to the implementation of commercial oil and gas occurrences within its constraints. Non-structural oil- and gas-accumulation zones also fit this range of targets.	V. S. Lazarev	1990

This definition covers all requirements providing for the uniqueness in the object identification. First, it contains a measure of commonness and connection which is necessary for the zone identification. Second, it is based on specific parameters. And last, it responds to a requirement of implementability.

The main tool in the zone identification providing for a necessary measure of commonality and connection is zoning by the actual concentration of oil and gas fields as proposed by Nalivkin (1974). Deposits in oil-gas-basins form a natural grouping of contiguous objects or are in an isolated position in relation to each other. Their non-uniform distribution is one of the results of epy major natural phenomena discreteness law shown everywhere. Discrete characteristics are expressed in two values of the remoteness of objects from each other. The first value is the distance between two fields in their natural groupings; it averages 10 km with variations from 5 to 20 km. The second value is the mutual remoteness of groups with a minimum value of 20 km. These indicators define the possibility of the primary allocation of naturally isolated oil-gas-accumulation zones.

In the sections devoted to the oil-gas-basins, the zones are allocated on the basis of belonging to mega-complexes, which are pre-established on the distribution in a case of proved resources and cumulative production of hydrocarbons.

Using the natural features of the real location of fields and their natural environmental groups for zones' allocation radically differs from rather controversial methods, which rely on the geological, geochemical and others usually multiple-valued and usually rather uncertain characteristics.

The subsequent analysis of the initially allocated zones assumes their compulsory and multi-faceted study, primarily, in the case of relations with the hydrocarbon generation zones.

Studies of the formation parameters for the accumulation of the corresponding rank are a mandatory element in the zonal forecasting. These parameters are numerous, and they are very diverse in the way they affect the conditions and parameters of the oil- and gas-accumulation zones. No study of a comparative significance of those parameters has been undertaken to date. Many attempts to determine the leading parameters are incomparable in terms of their results. Nevertheless, it is possible to identify the major factors in the zonal oil and gas accumulation. They encompass, first, those parameters that control the zonal oil and gas accumulation in most basins; second, those controlling zone formation and placement within the specific petroleum-geologic environments of the continental margins; and last, those determining the most important resource-related parameters of the zones and zone differentiation by those properties within the basin boundaries.

The study results of these factors are described in the following chapters.

Let us review in-brief the status of developing geochemical, geologic and thermodynamic criteria for the separate oil and gas forecast. It must be noted that those criteria were considered independently from one another. It is not just a happenstance that the problem of separate oil and gas forecast as applied to the aquatories is actually only at its formulation stage.

At the same time, when conducting qualitative and quantitative evaluation of zones and oil-gas-bearing complexes, the genetic, petrochemical, migrational and thermobaric criteria and parameters developed for the continental basins are often applicable to the aquatories.

An independent task in the process of the separate forecasting is the estimate of gas (or oil) fraction in the combined oil- and gas-accumulation areas and zones. Let us take a most general case when the oil and gas reserves of an individual complex within a zone are approximately similar. In such a case, according to V.I. Shpilman about 70 % of the oil resources and a comparable amount of gas resources concentrate in the combination gas-oil and oil-gas accumulations. Sverchkov and others proposed a technique for the evaluation of more complex situations (Sverchkov et al., 1991). Based on a substantial amount of data, he found that there is a linear correlation of the gas fraction in the gross recoverable reserves and its total content in combination accumulations and fields belonging to diverse size categories. That correlation is described by a simple system of empirical regression equations.

Modelevsky (1983) developed the thermobaric aspect of the separate forecast. He dealt with it at a qualitative level for basins with the continuous inherited subsidence, as well as for basins with a more complex evolution where subsidences might have alternated with uplifts. He proposed a diagram that quantitatively ties up the baric saturation coefficient of the formation fluids with the relative gas volume in natural accumulations. The technique requires the knowledge for each productive complex of the formation pressure and regional background pressure of oil with solution-gas saturation. Similarly to the previous techniques, this one assumes a rather high knowledge of the standard and forecast targets. In Modelevsky's words, "the forecast needs to be systematically updated, especially when there are numerous oil and gas sources and the field formation models are complex" (Methodological instructions..., 1983). Another drawback is that the above technique does not take into account the fluids' hydrocarbon composition which in many cases predetermines the phase specifics of the oil- and gas-accumulation areas and zones. It was taken into account by Anishchenko et al. (1986) who proposed a methodology of the separate oil and gas forecast. These authors performed a simple estimation of the formation fluid gas component not in volumetric but in mass (mass %) format and found the correlation between those parameters and the at fluid density formation conditions as well as with the baric saturation coefficient. These results may be utilized in a separate zonal forecast of oil and gas in some aquatories.

Starobinets made a significant contribution to the substantiation of a set of informative gas-geochemical and thermobaric indicators of oil and gas occurrences and forecast of hydrocarbon accumulation phase state and composition (Starobinets, 1986). These indicators are set for different stages of exploration and appraisal operations; so, they are of a particular interest for the evaluation of offshore areas. The author developed conceptual models of the hydrocarbon phase differentiation at lateral and vertical migration for the primary saturated gas-condensate and oil-gas systems as well within the accumulations proper. It is important that the HC phase state for oil and gas accumulations is controlled by the formation pressure and the effect of the differential capture, and for gas-condensate, by the ratio of the formation pressure and the staturation pressure (P_s). These writers believe that similar models generated mostly based on the data from West Siberia, Amu-Darya and Azov-Kuban depressions may be applicable for the aquatories where gas, gas-condensate and combination (oil and gas) accumulations dominate and where coaliferous, deltaic and near-shore marine source rocks are a major source of hydrocarbons.

The aforementioned clearly indicates the importance of taking into account migration processes together with thermobaric and geochemical factors for a separate oil and gas potential forecast in sedimentary basins or parts thereof.

One important element in the separate forecast is the identification of oil and gas sources in the aquatories and the corresponding hydrocarbon generation nodes (paleo-nodes), and analysis of their association with the proved oil and gas-accumulation zones. Models developed using data from continental margin and subaquatic basins (Galimov, 1986; Schoell, 1983) may be used for the identification of dominant gas source rocks.

Characteristic biomarkers among the normal and isoprenoid alkanes (the markers suggested by these writers in the studies of continental basins) may be partially utilized in the identification and mapping of oil source rocks and the associated formational-genetic types and subtypes of oils. That, however, must be supplemented by the abundant field data from numerous marine basins. For those, the paleogeographic reconstructions combine with the developed techniques for the oil source rocks identification based on the established complex of biomarkers in the polycyclanes and triterpanes. That significantly improves the reliability of the results. In view of these writers, the biomarker-paleogeographic technique in combination with the isotope-molecular data is quite objective, and maybe the only way to identify oil and gas source rocks, generation nodes, and to estimate hydrocarbon vertical range of occurrence, and their migration extent and type.

1.2. Study of the proved oil- and gas-accumulation zones

Proved oil- and gas-accumulation zones are natural congregations of field groups. In other words, they are oil and gas field concentration nodes. Their studies are the basis for the detailed forecast of the oil and gas potential for offshore areas. These studies provide for the generation of databases and standards for the subsequent forecast of the zonal targets, prediction of hydrocarbon phase state in the zonal accumulations, and analysis of factors affecting their formation and areal distribution. They are conducted in the best studied world oil and gas basins and major parts thereof.

The study and evaluation of a proved oil- and gas-accumulation zone includes the following: 1) vertically, identifying regions within the basin's sediment fill, identifying oil and gas complexes and thermobaric intervals, identifying which portions of the zone are associated with which stratigraphic complex; 2) laterally, outlining zonal field groups for each oil and gas complex and the entire sediment fill using a number of parameters; 3) identifying the phase state of hydrocarbons (where it is changing) within the basin boundaries, generating models of the formation of zonal accumulations; 4) summarizing the results of the region identification and finalizing zones' spatial boundaries and their most important geologically related resource characteristics.

The following items are determined to be the most important parameters in the identification and evaluation of the proved oil- and gas-accumulation zones: 1) number of fields within the zone (it controls the very possibility of the identification of zonal objects that must include at least two fields); 2) zone's areal extent: for most oil and gas basins, quantitative correlation is established between the area and resource parameters of the zonal objects; 3) the hydrocarbon resource zones which are the most important, basic parameter for the evaluation and subsequent analogies; 4) hydrocarbon resource density; this is the major parameter, it is evaluated together with the resources not only for each zone but also for most common and average targets of the largest-resources zones; 5) phase state of the hydrocarbons within the zone and differences in phase states within zone groups or for individual oil- and gas-accumulation zones; 6) vertical range of occurrence; 7) stratigraphic range of reservoirs; 8) size of the largest field within the zone (Oil and gas exploration ..., 1994).

The input parameters for estimating the potential of oil and gas occurrence are the information about the phase state of hydrocarbons within the discovered accumulations and source rock data (type, distribution, the extent of katagenic alterations). A special attention in the best-studied oil and gas basins is paid to the phase state of hydrocarbons within the lowermost and uppermost thermobaric zones. Care is also taken of the nature of the superimposed processes. Such processes may include thermal gas migration into the upper levels of the sediment cover or the appearance of early oil and gas generation within those levels. Analysis of that information enables estimation with some certainty of oil, gas and stable condensate ratios in the structure of geologic resources and their application for subsequent forecasts.

The above parameters turn out to be sufficient for a subsequent analysis of the formation parameters and specifics in the distribution of oil- and gas-accumulation zones within the oil and gas basins. What are determined as a first priority are major, general oil and gas accumulation factors that control the above resource-related characteristics and the zonal objects' positions within most continental margin oil and gas basins (Section 1.1). The analysis and classification of the distribution patterns are conducted in consideration of natural variations in the concentrated and dispersed distribution of oil- and gas-accumulation zones within the oil and gas basin (Section 5.2).

Oil- and gas-accumulation zones are autonomous natural objects that enter a hierarchical series of interrelated oil and gas elements of the uvosphere (Lazarev, 1990).

These elements are province – region (basin) – area – zone – field. Thus, it is only natural that the oil- and gas-accumulation zones' parameters and locations are controlled not only by their own properties but also by the regional conditions. Lazarev admitted the regional component in the zonal oil and gas accumulation and showed that the resource parameters of zonal objects vary depending on the extent of the resource concentration within the oil and gas basin (Lazarev, 1990). Therefore, it is mandatory to consider the entire aggregate of factors, regional to local, defining the zone properties. Such a consideration complements a study program of proved oil- and gas-accumulation zones and is especially important for the preparation and correct evaluation of reference standards and reference data for the subsequent forecasting.

A reference data set for intrabasinal standards includes the following information: location of proved oil- and gas-accumulation zones; hydrocarbon phase state distribution within the oil- and gas-accumulation zones, various correlations between the HC resources and their density, and the specifics of the trap section structure and zonal accumulation structure.

The aforementioned informations must be supplemented with the spatial parameter change study results for the proved oil- and gas-accumulation zones and with the average values of zonal parameters of the oil and gas basin and its parts.

Following is the main information for zonal objects of the external reference standards: (1) the proved oil- and gas-accumulation zone distribution by their resources; (2) average parameters of the entire aggregate of such zones within the reference oil and gas basin; (3) average object size of the most common zones and of the zone largest in terms of its reserves; (4) the information about the lateral and stratigraphic distribution and phase characteristics of the zones.

These are major directions and mandatory study results for the proved oil- and gas-accumulation zones. They enable to prognosticate the oil and gas potential at the needed degree of detail for the offshore oil and gas basins.

CHAPTER 2

SOME SPECIFICS IN STRUCTURE, EVOLUTION AND OIL AND GAS OCCURRENCES OF THE CONTINENTAL MARGINS

2.1. The doctrine of continental margins

During the recent decades the doctrine of continental margins was forming as a whole system of thought about a leading role of continental margins in the earth crust's oil and gas formation and accumulation.

The doctrine emergence was associated with deeper knowledge of the world ocean that defined the progress of geology over the second half of the 20th century. The progress encompassed all geologic disciplines, and particularly those that have been fundamental to the continental margin doctrine. Those disciplines include the paradigm change from the geosynclinal concept to the plate tectonic concept and the evolution of geodynamics, and the change in the perception of riftogenesis. They cover lithology (lithogeodynamics), petroleum geology and geochemistry (identification of HC ontogenetic regimes, of new oil and gas formations, etc.) All these were helped by an explosive growth in the amount of geologic data that resulted in the identification of continental margins as a fundamental geologic object.

It was previously believed that the underwater portions of the continents tectonically represent simple subsided extensions of continental structures (platforms and fold belts). Based on the aforementioned and contrary to the previous statement it was shown that continental margins are specific formations at the merger area of the global geostructures (continents and oceans) that are radically different from one another in their structure, nature and tectonic activity (Geology of Continental…., 1978; Grigorenko, 1979). It was also found that large sedimentary basins are particularly common for the continental margins. Based on that, Khain (1970) suggested that the continental margins are global petroleum objects.

Later down the road the ideas of the geological structure and evolution of the intra-continental areas were reconsidered in view of the plate tectonics concept. Fragments of ancient continental margins had been discovered on the continents, and the association of major oil- and gas-accumulation zones with those ancient margins had been established. Hedberg (1970) substantiated an idea that a major volume of marine deposits was associated with the continental margins of a respective age. He concluded that the main hydrocarbon resources are also connected with the ancient and present-day continental margins.

This conclusion by Khain and Hedberg was proved right by numerous major discoveries over the underwater continental margins. It covers not only shelf but also deep-water areas whose potential was traditionally not held in very high regard.

New geologic data and discoveries, together with theoretical research, enabled Khain and Sokolov (1984) to come to a conclusion that the continental margins are the birthplaces of oil and gas (Khain, Sokolov, 1984). Various studies confirm that the continental margins are exactly the places with a favorable combination of the factors facilitating the oil and gas occurrences on a large scale. They are the regions where phenomena like mantle diapirism, riftogenesis, subduction, obduction and collision processes with the development of regional nappes are very common. A consequence is the fragmentation, destruction, thinning of the crust, and the appearance of intermediate crust types like subcontinental and suboceanic crust, high-amplitude horizontal and vertical motions, volcanism, and seismic activity, elevated or highly differentiated heat flow, intense deposition.

A common feature of the continental margins is the presence of sedimentary basins extending almost continuously along their length. It is caused by the belonging of the continental margins to the Earth's areas with the accumulation of deposits continuous in time and consistent in volume. As an example, more than 40 % of the Earth's sediment volume (Geodekian et al., 1989; Ronov et al., 1986) had been formed on the underwater continental margins over the recent 150 million years (beginning in Late Jurassic through the present day).

As a result, being much smaller in terms or their areal extent, the present-day continental margins hold about the same volume of the Jurassic-through-Pliocene sediments as the continents proper (even with the onshore portions of the continental margins). That made Geodekian and Trotsyuk (1984) come to a conclusion that the marginal areas of the oceanic stratisphere (as opposed to much greater internal portions) are a global belt of oil and gas formation nodes.

The above specifics of the continental margins provide for an intense, avalanche-like oil and gas-generation. This is what makes them different from a dispersed form typical of tectonically passive areas (Dyakov, 1992). Thus, continental margins form global oil and gas-bearing belts. The processes over the margins are of the impulse nature. This, as well as the spatial and temporal alternating of those processes, results in numerous sedimentary basin types and in significant structural differences even among the same type basins. All these inexorably affect the oil and gas potential of specific objects. That is why studies of the continental margins are an important part of the doctrine as their properties determine their oil and gas occurrences. Of no smaller importance is the selection of parameters which may be used for global, regional or zonal forecasts (Mirchink et al., 1992).

An analysis of oil and gas occurrences over various continental margin types at different evolution stages was conducted. It indicated that the HC richness and average per-unit parameters depend on several factors. These factors include not only the type of continental margin, but also its position within the evolutionary series. That caused the introduction of the geologic history factor as a factor in the oil and gas forecast (Grigorenko, Andieva, 1992).

It was also noticed that the areas where the superposition and intersection of continental margins belonging to different types and ages occurs, are the most favorable in terms of oil and gas occurrences. They form peculiar oil and gas generation and accumulation nodes. Gramberg established a correlation between the ocean formation timing and oil and gas occurrence specifics and scale over the surrounding continental margins. It was discovered that the areal extent of favorable territories, HC resources and their degree of concentration in the giant fields over the margins all depend on the age of the oceans (Gramberg, 1998 a, b).

Therefore, following are the fundamental concepts in the petroleum geology of the continental margin doctrine:

1. Continental margins are large petroleum geologic systems. Their high hydrocarbon potential is based on optimal combination of factors responsible for the oil and gas generation, migration, accumulation and preservation.
2. Optimum oil-gas occurrence conditions for the continental margins are determined by a combination of properties acquired due to their transitional (present or past) position. That position is associated with the juncture areas of continents and oceans with their appropriate geodynamic regime (mantle diapirism, riftogenesis, subduction, collision, etc.)
3. A certain direction in their evolution and its stage-like nature that follows the evolution of the binary tectonic system "continent-ocean" is the fundamental property of continental margins. That property predetermines many other particulars of the continental margins.
4. Within the general evolutionary cycle of the continent-ocean system, continental margins play the role of destructing old and creating new continental geostructures. In the process, tectonic elements form, which serve as major collectors of sedimentary sequences over the transitional areas between the continents and oceans.
5. Sedimentary basins evolve as almost continuous zones of pericontinental deposition. They form over the continental margins' linear (belts) and areal (nodes) basin groups. They form oil and gas objects on a sub-global level, the objects that are alien to the continents. The component oil and gas basins of belts and nodes include numerous (more than twen-

ty) tectonotypes belonging to major stages of the continental margin evolutionary cycle (Table 2).

6. In the Phanerozoic evolution, the continental margins are the objects constant in time and variable in space. That determines their major contribution into the world oil and gas resource balance. Those resources are located mostly over the present-day margins and within the continental geostructures whose evolution was associated with the ancient continental margins.
7. In order to be able to make a qualitative and quantitative hydrocarbon resource evaluation of the above subglobal and regional elements, a consideration should be given to the geologic history factor in the continental margins' oil and gas occurrences. The factor implements itself in the association between sequential geologic transformations of the margins and their oil and gas occurrence parameters.

Therefore, the continental margin doctrine assumes a characteristic association between their structure, evolution and oil-gas potential, which includes the spatial distribution of oil and gas accumulations different in rank and size. It provides an opportunity for a fine-tuned, detailed scientific evaluation of oil and gas occurrences in the offshore geologic section, thereby attributing a forecast value to the doctrine. The cognition of continental margins' structure, evolution and oil and gas occurrence patterns is also helpful in a better understanding of oil and gas basins which are currently on the continents.

2.2. Continental margin structure and evolution

An integrated interpretation of continental margin structure and evolution is based on a more general concept of marginal objects. Marginal separating objects (Votakh, 1979) are not members of general systematics like the platform and mobile areas or continents and oceans. They are identified as purposive categories in the merger zones of such structures, and cover their peripheral areas. The marginal objects serve not only as separators but help understand the nature of the connection and general properties of the separated objects. Thus, the marginal objects are the loci of the "intersection", interlacing of the separated structure properties. At the same time, they acquire the specificity that strengthens their individual, separating nature.

Continental margins are viewed as geologic systems uniting geostructural aggregates. These aggregates emerge, form and transform into other forms in the process of evolution of each specific continental-oceanic structure. Occupying a transitional position (at present and in the past) at the contact of the interacting continent and ocean, they are the loci of the "intersection", interlacing of the properties pertaining to the global objects they separate.