International Journal of Research Studies in Science, Engineering and Technology
Volume 2, Issue 9, September 2015, PP 31-37
ISSN 2349-4751 (Print) & ISSN 2349-476X (Online)

# Oil Shale of Azerbaijan: Geology, Geochemistry and Probable Reserves

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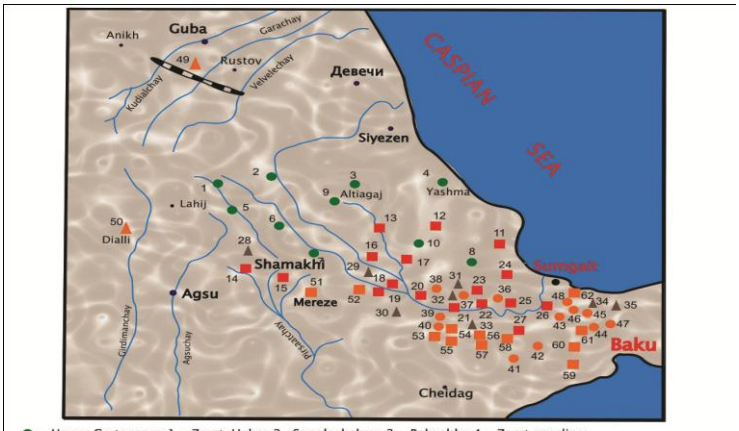
**Abstract:** *Azerbaijan is a classic country of oil and gas. The fact prevent use of other types of minerals which are spread over a wide range in some regions of Republic. However, in recent years, due to the dynamic development of the industrial and consumer sectors in Azerbaijan, the requirement for new energy resources are growing, and the idea of exploring alternative energy sources such as oil shale becomes very important. The article is devoted to the study of geology and geochemistry of oil shale, founded in the surface and ejected rocks of mud volcanoes, and estimation its probable reserves.*

*Oil shale manifestations and deposits are located mainly in Guba, Ismayilli, Shamakhi, Gobustan, Absheron and other regions in Azerbaijan, and associated with Cretaceous-Miocene sediments. The calculations of oil shale reserves (probable) were performed only using surface and extrapolation data. However, a study ejected products of mud volcanoes confirms that deeper sediments of mudvolcanic areas contain large stock of oil shale. There is no doubt that total reserves will increase with drilling deep wells in these areas.*

*In the paper, to estimate of hydrocarbon potential of deep sediments on the basis of geological and geochemical study of oil shale and oil-bearing rocks association in ejected products of mud volcanoes is the first investigation.*

**Keywords:** *Azerbaijan, oil shale, geology, geochemistry, probable, reserve, organic metter, kerogen, mud volcano.*

In addition to the oil and gas, there are others alternative energy resources such as oil shale, natural bitumen (oil sands) and etc. in Azerbaijan. Only the amount of oil shale manifestations and deposits are more than 60, and these are located mainly in the eastern part of the country (Figure 1).




● – Upper Cretaceous 1.– Zarat–Haber 2.–Sarydashchay; 3.– Bahyshly; 4.– Zarat syncline; 5.– Talyshnuri; 6.– Astrakhanka; 7.– Hilmilli ( Maikop); 8.– Kurkachidag (Maikop); 9.– Altiaghac (Lower Cretaceous); Kemishdag 10.– (Maikop);
■ – Middle Koun 11.– Yashma (Meotian); 12.– Charkishlak; 13.– Ambizlyar; 14.– Shamakhi (Maikop); Arabshalbash 15.– Erebshalbashy (Maikop); 16.– Agdere (Maikop); 17.– Shahandag; 18.– Tuva; 19.– Karadzhyuzlyu (Maikop); 20.– Kichik Siyaki (Maykop, Konk); 21.– Jangichay; 22.– Kecheller; 23.– Ashagikend syncline; 24.– Agburun syncline; 25.– Pirikeshkyul; Goytapa 26.– (Maikop, Meotian); 27.– Uchtepe (Maykop, Konk, Meotian);
▲– Upper Maikop 28.– Angikharan; 29.– Geradil; 30.– Shaiblyar; 31.– Kiblyadag; 32.– Jangidag; 33.– Boyanata (Meotian); 34.– Ordzhandag (Konk, Meotian); 35.– Fatmayi (Konk, Meotian);
○ – Konk 36.– Islamdag (Meotian); 37.– Mayash (Meotian); 38.– Boyuk Siyaki (Meotian); 39.– Sungur (Meotian); 40.– Baygushkaya (Meotian); 41.– Shorbulag (Meotian); 42.– Garaeybat (Meotian); 43.– Guzdek (Meotian); 44.– Zigilpiri; 45.– Masazyr (Meotian); 46.– Kechaldag; 47.– Binagadi (Meotian); 48.– Saray (Meotian);
△–Upper Sarmatian 49.– Guba; 50.– Diallinskoe;
□–Meotis 51.– Jeirli; 52.– Ahudag; 53.– Baygushtu; 54.– Alakyshlak; 55.– Garakyshlak; 56–Sarydash; 57.– Gyrdag; 58.– Kusmalidag; 59.– Atashgah; 60.– Shabandag; 61.– Khirdalan; 62.– Jorat.

*In brackets are indicate age of the deposits, which are associated with appearance of oil shale

**Fig1.** *Schematic map of Azerbaijan oil shale manifestations and deposits.*

Oil shale is an organic-rich fine-grained sedimentary rock, containing kerogen (a solid mixture of organic chemical compounds). Depends on its organic compounds, the color of oil shale can be black, gray or dark gray.

Oil shale manifestations and depositsare located mainly in Guba, Ismayilli, Shamakhi, Gobustan, Absheron and other regions in Azerbaijan, and associated with Cretaceous-Miocene [1-5]. The thickness of oil shale leyers grows from a few meters to tens and alternate along stratigraphic depths [3] (Figure 2).

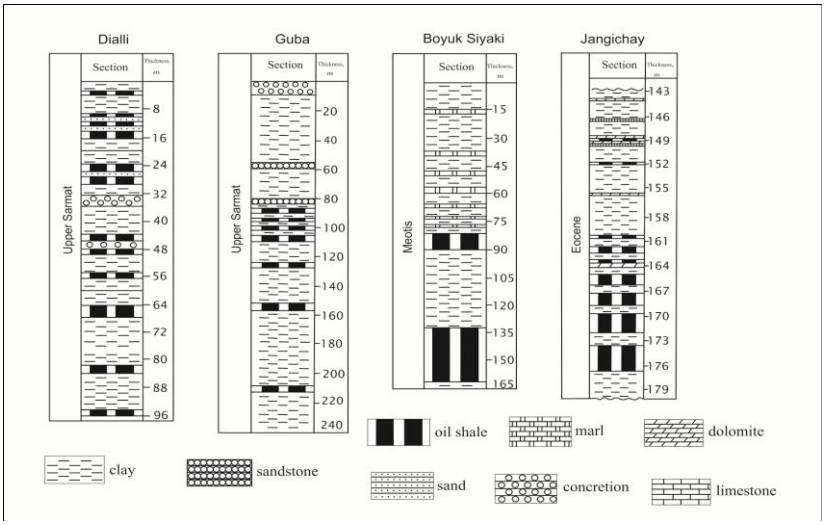



**Fig2.** *Alternation of oil shale layers along stratigraphic depths.*

The vast majority of oil shale manifestations and deposits (55) were found in Gobustan region. Their close proximity to each other, away from the residential area and forest cover are very important factors for their future development [3, 4].

**Gobustan region** is divided into three microblocks from north to south. Surface manifestations and depositsof oil shale are located mainly in Bayanata Microblock (Central Gobustan). In terms of geologic time, the formation of oil shale in the Microblock is related to Eocene and Miocene.

Such a regularity is observed in the distribution of oil shale in Gobustan that the major number of oil shale manifestations and deposits are developed in the southeastern part of the region. Depends upon increasing of depths, the thickness of oil shale layers are increasing too. But the numbers of oil shale manifestations and deposits, and the thickness of oil shale layers are sharply reducing in the northwestern direction of region.

In the region, oil shale associated with different types of geological structures. These structures are complicated by tectonic faults. All of these factors taken into consideration in calculating the probable reserve of oil shale.

Oil shale were found in both flanks of Kichik Siyəki syncline. The structure is asymmetric. South flank lies to the northeast at an acute angle (60-65°). But north flank lies relatively small angle (33°).

Oil shale is in south flank of Eocene, but in north flank of Maikop age. The differences are related to the fault, which crossed the southern flank and directed to the northwest (Figure 3).

Taking into account the fact, the stocks are calculated separately for both flanks. Total probable reserve: 56.34 million tonnes.

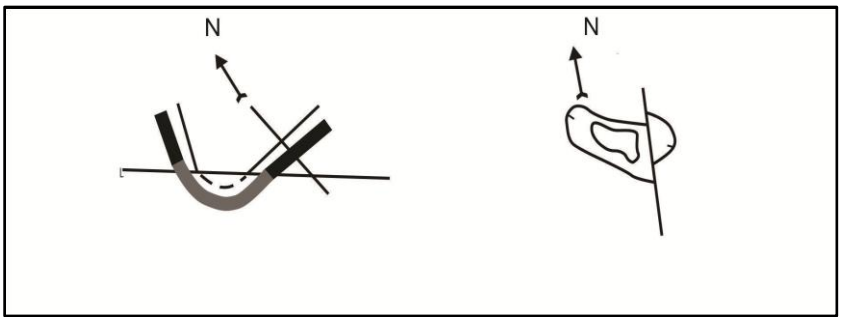



**Fig3.** *Kichik Siyaki syncline (Eocene, Maikop).*

It has been estimated total reserve of oil shale for both flanks in Jangichay anticline. Due to the fault extends from the bottom part of the southern flank and directed to the northwestern, oil shale in north flank of Middle Eocene, but the southern flank of Maikop age (Figure 4).

The reserves were calculated separately for both flanks. The total probable reserve: 73.43 million tons.

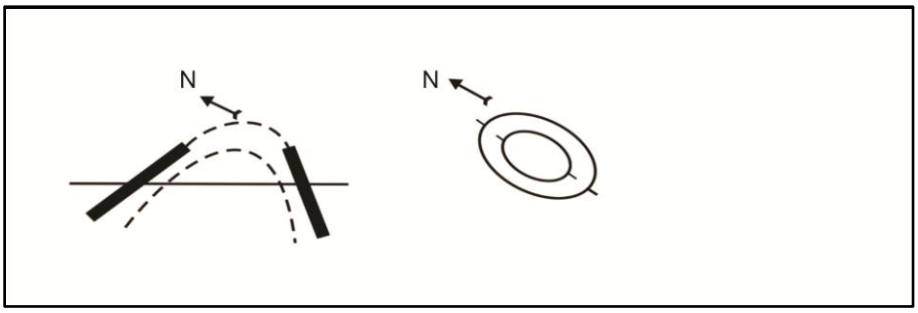



**Fig4.** *Jangichay anticline (Middle Eocene, Maikop).*

Related to reserves, oil shale containing structure divided into two parts: the manifestations (less than 10 million tons of reserves) and deposits (more than 10 million tons of reserves). The total probable reserves of oil shale more than 500 million tonnes in Gobustan. Some results of the calculations is shown (Table 1).

**Table1.** *Probable reserves of oil shale manifestations and deposits in Gobustan*

| Number | Manifestations and deposits | Type of struture | Proqnosis reserve (mil. tonnes) |
|---|---|---|---|
| Upper Miocene (Meotis) | | | |
| 1 | Garaislam | Syncline | 6,50 |
| 2 | Sungurdagh-Bayanata | Syncline | 2,74 |
| Middle Miocene (Konk and Karagan) | | | |
| 3 | Baygushgaya | Mold | 33,56 |
| 4 | Boyuk Siyaki (Meotis) | Anticline | 56,18 |
| 5 | Islamdagh | Anticline | 51,36 |
| Lower Miocene (Upper Maikop) | | | |
| 6 | KichikSiyaki (Koun, Konk) | Syncline | 56,34 |
| 7 | Jeyirli-Bozakhtarma | Anticline | 9,98 |
| 8 | Jangichay (Koun) | Anticline | 73,43 |
| 9 | Chobandagh | Anticline | 10,02 |
| Middle Eocene (Koun) | | | |
| 10 | Siyakiarasy | Syncline | 5,65 |
| 11 | Nabur-Garajuzlu | Anticline | 2,20 |
| 12 | Bekle-Bekdaraduz | Syncline | 11,05 |
| 13 | Sheytanud | Anticline | 2,23 |
| 14 | Birgut | Brachyanticline | 4,44 |
| 15 | Kecheller | Anticline | 51,92 |
| 16 | Rehim (I section) | Anticline | 5,22 |
| 17 | Rehim (II section) | Anticline | 13,02 |

Related to study of oil shale in the region, it was not drilled a deep well (to a depth of 200 m were studied by drilling) in Gobustan. The calculations were performed using surface and extrapolation data. However, a study ejected products of mud volcanoes confirms that deep sediments cointain large stock of oil shale in the region. There is no doubt that oil shale reserves will increase with drilling deep wells in it.

Oil shale manifestations in **Pre-Caspian-Guba region** are related to Eocene and Miocene ages. The sections of Eocene age oil shale were recorded in Siyazan, Surabad and Saadan aeras. Meotis age oil shale manifestations are observed in the southeastern parts of the region. There are two layers of oil shale in Yashma area [5-7].

The largest oil shale deposit of the region is Guba. The deposit is located 25 km far from Guba city. Oil shale of the deposit is associated with Samratian and in 27-255 meters section are found to 7-18 oil shale containing layers.The most attractive section in the Guba deposit is found between the rivers

Valavachay and Kudichay, and it lies along the southwestern and southeastern directions. In addition to, the others shows of oil shale layers are observed along the Gil-Gilechay River and they have not been studied enough well. From the northwestern to Kudlichay River, oil shale are found in the Anig Village. The total thickness of Sarmatian sectionaboute 1350 m and related to monocline fold. Larger sections of oil shale of Guba deposit are found between the Chagadchay and Garachay rivers. Guba is one of the largest deposits in Azerbaijan with its probable reserve.

The Dialli is largest deposit in Azerbaijan and developed 7 km far from the regional centr of **Ismayilli region**. Here found two molds of oil shale, related to Sarmatian age. The total thickness of oil shale containing sediments 300-700 meters.In the deposit,oil shale is observed as alternating layers in the section.

According to the geochemical study of the Diallı oil shale, in the low-temperature pyrolysis was appointed the amount of bitumen (0.52-4.72%) and gas (3.04-6.0%). The amount of kerogen varied in the range of 14.02-25.63%. In addition to, low sulfur content (0.36-0.92%) in Dialli oil shale is considered an advantageous in ecological point of view (Table 2).

**Table2.** *Geochemical compound of oil shalein the Diallı Deposit*

| Number | Compound, % | Sample 14 | Sample 23 | Sample 29 | Sample 30 | Sample 31 |
|---|---|---|---|---|---|---|
| 1 | Organic matter | 19.97 | 23.28 | 27.35 | 27.88 | 27.17 |
| 2 | Ash | 76.85 | 71.09 | 69.42 | 69.46 | 69.84 |
| 3 | Wetness | 4.60 | 3.43 | 4.99 | 5.50 | 6.08 |
| 4 | Carbonate | - | 1.80 | 0.89 | 1.00 | 1.20 |
| 5 | Sulfur | 0.49 | 0.92 | 0.36 | 0.37 | 0.38 |
| 6 | Solved organic matter | 5.95 | 4.62 | 2.05 | 2.25 | 2.05 |
| 7 | Kerogen | 14.02 | 18.66 | 25.30 | 25.63 | 25.12 |
| 8 | Pyrolysis water | 0.73 | 2.82 | 1.99 | 0.17 | 2.78 |
| 9 | Bitumen | 0.52 | 4.72 | 1.99 | 2.20 | 0.59 |
| 10 | Gas | 4.47 | 4.79 | 6.00 | 3.04 | 4.48 |

Mineral composition (gallium, germanium, silver, vanadium, rare earth metals, etc.) of oil shale is composed of 2/3 common elements [8]. Thus, the development of new technologies is changing the ratio of mineral parts. That is why the study was included a microelement composition research of Azerbaijan oil shale (Table 3).

**Table3.** *Microelement composition of Azerbaijan oil shale*

| Areas | Amount of microelements,g/t | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sr | Ba | Cu | Zn | V | Cr | Mo | Mn | Fe | Co | Ni |
| Jangicay (south) | 220 | 170 | 26 | 160 | 116 | 20 | 4 | 240 | 3.36 | 11 | 9 |
| Jangichay (North) | 168 | 145 | 77 | 245 | 103 | 23 | 5 | 185 | 3,87 | 17,9 | 13 |
| Jangidagh | 350 | 400 | 16 | 236 | 140 | 36 | <1 | 960 | 3,40 | 17 | 10 |
| Bayanata | 305 | 188 | 68 | 319 | 129 | 20 | 8 | 243 | 3.75 | 9 | 14.7 |

Eruption of mud volcanoes ends with emission of products at a depth of 6-8 km and more. These products are sole data, which contain information on geology of deep deposits of region, where have not been studied with drilling or detailed geophysical surveys.To study of hydrocarbon potential of deep sediments in a region on the basis of geological and geochemical research of oil shale and oil-bearing rocks association in ejected products of mud volcanoes is the first experience not only in Azerbaijan, as well as in the world. Almost all of mud volcanoes in Gobustan are ejecting oil shale and oil-bearing rocks (Figura 5).Gobustan is a model region to conduct these stdies.

**Fig5.** *Oil shale (ejected by mud volcano in Gobustan)*

There are more 100 mud volcanoes in the region (Figure 6).

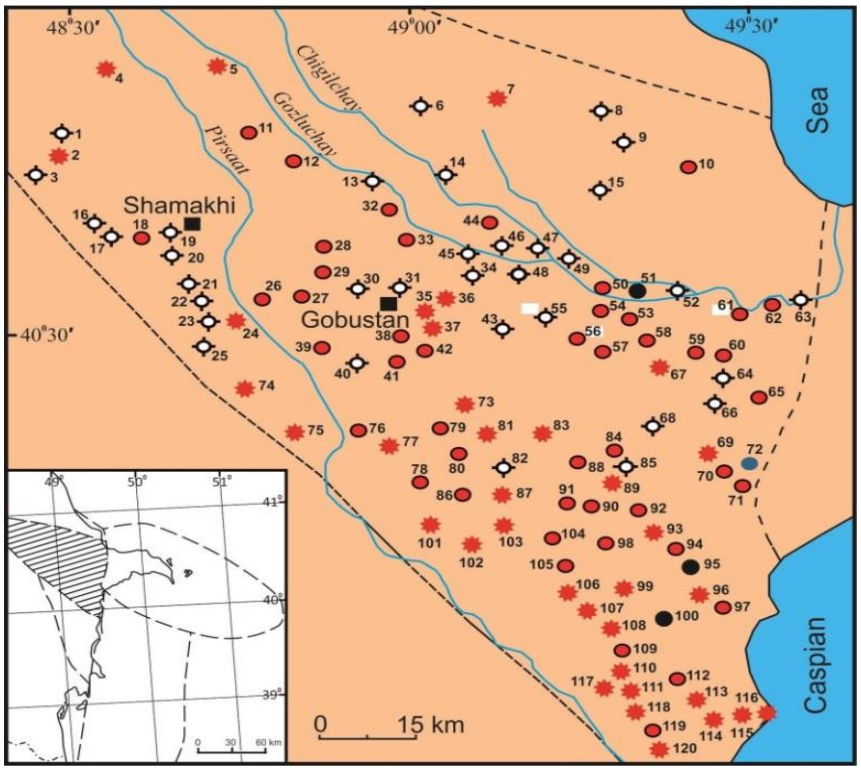



**Fig6.** *Location map of mud volcanoes in Shamakhy-Gobustan region.*

*1-Sarsura; 2-Zeiva; 3-Bizlan; 4-Demirchi; 5-Gyzmeidan; 6-Yailag-Tudar; 7-Gasymkend; 8-Kekhnagyady; 9-Kemchi; 10-Kurkachidag; 11-Hajyly; 12-Khilmilli; 13-Garayaz; 14-Agde-re; 15-Shikhandag; 16-Nohur; 17-Garanohur; 18-Madrasa; 19-Sarabil; 20-Kyalakhana; 21-Osmanbeili; 22-Charhan; 23-Nyuidi; 24-Melikchobanly; 25-Gyrlyg-Geoglyar; 26-Chy-rag-ly; 27-Akhar-Bakhar; 28-Jeirli; 29-Chalov; 30-Maraza; 31-Gurbanchi; 32-Nabur; 33-Chaigur-banchy; 34-Shimshadi; 35-Kichik Maraza; 36-Bozaakhtarma; 37-Shikhzarli; 38-Shorsulu; 39-Ekakhana; 40-Makhlajik; 41-Arabgadim; 42-Juan; 43-Gaiblar; 44-Yeldarasi; 45-Gara-jyuzlyu; 46-west Tuva; 47-east Tuva; 48-south Tuva; 49-Siyaki; 50-west Veis; 51-east Veis; 52-Neftik; 53-Jengi; 54-Syungur; 55-Iyimish; 56-Birgut; 57-Donguzdug; 58-Baigushlu; 59-Sarydash-Bayanata; 60-Gyrdag; 61-Pirekyashkyul MV group; 62-Agdag; 63-Arbat; 64-Gyrgyshlag; 65-Boransyz-Jylga; 66-Agzygyr; 67-Garyja; 68-Charani; 69-Chapylmysh; 70-Shakhgaya; 71-Chukhuroglybozu; 72-Gazanagyl; 73-Sheitanud MV group; 74-Gushchu; 75-Kolany; 76-Baidar; 77-Ayazakhtarma; 78-Ilkhychy; 79-Sheikh Novruz; 80-Sundi; 81-Nar-daranakhtarma MV group; 82-Kyurdamich; 83-Suleimanakhtarma; 84-Cheilakhtarma; 85-Gadridere; 86-Hajiveli; 87-Agnohur; 88-west Cheildag; 89-east Cheildag; 90-Galen--darakhtarma; 91-Umbaki; 92-west Davalidag; 93-east Davalidag; 94-Utalgi; 95-Agtapa; 96-Beyuk Kyanizadag; 97-Goturlug; 98-Gylynch; 99-Toragay; 100-kichik Kyanizadag; 101-Hajivelieri; 102-Dashmardan; 103-Shekikhan; 104-Agdam MV group; 105-Arzani; 106-Durandag; 107-Gotur; 108-Agtirme; 109-Emjek-emjek; 110-Solakhay; 111-Oyoug; 112-Gyogyarchin; 113-Dilyangyaz; 114-Dashgil; 115-Bala Bahar; 116-Bahar; 117-Garakyura; 118-Airanteken; 119-Saryboga; 120-Goturdag.*

Approximately all the mud volcanic structures in the Gobustan region are potentially oil-bearing. Duvanny oil and gas field is developing in Southern Gobustan (Productive series, Miocene). Commercial oil and gas content of the productive series V and VII horizons has been established (over the Garadag break-down suite) at the Dashgil mudvolcanic area; Kyanizadag gas condensate field has been discovered in the Productive series; commercial oil influx from the Miocene sediments (Chockrak horizon) has been obtained on the Dashgil structure.

A study aimed at obtaining new information on stratigraphic intervals and depths of hydrocarbon in the study area. To clarify the potential of hydrocarbon generation in Eocene and the Maikop deposits and its possible accumulation in relatively young rocks in the structures which are associated with mud volcanoes, the geochemical and geological indicators were analyzed.

İt was conducted geochemical studies of oil shale and oil-bearing rocks (Paleogene-Miocene), which sampled from mud volcanic products. The organic matter content of oil shale was determinated in the range of 7.56-42.55% (Diagram).

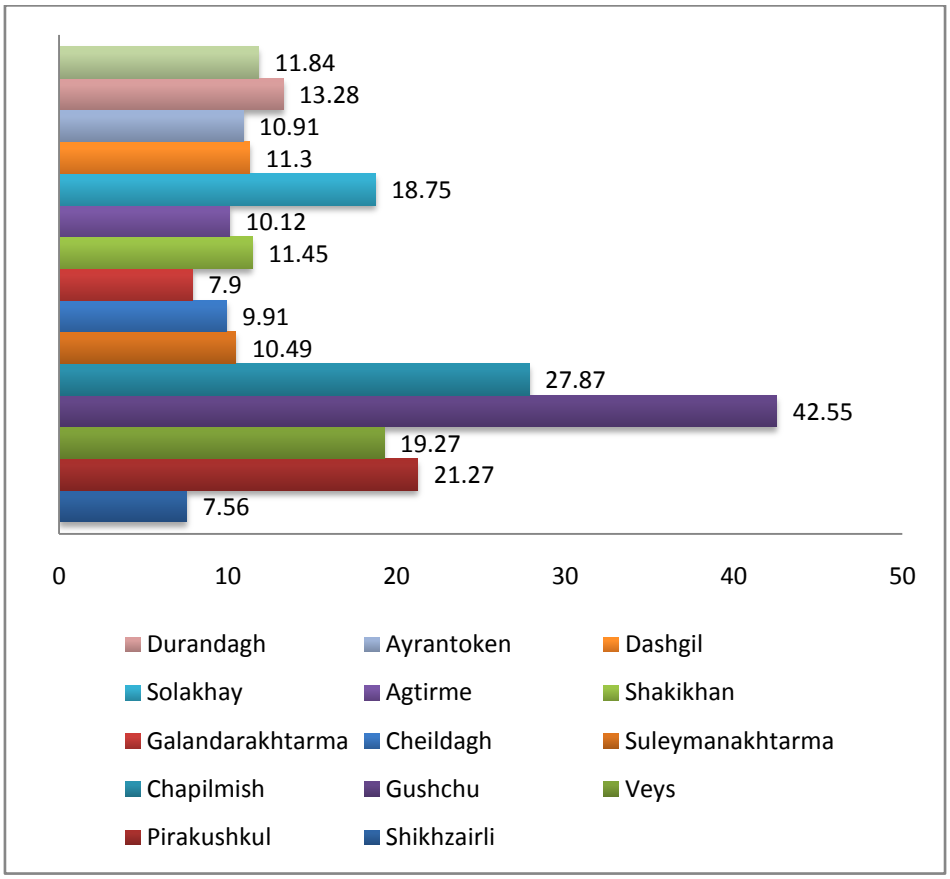



**Diagram.** *Organic matter content of oil shale in Gobustan mud volcanoes.*

The results of extraction, thermolysis and pyrolysis for oil shale indicates that related with re-changing of organic matter in its composition: long aliphatic C-C bonds are destroyed at the stage of ketogenesis, minerals and organic substances are separated from each other in kerogen composition and the whole process ends with formation of hydrocarbon.

The comparative analysis of bitumen, whch obtained from kerogen of oil shale (Paleogene-Miocene age) and oil-bearing rocks (associated with young deposits) confirms their close genetic relationship.

The results of geochemical studies show that Paleogene-Miocene deposits of the region (Central and Southern Qobustan) had a potential to generate hydrocarbon. Its accumulation may be related with fractured reservoirs of Eocene and as well as the relatively young sediments (Productive series and Miocene).

On the basis of comparative analysis is determined that the main geocemical parameters (organic matter (15-31%), sulfur (0.4-1.2%), ash content (65-85%) and calorific value (6.0-12MJ / kg)) of Azerbaijan oil shale deposits (Guba, Dialli, Jangichay and etc.) superior low-calorie oil shale deposits of the number countries (Germany, Romania, China, and others.).

**Table4.** *Geochemical comparison of Azerbaijan and foreign countries oil shale*

| Object | Organic matter, % | Sulfur, % | Ash content, % | Calorific value, MJ / kg |
|---|---|---|---|---|
| Azerbaijan | 15-31 | 0.4-1.2 | 65-85 | 6.0-12 |
| Forigen contries | 12 -28 | 0.7-6.0 | 51-79 | 4.0-10.5 |

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