

COMPARATIVE MINERALOGICAL-GEOCHEMICAL CHARACTERISTICS OF THE OIL-BEARING ROCKS OF EAST AZERBAIJAN WITH ATHABASCA (CANADA)

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Summary. This research evaluates the oil-bearing rocks of East Azerbaijan exemplified by the Akhtarma-Puta, Cheyildere, and Araliq areas by comparing them with Athabasca, one of the world's best-studied oil sand systems, to determine their mineralogical, major oxide, and organic-geochemical characteristics, as well as their similarities and differences. The study is based on the XRD and WDXRF results of 12 rock samples from the aforementioned areas, along with the determination of moisture content, extractable bitumen, and bitumen fractions in group samples. Compared to Athabasca, the average composition of the East Azerbaijan samples is characterized by lower quartz (28.92% vs. 51.30%), clay minerals (23.42% vs. 40.30%), and SiO₂ (46.29% vs. 78.82%), but higher feldspar (15.83% vs. 3.10%), carbonate (16.08% vs. 4.40%), and CaO (12.19% vs. 3.07%). The average bitumen content is 4.61% in the local samples and 7.15% in Athabasca, while the moisture content is 1.45% and 3.40%, respectively. Within the local areas, Cheyildere is distinguished by being quartz-rich and carbonate-free, whereas Araliq is characterized by bitumen with a high asphaltene content. These results indicate that the investigated oil-bearing rocks of East Azerbaijan possess distinct mineral-matrix and bitumen characteristics compared to Athabasca, alongside significant compositional variability within the local areas.

Keywords: East Azerbaijan, Athabasca, oil-bearing rock, mineralogy, major oxides, moisture content, bitumen

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Introduction

Azerbaijan has a rich and long-standing history of oil and gas production (Khuduzade et al., 2026). At the same time, the transition of some traditional fields into a mature development stage and the gradual year-on-year decline in national oil production make it urgent to reassess unconventional and secondary hydrocarbon sources alongside remaining reserves (Abbasov et al., 2026). In this regard, oil shales, natural bitumens, and oil-impregnated rocks in East Azerbaijan are of particular interest. In recent years, the distribution, mineralogical-geochemical characteristics, and hydrocarbon potential of Paleogene-Miocene oil shales have been investigated in detail using various approaches (Salaev et al., 1989; Aliyev et al., 2018; Abbasov et al., 2025; Aliyev, Abbasov, 2019a; Aliyev, Abbasov, 2019b; Aliyev et al., 2019). These results indicate that unconventional hydrocarbon systems are broadly repre-

sented in the region and possess prospective potential. In this context, the comparative evaluation of oil-bearing rocks within the same unconventional resource group in Azerbaijan is of special significance.

Worldwide, heavy oil and oil sand reserves constitute a major unconventional hydrocarbon base, the bulk of which is located in Cretaceous and Cenozoic reservoirs (Liu et al., 2019). The Athabasca deposit, located in the province of Alberta, Canada, and primarily associated with the Lower Cretaceous McMurray-Wabiskaw sediments, is one of the most thoroughly studied oil sand systems in terms of its geological structure, mineral matrix, bitumen composition, and extraction technologies (Hein et al., 2006; Osacky et al., 2013; He et al., 2013). Therefore, the Athabasca deposit was chosen as a reference system for comparison not due to superior resource quality, but because of its extensive and systematic database on geological structure,

mineral matrix, and bitumen properties. This approach allows for a clearer determination of the compositional position of the lesser-studied East Azerbaijan occurrences within global oil sand systems.

The aim of the present work is to comparatively evaluate the mineralogical composition, major oxide geochemistry, and organic-geochemical characteristics of the oil-bearing rocks of East Azerbaijan exemplified by the Akhtarma-Puta, Cheyildere, and Araliq areas against Athabasca, to identify their similarities and differences, and to formulate a general compositional picture of the East Azerbaijan oil-bearing rocks within this comparative context.

Geological setting and study objects

The study objects represent three different oil and gas regions of East Azerbaijan (Table 1): Akhtarma-Puta is located in Absheron, Cheyildere in Shamakhi-Gobustan, and Araliq in the Lower Kura depression. All three areas are as-

sociated with structures where mud volcanism is developed (Baldermann et al., 2020). In Akhtarma-Puta and Araliq, the samples are related to the Productive Series, whereas in Cheyildere, they are associated with the Miocene Chokrak regional stage. Since the samples occur in the form of sand and sandstone, both lithological and stratigraphic heterogeneity exist within the local areas.

Materials and Methods

A total of 12 samples were investigated (Table 1). Mineral phases were determined using a MiniFlex 600 X-ray diffractometer (XRD), and major element oxides were analyzed using an S8 TIGER Series 2 WDXRF spectrometer. The quantitative contents of quartz, feldspars, clay minerals, carbonates, and other mineral phases were evaluated from the XRD results, while the distribution of major oxides was assessed from the WDXRF data.

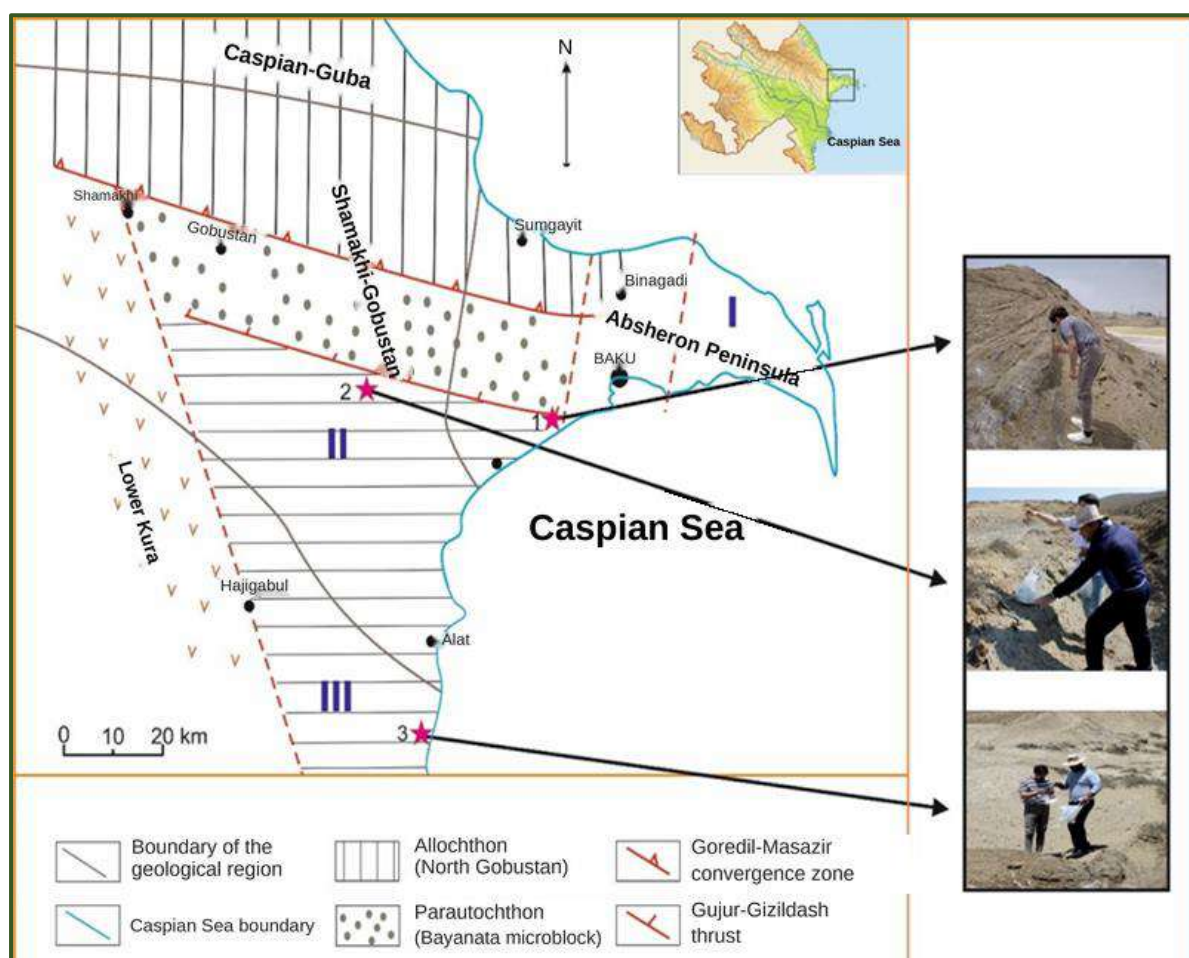


Fig. 1. Regional location of the Akhtarma-Puta (1), Cheyildere (2), and Araliq (3) areas

Table 1

Brief geological characterization of the study objects

Area	Oil and Gas Region	Stratigraphy	Lithology	Number of Samples
Akhtarma-Puta	Absheron	Productive Series	Sand, Sandstone	4
Cheyildere	Shamakhi-Gobustan	Chokrak	Sand, Sandstone	4
Araliq	Lower Kura	Productive series	Sand, Sandstone	4

In the organic-geochemical section, moisture content, extractable bitumen, oil, resin, and asphaltene fractions, as well as hydrocarbon groups, were evaluated across group samples. Indicators carrying identical or similar analytical significance compared to Athabasca were selected. For comparison with Athabasca, data from Osacky et al. (2013) were utilized for mineralogy and major oxides, and data from He et al. (2013) for the fractional composition of bitumen. Organic fractions obtained through different laboratory protocols were not treated as direct equivalents.

Results and Discussion

General mineral-geochemical comparison with Athabasca

The local samples are depleted in quartz and total clay minerals compared to Athabasca, while being richer in feldspars and carbonates (Table 2, Fig. 2). This difference is also reflected in the major oxide composition: the East Azerbaijan samples exhibit lower SiO_2 and Al_2O_3 , but higher CaO and Fe_2O_3 contents. Consequently, the average composition of the local rocks transitions from Athabasca's quartz-clay dominant matrix to a more feldspathic-carbonate matrix.

Table 2

Comparison of the average parameters of East Azerbaijan samples with Athabasca

Parameter	East Azerbaijan, average	Athabasca	Comparative feature
Bitumen, %	4,61	7,15	lower in local samples
Water, %	1,45	3,40	lower in local samples
Mineral fraction, %	93,94	89,40	higher in local samples
Quartz, %	28,92	51,30	lower in local samples
Feldspar, %	15,83	3,10	higher in local samples
Clay minerals, %	23,42	40,30	lower in local samples
Carbonates, %	16,08	4,40	higher in local samples
SiO_2 , %	46,29	78,82	lower in local samples
Al_2O_3 , %	9,54	13,03	lower in local samples
CaO , %	12,19	3,07	higher in local samples
Fe_2O_3 , %	4,98	2,00	higher in local samples

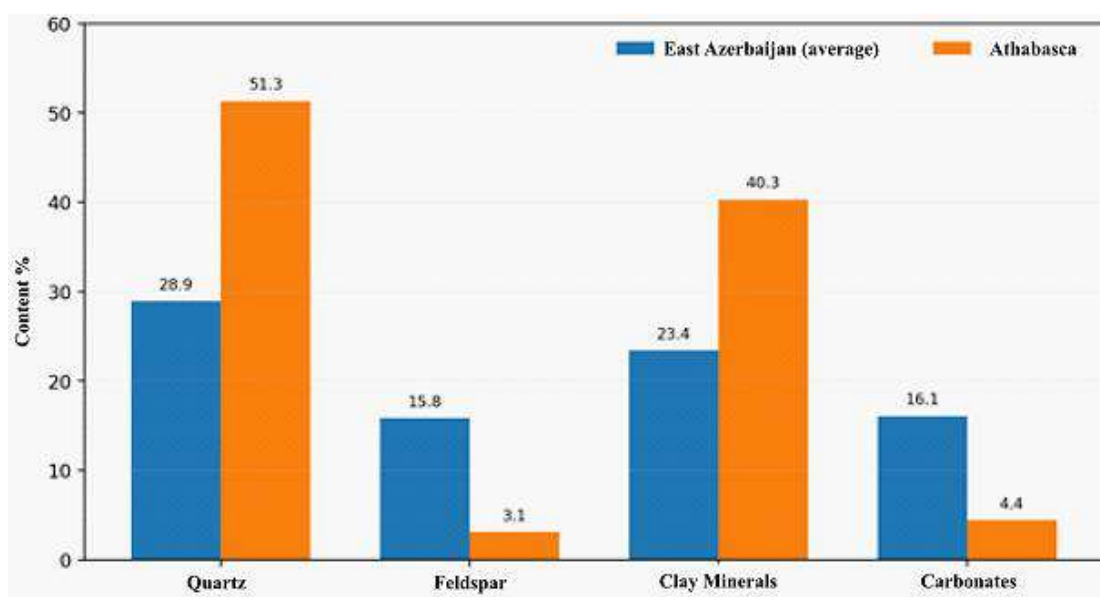


Fig. 2. Comparison of average mineral groups of East Azerbaijan with Athabasca

Differentiating features across local areas

The overall average values do not fully reflect the variability within the three areas. Cheyildere is distinguished by a high quartz and SiO₂ content, the absence of carbonates, and very low CaO (Table 3). In contrast, Akhtarma-Puta and Araliq exhibit lower quartz contents along with higher carbonate and CaO values. Although the total bitumen content is relatively similar across the three areas, their fractional composition is not identical, with Araliq clearly standing out due to its high asphaltene content. These spatial differences indicate that the average values calculated for East Azerbaijan are the generalized result of various local compositions and necessitate considering the intra-system heterogeneity in comparison with Athabasca.

Bitumen content and organic-geochemical characteristics

Although the total bitumen content in the local areas is relatively similar, its fractional and hydrocarbon composition varies noticeably

(Fig. 3). In Akhtarma-Puta and Cheyildere, the oil fraction is predominant, while asphaltene content remains at approximately 11%. In Araliq, against the background of a decreasing oil fraction, the asphaltene content rises to 41.65%. Regarding hydrocarbon groups, Akhtarma-Puta and Cheyildere are distinguished by the dominance of methane-naphthenic components, whereas Araliq is characterized by a high proportion of monocyclic compounds. Data on the SARA composition of Athabasca bitumen also indicate that it is characterized by a complex composition consisting of saturate, aromatic, resin, and asphaltene fractions (Osacky et al., 2013). Furthermore, the mineral and chemical properties of Athabasca oil sands demonstrate that the mineral matrix hosting the bitumen also plays a crucial role in the overall compositional character of the system (He et al., 2013). Consequently, compared to Athabasca, the East Azerbaijan bitumens exhibit distinct compositional characteristics not only in terms of bitumen content, but also regarding fractional properties and their interaction with the mineral matrix.

Table 3

Main differentiating parameters across local areas

Area	Quartz, %	Carbonate, %	SiO ₂ , %	CaO, %	Bitumen, %	Asphaltene, %
Akhtarma-Puta	14,75	22,75	30,42	18,24	4,69	10,74
Cheyildere	50,75	0,00	66,92	0,86	4,67	10,87
Araliq	21,25	25,50	41,53	17,48	4,48	41,65

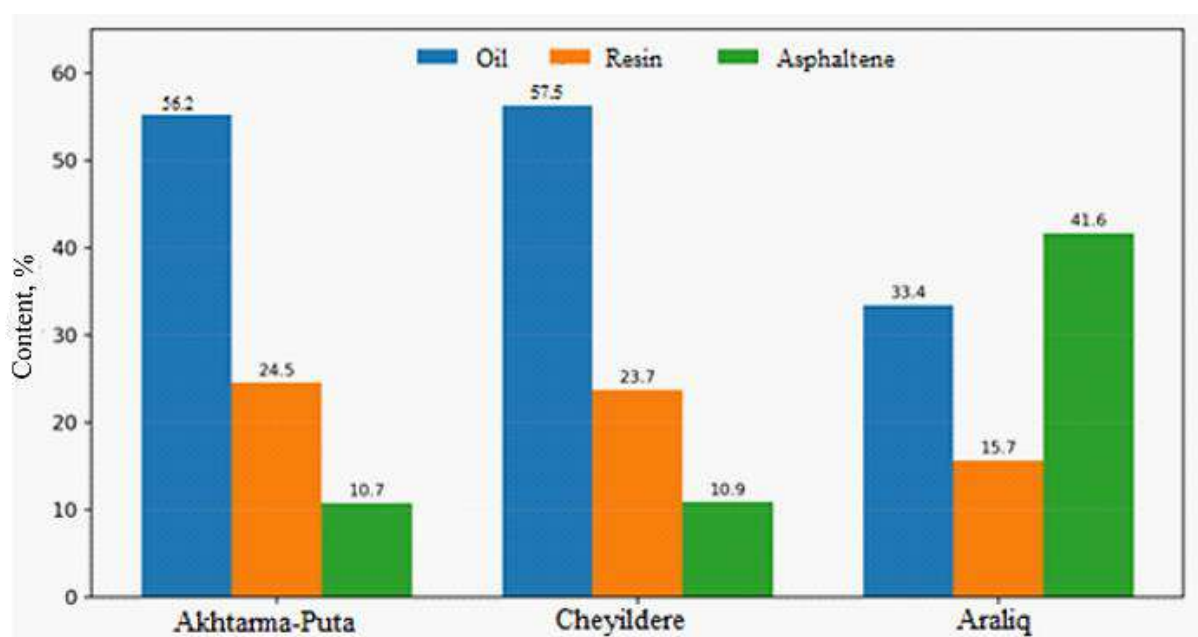


Fig. 3. Distribution of oil, resin, and asphaltene fractions of bitumen across local areas

Conclusion

The comparison with Athabasca demonstrates that the investigated oil-bearing rocks of East Azerbaijan possess a distinct regional compositional profile in terms of their mineral matrix and bitumen characteristics. While the average quartz content in the local samples is 28.92% and carbonate content is 16.08%, these values in Athabasca are 51.30% and 4.40%, respectively. The average bitumen content is 4.61% in the East Azerbaijan samples and 7.15% in Athabasca. These differences indicate that local oil-bearing rocks are distinguished

from Athabasca's quartz-clay-dominated system by a more feldspathic-carbonate mineral matrix and lower bitumen content. Furthermore, the differences identified among Akhtarma-Puta, Cheyildere, and Araliq confirm the existence of significant spatial heterogeneity within the regional profile, where the rise of asphaltenes to 41.65%, particularly in Araliq, shows that the fractional composition of bitumen varies substantially across areas. Therefore, the general comparison of East Azerbaijan's oil-bearing rocks with Athabasca must be complemented by a separate consideration of spatial characteristics.

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СРАВНИТЕЛЬНАЯ МИНЕРАЛОГО-ГЕОХИМИЧЕСКАЯ ХАРАКТЕРИСТИКА НЕФТЕНОСНЫХ ПОРОД ВОСТОЧНОГО АЗЕРБАЙДЖАНА И АТАБАСКИ (КАНАДА)

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Резюме. В данном исследовании проводится оценка нефтеносных пород Восточного Азербайджана (на примере площадей Ахтарма-Пути, Чейлдере и Аралых) путем их сравнения с Атабаской одной из наиболее изученных в мире систем нефтеносных песков с целью определения их минералогических, петрохимических (основные оксиды) и органико-геохимических характеристик, а также выявления их сходств и различий. Работа основана на результатах рентгенофазового (XRD) и волнодисперсионного рентгенофлуоресцентного (WDXRF) анализов 12 образцов пород из указанных районов, а также на определении влажности, экстрагируемого битума и группового состава битумных фракций. По сравнению с Атабаской, средний состав образцов из Восточного Азербайджана характеризуется более низким содержанием кварца (28,92% против 51,30%), глинистых минералов (23,42% против 40,30%) и SiO₂ (46,29% против 78,82%), но более высоким содержанием полевых шпатов (15,83% против 3,10%), карбонатов (16,08% против 4,40%) и CaO (12,19% против 3,07%). Среднее содержание битума в местных образцах составляет 4,61% (в Атабаске 7,15%), а влажность 1,45% и 3,40% соответственно. Среди исследованных местных площадей Чейлдере выделяется повышенным содержанием кварца и отсутствием карбонатов, в то время как Аралых характеризуется битумом с высоким содержанием асфальтенов. Полученные результаты показывают, что исследованные нефтеносные породы Восточного Азербайджана обладают специфическими минеральной матрицей и характеристиками битума по сравнению с Атабаской, наряду со значительной вариативностью состава внутри самих локальных участков.

Ключевые слова: Восточный Азербайджан, Атабаска, нефтеносная порода, минералогия, основные оксиды, влажность, битум

ŞƏRQİ AZƏRBAYCANIN NEFTLİ SÜXURLARININ ATABASKA (KANADA) İLƏ MÜQAYİSƏLİ MİNERALOLJİ-GEOKİMYƏVİ XÜSUSİYYƏTLƏRİ

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Xülasə. Tədqiqat işi Axtarma-Puta, Çeyildərə və Aralıq sahələrinin təmsalında Şərqi Azərbaycanın neftli süxurlarını dünyanın ən yaxşı öyrənilmiş neftli qum sistemlərindən biri olan Athabasca ilə müqayisə etməklə onların mineraloji, əsas oksid və üzvi-geokimyəvi xüsusiyyətlərini, oxşar və fərqli cəhətlərini müəyyən edir. Tədqiqat adıçəkilən sahələrə aid 12 süxur nümunəsinin XRD və WDXRF nəticələrinə, həmçinin qrup nümunələrində nəmlik, ekstraksiya olunan bitum və bitum fraksiyalarının təyininə əsaslanır. Şərqi Azərbaycan nümunələrinin orta tərkibi Atabaska ilə müqayisədə daha az kvars (28,92 və 51,30%), gil mineralları (23,42 və 40,30%) və SiO₂ (46,29 və 78,82%), lakin daha çox çölşpatı (15,83 və 3,10%), karbonat (16,08 və 4,40%) və CaO (12,19 və 3,07%) ilə səciyyələnir. Orta bitum miqdarı yerli nümunələrdə 4,61%, Atabaskada 7,15%, nəmlik isə müvafiq olaraq 1,45 və 3,40%-dir. Yerli sahələr daxilində Çeyildərə kvars ilə zəngin və karbonatsız, Aralıq isə yüksək asfaltlı bitumla seçilir. Bu nəticələr Şərqi Azərbaycanın tədqiq olunan neftli süxurlarının Athabasca ilə müqayisədə fərqli mineral-matris və bitum xüsusiyyətlərinə malik olduğunu, yerli sahələr daxilində də əhəmiyyətli kompozisional dəyişkənliyin mövcudluğunu göstərir.

Açar sözlər: Şərqi Azərbaycan, Atabaska, neftli süxur, mineralojiya, əsas oksidlər, nəmlik, bitum