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Geochemical and stratigraphic features of the Upper Jurassic formation in Southeastern Caucasus: Jimichay and Gilgilchay River basins (Azerbaijan)

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Геохімічні та стратиграфічні особливості верхньоюрської формації Південно-Східного Кавказу: басейни річок Джимічай та Гільгільчай (Азербайджан)

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This study presents the results of a detailed investigation of Upper Jurassic carbonate-terrigenous deposits within the Side Range structural formation zone of the Southeastern Caucasus. The research involved stratigraphic profiling, spatial correlation of sections, and systematic mineralogical and geochemical analysis sampling. The deposits primarily consist of fine- to medium-grained sandstones, pelitic and microcrystalline limestones, argillites, and fine-grained conglomerates, indicating accumulation on a steep continental slope. Geochemical data show a consistent composition across stratigraphic levels, suggesting moderate sediment maturity and a predominantly mechanical origin. Based on the petrochemical parameters studied, the Upper Jurassic rocks have been classified as lithogenic formations, which do not contain volcanic or terrigenous-pyroclastic impurities. They are categorized as normal siallites and pseudosiallites.

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Introduction

The Upper Jurassic deposits of the South-East Caucasus exhibit a complex mosaic structure and notable lithofacies variety, significantly complicating their stratigraphic interpretation. The scarcity of paleontological remains is particularly evident in the lower and middle sections, limiting the potential for biostratigraphic dating and correlation. However, despite extensive geological research conducted in recent decades (Khain, 1947; Vassoyevich et al., 1951; Shikhalibayly, 1956; Khain, Shardanov, 1957; Shurygin, 1961; Aghayev, Huseynov, 1973; Rostovtseva, 1992; Geology..., 2005; Kangarli, 2012; Kangarli et al., 2018), critical issues related to tectono-stratigraphic zoning and accurate age correlation of Upper Jurassic complexes in the Azerbaijani section of the Greater Caucasus remain unresolved. Upper Jurassic rocks' mineralogical and chemical composition has not been thoroughly examined. The investigation of the paleotectonic and paleoclimatic conditions surrounding the genesis of these deposits is especially noteworthy. This information is essential for developing validated sedimentation models in the eastern region of the Tethys Ocean. Contemporary tectonic theories require reevaluation in light of new field data from comprehensive lithological-stratigraphic, mineralogical, and structural studies of key Upper Jurassic sections in northern Azerbaijan. The collected data clarify the stratigraphic architecture of the Upper Jurassic complex and aid in reconstructing the sedimentary geodynamic environment, enhancing our understanding of the Alpine evolution in the Caucasus region and its role in the formation of late Mesozoic paleogeographic structures along the southern margin of the Eurasian continent.

The chemical composition of sedimentary rocks reflects the intricate interplay of climate, tectonic activity, and the availability of source materials during their formation (Strakhov, 1957; Rollinson, Pease, 2021). Since the mid-20th century, researchers have studied the chemical composition of sediments and the geochemical indicators derived from them to address various lithological and sedimentological issues (Yudovich, Ketris, 2000, 2011, 2018; Feyzullaev, Babazade, 2016; Obasi and Madukwe, 2016).

Materials and Methods

The rock samples collected by the author from various sections during fieldwork from 2015 to 2023 were analyzed under laboratory conditions. The chemical and mineral composition of the sediments was analyzed at the Analytical Center of the Institute of Geology and Geophysics of the Ministry of Science and Education of Azerbaijan. This analysis aimed to quantify the concentrations of essential rock-forming oxides and trace elements using an S8-Tiger wave-dispersive X-ray fluorescence spectrometer.

For the preparation of each sample, approximately 10 g was ground in an agate mortar to create a fine powder, after which a pressed powder method was utilized. The analytical accuracy achieved was within ±0.5 for SiO_2 and Al_2O_3, ±0.17 for Fe_2O_3 and Na_2O, and ±0.8 for MgO, K_2O, MnO, TiO_2, and P_2O_5. Mineralogical analysis was carried out using X-ray diffraction with a Miniflex 600 X-ray diffractometer. A quantitative evaluation of the mineral content in the samples was performed based on the intensity of the diffraction peaks.

Geological structure of the Upper Jurassic sections

Comprehensive studies indicate that the geological framework of the Southeast Caucasus in Azerbaijan encompasses deposits ranging from the Middle Jurassic to the Paleogene, with Upper Jurassic formations being particularly prominent. The most noticeable outcrops of Upper Jurassic deposits in the studied area are found in the Sudur, Shakhdag-Khyzy, and Guton-Gonagkend tectonic zones of the Side Range (Fig. 1). Studies have confirmed the presence of all Upper Jurassic stages in this area (Khain et al., 1951; Mammadov et al., 1985; Geology..., 2007). South of the Side Range structures, an area on the southern slope has thinner Malmian deep-water deposits in the pelagic sub-flysch facies.

In the Sudur zone, the Upper Jurassic succession includes the Tahirjal, Gushgala, and Gukhur suites, which together reach a thickness of about 500 meters. The lower portion of this sequence is characterized by lagoonal facies, which gradually transite to shelf facies at the upper levels. Red and black clay-rich rocks with sandstone interlayers and thin layers of limestone dominate the lower section. The number and thickness of the limestone and sandstone layers increase in the upper stratigraphic layers. Another significant feature of the Upper Jurassic rocks in the zone is their increasing thickness as one moves southward.

The Shahdag-Khyzy zone encompasses a vast area of Azerbaijan. Upper Jurassic rocks are crucial in forming allochthonous and autochthonous structural complexes within this structural-facial zone. The allochthonous Upper Jurassic facies comprises

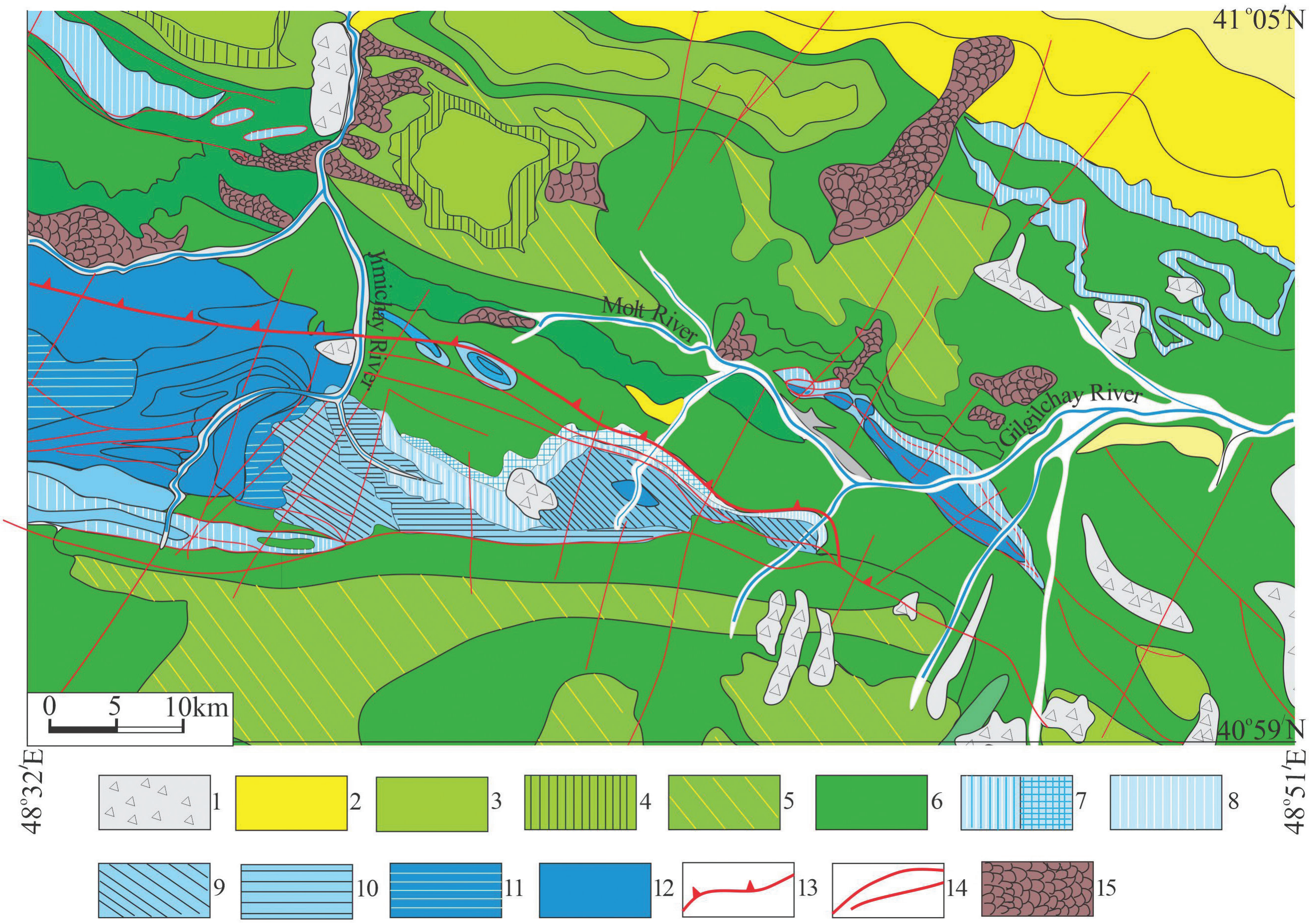

Fig. 1. Schematic geological map of the studied area: *1* – Quaternary deposits; *2* – Neogene-Paleogene; *3* – Campanian-Maastrichtian; *4* – Turonian, Santonian; *5* – Hauterivian-Barremian; *6* – Berriasian-Barremian; *7* – Kimmeridgian-Titonian (Khashy and Gukhur suites); *8* – Oxfordian-Titonian (Shahdagh suite); *9* – Upper Callovian-Oxfordian; *10* – Oxfordian stage (Garovulustu suite); *11* – Bathonian stage; *12* – Aalenian stage; *13* – Major Caucasus overthrust; *14* – faults; *15* – allochthonous plates

an alternation of massive dolomites and dolomitized, sandy, biogenic-reef, multicolored limestones. Based on the location, the thickness of the carbonatite massif ranges from 150–200 to 750–900 meters.

To the east of the Gudialchay River meridian, the Upper Jurassic is in tectonic contact with the Middle Jurassic and Lower Cretaceous, forming the central part of the autochthonous complex (Geology..., 2005; Kangarli, 2012). The basal coarse-grained layers of the Upper Jurassic, found exclusively along the Gilgilchay River, are classified as the Molt Suite and dated to the Upper Callovian–Lower Oxfordian interval (Kangarli, Mehdiyeva, 2017). This suite consists of alternating thick beds of fine- to medium-pebble conglomerates and brownish-black argillites, gradually transitioning into interbedded clayey sandstones, gravelstones, and conglomerates, totaling 130 meters. The Molt Suite is overlain by a green-colored sequence of flysch-type deposits, which consist of alternating sandstones and siltstones. This sequence includes weakly calcareous green siltstones of variable thickness and darker, non-calcareous, fissile interbeds of thin clay layers. This part of the sequence corresponds to the lower section of the Kimmeridgian Stage and is attributed to the Kyzylgazma Suite. Within this zone, the suite reaches a thickness of approximately 200 meters.

In the southern part of the Shahdag-Khyzy zone and within the Guton-Gonagkend zone, this complex consists of rhythmically interbedded carbonate, terrigenous, and clay formations, which are characteristic of continental slope and base-of-slope facies. The Upper Jurassic strata of the Guton-Gonagkend zone include the Garovulustu (Oxfordian), Gyzylgazma (Kimmeridgian), and Khashy (Tithonian) suites. Within the Guton-Gonagkend zone, two bands of Upper Jurassic formations are visible at the surface. The thickness of the section in the northern strip, which is exposed along the Istisuchay River and contributes to the formation of the northernmost structural features of the zone, is 230 m. Lithologically, these deposits consist of alternating massive, thin-layered, gray, and greenish-gray sandstones with interlayers of argillites and siltstones.

The deposits of the southern strip are exposed in the bend of the Jimichai River beyond the south edge of the village of Gonagkend (see Fig. 1). They consist of coarse terrigenous flysch with a thickness exceeding 600 m. The suite features alternating dark-gray to black, occasionally greenish-gray argillites and massive (up to 1.0 m) fine- and medium-grained calcareous sandstones containing pebbles of dark argillites and rare interlayers of marly limestones (60 m) (Khalifa-zadeh, Mehdiyeva, 2024). As one moves upward along the section, the thickness of sandy interbeds increases (1.5 m), with sandstones predominating in the middle. In both instances, the tectonic contact with the Middle Jurassic is mapped. Tithonian deposits (Khashy suites) are exposed in the Gilgilchay River's upper reaches along both Yerfi-Khashy anticline flanks. At the base of the Lower Khashy subsuite (175 m thick), there is a 7-meter-thick coarse-gravel basal conglomerate layer containing large boulders and blocks of limestone, as well as angular fragments of calcite and gypsum.

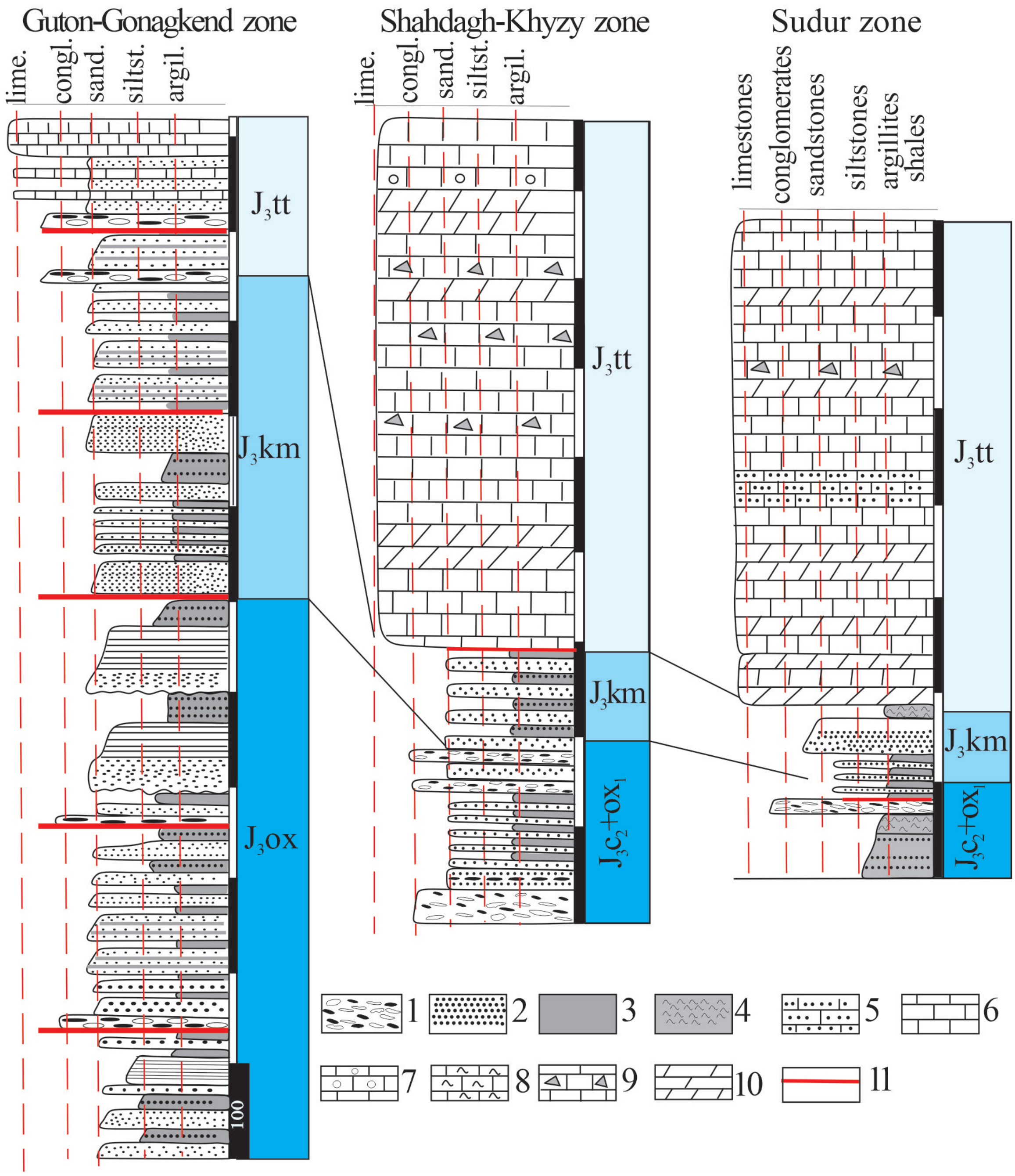

Fig. 2. Stratigraphic columns of the Upper Jurassic formations of the South-Eastern Caucasus: *1* – fine- and medium-pebbled conglomerates; *2* – Sandstones; *3* – Sandy Shales; *4* – Siltstones; *5* – Calcareous sandstones; *6* – Limestones; *7* – Sandy limestones; *8* – Pelitomorphic limestones; *9* – Breccia limestones; *10* – Dolomite; *11* – tectonic contact

The central part of the subsuite features a rhythmic alternation of green and greenish-gray sandy argillites and clayey sandstones, along with microangular and sandy limestones. Its top is brought into tectonic contact with the Lower Cretaceous succession of the Shahdagh-Khyzy zone, which occurs along the Shahdagh-Gonagkend downthrow.

An analysis and comparison of the precise lithological-stratigraphic sections indicates that the Upper Jurassic deposits in the Southeastern Caucasus demonstrate considerable regional heterogeneity within specific stratigraphic sections (Fig. 2). This diversity is intricately linked to the structural framework and morphological attributes of the paleobasin, which shaped sedimentation patterns and depositional conditions during that era.

Material composition and geochemical analysis of Upper Jurassic deposits

The Upper Jurassic sections in the Sudur, Shakhdag-Khyzy, and Guton-Gonagkend facies zones are characterized by diverse common rock types. These include mixed-pebble conglomerates, sandstones, siltstones, mudstones, and various limestones.

The lithological-geochemical analysis of Upper Jurassic rock samples has revealed that sandy-silty, clayey, and carbonate rock types, collected from various stratigraphic levels, are characterized by a consistent mineral and chemical composition.

Chemically, sandstones exhibit a relatively consistent composition. They mainly consist of quartz, which forms the bulk of the rock, providing a consistent silica-based structure. While minor variations in components such as feldspar or cementing materials can occur, the overall composition largely remains the same across different samples. Sandstones are dense, thin-bedded, medium to coarse-grained, and poorly sorted, with a notable enrichment of siltstone material. Compositionally, sandstones are polymictic and made up of minerals and rock fragments. Quartz dominates, accounting for 45–60% of the composition, followed by feldspars at 15–25% (Aliyev, Akayeva, 1957; Mazanov, 1969).

Calcite varies widely, ranging from 2–62%, while clay minerals account for 11–23%. Hematite is present in smaller amounts, typically 1–9%. Additionally, the sandstones contain fragments of clay, siliceous, carbonate, and volcanic (effusive) rocks. The thickness of the sandstone layers ranges from 5–10 cm to 40–60 cm, with occasional layers reaching 1–1.5 meters.

Silty sandstones are represented by medium – to fine-grained polymictic varieties with siliceous carbonate cement. They are more thinly bedded and less porous. The main components of siltstones are quartz (35–65%), feldspars (15–30%), and clay minerals (21–30%).

Clay rocks are represented by dense, non-wetting, noticeably calcareous siliceous shales and argillites. They are found in thin layers, ranging from 1 to 5 cm in thickness, alternating with medium-grained sandstones and fine-grained conglomerates.

The most common elements are silicon, aluminum, and calcium. The sandstones of the Garovulustu and Gyzylgazma suites contained higher concentrations of SiO_2 (Table 1).

Table 1. The minimum, maximum, and average values of the content of the main elements (%) in the composition of the Upper Jurassic rocks of the Southeastern Caucasus

Component	Garovulustu suite	Gyzylgazma suite	Khashy suite
SiO_2	38.65–65.82 / 44.45	29.91–63.00 / 40.36	26.13–61.00 / 38.40
TiO_2	0.64–0.84 / 0.72	0.15–0.69 / 0.41	0.19–0.69 / 0.45
Al_2O_3	8.11–16.65 / 13.56	3.44–15.27 / 7.97	5.98–14.22 / 9.58
Fe_2O_3	5.14–7.09 / 6.32	1.96–11.81 / 5.36	1.60–9.05 / 4.65
MnO	0.03–0.14 / 0.11	0.04–0.52 / 0.17	0.06–0.15 / 0,08
MgO	0.87–1.76 / 1.24	0.56–2.21 / 1.36	1.15–1.99 / 1.54
CaO	1.55–13.4 / 5.17	2.88–44.78 / 25.51	18.80–44.24 / 28.58
K_2O	2.15–4.14 / 3.22	0.58–3.75 / 1.61	0.83–2.76 / 1.86
Na_2O	0.64–1.59 / 1.4	0.33–2.16 / 1.12	0.52–0.86 / 0.65
P_2O_5	0.20–2.36 / 0.25	0.05–0.74 / 0.14	0.07–0.12 / 0.09

Note. The numerator indicates the minimum and maximum values, while the denominator represents the average values.

Compared with the average chemical composition of the Upper Continental Crust (Rudnick and Gao, 2014), the average amount of SiO_2, Na_2O, and MgO is lower in all Upper Jurassic rock samples. The Upper Jurassic sediments showed higher values of Al_2O_3, Fe_2O_3, K_2O, TiO_2, and CaO compared to UCC (Fig. 3). A higher Fe_2O_3 content (9.96% in sample No. 711) was recorded in samples from the Gyzylgazma suite.

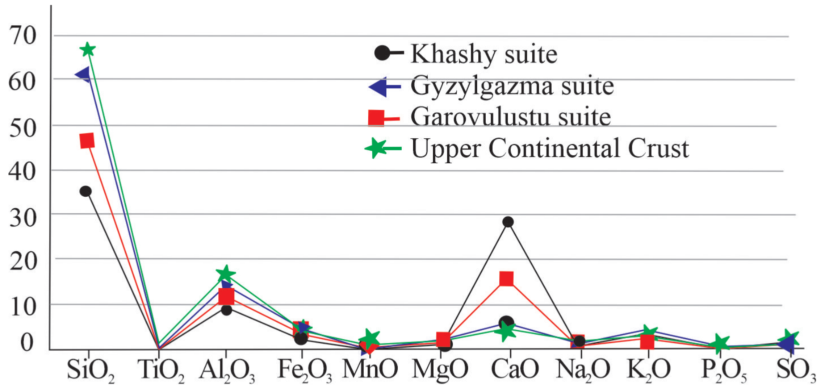

Fig. 3. Diagram of the distribution of the main elements for Upper Jurassic sediments normalized by the composition of Upper Continental Crust (UCC) (Rudnick and Gao, 2014)

At higher stratigraphic levels, specifically in the Kimmeridgian and Tithonian deposits, an increase in CaO and a decrease in total alkalinity and Fe_2O_3 are observed (Mehdiyeva, 2023). A binary comparison of the oxide content of the main elements with Al_2O_3 enables us to identify patterns in the distribution of various elements. Oxides such as TiO_2, SiO_2, Fe_2O_3, MgO, K_2O, and Na_2O exhibit a positive correlation with Al_2O_3. The covariance between CaO and Al_2O_3 reflects a negative linear relationship. This indicates that a significant portion of the calcium was not linked to aluminosilicates but formed in a carbonate-rich environment.

In the Upper Jurassic rocks, 20 minor elements were identified, including As, Cr, Ni, Co, Zr, Cu, Cd, Rb, Mo, Br, V, Pb, Zn, T, Nb, Tb, Ge, Ga, and Y. Among these, seven elements (T, Nb, Ge, Ga, Tb, Y) are sporadically present in concentrations ranging from 0.0002 to 0.03%. Most other discovered elements significantly surpass their standard Clarke values in sandstone by several times. Some elements (Co, Ni, Zr, Rb, and Zn) exhibit a clear positive correlation with Al_2O_3, indicating that these elements may be associated with the weathering products of clay minerals. Compared with UCC, the concentration of trace elements in Upper Jurassic rocks is very low.

Lithochemical modules for Upper Jurassic deposits

The utilization of lithochemical modules and modular diagrams (Yudovich, Ketris, 2011) facilitates an objective assessment of the composition of parent rock in eroded source regions, the degree of mechanical or chemical weathering and transport, the processes of sedimentation and maturity, and the lithogenic or petrogenic characteristics of the sediment.

Table 2 presents the mean values of lithochemical modules computed for Upper Jurassic rocks. The hydrolysate module serves as a quantitative indicator for assessing the chemical weathering of rocks and the hydrolysis processes that occur during sedimentation. Based on the hydrolysate modulus (HM = 0.34–0.48), most of the Upper Jurassic samples studied are classified as hypo- and normosiallites (see Table 2). However, five samples from the Gyzylgazma suite are categorized as myosiallites (HM = 0.21–0.30). In all the studied samples, the HM is less than 0.55, indicating an arid type of weathering (Yudovich, Ketris, 2000, 2011).

Table 2. Lithochemical modules calculated for Upper Jurassic rocks

Petrochemical modules	Khashy suite		Gyzylgazma suite		Garovulustu suite	
	Sandstones	Siltstone	Sandstones	Siltstone	Sandstones	Siltstone
HM	0.35	0.40	0.32	0.40	0.35	0.42
TM	0.051	0.055	0.049	0.056	0.050	0.052
IM	0.46	0.66	0.56	0.63	0.42	0.51
NKM	0.26	0.33	0.27	0.34	0.31	0.31
Na_2O/K_2O	0.46	0.51	0.78	0.55	0.46	0.32
Al_2O_3/SiO_2	0.22	0.23	0.19	0.23	0.23	0.26

Note: Formulas for calculating lithochemical modules: HM = $(TiO_2+Al_2O_3+Fe_2O_3+MnO)/SiO_2$; TM = TiO_2/Al_2O_3; NKM = $(Na_2O+K_2O)/Al_2O_3$; IM = $(Fe_2O_3+FeO+MnO+MgO)/(SiO_2/Al_2O_3)$.

The elevated alumina content in the Upper Jurassic sedimentary rocks, combined with the low aluminosilicate modulus (AM = Al_2O_3/SiO_2), indicates significant erosion influenced by arid weathering crusts. The Al_2O_3/SiO_2 ratio is a crucial indicator of sediment differentiation, where lower values signify greater differentiation in rocks. In Upper Jurassic sediments, this ratio ranges from 0.18 to 0.28 and strongly correlates with the geochemical (GM) index. However, three samples from the Garovulustu suite and six samples from the Gyzylgazma sandstones exhibit very low values for this modulus (AM < 0.20). These sediments primarily consist of normal aluminous rocks, characterized by Al_2O_3/Fe_2O_3 ratios exceeding one and aluminum content greater than 10%. Such characteristics suggest that the parental rocks were significantly enriched in aluminum. The presence of terrigenous iron-bearing minerals, fragments from sedimentary, igneous, and metamorphic rocks, authigenic oxides, sulfides, iron carbonates, and glauconite influences the ratio (Fe_2O_3+FeO+MnO+MgO)/SiO_2 in sandy rocks. Based on this ratio, Upper Jurassic deposits are considered typical, with values ranging from 0.08 to 0.25 (Yudovich, Ketris, 2000).

The titanium modulus (TM = TiO_2/Al_2O_3) reflects the process of dynamic sorting of terrigenous material. The titanium module is higher in rocks formed in shallow water basins and under humid lithogenesis (Yudovich, Ketris, 2000). The concentration of TiO_2 in the Upper Jurassic formations of the South-East Caucasus ranges from 0.19 to 0.70%, 0.29 to 1.01%, and 0.12 to 0.92% in the Khashy, Garovulustu, and Gyzylgazma suites, respectively, with TM values spanning 0.047–0.065, 0.049–0.069, and 0.041–0.061, respectively.

The association of titanium with the silicate component of carbonate rocks influences the correlation between TiO_2 and other elements. In samples of Upper Jurassic rocks, TiO_2 shows a negative correlation with CaO and a positive correlation with other components. All samples belong to the standard titanium group. The amount of titanium in carbonate rocks strongly depends on the proportion of silica (titanium-containing) in these rocks (Yudovich, Ketris, 2018). Upper Jurassic sandstones exhibit a reduced titanium modulus compared to silts, a characteristic common to lithogenic rocks (see Table 2).

The total alkalinity in the Upper Jurassic deposits ranges from 0.78 to 6.5, with an average value of 2.74. According to the normalized alkalinity (NA) value, all Upper Jurassic deposits are classified as normal-alkaline. The value of Na_2O/K_2O (0.24–1.75) corresponds to the typical range for normal siallites and pseudosiallites (0.30–1.0), indicating the absence of volcanic and terrigenous pyroclastic materials in these rocks. The alkaline modulus is higher than one in just three samples from the Istisuchay section and two samples from the Jimichay section (Mehdiyeva, 2023). The presence of feldspar pyroclastics (albite) explains the high alkaline modulus in this area. This ratio is typically below one in clay rocks, except where montmorillonite is dominant.

According to Cox et al. (1995), the K_2O/Al_2O_3 ratio varies from 0.1 to 0.3 in clay minerals, whereas in the range of 0.3–0.9 in feldspars. The fact that this value in samples of Upper Jurassic rocks falls within the range of 0.13–0.27 (with an average of 0.21) suggests that clay minerals are abundant in these rocks. The maximum value of the potassium modulus does not exceed the norm for muscovite (0.31) (Yudovich, Ketris, 2000). In addition, the alkaline modulus and the average normalized alkalinity are within normal limits, which suggests the absence of volcanic and terrigenous pyroclastic rocks in these rocks.

Paleoclimate and paleotectonics during sedimentation

A study (Smykatz-Kloss, Roy, 2010) revealed that the ratios of Na_2O/Al_2O_3, Na_2O/TiO_2, and Na_2O/K_2O in rocks fluctuate according to the climatic conditions during their formation. In other words, the differences between these ratios decreased as humidity increased and grew as droughts became more frequent.

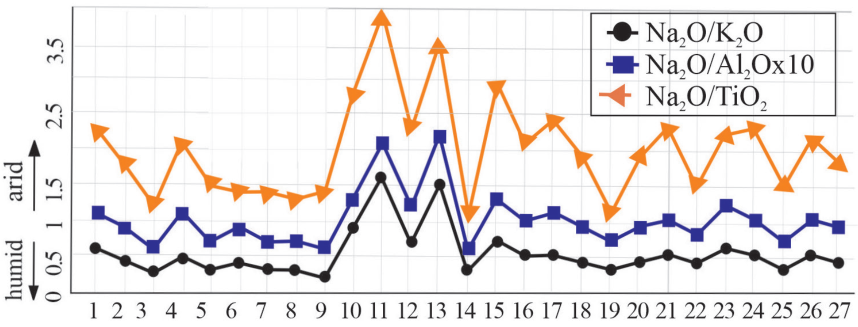

Fig. 4. Distribution graph of Na_2O/Al_2O_3, Na_2O/TiO_2, and Na_2O/K_2O ratios and their differences for Upper Jurassic deposits (Smykach-Kloss, Roy, 2010)

Calculations of these ratios from Upper Jurassic rocks suggest that they formed under arid conditions. A graph (Fig. 4) illustrates two distinct shifts (examples 11 and 13) towards very arid conditions.

According to sources (Bhatia, 1983; Roser, Korsch, 1986), the chemical composition of sediments varies between basins found in oceanic and continental island arcs and those situated along active and passive continental margins. Bhatia's study (Bhatia, 1983) showed increased K_2O/Na_2O and $Al_2O_3/(CaO+Na_2O)$ ratios during the transition from oceanic to continental island arcs and active to passive continental margins. At the same time, there is a decrease in (Fe_2O_3+MgO), TiO_2, and the Al_2O_3/SiO_2 ratio.

The Upper Jurassic deposits are unevenly dispersed in the tectonic diagrams (Fig. 5). Data points are more concentrated along active continental margins and continental island arcs. Analysis of the collected data suggests that the formation of these deposits occurred primarily in active continental margins and, to a lesser extent, in continental island arcs.

The studies (Alpine..., 2007; Rustamov, 2016) indicate that the sedimentary cover of the Caucasus was formed within an accretionary prism created by the pseudosubduction of the South Caucasian microplate beneath the North Caucasian microplate. At the end of the Middle Jurassic, a transition from a passive to an active regime occurred on the southern edge of the Greater Caucasus. The sandy-clay deposits of the indicated zones were formed in the relatively deep-water southern part of the Upper Jurassic basin. Terrigenous material entered the sedimentary basin from the south (from the South Caucasian plate) and from the northeast (from the western shores of the Turan plate). The rhythmic pattern of sedimentary layers can be attributed to the regular variations in the dynamics of the aquatic environment.

The sedimentation conditions in the Greater Caucasus basin during the Upper Jurassic era were primarily influenced by a combination of tectonic processes resulting from the collision between the Scythian platform and the Mesotethys, along with the effects of both constant and periodic deep-water currents (upwelling) and turbidity flows.

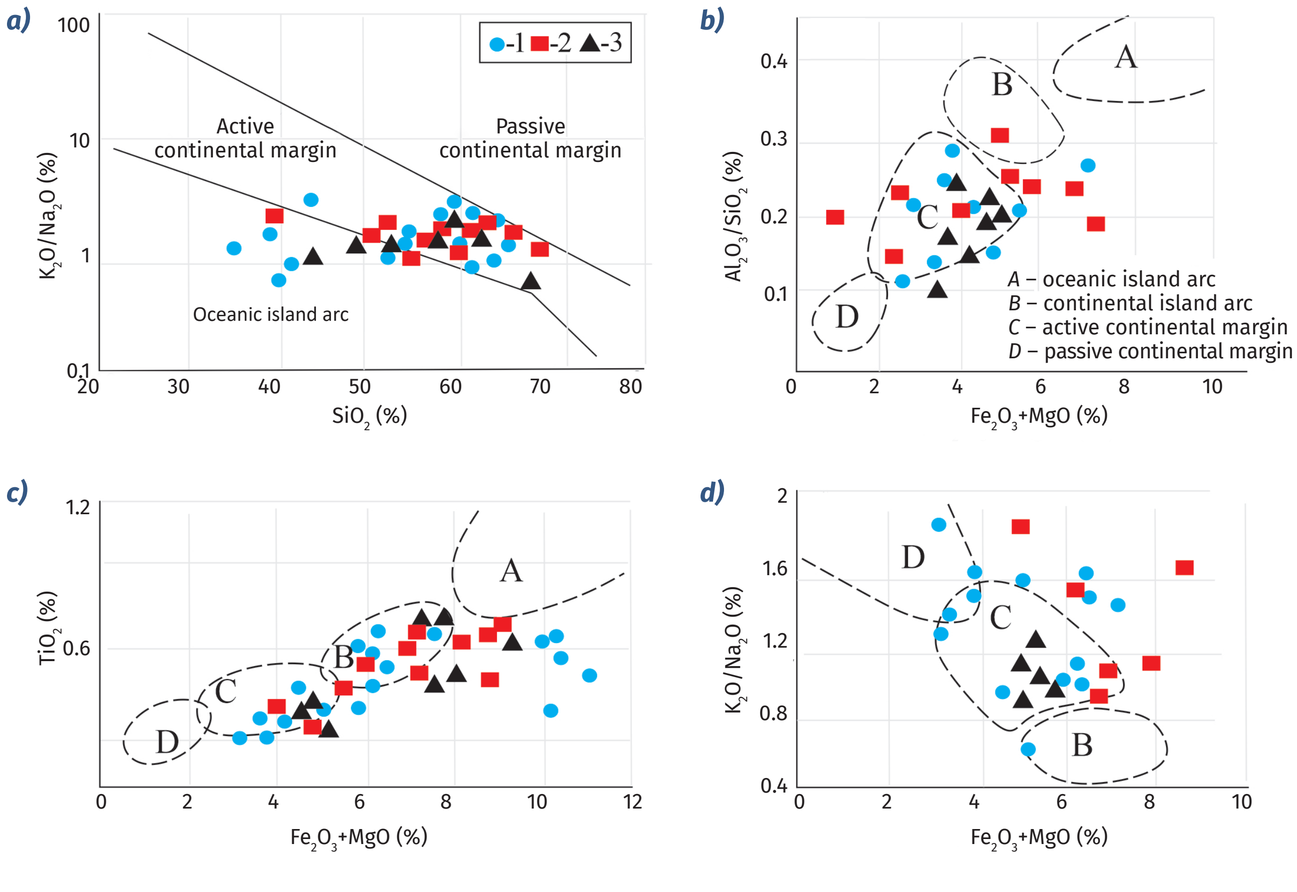

Fig. 5. Paleotectonic reconstruction of Upper Jurassic sandy-clay deposits by Roser and Korsch *(a)* (1986) and Bhatia *(b, c, d)* (1983): *1* – Garovulustu suite; *2* – Gyzylgazma suite; *3* – Khashy suite

Conclusions

The sedimentary basin likely derived its detrital material from several relatively stable sources throughout the Late Jurassic period. The high content of quartz and feldspar in the clastic portion of the sandstones, along with the predominance of hydromica in the clay minerals, suggests that the primary source of material for these rocks was eroded land composed of ancient granite, metamorphic, and sedimentary rocks.

The average calcium content in Upper Jurassic marine sediments increases from 5.17 % in the Garovulustu Formation to 28.58% in the Khashy Formation. This increase in calcium is linked to the gradual warming of the climate in the Southeast Caucasus, which occurred from the time the Garovulustu Formation was formed until the Tithonian.

For the first time, lithochemical modules have been calculated, and the petrochemical characteristics of the Upper Jurassic sedimentary complex in the South-East Caucasus have been analyzed based on silicate analysis. A low level of maturity suggests that these sediments primarily formed through the mechanical weathering of parent rocks. They exhibit a relatively low titanium content (average TM of 0.055) and elevated standard alkalinity (average NKM of 0.34).

Interpretation of lithochemical data indicates that sediment formation occurred mainly in an active continental margin and, to some extent, in a continental island arc.

Представлено результати детального вивчення верхньоюрських карбонатно-терригенних відкладів у межах Бокового хребта Південно-Східного Кавказу. Дослідження включало стратиграфічне профілювання, просторову кореляцію розрізів і систематичний відбір зразків для мінералогічного і геохімічного аналізів. Відклади складаються переважно з дрібно- та середньозернистих пісковиків, пелітових і мікрокристалічних вапняків, аргілітів і дрібнозернистих конгломератів, що свідчить про накопичення на крутому континентальному схилі. Геохімічні дані показують однорідний склад на всіх стратиграфічних рівнях, що засвідчує помірну зрілість відкладів і переважно механічне перевідкладення. На основі вивчених петрохімічних параметрів верхньоюрські породи були класифіковані як літогенні утворення, що не містять вулканічних або теригенно-пірокластичних домішок. Вони класифікуються як нормальні сіаліти та псевдосіаліти.

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