

INVESTIGATION OF THE FRACTIONAL COMPOSITION OF HEAVY OIL RESIDUE-BEARING ROCKS FROM THE CHIMYON AREA OF THE FERGANA REGION

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Abstract

This study investigates the geological, petrographic, and bituminological characteristics of heavy oil residue-bearing rocks from the Chimyon–Shor-Su area of the Fergana Region. Field observations showed that bituminous material is mainly distributed along fractures, pores, and cavities within the host rocks. The investigated samples included limestone, sandstone, marl, sulfur-bearing rocks, and bituminous “waxy stone.” Petrographic examination demonstrated that the bituminous matter occurs within carbonate-clayey aggregates, pore-filling cement, and rock fractures. Luminescence-bituminological analysis showed that the chloroform-soluble extract content ranged from 0.00016 to 0.160%, whereas the alcohol-benzene-soluble extract varied from trace amounts to 0.080%. The highest concentrations of neutral bitumoids were detected in shell limestone, sandy limestone, and calcareous “waxy stone.” Ozokerite-bearing rocks from the Shor-Su area were characterized by a high proportion of solid hydrocarbons, indicating enrichment in heavy, high-molecular-weight, and high-boiling petroleum components. The obtained results provide a scientific basis for further investigation of the fractional composition of the extracted organic matter and for evaluating its potential for thermal or catalytic processing.

Keywords: Chimyon, Shor-Su, heavy oil, natural bitumen, ozokerite, petroleum-bearing rock, fractional composition, bituminological analysis.

1. Introduction

Heavy oil residues associated with oil-bearing rocks represent a complex hydrocarbon resource containing high-molecular-weight compounds [1], resins, asphaltenes, heteroatomic substances, and mineral impurities [2]. In contrast to conventional crude oils, these materials generally exhibit high density, elevated viscosity, low volatility, and a significant proportion of high-boiling fractions. Their complicated composition limits direct processing and requires detailed physicochemical characterization before an appropriate extraction, separation, or upgrading method can be selected [3].

The fractional composition of heavy petroleum materials is one of the most important parameters for evaluating their processing potential [4]. Fractional analysis provides information on the distribution of hydrocarbon components according to their boiling ranges and makes it possible to estimate the proportions of light, middle, and heavy fractions [5]. The yield of individual fractions can also indicate the suitability of the extracted organic material for the production of fuel components, lubricating fractions, bituminous materials, or

feedstocks for thermal and catalytic conversion processes. A high residue content after distillation generally reflects the predominance of resins, asphaltenes, and other thermally stable high-molecular-weight compounds [6].

Oil-containing rocks may retain hydrocarbons within their pores, cracks, and mineral matrix [7]. Therefore, the characteristics of the extracted petroleum material depend not only on the original hydrocarbon composition but also on the mineralogical structure, porosity, adsorption properties, and degree of weathering of the host rock [8]. During long-term contact with the rock matrix, lighter components may be partially lost, while heavier polar compounds become concentrated and strongly adsorbed on mineral surfaces. Consequently, petroleum residues recovered from such rocks may differ substantially from freshly produced crude oil in both fractional distribution and processing behavior [9-10].

The Chimyon area of the Fergana Region is historically associated with hydrocarbon-bearing geological formations and contains rocks enriched with heavy petroleum residues [11-12]. Investigation of these materials is important for assessing their composition, identifying potentially recoverable hydrocarbon fractions, and determining possible directions for their rational utilization [13]. However, reliable evaluation requires the separation of the organic component from the mineral matrix followed by systematic fractional analysis under controlled conditions [14-15].

The present study aims to investigate the fractional composition of heavy oil residue-bearing rocks collected from the Chimyon area of the Fergana Region. Particular attention is given to the separation of the hydrocarbon-containing component, determination of the yields of fractions within selected boiling-temperature intervals, and evaluation of the heavy residue remaining after distillation. The obtained results are expected to provide a scientific basis for assessing the processing potential of these unconventional petroleum-containing raw materials and for selecting suitable methods for their further thermal, catalytic, or chemical upgrading.

2. Materials and Methods

2.1. Study area and sample collection

Heavy oil residue-bearing rock samples were collected from the Chimyon area of the Fergana Region, Uzbekistan. The sampling sites were selected based on the visible occurrence of dark-colored petroleum residues, oil-stained rock surfaces, and characteristic hydrocarbon odor. General views of the investigated area and the sampling locations are presented in Figure 1.

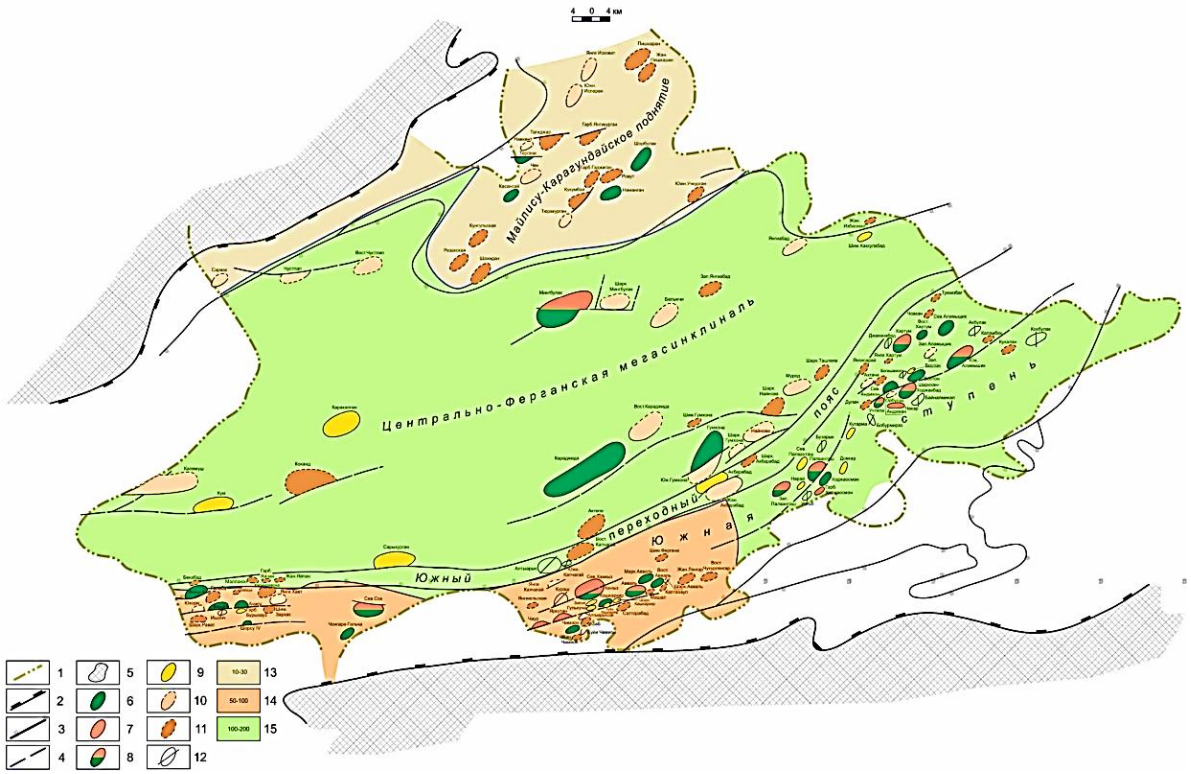


Figure 1. Location map of hydrocarbon fields and prospective areas identified, prepared for drilling, currently under drilling, and withdrawn from drilling, based on the petroleum geological zoning of the Fergana Region.

Legend:

1 - State border of the Republic of Uzbekistan;
2 - Boundary of the Fergana Depression;
3 - Boundaries of tectonic zones;
4 - Major faults;
5 - Surface exposures of the folded basement rocks;
6 - Oil fields;
7 - Gas and gas-condensate fields;
8 - Oil-and-gas and oil-and-gas-condensate fields;
9 - Structures currently under drilling;
10 - Prepared structures;
11 - Identified structures;
12 - Structures withdrawn from drilling;
13 - Concentration of prospective Category V hydrocarbon resources, thousand tonnes of oil equivalent per km^2;
14 - Concentration of prospective Category III hydrocarbon resources, thousand tonnes of oil equivalent per km^2;
15 - Concentration of prospective Category II hydrocarbon resources, thousand tonnes of oil equivalent per km^2.

2.2. Geological description of the sampling area

The investigated heavy oil residue-bearing rock samples were obtained from the Shor-Su sulfur mine area in the Fergana Region. The sampling site represents an open-pit quarry characterized

by steeply inclined to nearly vertical sedimentary formations. A general view of the quarry and the exposed geological layers is presented in Figure 2.



Figure 2. Shor-Su sulfur mine open pit in the Fergana Region. Bituminous impregnation of the rocks is observed along fractures on both sides of the quarry. The sedimentary layers are oriented nearly vertically.

Representative rock fragments were collected manually from different points of the investigated zone to obtain samples that reflected the general characteristics of the oil-bearing geological material. The samples were placed in clean, tightly sealed containers to minimize contamination and the loss of volatile components during transportation. Photographs of the collected heavy oil residue-bearing rock samples are shown in Figure 3.



Figure 2. Heavy oil residue-bearing rock samples collected from the Chimyon area.

After transportation to the laboratory, the samples were cleaned of loosely attached soil, plant residues, and other foreign materials. The rocks were then air-dried at room temperature, mechanically crushed, and homogenized. The crushed material was sieved to obtain a uniform particle-size fraction suitable for subsequent extraction and fractional analysis.

2.3. Preliminary preparation of the rock samples

A representative portion of each homogenized sample was weighed using an analytical balance. The prepared rock material was stored in sealed glass containers until analysis. Before extraction, the samples were additionally mixed to ensure uniform distribution of the organic and mineral components.

The moisture content of the samples was determined by drying a known mass at an appropriate temperature until constant weight. The mass loss was expressed as a percentage of the initial sample mass. This correction was considered when calculating the yield of the extracted organic material.

2.3. Extraction of the heavy petroleum residue

The organic component was separated from the mineral matrix by solvent extraction. A known mass of the crushed rock sample was placed in an extraction vessel and treated with an organic solvent capable of dissolving heavy petroleum hydrocarbons. The extraction was continued until the solvent phase became nearly colorless, indicating that most of the extractable petroleum material had been removed from the rock matrix. The combined extracts were filtered to remove fine mineral particles. The solvent was subsequently separated by controlled evaporation or distillation. The extracted material was stored in sealed glass containers prior to fractional distillation and physicochemical characterization.

2.4. Determination of fractional composition

The fractional composition of the extracted heavy petroleum residue was determined by distillation according to selected boiling-temperature intervals. A known mass of the extracted material was introduced into a laboratory distillation flask equipped with a thermometer, condenser, receiver, and heating system.

The sample was heated gradually to ensure controlled separation of the volatile and semi-volatile components. Distillate fractions were collected within predetermined boiling ranges.

Depending on the characteristics of the sample and the experimental conditions, the fractions may be classified as follows:

- initial boiling point to 200 °C;
- 200–250 °C;
- 250–300 °C;
- 300–350 °C;
- above 350 °C or the non-distillable residue.

The exact boiling intervals should be adjusted according to the experimental data used in the study. Each collected fraction was cooled to room temperature and weighed. The residue remaining in the distillation flask was also weighed and expressed as a percentage of the initial sample mass. The material balance was verified by comparing the total mass of all collected fractions and the residual fraction with the initial mass of the extract.

2.5. Determination of physicochemical properties

The principal physicochemical characteristics of the extracted heavy oil residue and selected distillation fractions were determined using standard laboratory procedures. Depending on the available analytical data, the investigated parameters may include density, viscosity, refractive index, flash point, pour point, ash content, sulfur content, and Conradson carbon residue.

Density was determined at a specified temperature using a pycnometer or digital density meter. Kinematic viscosity was measured using a capillary viscometer at selected temperatures. Ash content was determined by combustion of the sample followed by calcination of the remaining inorganic residue to constant mass.

Where applicable, the chemical structure of the extracted material and its fractions was investigated by Fourier-transform infrared spectroscopy. The spectra were recorded over the selected wavenumber range, and the principal absorption bands corresponding to aliphatic, aromatic, oxygen-containing, and sulfur-containing functional groups were identified.

2.6. Data processing

All measurements were carried out using representative sample portions. Where replicate measurements were available, the results were expressed as mean values with corresponding standard deviations. Fraction yields and mass-balance values were calculated using spreadsheet software. Graphical relationships between boiling range and fraction yield were prepared using Origin software.

The obtained data were used to evaluate the distribution of light, middle, and heavy hydrocarbon fractions and to assess the potential suitability of the extracted material for further thermal, catalytic, or chemical processing.

3. Results and Discussion

3.1. Geological and petroleum-geological setting

The Fergana petroleum-bearing region is one of the oldest hydrocarbon-producing areas of Central Asia. The Chimyon oil field was discovered in 1885, and by 2021 a total of 33 oil and gas fields had been recorded within the region. Most of these accumulations are associated with Paleogene deposits, although productive intervals also occur in Paleozoic, Jurassic, Cretaceous, and Neogene formations.

The Fergana Depression is subdivided into several major structural-tectonic elements, including the Southern Step, Southern Transitional Belt, Central Fergana Megasyncline, Maylisu–Karagunday Uplift, and Northern Thrust Belt. Faults, folds, and uplifted marginal zones

played an important role in hydrocarbon migration and the formation of natural bitumen and heavy-oil accumulations.

Table 1.

Distribution of oil and gas fields among the principal structural zones of the Fergana Region

Structural zone	Number of fields	Main productive intervals
Southern Step	25	Paleozoic, Jurassic, Cretaceous, Paleogene and Neogene
Maylisu–Karagunday Uplift	4	Paleogene and Neogene
Central Fergana Megasyncline	3	Paleogene and Neogene
Southern Transitional Belt	1	Paleogene
Total	33	Paleozoic-Neogene

The data show that approximately three-quarters of the known fields are concentrated within the Southern Step. This distribution reflects its complex fault-controlled structure and wide stratigraphic productivity. Paleogene deposits are the most important productive units, accounting for 26 of the 33 fields, while Neogene and Cretaceous formations also make significant contributions.

3.2. Occurrence of heavy oil and natural bitumen

Natural bitumen accumulations in the Fergana Region occur mainly in the Alay, Turkestan, Rishtan, and Sumsar Paleogene layers. Their formation is associated with the transformation of pre-existing petroleum accumulations under near-surface hypergene conditions. Sulfate- and carbonate-bearing host rocks likely promoted oxidation, degradation, and concentration of the heavier petroleum components.

Field observations in the Shor-Su quarry indicated that bituminous matter is concentrated along fractures, while the host sedimentary strata are nearly vertical. This structural configuration provides migration pathways for petroleum fluids and promotes their retention within cracks, cavities, and porous intervals.

Table 2.

Reported composition and occurrence of ozokerite-bearing rocks in the Shor-Su area

Parameter	Reported range or value
Ozokerite content in rock	2–8%
Solid hydrocarbons in ozokerite	50–70%
Resinous substances	2–27%
Liquid hydrocarbons	30–50%
Maximum ozokerite content in “waxy stone”	Up to 9.5%
Ozokerite content in “combustible stone”	Up to 2.92%
Ozokerite content in fractured limestone of Layer VII	1.5–5.0%

The relatively high proportion of solid hydrocarbons demonstrates that Shor-Su ozokerite represents a strongly transformed petroleum material enriched in high-molecular-weight paraffinic components. The presence of 30–50% liquid hydrocarbons nevertheless indicates that part of the material may retain extractable and potentially separable lower-molecular-weight fractions. Differences in ozokerite content among lithological units confirm that porosity, fracturing, and rock composition strongly affect bitumen accumulation.

3.3. Petrographic characteristics of the Shor-Su samples

Microscopic examination revealed that the Shor-Su samples consist of both carbonate and terrigenous lithologies. Sample 1a was identified as a fine-grained, locally clotted, clayey limestone with recrystallized calcite, oolitic relics, and bitumen-impregnated clayey-carbonate aggregates. Bituminous matter was also observed in fractures filled with carbonate-clay material. Sample 2a was characterized as a fine- to medium-grained calcareous sandstone containing quartz, feldspar, rock fragments, carbonates, and a heterogeneous clayey to bituminous cement.

Table 3.

Petrographic characteristics of the investigated Shor-Su rock samples

Characteristic	Sample 1a	Sample 2a
Main lithology	Clayey limestone	Calcareous sandstone
Texture	Fine-grained, locally clotted	Fine- to medium-grained
Main mineral features	Recrystallized calcite, oolites, shell detritus	Quartz, feldspar, rock fragments, carbonates
Typical grain size	Oolites: 0.3–0.6 mm	Mainly 0.3–0.5 mm; overall 0.2–0.7 mm
Carbonate features	Calcite nests up to 0.9 mm	Carbonates approximately 5% of detrital part
Detrital component	Minor quartz silt	Approximately 82%
Cement content	Carbonate-clayey material	Approximately 18%
Bitumen occurrence	Clay aggregates and fractures	Clay-bituminous and clay-carbonaceous cement
Structural feature	Strongly fractured	Porous and contact cementation

The limestone sample provides favorable locations for bitumen accumulation through fractures, calcite cavities, and clay-rich domains. In contrast, the sandstone sample contains a larger detrital framework and pore-filling cement, suggesting that hydrocarbon retention occurred mainly in pore spaces and at grain contacts. These differences indicate that the extracted heavy petroleum residue may vary in composition depending on the sampled lithology.

3.4. Petrographic characteristics of the Chimyon sample

The Chimyon sample collected near well No. 197 was represented by a poorly sorted clayey-calcareous sandstone. The detrital fraction accounted for approximately 80% of the rock and was dominated by rock fragments, quartz, and feldspar. The cement content was approximately 20%, comprising clayey, siliceous-clayey, carbonaceous-clayey, and less frequently carbonate and quartz components. The rock exhibited uneven primary porosity with pore sizes up to 0.1 mm.

Table 4.

Mineralogical and textural composition of the Chimyon sandstone sample

Component or parameter	Content or description
Detrital fraction	Approximately 80%
Quartz	Approximately 23%
Feldspar	Approximately 18%

Rock fragments	Approximately 59% of the described detrital assemblage
Dominant grain size	0.3–0.5 mm
Overall grain-size interval	Approximately 0.2 mm–0.8 cm
Cement content	Approximately 20%
Main cement types	Clayey, clayey-siliceous and carbonaceous-clayey
Minor cement types	Carbonate and quartz
Porosity	Uneven, predominantly primary
Maximum reported pore size	Up to 0.1 mm

The observed mineralogical heterogeneity and uneven porosity provide both adsorption surfaces and migration channels for heavy petroleum components. Clay-rich cement may retain polar resinous and asphaltenic substances, while larger pores and fractures are more favorable for the accumulation of relatively mobile hydrocarbon components. This lithological heterogeneity should therefore be considered during solvent extraction and fractional separation.

3.5. Group composition of Shor-Su and North Rishtan petroleum materials

The carbon isotope composition of paraffin-naphthenic hydrocarbons, aromatic hydrocarbons, benzene resins, and alcohol-benzene resins was reported for oils and malts from the Shor-Su and North Rishtan fields.

Table 5.

Carbon isotope composition of petroleum fractions from Shor-Su and North Rishtan

Component fraction	Shor-Su oil	Shor-Su malt	North Rishtan oil	North Rishtan malt
Paraffin-naphthenic hydrocarbons	28.0	28.8	29.1	28.9
Aromatic hydrocarbons	28.6	28.8	27.7	29.6
Benzene resins	26.4	27.2	27.2	28.0
Alcohol-benzene resins	28.9	28.7	28.0	27.5

Despite compositional transformation from oil to malt, the isotope values of corresponding fractions remain relatively close. This similarity supports a common genetic origin of the petroleum and natural bitumen materials. At the same time, variation among hydrocarbon and resin fractions indicates progressive oxidation, biodegradation, and conversion of high-molecular-weight aromatic compounds into resinous and asphaltenic products.

The transformation sequence from oil through malt, asphalt, and asphaltite is accompanied by decreasing hydrocarbon content, increasing oxygen concentration, and accumulation of resins and especially asphaltenes. The source material consequently becomes heavier and less volatile, which explains the expected predominance of high-boiling and non-distillable components in the extracted petroleum residue.

3.6. Luminescence-bituminological characteristics

The concentrations of chloroform-soluble neutral bitumoids and alcohol-benzene-soluble acidic bitumoids varied substantially among the Shor-Su lithologies.

Table 6.

Results of luminescence-bituminological analysis of Shor-Su samples

No.	Lithology	Chloroform extract (%)	Alcohol-benzene extract (%)
1	Shell limestone	0.005	0.005
2	Shell limestone	0.160	0.080
3	Calcareous "waxy stone"	0.040	0.010
4	Grey limestone	0.010	0.0025
5	Sandy limestone	0.080	0.010
6	Greenish-grey marl	0.0012	0.0012
7	Sulfur-bearing rock	0.00016	Trace
9	Dark-grey marl	0.0003	0.0003

The highest chloroform-extractable content was found in shell limestone sample 2, followed by sandy limestone and calcareous "waxy stone." These samples therefore contain the greatest proportion of neutral, solvent-soluble petroleum components. Marl and sulfur-bearing rocks showed only trace or very low extract yields, indicating limited hydrocarbon saturation or stronger retention of the organic matter by the mineral matrix.

The ratio between chloroform and alcohol-benzene extracts also varies by lithology. In shell limestone sample 2, the chloroform extract is twice the alcohol-benzene extract, whereas in the marls the two fractions are nearly equal. This suggests that limestone samples are relatively enriched in neutral bitumoids, while marl samples contain a comparatively larger proportion of polar acidic components, although their total organic content is low.

3.7. Implications for fractional composition

The reported geological, petrographic, isotope, and solvent-extraction data collectively indicate that the Chimyon–Shor-Su petroleum-bearing rocks contain highly transformed heavy petroleum materials. The prevalence of ozokerite, resinous substances, solid hydrocarbons, and bituminous impregnation in fractures and clay-rich cement suggests that the organic extract should be dominated by high-boiling hydrocarbons and non-distillable residue.

The highest potential extract yields are expected from porous shell limestone, sandy limestone, and "waxy stone," while marl and sulfur-bearing rocks are unlikely to provide significant recoverable hydrocarbon fractions. The mineral matrix may also influence extraction efficiency: porous and fractured carbonate rocks permit easier solvent penetration, whereas clay-rich rocks may strongly adsorb polar resins and asphaltenes.

However, the supplied source does not contain experimental fractional-distillation results, such as fraction yields below 200°C, 200–250°C, 250–300°C, 300–350°C, or the residue above 350°C. Therefore, numerical fractional-composition tables cannot be produced reliably from these data alone. The current results section fully characterizes the geological occurrence, lithology, extractable bitumen content, and group composition, but the article's central fractional-distillation subsection must be completed using the actual masses or percentage yields of the collected boiling fractions.

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