ASPECTS OF ORIGIN MECHANISM FOR CONTINUOUS (IN SITU) HYDROCARBON ACCUMULATIONS

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ABSTRACT. The purpose of this work is to reveal the principal factors, controlling processes of origin mechanism of known nowadays certain continuous (in-situ) concentrations and those, known as "quasi-continuous. Through comparative analysis of the certain exploitation practice, and especially from Bakken Fm. (Williston Basin, USA), we discuss the role of kerogen concentration; migration processes; driving forces, including "constructive" type that initiate mobility and "unconstructive" or restrictive, acting against; rock hosted space, which consists of primary (matrix or mineral) and "organic" porosity and ratio of actual pore pressure vs. the normal hydrostatic pressure (pressure coefficient P_{pc}) at the same depth.
As a result of the performed analyses, we conclude:
When the primary migration is 100 % restricted a certain continuous accumulation is formed; $P_{pc} < 1.22$.
In case of limited transfer of HC products, a quasi-continuous accumulation is expected; $1.22 < P_{pc} < 1.9$;
When high level of expulsion efficiency is in force and petroleum products undergone notable buoyancy effect, than occur typical conventional accumulations;
If $P_{pc} > 1.9$ more likely to occur natural hydro fracturing, changing the original tight rocks into the conventional fractured reservoirs.

Keywords: origin mechanism, continuous, quasi-continuous accumulations, shale gas

АСПЕКТИ ОТ МЕХАНИЗМА НА ФОРМИРАНЕ НА НЕПРЕКЪСНАТИТЕ (IN-SITU) ПЕТРОЛНИ АКУМУЛАЦИИ

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РЕЗЮМЕ. Целта на работата е да се разкрие ролята на основните фактори, които контролират образуването на известните понастоящем същински непрекъснати петролни акумулации и разновидността, позната като „псевдо-непрекъснати" акумулации. Посредством сравнителен анализ на данни от добивни полета и специално от практиката на формация Bakken (басейн Williston, САЩ),се обсъжда ролята на съдържанието на органично вещество в скалите; миграционните процеси; движещи сили, в това число „конструктивни", които подпомагат движението на генерирани продукти и „рестриктивни", които го ограничават; вместващия скален обем, който включва първична (матрична) и вторична – органична порестост; коефициента на свръхналягане (P_{pc}), изразен като отношение на пластовото към хидростатичното налягане за дадена дълбочина.
В резултат на проведения анализ са формулирани следните изводи:
При 100 % възпрепятствана първична миграция се формира същинска (In-situ) непрекъсната акумулация; $P_{pc} < 1.22$;
Ако тя е частично реализирана, с ограничен миграционен път – са налице условия за „квази-непрекъсната акумулация"; $1.22 < P_{pc} < 1.9$;
При мащабен трансфер на автономно сепарирана въглеводородна фаза се образува конвенционално насищане в геокапан от познатите конвенционални типове, може да бъде и с термо-бaричен генезис, както това е доказано за газохидратните насищания;
Ако $P_{pc} > 1.9$ е най-вероятно да настъпи естествен хидро-фракинг, съпроводен с трансформиране на първично плътните скални тела в конвенционални напукани резервоари.

Ключови думи: механизъм на формиране, непрекъснати, псевдо-непрекъснати акумулации, шистов газ

Introduction

The registered remarkable results of shale gas and shale oil production worldwide have stimulated specialist to distinguish this kind of petroleum plays as a new specific ontogenetic branch. These natural hydrocarbon resources have been described later as "continuous petroleum accumulations", named also as "self-sourcing" plays (Schmoker, 1995; Qing Li et al., 2017; Jordanov, 2018, a,b and others). In order to achieve valuable growth in exploration efficiency, a lot of efforts have been made toward revealing their basic distinguished features. However, a range of important fundamental questions, regarding certain origin mechanism, have not been adequately answered. The purpose of this work is to reveal the principal factors, controlling processes of enrichment mechanism of known nowadays variety of continuous petroleum accumulations worldwide. The analysis covers the certain continuous (in-situ) concentrations and those, known as "quasi-continuous", where the primary migration is partly realized and buoyancy forces have negligible effect. Because of fundamental differences in origin and enrichment pattern of methane-hydrates localizations, they have not been included into the scope of this work.

Methodology

The methodological priority of the current analysis lies at the root of the petroleum-system fundamental principles. However, the main attention was placed only to those postulates, which can be used as a framework for model developing of continuous accumulations origin mechanism. As mentioned above, these types of natural petroleum products could be classified as: a) "curtain" (in-situ) and b) "quasi-continuous" accumulations (Fig.1). From this point of view, the stress below is addressed on the role of:

- *source rocks and organic matter (OM)contents*;
- migration processes (physical constrains and acting forces);
- concentration (trapping) mechanism;
- origin and principal characteristics of the hosting rocks.

Aspects of origin mechanism for continuous (in situ) petroleum accumulations

Source rocks and organic matter (OM) contents

There is not considerable concept regarding critical content of rock OM as crucial control on the continuous accumulation origin. Therefore we chose to proceed from the assumption that such information could be extracted from the cases of worldwide organic rich basins, containing economically viable and producible continuous plays (Table 1). Through comparative analysis of the average lower limit values of OM of chosen examples, we assume that such approach could outline the framework of the problem. From this point of view, and from the certain exploitation practice, and especially from Bakken Fm. (Williston Basin, USA), we conclude that optimal weight % of kerogen concentration (or TOC) should hesitate near 6-8 %. Otherwise there are no suitable conditions for continuous plays origin. More precise arguments for this value (6-8 %) we shell give in the next sections below.

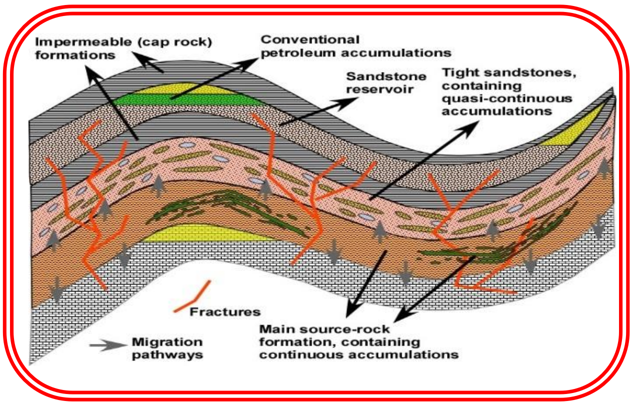


Fig. 1. Schematic illustration of conventional and continuous petroleum accumulations

Nevertheless of the precise analysis of the database from unconventional concentrations, we cannot identify any visible relationship between kerogen type and their enrichment mechanisms. The absence of mutual dependence of these parameters allows concluding that the influence of kerogen type on the enrichment pattern of continuous plays is negligible. As concerns the thickness of the charging source rocks intervals, there are some regularities which can develop further stable trends through additional field data gathering. For widespread intracratonic basins like those of West Siberia, North Sea, as well as basins belonging to the large scale shelf areas (Maracaibo basin etc.), the thicknesses of the sourcing intervals are 30-120 m (averages near 30-40 m, Table 1). No such trends could be recognized for rift-controlled sedimentary basins, where exists high or rapid accumulation rates. In these cases it is supposed continuous plays to include thick rock suits (more than 1000 m), with typical multilayer architecture. The Mycopian Formation (late Oligocene-Miocene) from the ancient Peri-Tethyan basins is the quite proper examples.

As results of the large scale field and exploration works performed in the Bulgarian Phanerozoic onshore territory, no widespread rock series have been identified, containing overcritical volume of kerogen (TOC), covering the requirement for continuous accumulations origin.

Migration processes

Migration type and magnitude

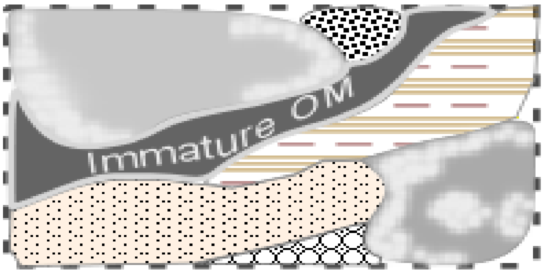
In order to develop more detailed model for unconventional localizations few principal attributes should be discussed, accounting for all aspects of acting (driving) forces. Such kind of analysis requires presenting the acceptable consistency regarding origin, expulsion and emplacement of petroleum. This phenomenon is known as "primary and secondary" migration. We consider that migration should be presented as tree-steps process, as pointed out below.

- Origin of autonomy hydrocarbon (HC) phases, as result of initial kerogen transformation and its separation into sorption and probable expulsion portions. The sorption processes can occur on the matrix as well as on the kerogen surface, whereas probable expulsion portions may fill existing matrix pores and pore space within the kerogen (organic porosity). This first episode we describe as very primarily expulsion step or "auftakt" migration. When this process ranges the space of the source rock body only, a certain (in-situ) accumulations are supposed to be formed.
- The migration of the generated HC products from the source rock into the adjacent host-strata we define as a certain primary migration. In this case, two scenarios are possible: if there is not visible mobility of the generated HC products, subsequently no buoyancy effect, than a "quasi-continuous" (or "source-contacting") accumulation is expected; otherwise a conventional play will occur (Fig.2).
- Secondary migration, which some researchers subdivide into "interior" and trans-reservoir transport of HC products. This kind of migration is typical for conventional plays.

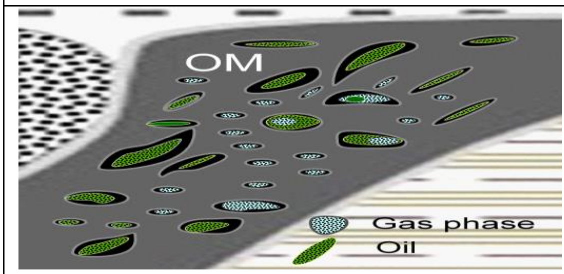
Table 1. *Comparative data analysis of world leading continuous developments*

Basin (region)	Formation	Stratigraphy	Average TOC content (weight %)	Average thickness (m)
West Siberian	Bagenov	Tithonian-Berriasian	12	< 60
North Europe England-Paris basin	Posidonia	Early Jurassic, Toarcian)	10	30
Maracaibo	La Luna	Cenomanian-Santonian	4-5	< 100

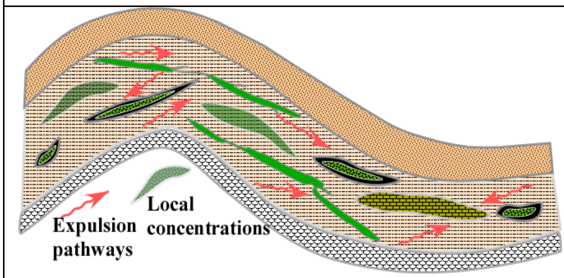
Persian gulf (Saudi Arabia)	Hanifa	Oxfordian-Early Cimmerian	3-5	< 150
USA, North Dakota and Montana (Williston)	Bakken Shale	Devonian-Early Carboniferous	12-14	< 40
South Caspian region	Maikopian	Oligocene-Miocene	1.2-10 > 10 (Middle Maikopian formation)	70-250
North Sea	Kimmeridgian Clay	Late Jurassic	2-9 (средно 5)	15-30 for 'hot shales'



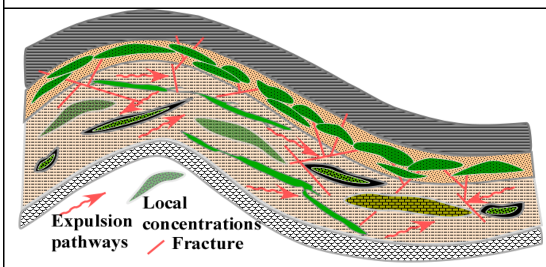
Immature organic matter
R_o < 0.55-0.60 %
No expulsion processes



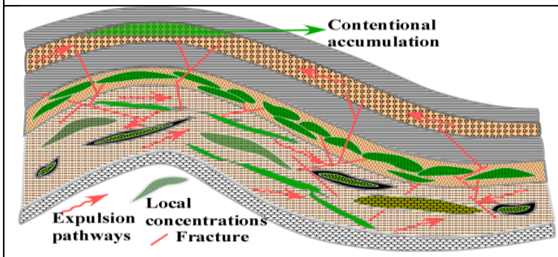
Onset of petroleum generation
Ro > 0.60 %
A very primarily expulsion step or "auftakt" migration (emigration) of predominantly gas phase.



Coexisting of source and reservoirs. No buoyancy effect. Expulsion transfer of the generated hydrocarbon (HC) products only within boundaries of the source rock formation. No buoyancy effect. Continuous type of plays.



Limited transfer of HC products to nearest beds or partly realized migration (emigration). Condition for quasi-continuous accumulation to be formed. No buoyancy effect.



Intense migration efficiency is in force (primarily and secondary migration) and petroleum products undergone notable buoyancy effect. These settings are typical for enrichment pattern of conventional accumulations

Fig. 2. Schematic illustration of the migration processes during petroleum accumulations origin

Restrictive and constructive driving forces

There is a broad agreement regarding the crucial role of the rocks petrophysics on the processes of HC mobility. Therefore, the postulates of this concept were implemented in the current analysis of the main driving forces, acting during the continuous accumulations origin. The mobility of the generated HC occurs mostly in fine-grained, organic rich rock bodies, developed within subsiding sequences, undergoing increasing thermal load. The dominant feature of such type fine-grained layers is their limited filtration properties (< 0.1 μD). These characteristics suggest presumably arising of two type driving forces: "constructive" that initiate mobility (chiefly formation overpressure and buoyancy effect) and "unconstructive" or restrictive, acting against (filtration barriers, capillary pressure, adhesion etc.). Consequently the magnitude of petroleum mobility entirely depends on the interaction between mentioned forces. It means that, if the restrictive forces are equal or greater than those presented as "constructive", no common expulsion processes will take an effect. As a result a continuous play should occur (Fig. 3).

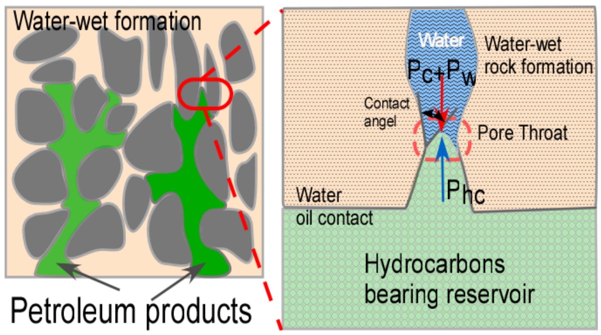


Fig. 3. Schematic illustration of the "constructive" forces, mainly micro, mezzo and local formation overpressure pots (P_{hc}), causing petroleum products mobility and restrictive forces (chiefly capillary and formation water pressure- P_c+P_w), acting against

Generally, *the restrictive forces*, it's believed to be depending mostly on the primarily diagenetic environment, i.g. on the initial properties of the fine-grained sedimentary fill. During the early subsidence episode these deposits underwent intensive changes of the rock matrix porosity and permeability (mainly through compaction and mineral transformation). This process continuous up to the depths of 800-1200 m and further subsidence will not lead to substantial changes. Consequently, the influence of burial at depth greater than 1000-1200 m, when the sediments enter into the oil window, has minor effect on the mobility of the generated HC products. Therefore we conclude that magnitude of restricted forces was almost stabilized at the end of this initial (very often rapid) compaction phenomenon (up to 800- 1200 depth). As a result, the migration ability of the generated HC products at the oil-window depths should have been govern chiefly by the size and shape of pore-throats, as well as capillary pressure values (Magara, 1982 and others). Additionally, to the end of the diagenetic rock transformation, the matrix surface it is expected to preserves its initial wettability; hence after the main compaction episode the capillary pressure depends only on the pore-throats radius, and remains relatively stable during the rest stages of the lithogenesis. Exceptional cases, when the fine-grained sequences are affected by the local or bulk natural fracturing, should be addressed to the special petrophysical analysis.

A special attention to better understanding of the discussed above enrichment pattern should be addressed also to the behavior and treatment of the *"constructive" forces* (defluidization, buoyancy effect, diffusion, intra-formation pressure anomalies and others). The crucial importance belongs to the micro and local pressure anomalies, arising as a result of OM and some matrix minerals transformation. In the early stages of this process, i.g. when the source rocks enter into the oil window, local or point-size (embryonal) formation pressure anomalies arise. Coeval to subsidence, respectively to increasing thermal load, these anomalies expand, achieving magnitude of broader anomalies and finally to origin of overpressured strata. An outlook over this problem has been given in previous author's paper (Jordanov, 2013), where an attempt of calculations was made. These schematic calculations were focused on the fluid volume changes during the phase transformation of following couples: kerogen-oil; oil-gas; condensate-gas. Let us assume the following example: rock sample with 2.45 g/cm^3 density contains 6 weight % kerogen, 1.15 g/cm^3 density. Assume also that 50 % of kerogen will undergo conversion into oil of 0.8 g/cm^3 density. Then this half part of kerogen will give only 0.028 cm^3 / cm^3 additional (extra) volume, or near 3 %. Obviously this extra volume will generate insignificant pressure built-up anomaly. Quite different effect is expected when liquid phase (e.g. oil) is converted into gas. It is well known that 1 barrel of crude oil dives near 85 m^3 gas phase and 15-18 % bituminous residue. Such types of transformations generate considerable by magnitude pressure anomaly. Compare presented above simplified calculations is clear that transformation "kerogen-to-oil", even though higher degree of metamorphism, has no potential to generate overpressure that can act as a notable driving control. It is believed also that such kind of pressure anomaly should be absorbed by pore-rock system elasticity. Presented suggestion is supported by Tongwei Zhang et al. (2013) data from Bakken Fm. (USA). Cited authors have calculated generation of 13 mg/g rock oil and almost all oil volume was retained into the pore-rock system. Authors also consider that maximum expulsion efficiency do not exceed 41 %. An analogical pattern is in force probably for the prolific oil-prone Bagenov formation from West Siberia (Kalmikov & Balushkina, 2017 and others). The both petroleum producing regions contain minor volume of soluble gas phase. Presented above assumptions may arouse suspicion, but generally there is no notable inconsistency to the fluid-mechanical behavior of the source rocks contain I-II type kerogen.

As it was mentioned above, the formation pore pressure profile is quite different in case of abundant gas phase generation. The similar effect arise also when source rocks underwent intensive thermal load (temperature > 135-145 ^{0}C), giving start for secondary conversion of generated oil into gas. This predominantly wet gas may exist as free volume, dissolved within the oil as well as adsorbed on the matrix and inert kerogen surfaces. Such model of multiphase rock saturation, it is believe to generate tremendous overpressure anomalies. In practice they act as a crucial "constructive" driving control. Obviously presented pattern can take place as local, zonal or regional anomaly, forming by this way overdressed formation of basin scale extent. The typical natural examples are the well-known basin-centered unconventional accumulations (Basin-centered gas systems

…2000; Fall,A. et al., 2012 and others). If the magnitude of formation overpressure, i.g. integral magnitude of "constructive' forces, exceeds the counteraction vector of "restricted" forces, conventional petroleum accumulations must be formed; otherwise unconventional pattern of petroleum concentrations should exist, being of certain "in-situ" continuous or quasi-continuous type. As results of the performed analyses, we conclude: *if filtration barriers restrict 100 % of primary migration, a certain continuous (in-situ) accumulation forms; if the primary migration is partly realized the quasi-continuous concentrations exist.* Under the conditions of scaled primary migration as well as good secondary migration within the reservoir rocks, a conventional accumulation is expected. We also consider that presented limitations for origin of a certain (in-situ) continuous accumulation should be addressed at extreme (endmost) environment, such as those shown in the Table 1.

Trapping mechanism

The development of a reliable model of adequate trapping mechanism for discussed type of accumulations is still difficult because of their broad diversity, hence lack of reliable data base. It is widely accepted that the proper trapping mechanism is dominantly controlled by force equilibrium between hydrocarbon-generation pressure anomalies and capillary pressure barriers. The text below highlights some aspects of this problem for certain (in-situ) continuous and quasi-continuous accumulations.

Aspects of trapping mechanism for certain (in-situ) continuous plays

It is believed that the oil/gas enrichment phenomenon for this type plays can be characterized by: a) broader, multi-points pseudo-migration process, instead of prevailing often single stream-like mechanism, typical for conventional accumulations; b) very short migration pathway; c) Darcy's law cannot be applied and buoyancy-driven forces may take an minor or negligible effect. Liu Guangdi et al. (2013) define this enrichment pattern as intra-formation "multi-point piston mechanism".

In conjunction with presented above characteristics, there are important exceptions known as „sweet sports". Practically they are localities, preserving higher porosity and permeability. Their petrophysics is closer to the reservoirs. As a rule they have diffusive contact in the environment and no detectable dependence on the formation water. We suggest for this special case invasive (repressive) charging, controlled by local or zonal pressure anomalies. Very often the „sweet sports" appear as lithological traps and are the main targets of the industrial interests. It is thought that presented scenario is inherent for the 40-50 m thick Bagenov Formation from West Siberia. This rock formation consists of fine-grained carbonate, shale and flint clastics, containing 8-12 % organic matter. Its lithological profile is quite heterogeneous with number of huge lens, equivalent to enigmatic „sweet sports". They are the main producing objects. Additionally to the presented above model, Kalmikov & Balushkina (2017) consider that charging process of Bagenov's „sweet sports" occurs mainly by micro-fractures as well as by single, relatively bigger pores.

II.3.2 Aspects of trapping mechanism for quasi-continuous plays

The main features controlling trapping mechanism of these type petroleum accumulations should be outlined from the specific characteristics of the hosted rocks. Practically, the matrix of such environment contains predominantly micro- and nano-sized pore space. Additional important feature of the quasi-continuous plays is also their direct and extensive contact to the main (chief) source rock body (Jordanov, 2018; Zhengjian Xu et al., 2017; Hua Yang et al., 2016; Jingzhou Zhao et al., 2012). This specific construction of "source rock-host strata" motivated some authors to introduce "source-contacting accumulations". Following presented above basic principles, it seems correctly to assume analogous to "in-situ" plays trapping mechanism. It has to be governed by the same controls: generated overpressure due to OM conversion as folows: kerogen to gas; oil to gas; condensate to gas. Obviously, such model of charging will occur when the generated overpressure overcomes the filtration obstacles, developed on the boundary between source rocks and adjacent quasi-reservoirs (capillary pressure, adhesion forces and other minor of importance barriers). But, for this type of nano-pore system, accounting also for pore-throats abundance and its crucial role on the capillary pressure profile, it seems unacceptable to apply standard models of HC transition through pores and related its pore-canals. This is the reason to suggest that the main pattern of enrichment goes through micro-fractures and single pore-canals near or > 0.1 µm in size. Performed below simple calculations may argue for described idea. Let us take common Laplacian equation, assuming 40 mN/m surface tension on the "gas-formation water" boundary and effective pore radius of 0.01 µm (10 nm) (Xiaojun Zhu et al.,2019; Cheng Zhang and Qingchun Yu, 2019 etc.). Then for the fully hydrophilic media, the capillary pressure (P_c) value is 8 MPa. According to the published field data of number of authors (Zhengjian Xu et al., 2017 etc.), formation overpressure from the OM transformation may reach 5-10 MPa. Overpressure of such magnitude is enough to overcome capillary pressure counteraction. However, such breakthrough (displacement) pressure, that guarantees petroleum mobility, will be accompanied by opening of the principally closed fluid system. It unavoidable lead to pressure drop (pressure cooker principle). Such type of scenario may "push" the HC products to the places of accommodation (lithological traps), but the length of emigration will not exceed few to 10-20 m, charging practically number of local spots of the quasi-reservoirs beds. It is also important that such scenario of temporary "opening" of the pore-system, as a rule, suppose arising of multi-episode emplacement. Such pattern has been observed by many authors and as a typical case we give results of Zhengjian Xu et al (2017) for Ordos basin. The cited authors determine at least three episode of emplacement (Fig.12 of the paper).

Besides presented "invasive" enrichment pattern, it is necessary to account for possible diffusive mass transport. According to the Adolf Fick's law, given diffusion coefficient D= (1.5-2.5).10^{-6} m^2/s), seems logical to expect this effect. However, based on the performed large number of experimental works, J. Hunt (1995) concludes that mass transport by diffusion through tight porous media may take negligible effect. Cited author calculates that a volume of methane should pass by diffusion through 1740 m rock matrix for 140.10^6 years (p.257).

Presented model of trapping (enrichment) mechanism for quasi-continuous plays principally requires strong dependence on the intensity of gas generation rate in order to give start of petroleum mobility. There are theoretical postulates giving a possible lower limit of generation rate. In the current analysis however an advantage is addressed to the certain field data, acquired from the real plays. Such a typical example is the working plays from Ordos basin (CN China), where at least 5 large tight gas/oil fields have been discovered. Through the last few decades, large number of detailed geochemical and petrophysical services have been done, focused on the Ordos's Carboniferous and Permian petroliferous strata, producing nowadays shale oil and shale gas from micro, nanopore hosted media (Jingzhou Zhao et al., 2012 et al.). Some researchers (Zhengjian Xu et al.,2017; Hua Yang et al.,2016; Jingzhou Zhao et al.,2012 et al.), have presented arguments allowing lower limit of gas generation rate to be defined. Data from more than 700 wells have been analyzed by the cited authors, which came to the conclusion that commercial saturation of quasi-continuous plays occur when intensity of gas generation exceeds 10^8 m^3/km^2. This lower limit value is close to the analogous regions from Russian Federation's continuous plays - 20-30.10^8 m^3/km^2.

Summarizing, it should be mentioned that essential element of the presented trapping pattern depends chiefly on the magnitude of generated formation overpressure, which should overcomes all the filtration obstacles and fill invasively adjacent micro-, nano-pore system of the quasi-reservoirs. The absence of buoyancy effect as well as no visible trap boundaries is the dominant characteristics of this process, vice versa to the conventional analogues.

Independently of the presented above arguments supporting ideas for quasi-continuous plays enrichment, we consider that the development of the charging model, that will achieve reliable degree of adequacy to the real geological environment, requires lots of additional field and analytical efforts.

Origin and characteristics of the hosted porous beds

As it was mentioned above, the dominant feature of the continuous plays is their hosted space, which consists of *primary* (matrix or mineral) and "organic" porosity. The letter genetically arises as a result of OM (kerogen) conversion into HC products. Therefore it has to be classified as secondary. As a rule, the porosity volume is built up mainly by micro-nano pores. The initial matrix porosity (depositional pores) and its diagenetic rework totally is small (not exceeding 5-6 %), whereas the volume of organic pores may be equal or more than primarily. Due to the certain genetic differences of both type of hosted pore space, they are analyzed autonomy in the text below.

Origin and characteristics of the matrix porosity in clastic deposits

The hosted rocks most often are presented by tight clastic deposits (shale, siltstone, mudstone, chemogenic carbonates, silty sandstone, marl and others). In majority of the cases their matrix contains predominantly micro-nanoscale pore space. The total porosity of this kind of rock averages between 2-8 %; permeability do not exceeds 0.5 mD. The matrix voids include micro, nanopores, bounding its channels and deferent by geneses, size and extend micro-fractures. A detailed outlook on the variety of pore types that exist in the hosted beds of the continuous plays is given by R. M. Slatt and N. R. O'Brien (2011). Based on the data from Barnett Shale in north Texas and the Woodford Shale in southeastern Oklahoma, cited authors specify: a) porous floccules, organopores, fecal pellets, fossil fragments, interpartical grain/pores and microchannel and microfractures (Fig. 16, p 227). In all these recognized pore spaces dominate microscale and nanoscale porosity. The pores cover an interval of 10-30 up to 300 nm in width.

Coeval with the dominating nanopore spaces there are small localities known as "sweet spots". These local reservoirs may arise due to depositional diversity as well as due to disequilibrium compaction in thick fine-grained sequences (Tingay et al., 2013; Jordanov, 2013). The latter phenomenon produces pressure anomalies, acting against compaction, respectively preserve porosity reduction and forming the enigmatic "sweet spots".

Origin and characteristics of the matrix porosity in coal beds and coal-bearing strata

The remarkable results of coal-bed-methane (CBM) production from number of USA and China developments, give strong contribution for better understanding of enrichment mechanism occurring in coal seams and coal-bearing strata (Tim A. Moore, 2012; Yu Liu, Yanming Zhu, 2016; Chenghua Ou et al., 2018 and others). The gas phase exists as free, adsorbed and dissolved form. The large number of investigation has shown that the volume of adsorbed gas has a greatest significance while the other both types have minor importance. Summarizing the observation of the enrichment patterns of the coal basins worldwide, including the great Zonguldag basin (Turkey), researchers define the statement that CBM fills chiefly nano-pores and micro-fractures. The latter is assumed to play important pole as possible micro-migration pathways for gas phase movement into the direction of smaller formation pressure.

The common characteristics of the coal basins worldwide are their multilayer profile. It includes coal seams (beds, layers), coal-bearing strata, as well as non-coal intervals of different thicknesses. The latter consist more often of clastic deposits (sands, silts, conglomerates etc.), which should be addressed to the group of tight reservoirs. The typical examples of Bulgarian Paleozoic section are few Formations from the Greatest Dobroudja coal basin (Velkovo, Polianska Fm. and others (Hristov, Zd., et al., 1988)). Despite certain domination of the sandstones of their rock profile, they have not been assessed as promising targets for coal-bed-methane (CBM) resource.

Regarding CBM storage mechanism, Yu Liu & Yanming Zhu (2016) and others, argue the statement that in most of cases in coals dominate semi-closed micro pores (< 10 nm) and transitional (connecting) channels larger than 10-100 nm. The analogous pore size interval is typical also for clastic deposits which gives us motivation to conclude that the origin and characteristics of the coal pore space should follow the same principals as those of clastics.

Origin and characteristics of the "organic" porosity volume

This problem has been discussed in large number of papers (Jordanov, 2013; Maria-Fernanda Romero-Sarmiento et al., 2013; Vitaly Kuchinskiy, 2013; Zhuoheng Chen & Chunqing Jiang, 2016; Yuanjia Han et al., 2017 and others). The majority of authors consider origin of this type of porosity as results of rock OM (kerogen) transformation into HC products due to thermal load from the Earth heat flow. During the burial the solid kerogen turns into liquid or gaseous phase (changes in kerogen density). This transformed part of the kerogen is considering as its labile content and usually account for 30-80 volume % of the initial volume. Being as labile HC phase, these products appear as moving substance, that occupy the “free” space, e.g. specific volume, named “organic” porosity. The published data, regarding the size interval of the new originated voids shows domination of nano-pores (20-50 nm). According to the Yuanjia Han et al. (2017) results, the pore shape depends on the kerogen maturation intensity. During the early stages of kerogen conversion isolated bubble-like pores start to occur. Further, coeval with increasing temperature, isolated bubble increase in volume and become more significant, taking a sponge-like appearance. Furthermore it is thought that organic voids occupied more and more space, forming by this way “micro-jails”, possessing capacity for HC products retention.

The problem of dependence between organic porosity and kerogen content is of great importance for petroleum society. Comprehensive review on this matter dive Fernanda Romero-Sarmiento et al. (2013). The cited authors have modeled organic porosity evolution and tested the model on the world leading Barnett shale development. They assume that current average organic porosity of this shale is 4.3 % and it comes from the current TOC of 4.83 weight %. Summarizing, they have come to the conclusion that for every weight % of TOC may correspond 0.35-0.84 % porosity. Within this interval should be included also and the expected organic porosity of the most observed II type of kerogen. Formally we assume the value of 0,5 %/1 % TOC for this kind of kerogen. Even though, there are number of analytical technics for organic porosity calculation, we consider that there are lots of controls that cannot be assessed adequately (kerogen type, temperature profile, burial modeling and others). Therefore these efforts have not been widely accepted as a reliable decision.

In the context of the above presented understanding of the organic porosity origin, it should be of practical interest to develop an approach for TOC lower limit determination. Although it is possible to find out analytical (numerical) decisions, we prefer to give advantage to the data, extracted from the real field objects. On the base of the results obtained from the leading world etalons (Barnett shale, Bakken Form. from USA, Posidonia Form. from W. Europe, Bagenov Form. from W Siberia etc.), the measured organic porosity hesitates near 3-4 %. If formally assume 3 % as average value and implement Fernanda Romero-Sarmiento et al. (2013) findings, the critical TOC content (i.g. lower limit) for II type kerogen, should exceed 6 weight %.

(6 % weight TOC X 0,5 = 3 % organic porosity)

It should be mentioned that our perception for lower limit of 6 % TOC for source rocks should be accepted only for the current technical state-of-the-art and the future improvement will definitely introduce new modern decisions.

Aspects of quantitative approach to determine overpressure control on the migration processes magnitude

We assume that such a relation could be extracted from the following logical construction. As it was mentioned above, continuous accumulation is formed when filtration resistances within the source rock could not be overcome by overpressure generated due to OM transformation. The main control on this process is attached to the capillary pressure (P_c), which acting again formation fluids mobility. Basically it depends on the size (radius) of the biggest pore-throats. Consequently, the ratio of overpressure vs. capillary pressure appears as a chief parameter, controlling petroleum products mobility. The arising overpressure is an integral result of multiple impact of number of parameters that characterize principal stresses in the rock environments. They are: hydrostatic pressure (P_h); formation (or pore) pressure (P_f); overburden (or lithostatic) (P_l) pressure. In order to justify P_f and P_h a pressure coefficient (P_{pc}) was introduced. This coefficient is a ratio of actual pore pressure versus normal hydrostatic pressure at the same depth. There is general agreement that the regime is determined as overpressured if P_{pc} > 1.15-1.20 (Tingay, M. et al.,2013 and others). It is well known that P_{pc} reaches 2.0-2.5 in number of basins worldwide. It corresponds to the super overdressing regime, initiating natural hydro fracturing. From this point of view we suppose that it is possible to introduce lower and upper limit of P_{pc}, controlling petroleum products mobility.

Despite of all our efforts, we cannot find out reliable analytical or field data discussing the problem of P_{pc} lower limit. Therefore we speculate that common information of the pore-throat size of continuous plays could help in searching of a proper decision. As it was discussed above, this type of plays covers rock strata, containing nano-micro structure of the pore space. The size interval more often averages near 0.05-50 nm (0.005-0.05 μm). Consequently, implementing standard calculation procedure, capillary pressure is expected to be in the interval of 1.4-14.0 MPa. This suggestion is in agreement with Zhengjian Xu et al (2017) results, obtained for Triassic Chang 6 Member in the southwest Ordos Basin, China. Cited authors, performing modern techniques, have measured values for trapping pressure, which hesitate near 5-10 MPa excess pressure (Fig 5 and Table 5 of the work). Through recalculation of the author’s data we obtain values for corresponding pressure coefficient 1.12-1.36 (average 1.22). Consequently, if the formation pressure of the source rocks forms P_{pc} > 1.22, generated petroleum products may leave the “birthplace”. This suggestion is supported by the field data of the cited authors. They formulate the conclusion that calculated excess pressure overcomes filtration obstacles and gives start for filling the tight reservoirs of Member 6. Based on this, we conclude that the searching lover limit of the P_C may be drown speculatively near 1.20-1.25.

As regards the upper limit, there is broad consensus that P_{pc} values > 1.8-1.9 corresponds to the stress regime initiating process of natural fracturing that is, generating of filtration conduits, providing fluid mobility. Detailed information over this matter was provided by comprehensive investigation of Wanzhong Shi et al. (2013). They collect large scale field data from Qiongdongnan basin (China) and give evidences that P_C > 1.9 leads to hydro fracturing.

The presented above logical construction, regarding lower and upper limit of P_{pc} may schematically be summarized as follows:

1. if P_{pc} within the formation source rocks < 1.22, then HC products mobility practically is negligible, which leads to the origin of a certain (in-situ) continuous accumulation;
2. if 1.22< P_{pc}<1.9 a quasi-continuous plays is likely to form;

3. if P_{pc}>1.9 more likely to occur natural hydro fracturing, changing the original tight rocks into the conventional fractured reservoirs.

Accounting for the broad diversity of principal stress profiles of rock sequences from basins worldwide, the presented above concept, regarding the role of P_{pc} values, should be accepted only as a preliminary attempt. However, we believe that the described rough ideas of a quantitative approach to determine overpressure control on the migration processes may help to better understanding of continuous play origin.

As final remarks to the presented above aspects of continuous accumulations origin, author is far away from the assumption that outlined postulates will address all the petroleum accumulations within the presented framework. The spectrum of petroleum localizations worldwide is too large, which unavoidably suggests vast existence of intermediate position and/or borderline field cases. It also means that the problem of continuous accumulation comprehensive description is still "open" and its decision appears as the main purpose of the future development of theoretical and practical petroleum geology.

Conclusion

As a result of performed analysis, we propose a new model for continuous accumulation origin, in which the magnitude and style of primary migration have the leading role. These parameters, as an integral result of the cumulative influence of number of factors, may control the formation processes as follows:

- If the primary migration is 100 % restricted by filtration barriers a certain (in-situ) continuous accumulation is formed; in this case pressure coefficient (P_{pc}) is more often < 1.22.
- In case of limited transfer of HC products to nearest beds or partly realized migration, there are condition for quasi-continuous accumulation to be formed; pressure coefficient is 1.22< P_{pc}<1.9;
- If P_{pc} >1.9 more likely to occur natural hydro fracturing, changing the original tight rocks into the conventional fractured reservoirs.
- When high level of expulsion efficiency is in force and petroleum products undergone notable buoyancy effect, than these settings are typical for enrichment pattern of conventional accumulations;
- The portion of the expelled products of continuous plays is quite smaller than the portion of the products not affected by the expulsion (e.g. in-situ products), which suggests broad genetic diversity of unconventional plays, compare to the conventional analogous.

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