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Development of geospatial database on hydrocarbon extraction methods in the 20th century for large and super large oil and gas deposits in Russia and other countries

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Abstract. The project targets a geospatial database on hydrocarbon extraction methods in the 20th century for large and super large oil and gas deposits in Russia and other countries. The work was executed in sequential steps. At first domestic and international relevant sources of information were collected, merged and analyzed. The list of the attribute data base tables and their values have been elaborated from this analysis. The project's main objective is a comparative analytical study of the hydrocarbon extraction methods to assess the role of the RF on the global scale. To increase effectiveness of the results a multifunctional web-service is being developed based on the Esri Geoportal Server platform. The later is characterized by the following features: multi-level access to data; search by parameter presets; viewing and filtering of selected data layers using online mapping applications; sorting

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of metadata, including bibliographic information for each field. Such a complex approach as well as a multidisciplinary database will play an important role for solving various tasks in the area of oil and gas exploration and extraction. This article will present the results of this systems analysis study concerning the positions of different oil and gas countries in the list of leaders.

1. Introduction

This project is being developed in the framework of the program No. 28P of the Russian Academy of Sciences "Study of historical process of science and technology development in Russia: its place in the world scientific community, social and structural transformation".

Any scientific research in the field of natural science – spatial or object-oriented, in rare cases, can do without the study of large amounts of data information. Typically, the collection of such data sets requires considerable time and subsequently serious analytical research. The most convenient way for structuring and organizing large data sets is to create and further work with computer databases, in order to handle large volumes of data.

In the framework of the program of the Russian Academy of Sciences "Study of historical process of science and technology development in Russia: a place in the world scientific community, social and structural transformation" on the topic "Comparative analytical study of hydrocarbon production methods in the Russian Federation and other countries in the 20th century using computer technology, including spherical visualization", the authors carried out a comparative analytical study on the development of the hydrocarbon extraction methods in Russia and other countries for the period 1900–2000.

An integral part of this research was the creation of the database. Among the general requirements for the developed database we should include its legible logical structure that meets all the requirements of a specific scientific domain, that is essential for further effective interaction with the database and carrying out analytical research of the development of hydrocarbon production methods in the 20th century.

The database contains all the necessary initial information to study the development of production techniques in order to assess the global role of the Russian state in the field of the oil industry.

The database development consisted of a sequence of stages. The first one focused on the development of the concept of its creation. At this stage the authors have thoroughly studied the subject itself, including the list and description of objects, concepts and their parameters, especially the peculiarities of Russian and foreign terminology. A considerable amount of literature was examined and, using their own knowledge in the field of study, the authors have developed a primary database model, including a list of attribute fields, which were elaborated in the course of the second phase of the work.

At the second stage of the database development the authors collected a large amount of data for further analytical research and filling the database. The sources of information included multiple directories; monographs; articles by leading Russian and foreign authors in peer-reviewed journals; theses of Russian and international conferences; records of the Ministry of Natural Resources and Environment of the RF; library materials; reports on the balance of mineral resources of the Russian Federation and also open Internet sources (sites of oil companies, academic specialized dictionaries etc.). To draw up an attribute table, the authors took into account the fact that all accumulated data on mineral deposits could be divided into two types: static and dynamic. Static data included the deposit parameters that do not change over time. On the other hand, dynamic data is constantly changing. Thus, the above accumulation and analytical review of relevant information made it possible to develop a database for large and extra large deposits of hydrocarbons, according to specified fields of the attribute table.

2. Database

Fields of attribute information include both static and dynamic parameters, which is a necessary prerequisite for carrying out a comparative analysis of hydrocarbon industry development in the 20th century. Static parameters include: the name of mineral deposit; its exact coordinates; location; the type of deposit; opening date; information about the developer; oil density; developing enterprise; amount of oil. Dynamic data comprise the data, periodically changing with time: mining methods; production technology; technological features; well production rate.

The authors describe further the static and dynamic elements of the database.

2.1. Database static elements

Hydrocarbon deposits have been listed in the attribute table in two languages: Russian and English, due to different interpretations of the names of deposits of various countries in different languages.

Coordinates of mineral deposits are shown in the attribute table mainly for further visualization of the database using special software and advanced visualization tools. However, without the use of special programs the coordinates themselves are not sufficiently informative. Therefore, the next column of the table provides physical and geographical position of deposits, which gives an overall picture of confinement of large and extra large hydrocarbon deposits in certain countries.

The "classification of deposits" section contains data on the phase relationship and the composition of major hydrocarbon compounds of oil and gas fields. In this paper we used a classification approved by the Ministry of Natural Resources and Environment of the RF. This classification includes six types of deposits:

- oil deposits, containing only gas saturated oil in varying degrees;
- gas and oil deposits, where the bulk of deposit is

oil and its gas cap does not exceed, in terms of equivalent fuel, the oil part of the reservoir;

- oil and gas deposits, which include gas reservoir with oil rim where a part of the oil is less than 50% in terms of equivalent fuel;
- gas deposits, containing gas only;
- gas and condensate deposits, containing gas and condensate;
- oil, gas and condensate deposits containing oil, gas and condensate.

The following two graphs of the attribute table include a deposit's discovery date and a date of commencement of hydrocarbon production on an industrial scale. There is often a significant delay between the discovery of deposits and the onset of hydrocarbon production, which is due to a large volume and complexity of the exploration work necessary to clarify the exact amount of reserves. The main task at this stage is the economic feasibility study of deposit development.

The next important item of the attribute table is the information about the rocks, accumulating liquid and gaseous hydrocarbons. This section includes their lithological parameters, in other words, the material composition and the age of rocks, according to the International stratigraphic (geochronological) scale provided by the A. P. Karpinsky Russian Geological Research Institute (VSEGEI).

Oil density is one of the most important characteristics, reflecting its quality in terms of industrial use and marketing. The density of oil depends on the content of paraffinic hydrocarbons and resins. The smaller their amount in crude oil (obtained directly from wells without any processing), the better is the oil. The most valuable are lighter grades of crude oil, because their smaller density makes the process of refining easier and increases the quality of oil products.

The next item of the attribute table focuses on the developing companies. As a rule, they are the world's leading companies and their subsidiaries, which are the pace-makers in the field of hydrocarbon production and processing.

Hydrocarbon reserves are the final graph of the attribute table. In this paper, the term "reserves" refers directly to geological reserves – the amount of oil and gas and accompanying mineral components of the deposits, studied by drilling, whose presence in the depths has been confirmed by a trial or commercial operation or by testing of the well, or is justified by geological and geophysical studies (according to the classification established by the Ministry of Natural Resources and Environment of the RF.

2.2. Database dynamic elements

All the indicated parameters are recorded in the table with an interval of one year.

Historically, the methods and hydrocarbon production technology (the following two major parts of the attribute table), in particular oil production, depending on the pressure inside the reservoir and its maintenance techniques, are divided into three types. This division of methods is accepted almost uniquely by the world oil industry, and, of course, appears in the classical textbooks of Soviet and Russian scientists. Let us further consider each of the three methods:

Primary method.

Oil is supplied from the reservoir under the influence of natural forces maintaining high reservoir pressure. The reservoir pressure is not always sufficient to raise oil from the bottom of the borehole up to the surface, requiring the use of special pumps. As a rule, at the early stages of production, hydrocarbons are mainly extracted by the primary method, because the fluid output is due to the difference in pressure in the reservoir and at the wellhead.

Secondary method.

After the exhaustion of the natural resources of pressure support, when it is no longer enough to lift the oil, the application of secondary methods begins [*Surguchev*, 1985]. Production technology of this method is to bring external energy into reservoir in the form of injected fluid (e.g. fresh water), natural or associated gas. It is worth noting that water injection increases the water content of oil, which requires further efforts for their subsequent separation. However, the secondary method is widely used in oil industry and is intermediate between the most primitive and low-cost primary method and tertiary methods which are most frequently and widely applied for the longest period of wells operation.

Tertiary method.

The method of enhanced oil recovery, carried out not only by artificial maintaining of reservoir energy, but also by artificial changes in physical and chemical properties of oil. Using this method allows to increase the recovery factor for the field by 30–60%, whereas the first two methods can only reach their maximum of 40%.

Technological parameters of this method are very diverse and have no specific classification [*Badretdinov, Karpov*, 2014]. By the type of impact on oil and oil reservoir, as well as the type of operating agents we can use the following conditional classification: thermal methods (injection of hot water, steam); gas methods (injection of carbon dioxide, hydrocarbon gases to liquefy the oil); hydrodynamic methods (boundary and peripheral water flooding, fracturing); physical methods (vibrowave impact, plasma-impulse excitation); chemical methods (chemical injection), and many others.

Technological features of production, shown in the next column of the table include a range of activities with the use of special equipment. As a rule, the technological features are very individual for each deposit and are based on many factors, including properties of hydrocarbons, reservoir parameters, deposits characteristics etc.

The next parameter is dynamically changing over time (with a one-year interval) during all stages of field development. This is a commercial flow, or the amount of oil flow and/or gas from a well when the development of a reservoir (well) at this stage is considered cost-effective (according to the terminology adopted by the Ministry of Natural Resources and Environment of the RF).

Measurement units in this case are million tons and billion cubic meters for oil and gas respectively.

3. Comparative analysis of the oil and gas industry development in the 20th century

Extensive geological reserves of the countries, over the last few decades of the last century occupying the leading position in the supply of hydrocarbons, have not only significantly improved the economic situation in each country and its global status, but also served as a major incentive for the development of new exploration and production techniques of oil and gas fields. The use of new technologies that increasingly provide a higher average debit had a positive impact on the economic situation of the country as a whole. Thus, dynamic data of the database to a great extent characterize the development of science and technology in the world and can serve as a basis for an analytical review of the program.

Our research has shown that, in general, there is a tendency of increasing production in the major oil and gas producing countries. The most important factors are the development of existing deposits by new methods of exploration, that allows to identify new promising areas and to increase the recoverability rate, in order to ensure high level of economic efficiency.

About 2/3 of the world geological oil reserves is concentrated in the Middle East (Saudi Arabia, Iraq, Iran et al.) [*Krayushkin*, 2008]. North and South America (Venezuela, Mexico, United States) hold the world's second largest reserves – 15.2%. Africa occupies the third position, with its share of about 6.8% of the world's geological oil reserves (Libya, Nigeria, Algeria). Post-Soviet states are only on the fourth line of the list: Russia (4.7%) occupies the first place in the world production according to 2012 data [*Dyuldev*, 2013].

Let us consider the diagram, which presents data from 1970 for the leading oil-producing countries in the world (Figure 1).

In Saudi Arabia, (the current leader in oil production) the volume of production in the reporting period – from

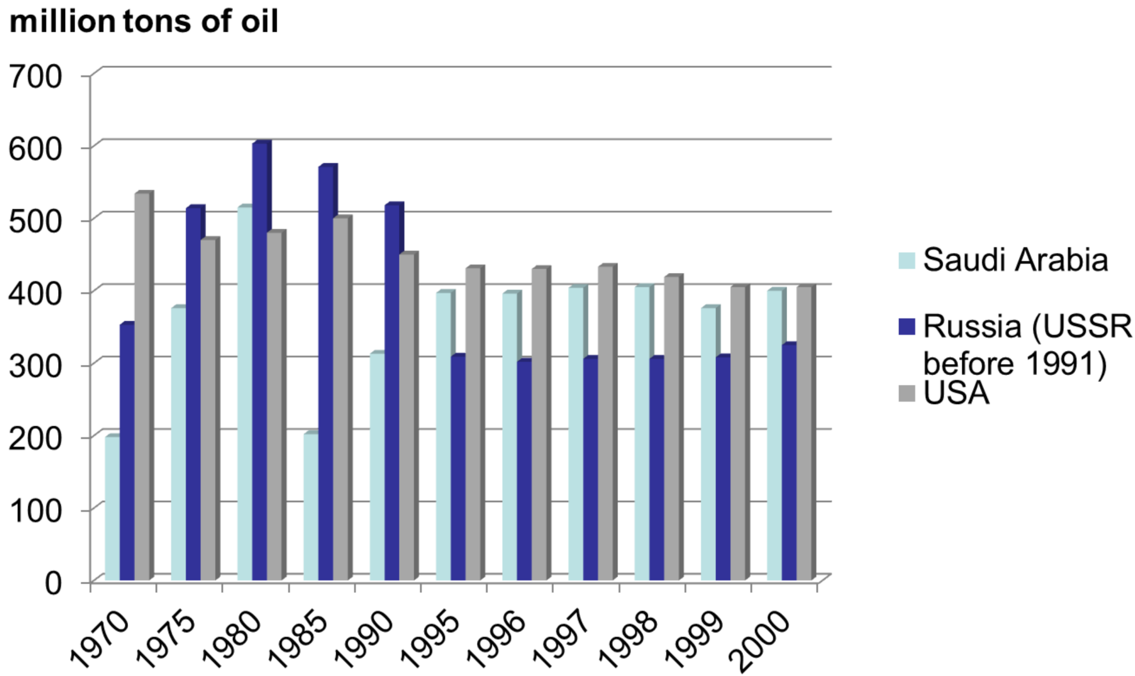

Figure 1. Data from 1970 for the leading oil-producing countries in the world (according to the International Energy Agency) [*Voronina*, 2003]

1970 to 1995 – considerably varies, due not only to the development of promising new areas, introduction of new methods of exploration and mining, but (mostly) to the regulation of oil prices by OPEC to limit the scope of oil production in the country. After 1995, the oil production has stabilized, and now SA occupies its dominant position in the global oil market.

As for Russia (and the former USSR), the oil production reached its peak in 1980. Later, in the mid-1990s, the level of production significantly decreased (in connection with the collapse of the Soviet Union and the crisis). However, by the early 2000s, the oil production has grown significantly, which allowed the Russian Federation to take a leading position in oil production at the moment (slightly lagging behind Saudi Arabia: in 2014 543 million tons were extracted by Saudi Arabia versus 534 million tons by the RF).

Oil production in the US (its largest customer), reached its peak in the period 1970–1980, and since then it decreased. By 2002, the decline was about 20%. This is due to the fact that in the US the cost of oil is relatively high, and government policy is to acquire cheaper oil from the OPEC countries and Mexico. Nowadays the United States is one of the three leaders – 519 million tons of oil produced in 2014.

4. Conclusion

In the framework of this study we have developed a database on hydrocarbon extraction methods in the 20th century for large and super large oil and gas deposits in Russia and other countries. DB contains both static and dynamic parameters for each deposit.

Static parameters include: the name of mineral deposit; its exact coordinates; location; the type of deposit; opening date; information about the developer; oil density; developing enterprise; amount of oil.

Dynamic data comprise the following data: mining methods; production technology; technological features; well production rate.

The data were collected with an interval of one year.

The database is a unique research product that has no equivalents. It allows a comparative analytical overview of the global development of science and technology in the 20th century to be carried out. Extensive geological reserves of the countries, over the last few decades of the last century occupying the leading position in the supply of hydrocarbons, have not only significantly improved the economic situation in each country and its global status, but also served as a major incentive for the elaboration of new exploration and production techniques of oil and gas fields.

References

Badretdinov, I. A., V. G. Karpov (2014), Classification of methods of enhanced oil recovery (economic approach), *Petroleum Geology. Theory and practice, 9*, No. 1, 6. doi:10.17353/2070-5379/5_2014

Dyuldev, A. A. (2013), Promising directions in hydrocarbon production in Russia, *Journal of Russian entrepreneurship*, No. 11, 91–103.

Krayushkin, V. A. (2008), The nature of the supergiant accumulations of oil and gas, *Geology and mineral resources of the world ocean*, No. 1, 19–54.

Surguchev, M. L. (1985), *Secondary and tertiary methods of enhanced oil recovery*, 308 pp., Nedra, Moscow.

Voronina, N. V. (2003), World oil market: development tendency and features of pricing, *Practical marketing*, No. 10, 24–45.