

СЕКЦИЯ 20  
 ГЕОЛОГИЯ, ГОРНОЕ И НЕФТЕГАЗОВОЕ ДЕЛО  
 (ДОКЛАДЫ НА АНГЛИЙСКОМ И НЕМЕЦКОМ ЯЗЫКАХ)

PETROLEUM GEOLOGY IN THE 21<sup>ST</sup> CENTURY

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Hydrocarbons are reported to be found in all strata of the Earth's crust and are supposed to occur in the cosmic space, too. As to genesis of hydrocarbons, there are various equally authoritative positions.

The myth of «Peak Oil» has been refuted with new evidence and facts. The oil recovery rates may depend on various natural and technogenic fluctuations as well as geopolitical situation. However, a great variety of hydrocarbon sources, both conventional and unconventional, have been discovered and are still being discovered; innovative methods and technologies for hydrocarbon production and utilization are being created.

On the whole, it shows that the era of hydrocarbon civilization will never end (Fig. 1-4).

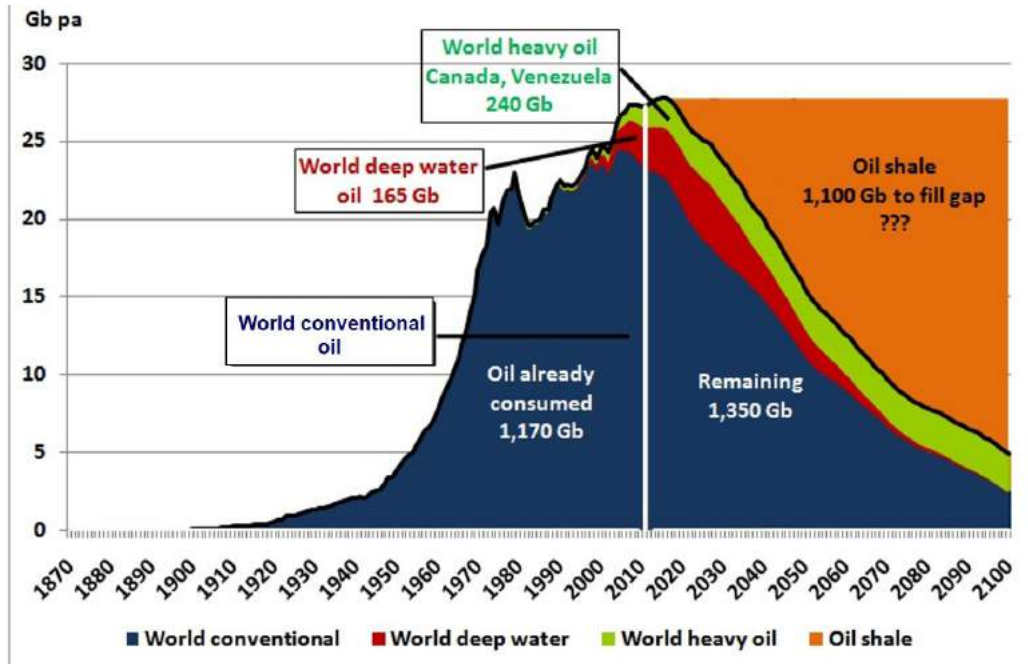


Fig. 1. World production oil by years  
 (Bureau of Infrastructure, Transport & Regional Economics, Australia, report No 117)

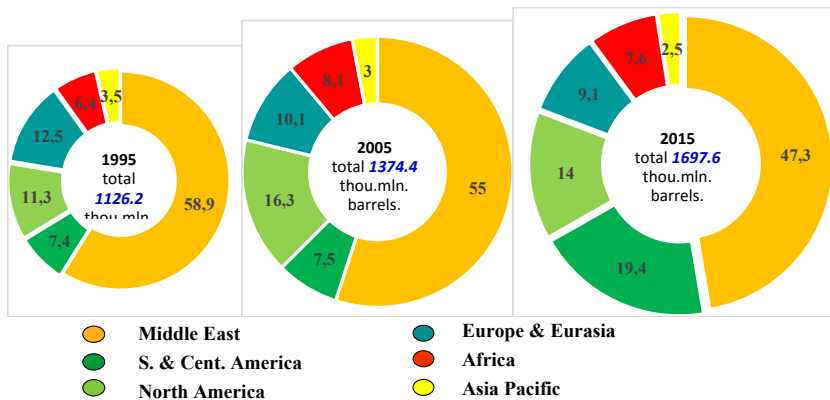


Fig. 2. Distribution of proved oil reserves in 1995, 2005 and 2015, %  
 (BP Statistical Review of World Energy 2016)

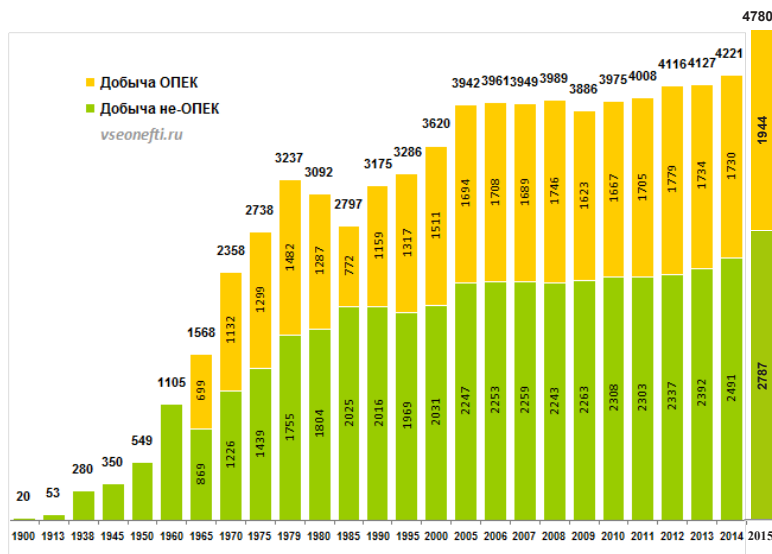


Fig. 3. Oil production in the world, mln. tonnes (BP Statistical Review of World Energy 2016)

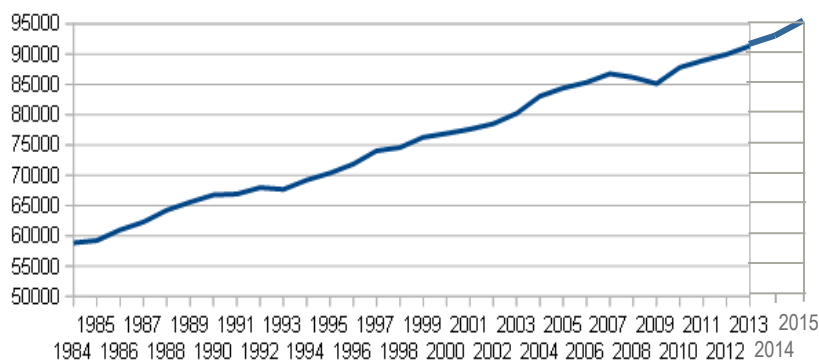


Fig.4. Dynamics of oil consumption in the world, thou. barrels per day (BP Statistical Review of World Energy 2016) (2014 – 93109; 2015 – 95008)

70 countries in the world possess proven oil reserves; over 65 countries carry out oil production; and practically all countries in the world, in a varying degree, use hydrocarbon raw material for various purposes.

Our Earth is turning into a giant oil planet.

It is clear that there is a great amount of hydrocarbon resources in the Earth, but it is essential that this immense wealth so important for humanity should be used in a rational way.

In Russia, oil production is also constantly growing, except for the period of 1989-2001 (Fig.5).

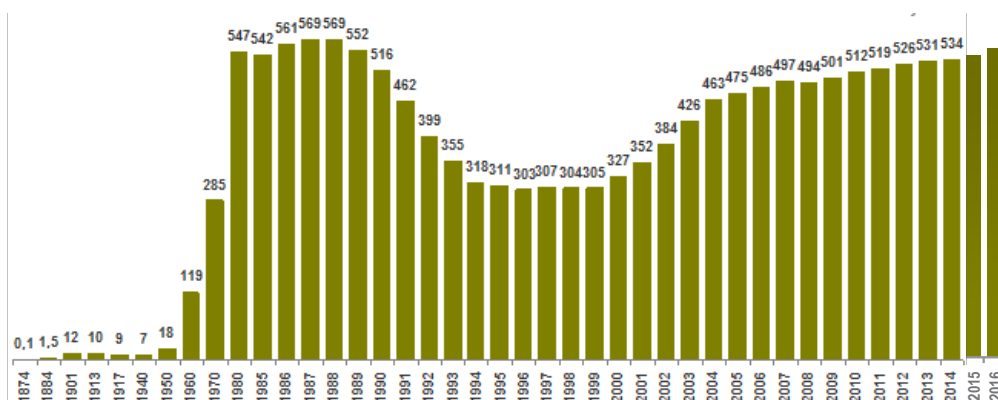


Fig. 5. Oil production in Russia, mln. tonnes (<http://vseonefti.ru/>)

The role of alternative energy sources can be illustrated by the example of India. India uses all possibilities to develop various power sources: wind energy, solar energy, gas hydrates, tidal power, dry manure fuel, producing methane from coal layers etc. Through using all available sources of energy, it is planned to increase energy consumption in India up to 400.000 MW in 2030 against 130.000 MW in 2008.

However in the 21<sup>st</sup> century the traditional source of energy – oil and gas – will remain the key factor in Indian industry (energy, motor fuels, and petrochemicals). In 2014, oil demand in India was over 3,8 mln bpd, or almost 200 mln tonnes per year; in 2040, oil demand in India will be 9,8 mln bpd, or 511 mln tonnes per year.

An inspiring fact: Digboi oilfield (state of Assam, India) was discovered «with the help of elephants» as long ago as in 1867 (Fig. 6), and is still in operation.

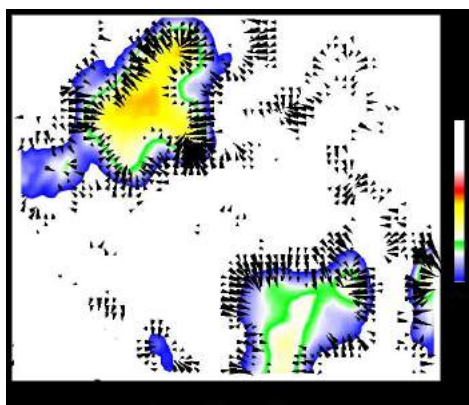


*Fig. 6. The wooden rig at Digboi: the first oil well of India*

Oil-and-gas-saturated stratum is an integral interrelated system of rocks (minerals) and fluids (oil, gas, and water). An oilfield is a «living» fluid-rock system, subject to the laws of spontaneous autoregulation [7]. It is necessary that research and practical efforts be focused on study and control of the oilfield «life». This «life» depends on a great number of rapidly changing factors with regard to their gradients; oil deposits may be formed, then dissolve, and after that regenerate again [2]. This is why many of oil-and-gas accumulations are young.

At present, forced commercial development of oilfields is being practiced all over the world, in order to quickly produce easy-to-extract oil with the use of all available super-intensive methods and technologies (Enhanced Oil Recovery). As a result, the residual oil (reserves) now amounts to 55-70%. To extract this residual (hard-to-extract) oil from the productive strata, conceptually new ideas and technologies are required. Efforts should be focused on developing mature oilfields in a soft, sparing and non-damaging way (Improved Oil Recovery).

Nowadays a lot of such innovative techniques are available, including aerial and space survey. One of the examples is **DFM-method** (dynamic fluid method, V.B. Pisetsky, Yekaterinburg, Russia) [4] (Fig. 7).



*Fig. 7. DFM-method: map of differences of fluid-dynamic parameters. The raster color shows the changes in fluid pressure gradients; the arrows show differentiated fluid flow vectors.*

DFM-method (dynamic fluid method) for estimating the gradient pressure is based on a complex analysis of the seismic parameters and other geologic and geophysical data. DFM-technology is aimed at mapping the productive zones (foci) with active fluid cross-flows.

Another two examples are **SAM-technology** (spectral analysis of microseisms, G.V. Vedernikov, Novosibirsk, Russia) [6] which, like DFM-method, allows distinct determination of the highly productive foci during exploration and production of oilfields, and **GasGun® technology** (Dr. R.A. Schmidt, GasGun Inc. Co., USA) [5].

In fact, GasGun® technology (Fig. 8) is an improved and more efficient version of hydraulic fracturing technique (Improved Oil Recovery). Its results are shown in Fig. 9.

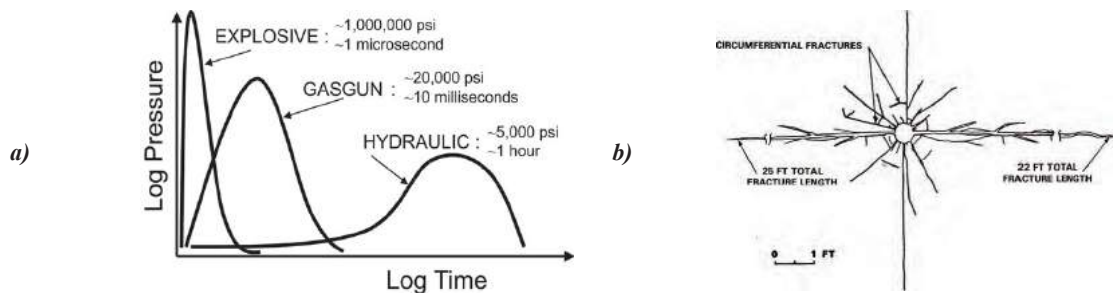


Fig. 8. Gasgun®: technology of stimulating wells with solid propellants which create oscillating gaseous jets in the perforated well or even in the open hole. a) Schematic dependence between pressure and time for three various stimulation methods. b) Typical fracture pattern produced by the Gasgun® method in underground experiment

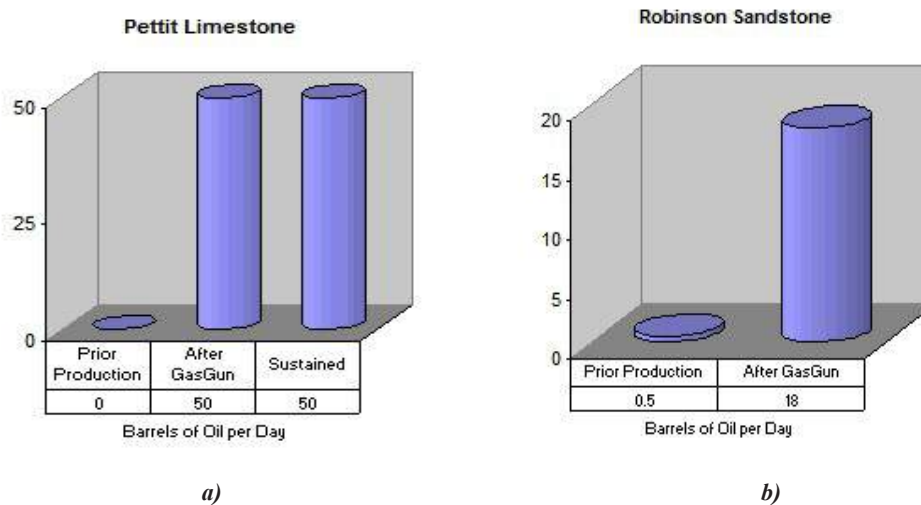


Fig. 9. a) Arkansas. Formation: Pettit Limestone (new well) Formation Depth: NA Prior Production: 0 BOPD After Stimulation: 50 BOPD Sustained: 50 BOPD.  
b) Illinois Formation: Robinson Sandstone Formation Depth: 892' Prior Production: 0.5 BOPD After Stimulation: 18 BOPD

All these technologies are patented.

All points considered, a number of conclusions can be made:

1. Oil deposit is a living fluid-rock system with properties and parameters rapidly changing under the influence of natural and technogenic factors.
2. Oil deposit can be formed, dissolved, and re-assembled. The hydrocarbon components may increase or decrease with time. It may be replenished either at the expense of newly formed hydrocarbon masses inside the system, or at the expense of additional inflow from other parts of the Earth's crust.
3. To look at special source rocks as the key factor of oil genesis is a wrong position, which should be excluded from petroleum theory and practice.

As early as in the middle of the 20th century, A.I. Levorsen (California, USA) arrived at the conclusion that oil-source rocks have no concern with actual prospecting and exploration works. In his famous «Geology of Petroleum» (1967) he stated (cited in a reverse translation from the Russian edition): «The problem of oil-and-gas origin now loses its significance as a necessary prerequisite in planning the exploration works. The reason is that petroleum-like hydrocarbons are discovered in almost any non-reservoir rocks. The amount of residual oil [micro-oil] dispersed in these rocks exceeds all the proved reserves in the Earth. Therefore, there is no need in search for special source rocks» [3].

In separate regions highly-bituminous strata (the so-called oil-source formations) are likely to be considered as prospective objects for shale-oil production with the use of improved techniques. However, the possibility of environmental harm and of injurious changes in the upper crust should be strictly kept in mind.

1. In petroleum geology, the key factor is dynamics of the system state depending on a large number of uncertainties. My friend Mr. Subir Raha, former President of ONGC (India), paid special attention to this feature: «The generation-migration entrapment of hydrocarbons involves innumerable variants, which leads to uncertainties and inherent risks in exploration. Geo-scientists have an important role to play in reducing these uncertainties and risks, and converting them into profitable opportunities» (Geological conference, Mumbai, 2004). We are obliged to find ways to raise the effectiveness of scientific research and practical results in upstream and midstream.

2. Global-scale development of the great Arctic mineral resources, including oil and gas, is likely to become possible only in the end of 21<sup>st</sup> – beginning of 22<sup>nd</sup> centuries, both because of natural difficulties, lack of technological and financial resources, and geopolitical games. Besides, environmental aspect is not properly elaborated as yet. This is especially true for Russian Arctic territories. All the strategies, plans, expert findings that are now being developed in this sphere are in fact only approbation of methods. However they are useful as a basis for preparing future joint projects, such as far-distance space flights.
3. In my opinion, for most regions of the world, the key factor in oil production in the 21<sup>st</sup> century will be the residual (hard-to-extract) oil at large oilfields already in operation where a well-developed diversified infrastructure is available. It amounts to 2/3 of all proved oil reserves. To extract this oil, novel methods and technologies are required (Improved Oil Recovery).
4. To be in proper control of the oil-production technological processes, a detailed study of the fluid-rock systems (oil deposits) should be made through bottom-hole apparatus with a wide use of smart (IT) gauges. There is a lot of research and methods already available; all that is needed is practical deeds. For this purpose, it would be useful to have R&D Petroleum Polygons, or at least test wells or sections, in the oil production regions.
5. Omar Khayyam wrote: «Thousands of observations and thousands of measurements are needed to avoid a single error». It is clear that only natural full-scale models are authentically reliable and effective.
6. To restore energy potential and other parameters of oil deposits, rehabilitation cycles are utterly necessary [1].

A living system requires medical approach. This is the essence of ecological paradigm!

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## MOOS WIE BIOINDIKATOR DER UMWELTVERSCHMUTZUNG

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Unter Bioindikation versteht man die Anzeige von abiotischen und biotischen Standortfaktoren durch biologische Systeme [4]. Als Bioindikatoren im weiteren Sinn bezeichnet man dementsprechend Organismen oder Organismengemeinschaften, die als Zeiger für bestimmte Umweltfaktoren natürlicher Art oder infolge menschlichen Einwirkens verwendet werden können.

Nach dieser weitgefassten Definition ist jede biologische Art ein Bioindikator, da sich im Laufe der Evolution jede Art an einen Komplex von Standortfaktoren angepasst hat und diesen im Besetzen der ökologischen Nische anzeigt. Diese natürliche Bioindikation macht man sich in der Land- und Forstwirtschaft, der Vegetationskunde und anderen Disziplinen schon seit langem zunutze. So sagt man, dass eine Art Feuchte- oder Kalkzeiger ist usw. Seit einigen Jahrzehnten interessiert man sich jedoch zunehmend für solche Bioindikatoren, die anthropogene Faktoren anzeigen. Im Zuge zahlreicher Programme und Projekte der Umweltüberwachung hat man weltweit schon eine unübersehbare Zahl an tierischen oder pflanzlichen Organismen als Bioindikatoren eingesetzt. Somit sind Bioindikatoren im engeren Sinn Organismen, die auf Schadstoffbelastungen mit Veränderung ihrer Lebensfunktionen antworten, also eine möglichst spezifische Reaktion (Reaktionsindikatoren) zeigen oder den bzw. die betreffenden Schadstoffe aufnehmen und anreichern (Akkumulationsindikatoren), also ,akkumulieren [1].

Moose sind eine Gruppe der Pflanzen und werden zusammen mit Flechten, Pilzen und Algen bezeichnet. Moose finden als Schadstoffindikatoren in vielen Ländern Verwendung, aber ihre Einsatzhäufigkeit spiegelt ihre besonders gute Eignung als Bioindikator bei weitem nicht wider, was vielleicht darauf zurückzuführen ist, dass die Bestimmung - von wenigen leicht kenntlichen Moosen abgesehen - relativ schwierig ist und einige Erfahrung erfordert.

Die Moose spielen eine sehr wichtige Rolle im globalen Ökosystem. Dort, wo Moose häufig sind, wie in Bergwäldern und Mooren, haben sie eine wichtige ökologische Rolle im Nährstoffkreislauf, da sie die Nährstoffe aus dem Niederschlag filtern, ferner für den Wasserkreislauf, da sie zum einen Nebel ausfiltern können und zu einem gewissen Grad auch den Niederschlag speichern können.

Mehrere Eigenschaften machen die Moose zu sehr guten Bioindikatoren: Sie nehmen Wasser und Nährstoffe über die Oberfläche auf und sind so der direkten Wirkung von Schadstoffen ausgesetzt; ihr kurzer Lebenszyklus führt zu raschen Reaktionen auf Umweltveränderungen; sie sind makroskopisch bestimmbar und sind ganzjährig präsent. Moose werden jedoch bis jetzt nur in Europa, Kanada, Japan und Neuseeland als Bioindikatoren verwendet.

Moose haben im folgenden genannte Eigenschaften, die sie als Bioindikatoren geeignet machen [2]: Moose decken