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21st-Century Oil and Gas Industry Research and Practices: New Petro-Geological Teaching

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Abstract

The article discusses a new approach to the processes of oil formation. The author offers his own paradigm, or angle of vision into origin and life (space-time dynamics) of an oil and gas play. Special attention is paid to the analysis of risks and uncertainties in the petroleum business.

Keywords: Genesis of oil, A living fluid-dynamic system, Risks and uncertainties, Rehabilitation cycles

Introduction

The 21st century has been marked by many unexpected events to humanity in various spheres of life and economics, including oil and gas industry. While petroleum, or crude oil, mean energy source, fuel and raw material (a feedstock) for many industrial needs, upstream oil and gas companies identify, extract, or produce raw materials.

Advancements in R&D field of the "petroleum business" have largely been the primary concerns of humanity. About 70,000 oil fields have been discovered in the world, of which 1,500 are large. As many as 70 countries have proven oil reserves, more than 65 countries produce oil on their territory. New sources of hydrocarbons found in conventional, as well as tight and shale reservoirs have been discovered, with application of innovative methods and technologies for their extraction and utilization.

In the 20th century, most scientists adhered to the organic (sedimentary-migration) theory of the origin of oil, however there were some drawbacks which with the advent of the 21st century have been translated to more contradictions and questions. For the time being, there are about a dozen different authoritative concepts (theories) of oil formation in the world, including biospheric, abiogenic, magmatic, etc.

In his early career of a geologist, the author was an active supporter of the organic theory of the origin of oil. Thus, in 1962 he defended his PhD thesis titled "Geological and geochemical characteristics of Mesozoic deposits and oil and gas potential in the Ob-Irtysh interfluve", which presented the first comprehensive geochemical study of the Mesozoic of Western Siberia. N.B. Vassoevich, one of the founders of naftide genesis theory, agreed to be an opponent for this dissertation. Its importance consisted in establishing geochemical member A (in the cross-section of the Kulomza formation, which later became known as Bazhenov Formation) was recognized as oil play.

Many years of experience in oil and gas geology led the author to the conclusion about the limited applicability of the classical theory, since accumulations of hydrocarbons are found everywhere. In his famous (Geology of Petroleum), A.I. Levorsen (California, USA),

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stated at the end of the 20th century : " The problem of oil-and-gas origin now loses its significance as a necessary prerequisite in planning the exploration works <...> there is no need to look for any special source rocks" [p. 488].[1]

Now the author holds to the view that does not suggest adherence to any concept of the origin of oil. It would seem, that it is all but impossible to create a general theory of naphthidogenesis suitable for any geological settings. No catagenetic stages are deemed to be universal, either. Academician Andrey A. Trofimuk stated: "The lower boundary of the zone of oil generation should be lowered to a depth of 8000-10000 m. Deep drilling technology has proved that at these depths oil formation occurs in apocatagenesis, rather than under conditions of mesocatagenesis, alone. The expansion of the boundaries of oil formation zones entails a significant increase in the predictive estimates of hydrocarbon reserves and resources" [p. 333].[2]

Uncertainties, Risks and Accidents in the Upstream Oil and Gas Industry

Due to the scale of risks, uncertainties, errors and catastrophic accidents associated with prospecting, exploration and production of hydrocarbon accumulations we are confronted with the need to review the fundamental principles of the oil and gas business.

Geological and geophysical factors that a scientific forecasst draw on are of particular importance. As an example of erroneous predictive geological estimate, we can mention the attempts to discover the “giant”Mukluk field near the Prudhoe Bay, North Slope of Alaska, where a test well worth of $ 1 billion was drilled in 1983, which, however, encountered at a depth of 2438 m only salty water instead of what was anticipated to be a producing reservoir. Another type of factors – technological errors – can be illustrated by the accident that occurred on April 20, 2010 in the Gulf of Mexico, when the oil drilling rig *Deepwater Horizon*, operating in the Macondo Prospect in the Gulf of Mexico, exploded and sank resulting in the largest spill (75 thousand km^2) of oil in the history of marine oil drilling operations.

Many geophysical methods certainly require improvement. V.S. Mogilatov , one of the leading geophysicists, an employee of the Trofimuk Institute of Petroleum Geology and Geophysics SB RAS (Siberian Branch of the Russian Academy of Sciences): " Errors are inherent to any geophysical interpretation, there is no 100% reliable one."

In addition, the geopolitical factor is of great importance – the lack of coherence between the main oil-producing countries and the fierce struggle for markets leads to a global planetary crisis.

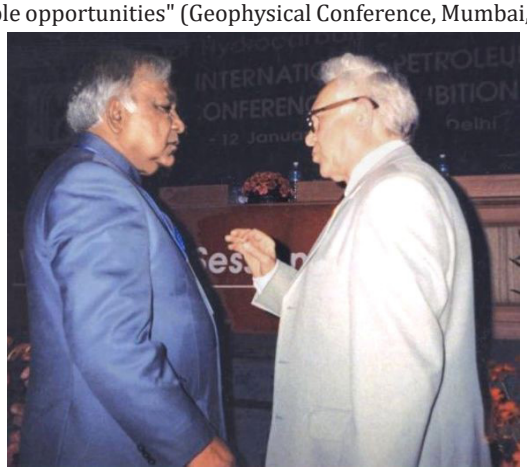
The following symbolic formula is proposed to describe these risks:

P = H + H + G1 + G2 + G3 + T1 + T2 + E + K + F + P,

where H is fundamental science, H is the human factor (professionalism of the personnel and management); G1, G2, G3, – geological, geophysical and geographical information in full, with generalizing models; T1, T2 – engineering and technology, taking into account innovative methods and systems of effective management of production processes; E, K – environmental factors, natural disasters; F – financial (investment) opportunities; P – political factors. Depending on changing circumstances, some of these factors may be decisive. Each of them requires an updated paradigm.

The author believes that the main object of oil and gas research is the fluid–rock system which suggests reservoir rocks in which oil has accumulated (or an emergent accumulation of hydrocarbons).[3-6]

The fluid-rock system behavior is a crucial moment in petroleum geology, since it depends on a large number of uncertainties. This was especially noticeable in India.[4] Mr. Subir Raha, the then CMD, ONGC paid special attention to the generation-migration entrapment of hydrocarbons involves innumerable variants, which leads to uncertainties and inherent risks in exploration ("Hydrocarbon formation, migration and accumulation - he said, - may occur in countless ways, which leads to uncertainties and inevitable risks in exploration. Geo-scientists have an important role to play in reducing these uncertainties and risks, and converting them into profitable opportunities" (Geophysical Conference, Mumbai, 2004).



A one-on-one conversation of the professionals Mr. Subir Raha, the ONGC President with Nikalay P. Zapivalov Petrotech-2003. Deli, India

Among the currently prevailing numerical mathematical and laboratory modeling methods none allow for confidence in model-based predictions. In this regard, it may be recalled that many a priori geological and geophysical models proved to be untenable at the Kola ultra-deep well. Professor George Box , a well - known expert in mathematical statistics and modeling , wrote: "In essence, all models are wrong, but some of them are useful". The same was

clearly shown in his lectures in 2015. The same was clearly shown by Xiao-Hui Wu, Senior Earth Modeling Advisor at ExxonMobil Upstream Research Company. He asserted: "It is possible to reduce the source of uncertainty by reducing modeling and numerical errors with the use of parameters based on field data".

Some well-known scientists and industry professionals had a special intuition rooted in extensive experience based on a "broad search" strategy. Among them are AA Trofimuk, NA Kalinin, NN Rostovtsev.

Author's Concepts

After 70 years of educational, practical and scientific work in petroleum geology, developing the basics of geofluidodynamics of oil and gas saturated systems, the author has arrived to a conclusion about the need to develop a new paradigm.

A detailed overview of modern theories and concepts is given in the book "Fluid dynamic models of oil and gas reservoirs".[3] In their work, the authors make a special focus on local fluid dynamic systems, such as oil and gas accumulations, in other words, natural and technogenic objects during their exploration and development. Such objects, unlike oil and gas-bearing basins and large geosystems, can be subjected to accurate measurements, systematic observations and management of individual processes.

- Hydrocarbons have been found everywhere and will always be ubiquitously widespread. Oil and gas generation and distribution are associated with the location of the maximum fluid-saturation zones (foci).[7]
- By his paradigm the author asserts that an oil reservoir is a live (acting) fluid-source rock system. Assuming that oil deposit as a fluid-rock system is highly changeable, we conclude that continuous systematic observation is needed, with an incessant registering of the key parameters of the system. In particular, the values of hydrophilic and hydrophobic properties change with time in all such systems, and these values are to be known at each specific moment of the system's life
- It is established that the actual reserves of oil and gas can be replenished in the process of newly generated hydrocarbon masses within the system or their migration from other parts of the Earth's crust. Therefore, as data in different regions of the world confirm, many oil and gas clusters are young.[5-12]

Paradigm (from Greek paradeigma) is a strictly scientific theory embodied in a system of concepts expressing essential features of reality.

Soviet Encyclopedic Dictionary, 1980, p. 977

To clarify the processes of fluid-rock systems, I turned to Ivan Y. Kulakov, Head of the Laboratory of Seismic Tomography, Corresponding Member of the Russian Academy of Sciences, with some questions: What are the changes in volcanic matter on the surface and in the depth of volcanos? How fast and deep do these changes proceed? Here is the answer: "We investigated changes inside volcanos Spurr and Nevado del Ruiz during their eruptions. In the case of Spurrwe could see that during the year the enhanced Vp/Vs ratio anomaly shifts upwards by more than a kilometer. Under Nevado del Ruiz, the anomaly that existed there at the beginning of the degassing period tend to gradually vanish. Assumingly, such fairly rapid changes are associated with the migration of fluids and their conversion into gas. With our methods, we cannot detect faster changes, although they may be taking place. Related surface deformations can be observed using satellite technologies. Obviously, the deeper, the smoother the changes".[10]

Thus, my assumption is confirmed that fluid- source rock systems in a wide variety of settings can work on a similar principle.

- An oil and gas saturated reservoir (deposit) consists of two interconnected subsystems: rocks (minerals) and fluids (oil, gas, water) and is an integral system having the properties of fractal structures. Fractal properties were studied at the Verkh-Tarskoye oilfield (Novosibirsk region) using special time series characteristics – the Hausdorff dimension and the Hurst exponent. In the process of oilfield development, the composition and properties of all components of the system, fluid and mineral, change repeatedly and significantly, including mineralogical changes during metasomatism.
- Fluid dynamic systems are highly mobile and reactive. Depending on the provoking external influences, they are either stable (equilibrium state) or perturbed (nonequilibrium state). The perturbed system has all the signs of disorder (chaos).[3]

Active works during development of an oilfield produce a strong perturbation in the near-equilibrium system, and substantially deform its natural parameters. In case of a moderate perturbation, the selforganizing system restores its balance; a prolonged or intensive perturbation considerably exceeding the critical threshold will destroy the system. As a result, formation pressure drops, the flow rate dramatically decreases, the reservoir becomes flooded and the rock mineralogical composition changes.

- Experience shows that the maximal draw-down pressure (formation pressure – bottom-hole pressure) must not exceed 5-8 MPa (FP – BHP: ≤ 5÷8 MPa.
- The formula of the energy state of the deposit: $dT/dP = 1/Sv$, where Sv is the volume entropy density.
- Rehabilitation cycles should be used to restore the energy potential of the system.
- Over-intensive (forced) production of easy-to-recover oil re-

serves (EOR, Enhanced Oil Recovery) with prolonged use leads to rapid depletion and destruction of deposits.

Many of these concepts have been discussed in numerous publications by the author in Russia and abroad.

Conclusions, Suggestions

Now it is necessary to concentrate efforts for the extraction of residual (hard-to-recover) oil in developed or mothballed fields, including in Western Siberia and newly generated volumes of hydrocarbon masses. The amount of such oil can now reach more than 50% of previously explored reserves. Rehabilitation cycles in the process of developing an oilfield and gentle (moderate) methods of oil recovery are the basis of extension of oilfield life and allow its longtime development. This allows getting maximum oil recovery. (IOR, Improved Oil Recovery) as opposed to over-intensive commercial production by intensive, forcible methods that destroy the oilfield as a system (EOR, Enhanced Oil Recovery). I have published an article on this issue,[11] which has become very popular in the ResearchGate rating international scientific community.

Currently prevailing numerical mathematical and laboratory modeling methods do not allow for a confident forecast. In order to obtain reliable information, full-scale modeling is required.

In order to properly manage the oil production, it is necessary to study the oil deposit in detail in a continuous mode using special sensors located directly inside the humanity

It is extremely important to have permanent research sites at the fields being developed, as well as to carry out regular monitoring at all previously drilled wells. The author insists on arranging a integrated research and practical test ground on the basis of the Verk Tarskoe and Maloicheskoe oilfields in the Novosibirsk region.

Special attention should be paid to the problem of replenishment of hydrocarbon reserves in developed and mothballed fields.

It is necessary to apply rehabilitation cycles to restore the energy potential of the system.[8] Methods and technologies of active rehabilitation (as in medicine) should be provided. To achieve an effective and fast result.

It is necessary to protect and replenish hydrocarbon resources, because they are necessary for humanity in the long term.

The modern market-governed license-granting system of subsurface use in Russia is not correct. The need to replenish reserves and scientific research of the subsoil strongly dictates other forms of the subsoil management.

A Few Words About the Prospects of Western Siberia

Currently, the fate of the main oil and gas region of Russia is seen by many in the rapid acquisition of large production potential due to the Bazhenov formation and Paleozoic. Especially big bets are placed on bazhen, due to which it is expected to have 20 billion tons of oil reserves in the near future. But it must be borne in mind that this suite has small thicknesses and very different properties and parameters that determine the focal nature of possible productivity. In many regions of the world, the development of such facilities is abandoned for environmental reasons.

As for the Paleozoic project, this is another epic. The "Paleozoic basement" means a huge and diverse complex of rocks (Proterozoic and Paleozoic) occurring at different depths, which determines the possibility of oil formation and oil saturation in different rocks and tectonic blocks. This is confirmed by geological and geophysical data.[5,11] Deep petrothermal (heat) energy contributes to the desired geofluidodynamic processes. However, the Paleozoic project in Western Siberia remains at the stage of studying and learning new facts and patterns.[9] Granitoid bodies and other focal zones with active modern geofluidodynamics (gradient entropy) are designated as promising objects. It is necessary to drill deep wells (up to 15 km), comprehensively and patiently test interesting objects. In case of weak inflows or viscous (bitumen) oil, it is recommended to use vibration technologies (Institute of Mining SB RAS, Novosibirsk). They belong to the Improved Oil Recovery (IOR) category.

In the geo-sciences, numerous geological and geophysical research directions are developing relatively successfully, however there is no unified scientific and practical program, with the main objective to study processes of the Earth's evolution, which control global and local-level processes and natural disasters. We need to develop new ways of thinking in the global knowledge full of contradictory ideas and concepts, in order to design better solutions, services and experiences that solve our current problems.

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Conflicts of Interest

Author Declares that there is conflicts of interest.

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