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FEATURES OF DISTRIBUTION OF OIL AND GAS DEPOSITS IN THE EARTH'S CRUST

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ОСОБЕННОСТИ РАСПРЕДЕЛЕНИЯ НЕФТЯНЫХ И ГАЗОВЫХ МЕСТОРОЖДЕНИЙ В ЗЕМНОЙ КОРЕ

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Abstract. Hydrocarbon deposits within oil and gas-bearing territories are distributed very unevenly both in area and in the section of sedimentary deposits, which is the main geological feature of oil and gas placement in the subsurface. The formation of hydrocarbon accumulations in the sedimentary cover is due to a set of genetic factors, which ultimately determines the patterns of placement of oil and gas accumulations along the section and area of the sedimentary cover. The study of the factors determining the zonation of oil and gas accumulation and genetically her condition, zoning of oil and gas formation, contributes not only to expanding our knowledge on the fundamental problems of petroleum geology, but also improve the efficiency of exploration.

Аннотация. Залежи углеводородов в пределах нефтегазоносных территорий распределены крайне неравномерно как по площади, так и по разрезу осадочных отложений, что является главнейшей геологической особенностью размещения нефти и газа в недрах. Формирование скоплений углеводородов в осадочном чехле обусловлено совокупностью генетических факторов, что, в конечном счете, и предопределяет закономерности размещения скоплений нефти и газа по разрезу и площади осадочного чехла. Изучение факторов, определяющих зональность нефтегазонакопления и, генетически ее обуславливающей, зональности нефтегазообразования, способствует не только расширению наших знаний по фундаментальным проблемам нефтегазовой геологии, но и повышению эффективности поисково-разведочных работ.

Keywords: hydrocarbons, oil, natural gas, condensate, field, deposit, resources, geological and recoverable reserves, zoning, section, area, lithological-stratigraphic, unconventional hydrocarbons.

Ключевые слова: углеводороды, нефть, природный газ, конденсат, месторождение, залежь, ресурсы, геологические и извлекаемые запасы, зональность, разрез, площадь, литолого-стратиграфический, нетрадиционные углеводороды.

Approximately 35,000 oil, gas, and bitumen deposits have been discovered on all continents of the world (except Antarctica) and most of the seas and oceans that surround them. However, the detected hydrocarbon deposits are very unevenly distributed across the area at the boundary of the oil and gas regions and along the cross section of the sedimentary deposits. This is the main geological feature of the location of oil and gas in the depths of the earth. For example, significant concentrations of oil and gas resources are concentrated in the Middle East (Saudi Arabia, Iraq, Iran, Kuwait, etc.), North Africa (Libya, Algeria), the Gulf of Mexico, the North Ocean, the Russian Federation (Western Siberia, Ural-Volga region) and identified in other regions. Alternatively, a very large number of small and medium deposits are known.

According to most researchers, the location of oil and gas resources, types of local and regional collections are closely related to the history of geological development of certain geosystem elements of the earth's crust and the composition and structure of the sedimentary deposits that make them up. All known accumulation sites are located with groups, zones, associations, forming regional clusters of different categories of oil and gas. Therefore, knowledge of the laws of location of oil and gas deposits in the earth’s crust allows to scientifically predict the oil and gas content of the earth’s crust and to select effective areas of geological exploration.

We now have a sufficiently in-depth knowledge of the conditions and laws of formation of oil and gas deposits in the earth’s crust, and on this basis we can form the theoretical criteria for predicting the oil and gas content of the earth’s crust. Perhaps this issue has intrigued people since the first time they knew that, thanks to natural sources of oil, they could significantly ease their living conditions, obtain heat, light, and materials for military and domestic needs. It really makes you wonder why oil is coming out right here, not far from here? This, of course, may not have been of interest to the researchers of that period. We can therefore conclude that the formation of petroleum geology began when researchers focused on the uneven distribution of identified oil and gas deposits in the sedimentary crust and began to investigate the various factors that caused this unevenness. Therefore, in the early stages of the development of petroleum geology, it was possible to apply only geological methods of research, and an anticline theory of the formation of hydrocarbon deposits was developed. Sometime later, paleogeological, paleotectonic, lithological-facies, hydrogeological, geochemical, thermobaric and other methods of studying the conditions of formation and distribution of hydrocarbon deposits were developed [1–3].

A comprehensive analysis of the conditions for the location of oil and gas deposits in different geological conditions at the boundaries of continents and waters suggests that the formation of hydrocarbon deposits in the earth's crust is associated with a number of genetic factors. This determines the laws of distribution of oil and gas deposits over the cross-section and area of the earth's crust.

In order to organize geological exploration for oil and gas, it is necessary to know their location in the lithosphere in order to make predictions and identify promising objects. To do this, you need to specify:

–at what depth intervals (pressure and temperature) the oil and gas package can be located — depth (vertical) zoning;

–in what lithological-stratigraphic complexes they occur — lithological-stratigraphic zoning;

–what tectonic elements are associated with oil and gas deposits — structural zonation.

Depth zonation is also reflected in the spatial distribution of hydrocarbons across the lithosphere, as well as the location of their reserves [4].

To date (as of 2017), industrially important oil and gas deposits have been identified over a wide range of depths — up to 11 km above ground level in practice.

According to data on the distribution of reserves of unique and large oil and gas fields at different depths in the world, about 82% of the initial geological and recoverable hydrocarbon reserves are located at depths up to 3000 m. This section of the section contains 88% of initial recoverable oil reserves, almost 75% of free and dissolved natural gas, and 75% of condensate reserves (Figure 1).

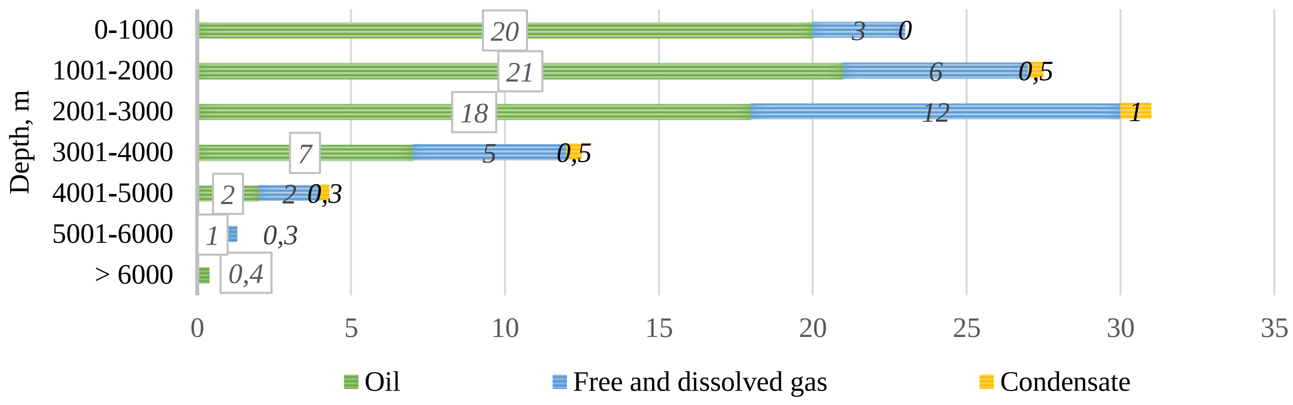

Figure 1. Hydrocarbons in rare and large deposits of the world along the depth of the initial geological reserves of distribution, %.

There is also a difference in the distribution of oil, gas and condensate reserves along separate sections of the section. For example, the maximum concentration of extractable oil reserves is associated with a depth of 1000 to 2000 meters, and gas - from 2000 to 3000 meters (Figure 2).

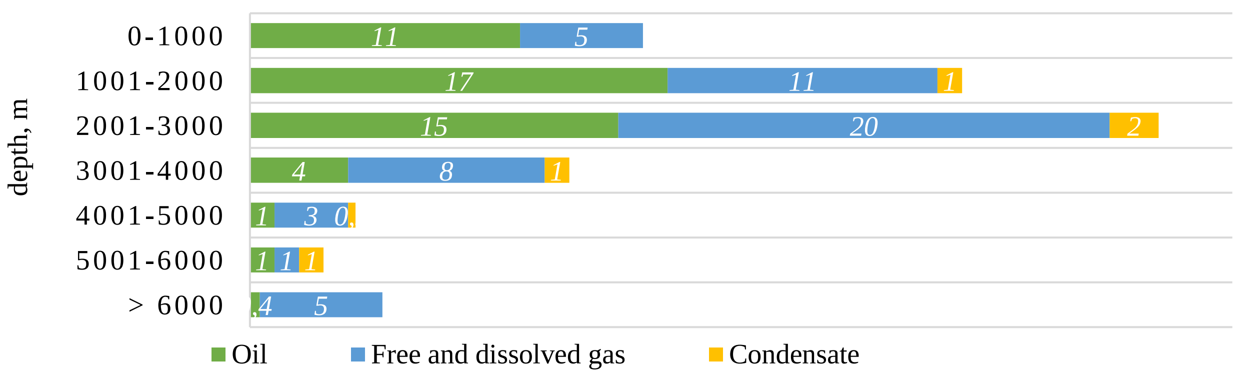

Figure 2. Hydrocarbons in rare and large deposits of the world along the depth of the initial removable reserves of distribution, %.

It should be noted that because of exploration of deep horizons, the share of detected hydrocarbon reserves at depths greater than 3000 m is increasing. For example, the share of initial recoverable oil reserves in the fields discovered before 1976 was 7.4%, free and molten gas was 21.1%, but now it has increased to 12.0 and 25.1%, respectively.

Due to the presence of liquid hydrocarbon dissolved in the gas under condensate pen conditions, the distribution of its reserves across the depth is naturally affected on the one hand by the reserves of free gas at the appropriate depth (the more free gas reserves the more condensate reserves), on the other hand the thermobaric conditions [5–6].

The main reserves of oil and gas are discovered in the following rare and large deposits at depths of more than 5.5 km:

–Sagitario — 2013, Brazil, Santus Oil and Gas Basin (NGH), 6200 m, gas condensate oil field.

–Keshen 2 — 2008, China, Tarim NGH, 6500 m, gas condensate field.

–Yuanba - 2007, China, Sichuan NGH, 7081 m, gas field.

–Gomes — 1963, USA, Perm NGH, 6040 m, gas field.

–Cascade — 2006, USA, Gulf of Mexico NGH, 9429 m, oil field.

–Apsheron — 2001, Azerbaijan, South-Caspian NGH, 6450 m, gas condensate field.

–Tyber — 2009, USA, Gulf of Mexico, 10690 m, oil field.

Most of these deposits are in the waters of the seas and oceans and were discovered after 2000 [7].

In 2009, British Petroleum announced the discovery of a unique deposit in the Gulf of Mexico in U.S. territorial waters at the Tyber (Tiber) area at a depth of 10,690 m. For the first time, a large industrial mine was discovered at such a depth.

The depth of the ocean in the area of the Tyber deposit is 1.3 km, oil content has been determined in the Neogene and Paleogene subsalt deposits. The depth of the pile is 10–12 km. Geological reserves of oil are estimated at 1.8 billion barrels. tons, initial reserves 1 bln tons. The layer temperature is 127 °C at a depth of 10.6 km [8].

More than 1,000 oil and gas fields are currently being exploited worldwide at depths of 4,500-8,100 m.

–Rare and large hydrocarbon deposits are also present at small depths: Duri — 1941, Indonesia, Cental Sumatra, 95 meters, oil field;

–Mesdjed-Soleyman — 1908, Iran, Messopotam NGH, 75 m, oil field;

–Faxud — 1964, Oman, Oman NGH, 15 m, oil field;

–Kern River — 1899, NGH, California, USA, 30 m, oil field;

–Nizhnechutinskiy - 1934, Russia, Timano-Pechor NGH, 18 m, oil field.

Most of these deposits are heavy oil fields and, as a rule, they are in the oil and gas basins of tectonic active regions [7–8].

At the global level, the depth distribution of different types of hydrocarbon reserves is more closely related to the zoning (generational zoning) of oil and gas formation processes. This in turn is determined by the type of organic matter of the oil and gas-producing rocks and the degree of its variability.

Migration processes also affect the depth zoning of the distribution of hydrocarbon reserves. Comparing the phase (zone) of oil and gas formation with the depth distribution of hydrocarbon reserves, it can be seen that the main zone of oil accumulation (1000÷3000 m) shifted upwards along the section relative to the main oil formation zone (2÷5 km). Similarly, the maximum concentration range of gas reserves (2000÷3000 m) shifted upwards along the section relative to the main gas formation zone (5÷7 km).

This relationship of hydrocarbon generation and accumulation zones is explained by the effect of lateral and vertical migration of oil and gas in the formation of clusters.

For syngenetic oil and gas complexes, the zoning of oil and gas distribution along the depth is much closer to the generation zoning. They are dominated by lateral hydrocarbon migration. For epigenetic oil and gas complexes, the zoning of oil and gas distribution at depth differs significantly from the generation zoning.

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Lithological-stratigraphic zonation is well observed in a number of oil and gas provinces. For example, on the border of the Western Siberian Plate, most of the oil resources are discovered in the lower chalk deposits, and gas — in the upper chalk deposits. The main resources of gas relate to chalk deposits at the boundary of the Turan plate, and with Jurassic deposits — oil.

The zoning of the distribution of hydrocarbon reserves by stratigraphic units is also well observed globally. The major share of the world's unique and large UV deposits in the world's identified geological and recoverable reserves is concentrated in the deposits of the Mesozoic system (48.7% and 55.3%, respectively). The chalk deposits are relatively productive (32.9% and 36.3%, respectively), the Jurassic and Triassic deposits are less productive (13.9% and 17.2%, respectively, in the Jurassic deposits, 1.9% and 1.8%, respectively deposits) (Figures 3–4).

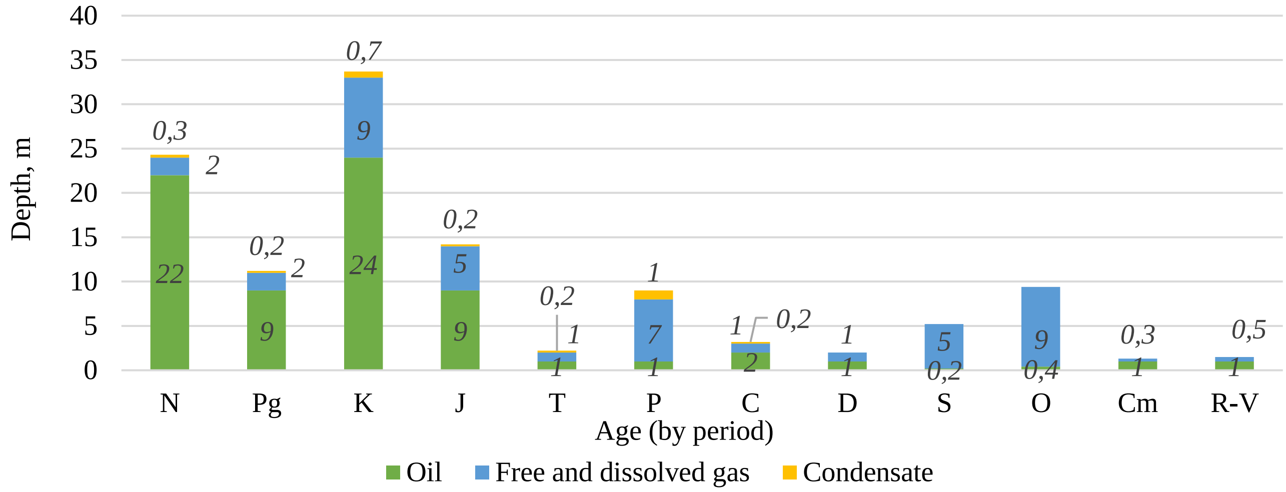

Figure 3. The beginning of the world's unique and largest UV deposits on stratigraphic subdivisions f geological reserves distribution, %.

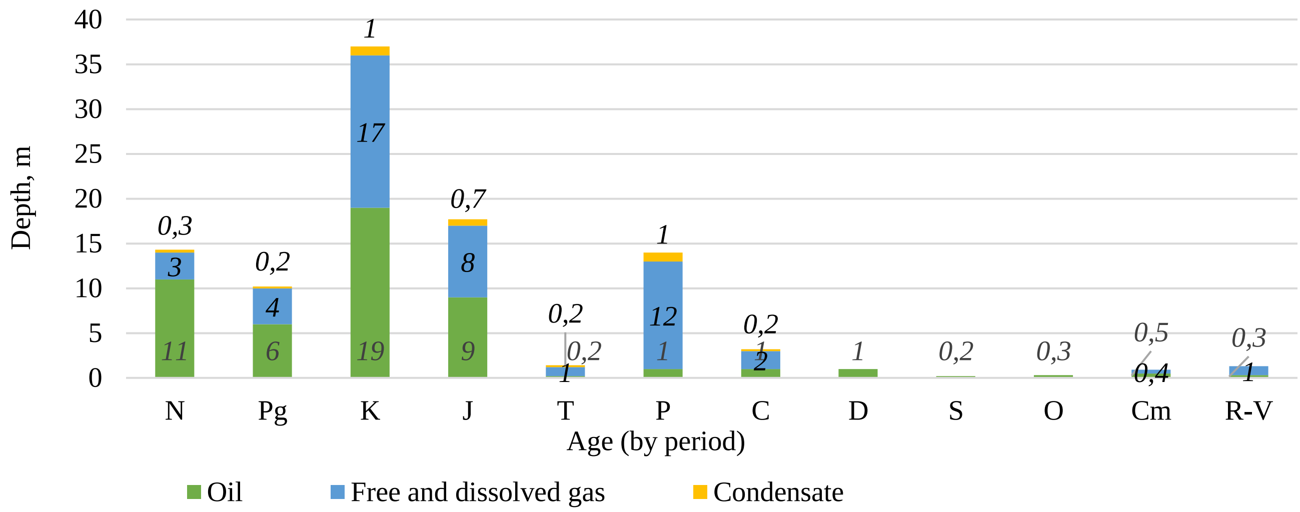

Figure 4. The beginning of the world's unique and largest UV deposits on stratigraphic divisions of recoverable reserves distribution, %.

In second place in terms of geological and extractable hydrocarbon reserves are Cenozoic deposits, which account for 35.0% and 23.4%, respectively. The Paleozoic and older deposits account for 16.3% of the world's unique and large hydrocarbon deposits of geological and 21.3% of extractable reserves (Figures 3–4).

The most enriched with oil reserves are chalk (38.8% of recoverable reserves), Neogene (21.7% of recoverable reserves) and Jurassic (18.1% of recoverable reserves) deposits [9–10].

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The recoverable reserves of free gas and dissolved gas are much more evenly distributed: 34,7% in the chalk deposits.

–24.3% in Permian deposits.

–6.3% in Jurassic deposits.

Most researchers attribute the uneven distribution of oil and gas reserves by stratigraphic units to the geological history of the Earth and the paleogeographic and geochemical conditions of sediment accumulation in each period.

This relationship is more clearly illustrated in the example of perm deposits. The climate of the Permian period is characterized by clearly defined zoning and increasing drought. During the Permian period, the humid tropical climate zone was clearly separated, on the border of which there is a vast ocean — Tethys. To the north of it is a hot and dry climate zone, which corresponds to the prevalence of saline and red deposits. Further to the north is a temperate region with significant moisture accumulated in intensive coal [11–12].

The Permian deposits are associated with the following fields with initial gas reserves greater than 1 trillion cubic meters:

–Northern (Qatar) and Southern Pars (Iran) — Arabic Platform;

–Groningen (Netherlands) — Western European platform;

–Panhandle-Hugoton (USA) — Anatolian Basin;

–Northern Pars (Iran) — Mesopotamian Basin.

Reserves of non-conventional oil are geographically more unevenly distributed than reserves of conventional oil. According to the US Geological Survey (USGS) [13] and the EIA [14], the world's technically recoverable reserves of unconventional oil are estimated at $ 200 billion. t. n. e. estimated at more than. This is similar to the reserves of conventional oils. Two-thirds of non-traditional sources are located in North and South America.

Most experts estimate that reserves of high-viscosity oils and natural bitumen are estimated at $ 790 billion. 1 trillion tons. tons, which is about 162 billion. tons, which is 5-6 times more than the residual reserves of low and medium viscosity oil. This figure is significantly higher than light and low viscosity oil reserves. Therefore, one of the potential ways to stabilize oil production and increase recoverable reserves is to launch hard-to-recover reserves. In a number of developed countries, high-viscosity oils are not seen as a reserve for oil production, but as a major base for its development in the coming years [15].

The world's recoverable reserves of natural bitumen are distributed as follows: Canada — 75%, Russia — 22%, the rest of the world — 3%. The world's reserves of heavy oil and natural bitumen are in 63 geological provinces and amount to 1 trillion tons m^3, of which about half are proven reserves, and the rest are estimated [16]. In the field of high-viscosity oils and natural bitumen, the technology has been used for several years in Russia, Uzbekistan and other countries. And it is possible that in the near future the use of heavy oil will be a major part of the entire production.

The world's reserves of heavy oil are estimated at $ 350 billion. m^3 and mainly located in Venezuela (Orinoco stem), Canada, China, India. About one-third of these reserves are considered approved.

The largest reserves of natural bitumen are found in Canada. The next places are occupied by the United States, Russia and others. The largest bitumen deposits in Canada are: Atabasca, Carbonate — Trend, Could Lake, Bad River, Vabaska; Venezuela — Ofisina-Temblador; In the USA — Asphalt ridge, Sunniseid, Uiterok, Edna; In Madagascar — Bemolonta.

Russia is the third largest producer of heavy hydrocarbons after Canada and Venezuela. According to Schlumberger, Russia's heavy oil reserves are estimated at 13.4 billion barrels. tons, and natural bitumen — 33.4 billion tons. Heavy oil reserves and resources are mainly concentrated in the Western Siberia, Volga-Ural and Timano-Pechor regions [17–18].

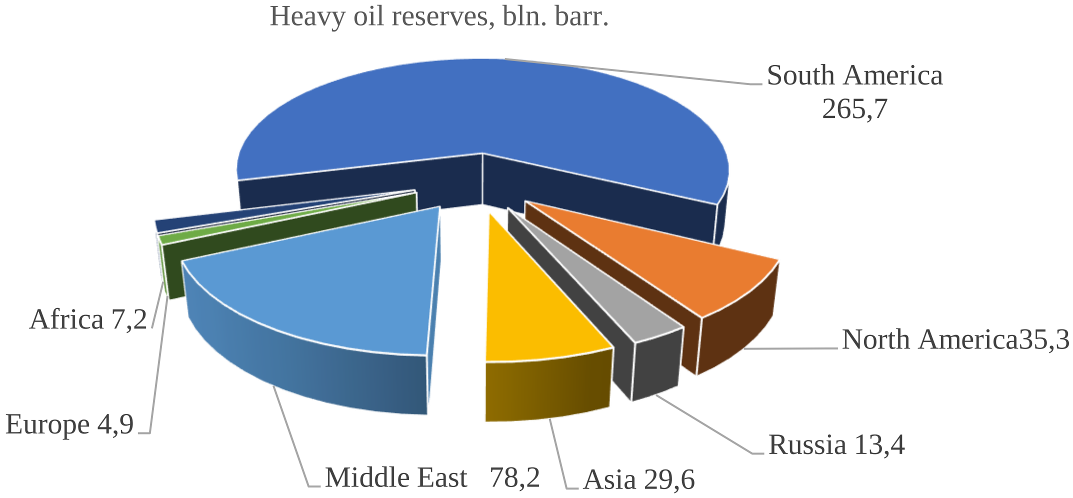

Figure 5. Regional location of heavy oil reserves.

The regional distribution of heavy oil and natural bitumen reserves is shown in Figures 5 and 6. The distribution of heavy oils by regions of the world indicates that more than 80% of the world's heavy oil reserves are located in Eastern Europe, Central and North Asia [19–20].

Significant collections of high-viscosity oil and natural bitumen have been accumulated in a number of countries.

The largest reserves of heavy oil and bituminous oil are located in Canada, with reserves of 522.5 billion t. and concentrated in the following provinces: Alberta — 374.5 billion t.; Athabasca — 131.1 billion t.; Vabaska — 16.9 billion t. Venezuela has the second largest reserves of this type of oil at 177.9 billion barrels t. and collected in Orinoco bituminous stems. Mexico, the United States, Russia, Kuwait and China also have significant reserves. In Norway, high-viscosity oil is extracted using a number of large fields, such as the Gray on the North Sea shelf, with recoverable oil reserves of 105 million barrels t., is one of the largest oil fields in the Norwegian sector [21–22].

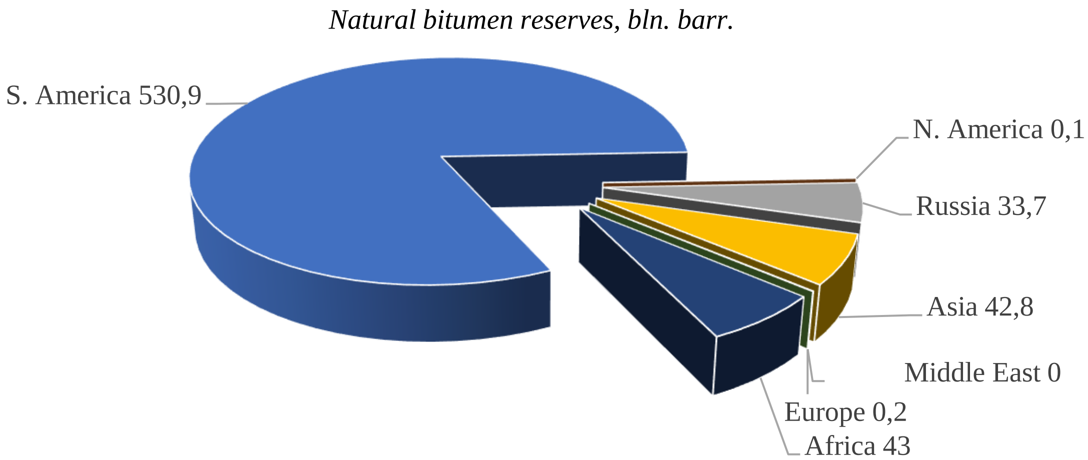

Figure 6. Regional location of natural bitumen reserves.

An oil geologist who has been searching for oil and gas deposits and has been working in a single oil and gas region for many years, in his practice relies primarily on local and zonal, sometimes regional, features of oil and gas accumulation and uses it as a guide. Global laws are of “theoretical” interest to him. At the same time, the study of the location patterns of hydrocarbon deposits on a global scale allows to identify a number of basic principles of this approach and to see the similarity of oil and gas conditions of regions separated by large distances. In turn, the method of geological similarity is widely used in geological exploration of oil and gas. Due to him, deposits of various scales — from large oil and gas regions to oil and gas accumulation zones and individual fields - have been discovered. Therefore, the study of oil and gas formation zoning and oil and gas accumulation zoning allows us to expand our knowledge not only on the fundamental problems of oil and gas geology, but also to increase the efficiency of exploration work.

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