DISCUSSION ARTICLE

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New representations on oil and gas origin in connection with the opening of the phenomenon of reserves replenishment in exploited oil fields

A.A. Barenbaum

Institute of Oil and Gas Problems of the Russian Academy of Sciences, Moscow, Russian Federation

E-mail: azary@mail.ru

Abstract. New ideas about the origin of oil and gas are discussed. They are caused by the discovery of the phenomenon of replenishment of oil and gas reserves in exploited fields. This phenomenon was discovered by the Russian geologists a quarter of a century ago, and a little later it was theoretically justified on the basis of the biosphere concept of oil and gas formation. As a result, the well-known «organic hypothesis» and «mineral hypothesis», which have long time competed in oil and gas geology are being replaced by new representations today, according to which oil and gas are the inexhaustible useful fossils of our planet. And their deposits are traps of movable carbon that circulates via the Earth's surface in three main cycles with periods of ~10^8-10^9, ~10^6 -10^7 and ≈ 40 years. The 40-year carbon biosphere cycle, which was not previously taken into account at all, plays a main role in replenishment of deposits. Its accounting makes it possible to balance the carbon and water cycles in the biosphere, taking into account the economic activities of people and modern formation of oil and gas in the bowels, and also open up the possibility of exploiting deposits as constantly replenished sources of hydrocarbons.

Keywords: oil and gas origin, carbon circulation via Earth's surface, replenishment of reserves exploited deposits

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Introduction

In the early 1990s, geologists of our country noticed that a number of fields where oil and gas production was suspended due to the collapse of the USSR, the war in Chechnya and/or property redistribution, began to produce industrial hydrocarbon inflows (HC) again after a few years. It was possible to notice these inflows in deposits that have been in operation for 50 years or more (Muslimov et al., 1991; Sokolov, Guseva, 1993; Dyakonov, 1998; Korneva, 1999; Smirnova, 1999; Ashirov et al., 2000; Zapivalov, 2000; Korchagin, 2001; Gavrilov, Skaryatin, 2004; and others). First, inflows were tried to be associated with an underestimation of the amount of recoverable reserves, or with the recharge of deposits from neighboring unproductive formations. However, by the 2000s, the widespread prevalence of this phenomenon became apparent, which led geologists to conclude that there is a constant inflow of new portions of hydrocarbons into the deposit. This phenomenon was not supposed to be known at that time as the organic and mineral hypotheses of oil and gas formation, which, according to the author (Barenbaum, 2014), was the reason for the scientific revolution by T. Kun (Kun, 1977), which occurs today in oil and gas geology. The revolution began with the birth of a new oil and gas paradigm a quarter century ago in our country. Its essence was first understood and formulated by B.A. Sokolov and A.N. Guseva (1993), stating: "oil and gas are renewable natural resources, the development of which should be based on a balance of hydrocarbon generation volumes and the possibilities of their extraction in the process of field exploitation".

In the early 2000s, these new views on oil and gas received the necessary theoretical justification in the biosphere concept of oil and gas formation (Barenbaum, 2004, 2014), which, based on more general concepts (Barenbaum, 2010), linked the formation of hydrocarbons with the circulation of carbon through the Earth's surface three cycles. Of these, the longest cycle of ~ 10^8-10^9 years is caused by the immersion of carbon-containing rocks during subduction of lithospheric plates and, as a whole, as a result of geodynamic processes. The second ~ 10^6-10^7 years is due to the conversion of organic matter (OM) and carbonates in the Earth's crust

during sedimentation. And the third, fastest – 40-year cycle is associated with the carbon cycle in the biosphere, including its underground part. This biosphere cycle is a consequence of the transfer of CO_2 from the atmosphere to the sedimentary cover by meteogenic waters during their climatic cycle.

At present, the carbon cycle system on Earth is in a state close to dynamic equilibrium (Barenbaum, 1998, 2004, 2014). Moreover, due to participation in the biosphere cycle, all cycles are closely interconnected and occur above the Earth's surface, which plays the role of a geochemical barrier, mobile carbon mainly circulates in the form of CO_2, and under it is restored to HC. Crossing the surface, and being part of either living organisms or mineral aggregates, it participates in oxidation-reduction processes, changing the chemical form and isotopic composition. Under the Earth's surface, carbon turns into hydrocarbons, which, due to low solubility in water, form their own accumulations in the form of oil and gas under favorable conditions.

Before the creation of the biosphere concept, a debate between proponents of organic and mineral hypotheses was on the question, which of the two geological cycles dominates the formation of oil and gas. The first claimed that the cycle was ~ 10^6-10^7 years, and the second that ~ 10^8-10^9 years. Cycle was not supposed to participate in the oil and gas formation of the biosphere. But it is plays the main role in replenishing the hydrocarbon of the developed fields.

The fact of the matter is (Barenbaum, 2012) that the volumes of carbon fuels consumption in the world are so great today that by extracting oil, gas and coal and burning them on the surface, a human being thereby violates the equilibrium between the cycles that has been developed on Earth over millions of years. As a result, carbon from the geological cycles enters the 40-year biosphere cycle. Being included in the biosphere cycle, this carbon replenishes the vacant traps of exploited deposits, however, it is mainly deposited on the shelf of the oceans and seas in the form of aquamarine methane hydrates (Barenbaum, 2007, 2017).

At present, a firmly established fact can be considered that the main mechanism of oil and gas formation in the bowels is the polycondensation synthesis of hydrocarbons from carbon and hydrogen oxides, which occurs in a water-saturated mineral matrix of rocks mechanically activated by natural seismotectonic processes (Chersky et al., 1985). This mechanochemical mechanism, called "geosynthesis" (Zakirov et al., 2013), was actually established by domestic scientists 40 years ago and was officially approved as Scientific discovery No. 326 in the USSR (Trofimuk et al., 1982). With this mechanism, the hydrogen donor in the hydrocarbon is water, and the carbon is organic matter, water-soluble CO_2, and readily soluble carbon-containing minerals.

The essence of the phenomenon is that, under the action of seismotectonic processes in rock minerals, intracrystalline defects are generated (Chersky et al., 1985). Diffusing to the surface of mineral grains, these defects form an energy-saturated layer that reduces the Gibbs energy of chemical reactions (Semenov, 1959). As a result, reactions that are thermodynamically possible at a temperature of 500 °C or more in a mechanically activated mineral matrix of rocks can also occur under "standard" conditions (T = 25 °C and P = 1 atm.). Such reactions, as shown by V.I. Molchanov (1981, 1992) and N.V. Chersky, V.P. Tsarev et al. (1984, 1985, 1986) include the decomposition of H_2O with the evolution of hydrogen, which is involved in the synthesis of hydrocarbons from carbon oxides (CO and CO_2). It should be emphasized that the composition of oil during field operation may vary (Barenbaum, 2017). At the exploration stage and at the initial stage of field development, "old" oil comes to the surface, which was formed in accordance with the ideas of the supporters of the organic hypothesis from the buried OM in the cycle of ~ 10^6-10^7 years. This oil may include OM and chemofossils deposited in the host rocks also in the carbon cycle of ~ 10^8-10^9 years. However, in the process of field development, especially in the late stages of their exploitation, hydrocarbons are accumulated in appreciable quantities in the released traps, which were also formed during geosynthesis from CO_2 and H_2O. As a result, "young" light oil, which arose in 40-year biosphere carbon cycle.

The mineral hypothesis insists on the fact that hydrocarbons are synthesized, but not formed from OM of sedimentary rocks. Thus, supporters of the organic and mineral hypotheses are right in their own way, but on different issues: the first is that the source of carbon in "old" oils is dead OM, and the second is that hydrocarbons of all oils are formed as a result of synthesis, although not specifying its mechanism.

This mechanism is geosynthesis. Irrefutable evidence of its participation in the formation of hydrocarbons of non-biodegraded oils, natural gases, and bitumens is given in (Glebov, 2002; Barenbaum, 2007a, 2019; Barenbaum, Ablya, 2009). The biosphere concept goes beyond this conclusion. Theoretical calculations of the balance of carbon and water during a cycle through the Earth's surface, based on the results of laboratory experiments (Barenbaum, Klimov, 2015), lead to the conclusion (Barenbaum, 2018) that a large volume of underground (meteogenic) water containing CO_2 is destroyed during geosynthesis, and the process mainly occurs in the upper ≈ 5 km layer of the Earth's crust. At the same time, if H_2, the overwhelming part of CH_4, dissolved in air N_2, and non-reacted CO_2, which has arisen from water, is degassed into the atmosphere, then liquid and solid hydrocarbons, as well as some methane,

remain in the bowels, creating large accumulations in geological structures – traps. Thermobaric conditions and the quality of the traps define whether there will be oil or gas in them. If there are good impermeable beds, gas accumulates in the deposits, and not very good impermeable beds – oil.

Another important conclusion is (Barenbaum, 2012) that the volumes of oil, gas, and coal mined in the world today are so great that the geochemical system does not manage to utilize the CO_2 generated during their combustion. As a result, the CO_2 content in the atmosphere increases, the processes of subsoil degassing and methane hydrate deposits on the World Ocean shelf are intensified, and the rate of filling of exploited fields with anthropogenic oil increases.

In all these processes, the 40-year biosphere cycle plays a major role. Its contribution to the replenishment of hydrocarbon reserves in exploited fields is incomparably higher than geological cycles with characteristic times of ~ 10^6-10^7 years and ~ 10^8-10^9 years, with which proponents of the organic and mineral hypotheses, respectively, associate the formation of oil and gas. The participation of different cycles of off-gas formation is inversely proportional to their periods; therefore, the biosphere cycle contributes ~ 10^4 times more to the replenishment of deposits than the first geological cycle and ~ 10^7 times more than the second.

The above results are reflected in many publications of the author. This article draws attention to the fact that the proposed explanation of the replenishment phenomenon actually "transfers" the solution to the problem of the origin of oil and gas from the exclusive conduct of oil and gas geology to the jurisdiction of other sciences. The author qualifies this fact as a scientific revolution in oil and gas formation. Its essence is discussed below with the involvement of the general theory of scientific revolutions T. Kun (1977).

Theory of Scientific Revolutions of T. Kun

T. Kuhn showed in his fundamental work that scientific revolutions are a natural stage in the development of mature natural sciences in which revolutions occur according to a scheme that is uniform for all sciences. The main provisions of this theory are as follows:

1. The basis of each mature science is a paradigm – a certain body of knowledge, which for a fairly long time has been recognized by a certain scientific community as the basis of its practical activity.

2. In their development, all sciences are experiencing crisis conditions. A symptom of a crisis is the presence of an anomaly, i.e. a certain natural phenomenon whose existence is not assumed by the paradigm or even contradicts it. Anomalies are almost always present, and overcoming them within the framework of the existing paradigm is the most important task of any science. Only anomalies lead to the crisis, which, firstly, occupy a prominent place in this science, and, secondly, for a long time resist scientists' attempts to include them in the paradigm.

3. The absence of a universally recognized paradigm calls into question the existence of this science. All members of the scientific community seem to be engaged in science, but the combined result of their efforts hardly resembles science in general.

4. Crisis ends with one of three possible outcomes: 1) normal science, in the end, is able to solve the problem that causes the crisis; 2) the problem, despite all efforts, is not amenable to solution and is left to the inheritance of future generations. And 3) the crisis is resolved as a result of the scientific revolution, which leads to the emergence of a new contender for the place of the old paradigm.

5. The latter case is the main path of development of science. There are two requirements for the new paradigm. The first is that it must solve some controversial and generally conscious problem that cannot be solved in any other way, and the second is to promise to maintain the ability to solve all other problems that have accumulated in science thanks to the previous paradigms.

6. When changing the paradigm, significant changes usually take place in the criteria that determine the correct choice of problems and their solutions. Some old problems may be transferred to another science or declared completely "unscientific". Other problems that were previously not significant in the new paradigm may themselves become prototypes of significant scientific achievements.

7. Such a restructuring is very painful for the scientific community. Any mature science is aimed at developing those phenomena and theories whose existence the paradigm obviously implies. New phenomena are often overlooked altogether. Scientists, in line with normal science, do not set themselves the goal of creating new theories, usually they are also intolerant of others creating such theories.

The specifics of the scientific revolution in oil and gas geology

Transition to the new oil and gas paradigm of B.A. Sokolov and A.N. Guseva (1993) in oil and gas geology is fully consistent with the theory of T. Kuhn. Everything is needed here: the discovery of an anomalous phenomenon – replenishment of oil and gas at exploited fields, and the futile attempts of geologists over the past 25 years to solve this problem, and, finally, the emergence of a new contender for the place of the old paradigm – the biosphere concept of oil and gas formation. However, to understand the essence of this

revolution, it is important to emphasize that, following T. Kuhn, gas-oil geology in its present state is not able to solve the problem of oil and gas formation. For the first time, the biosphere concept has become a science (Barenbaum, 2013, 2015). But what was before the biosphere concept? What problems has oil and gas geology been solving for at least the last 100 years? The situation here is as follows. All this time there have been two hypotheses – "organic" and "mineral", which played the role of independent scientific paradigms in oil and gas geology. Supporters of the first argued that oil and gas arise in the deposits themselves from organic matter coming "from above" – from the Earth's surface. Whereas the latter insisted that gas and oil hydrocarbons enter the fields "from below" – from deep Earth bowels, where they are formed. Each of the paradigms was supported by a large number of supporters and relied on the results of numerous experiments and theoretical studies. Nevertheless, this did not eliminate the known difficulties inherent in the paradigms themselves, which did not allow the scientific community to make the final choice in favor of one of them. Adherents of different paradigms blamed each other for these difficulties, but did not take it personally. The absence of a universally recognized paradigm regarding the origin of oil and gas – and this is a key issue in oil and gas geology, according to Section 3 of T. Kun's theory, casts doubt on the fundamental ability of oil and gas geology to solve this problem. Kuhn's verdict that in such a situation "All members of the scientific community seem to be engaged in science, but the combined result of their efforts hardly resembles science in general," is convincingly confirmed by the years of irreconcilable struggle of supporters of organic and mineral hypotheses on oil and gas formation. This fight is happening today. However, its purpose is not to establish the truth, but to dissociate itself with the supporters of the opposing side and identify weaknesses in their position. The key concepts used by both sides in their confrontation fully reflect the ups and downs of this struggle. Here are some of them: "organic and inorganic carbon", "oil and gas potential of the subsoil", "biogenic and abiogenic genesis of hydrocarbons", "sedimentary cover", "crystalline basement", "deep degassing", "oil source formations", etc. In the biosphere concept, these concepts are either devoid of physical meaning or not important. So, it is obvious that in nature there are no "organic" and "inorganic" carbons, but there is simply carbon, which changes its isotopic composition during chemical reactions. The phrase "oil and gas potential of the subsoil" loses its meaning. What kind of "potential" can we talk about if hydrocarbons are continuously replenished in deposits, and the speed of this replenishment depends on the technologies of field development, as well as on (Barenbaum, 2015), whether hydrocarbons are consumed in the region where they are extracted, or transported from places production over thousands of kilometers? In addition, in connection with the revision of views on the origin of oil and gas, oilmen are tasked with turning the fields being developed into "inexhaustible" hydrocarbon sources (Barenbaum, 2015). The concepts of "naftidogenesis" and "polygenesis", as well as the "mixgenetic" genesis of hydrocarbon oil are deprived of their foundations. According to the laws of chemistry there is neither "biogenic" nor "abiogenic" formation of hydrocarbons. And there is one mechanism – mechanochemical geosynthesis, based on the discovery of Russian scientists (Trofimuk et al., 1982). This mechanism refers to the reactions of polycondensation synthesis of hydrocarbons from carbon oxides (CO, CO_2) and hydrogen (H, H_2O), which are widespread in nature (Rudenko, 1969). Water serves as a hydrogen donor in hydrocarbons during geosynthesis, and carbon matter can be organic matter, water-soluble CO_2, and carbon-containing minerals. Geosynthesis occurs in a water-saturated mineral matrix of rocks mechanically activated by seismotectonic processes, and is accompanied by the decomposition of a large mass of groundwater into oxygen and hydrogen. It is the process that creates degassing, and not the intake of CH_4, H_2, CO_2, N_2, and other gases through the "degassing channels" from the "deep bowels" of the Earth.

The consequences of the scientific revolution

The above views are presented on the formation of oil and gas on our planet, initiated by the discovery of the phenomenon of replenishment of deposits and its explanation on the basis of the paradigm of B.A. Sokolov and A.N. Guseva. These ideas, while upholding the conclusions and recommendations of organic and mineral hypotheses on the search for new oil and gas fields, substantiate previously unknown possibilities of exploiting already discovered fields as "inexhaustible" sources of hydrocarbon raw materials. On the whole, new views on the origin of oil and gas are in very strong contrast with the ideas of organic and mineral hypotheses, so the transition to them is hardly a scientific revolution in the problem of oil and gas formation. Therefore, we focus on a number of provisions of new ideas, which the author considers as the result of a scientific revolution in oil and gas geology.

- Oil and gas are the inexhaustible minerals of our planet, formed during the geochemical cycle of carbon in the biosphere and water through the Earth's surface. Currently, this system of the cycle is in a state close to dynamic equilibrium, which provides a balance between the descending and ascending flows of carbon during its circulation through the surface.

- In the system of the carbon cycle, three interacting cycles should be distinguished: two geological ones with

characteristic times of ~ 10^8-10^9 and ~ 10^6-10^7 years and climatic ≈ 40 years. The first cycle (geodynamic) is associated in part with the subduction of lithospheric plates. The second cycle (sedimentary) is due to the burial of OM in sedimentation processes. And the third (biosphere) cycle is caused by the transfer of water-dissolved CO2 from the atmosphere to the sedimentary cover by meteogenic waters during their climatic cycle.

- All three cycles are involved in oil and gas production, but in different ways. The processes of the first cycle at times of ~ 10^8-10^9 years form large geological structures that serve as hydrocarbon traps and today act as oil and gas fields. The processes of the second cycle take part in filling these traps with hydrocarbons formed from OM of sedimentary rocks over a period of ~ 10^6 years. And the third cycle is the modern process of oil and gas formation due to the climatic cycle of water.

- The mechanism of hydrocarbon formation from OM (second cycle) and from groundwater CO_2 (third cycle) is the same. This is the mechanochemical geosynthesis of hydrocarbons in a water-saturated mineral matrix of rocks activated by seismotectonic processes, leading to the formation of gas-oil hydrocarbons and free hydrogen H_2.

- Replenishment of exploited hydrocarbon deposits is a consequence of modern economic activity of people. Removing oil, gas and coal from the bowels, a person violates the carbon cycle system that has developed on Earth over millions of years. As a result, carbon, which previously participated in long geological cycles, enters the 40-year biosphere cycle, where it is redistributed over all reservoirs of the biosphere.

- Maintaining a state of dynamic equilibrium, the biosphere system removes excess carbon from the biosphere cycle through various processes. In one of them, excess carbon entering the Earth's surface is converted into hydrocarbons, which fill the vacated traps of the developed deposits. It is this process, and no other, that replenishes depleted deposits with light hydrocarbons.

- The formation of aquamarine methane hydrates, which are now deposited on the shelf of the World Ocean in places of underground water flow from the continents, is even more effective (Barenbaum, 2007). Methanohydrates act as "chemical" carbon traps in the form of methane. According to some estimates (Solov'ev, 2003), methane hydrates contain more than half of all known hydrocarbon reserves of our planet. Moreover, as calculations show (Barenbaum, 2017a), the amount of methane hydrates themselves is growing by about 0.5 % per year. In addition to methane hydrates on the shelf of the World Ocean, conventional hydrocarbon accumulations are actively forming today (Barenbaum, 2015).

Conclusion

Summing up, the author of the article is convinced that these new ideas in the future will certainly receive recognition from experts who today adhere to the positions of organic or mineral hypotheses. However, it is still difficult to predict when this happens. Time will tell.

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About the Author

Azariy A. Barenbaum – PhD (Physics and Mathematics), Leading Researcher, Institute of Oil and Gas Problems of the Russian Academy of Sciences

3, Gubkina st., Moscow, 119333, Russian Federation

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