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Lithostratigraphic Characteristic and Lithology of Triassic–Paleozoic Rocks of Southern Mangyshlak

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Abstract—The paper considers principles of the subdivision and correlation and a new petrographic model of Triassic–Paleozoic rocks based on their lithogenetic features. The structure of the folded basement and quasi-platform complex of southern Mangyshlak, as well as petrological–mineralogical features of Variscan granites and products of their hypergene weathering, are analyzed.

At present, Mesozoic, particularly Permian–Triassic, rocks (quasi-platform complex) are the principal object for prospecting and production of hydrocarbon fuel in western Kazakhstan. In this context, Permian–Triassic rocks of the South Mangyshlak Basin and adjoining Kazakhstan sector of the Caspian Sea have a high potential. Therefore, they need additional high-tech investigations, including 3D seismics coupled with stratigraphic-sedimentological, petrophysical, and lithological-paleogeographic studies. This is indicated by the discovery of the giant Kocharan oil area in Paleozoic rocks in the northern Kazakhstan sector of the Caspian Sea. The effectiveness of exploration-reconnaissance works can be significantly enhanced by a complex of sedimentological studies of the Permian–Triassic rocks of southern Mangyshlak.

MATERIALS AND METHODS

This work is based on the integral study of cores from exploration, prospecting, and stratigraphic wells drilled in different structural-facies zones of southern Mangyshlak.

We used different laboratory methods, including the microscopic, X-ray diffraction, spectral, and electron microscopic analyses. Vitrinite reflectance in clastic and clayey rocks of the Permian–Triassic complex was determined at the Geological Faculty of Moscow State University. The microscopic and diffractometric analyses and determination of physical properties of the Triassic–Paleozoic rocks were carried out by the author in laboratories of the Department of Mineralogy, Petrography, and Lithology of the Azerbaijani State Petroleum Academy.

At present, Triassic and, partially Paleozoic, rocks of southern Mangyshlak have been recovered by hundreds of deep exploration and parametric wells within the Zhetybai–Uzen Terrace, Karagie Saddle, Peschanyi Mys–Rakushechnoe Uplift, and Akhsu–Kenderla Swell. Data from these wells have been scrutinized and summarized in works by Krylov *et al.* (1975), Chebryakova *et al.* (1984), and Popkov *et al.* (1986). In these works based on the paleontological and lithological studies of the Triassic complex, as well as consideration of the regional and industrial geophysical data, the Triassic rocks of southern Mangyshlak have been divided into regional-stratigraphic subdivisions and lithological sequences with specified stratigraphic positions based on the analysis of ammonite, pelecypod, ostracod, and, partially, foraminifer remnants, as well as spore-pollen spectra. Special lithological studies of oil reservoirs, especially carbonate ones, were carried out by Orudzheva *et al.* (1984). Popkov subdivided the pre-Jurassic rocks of southern Mangyshlak and supplemented the local formations with several homogeneous lithological sequences, traced over different-order structures of southern Mangyshlak. Their reservoir properties and oil potential were also determined. He justly considered the pre-Jurassic rocks of southern Mangyshlak an intermediate complex and distinguished two structural-lithostratigraphic stages. The lower stage is composed of Upper Paleozoic weakly metamorphosed arkosic graywackes (upper molasse), whereas the upper stage consists of Triassic rocks.

In our works, the subdivision and correlation of the homogeneous Triassic sequences are based on the detailed investigation of the lithology of rocks from 17 prospecting areas with the identification of their characteristic mineralogical features.

In addition to their lithology, other indicators, such as metamorphism grade and dislocation coefficient, were also used in the subdivision of the Paleozoic rocks. On the whole, based on the metamorphism grade and analogy with the Buzachi Swell and eastern Ciscaucasus, the exposed part of the Paleozoic section was subdivided into two large sequences represented by the weakly metamorphosed Carboniferous–Permian rocks and the strongly metamorphosed Middle Paleozoic muscovite–chlorite schists.

We scrutinized Paleozoic rocks of the folded basement based on materials from deep parametric and prospecting wells in the following areas: Severo-Rakushechnoe, Oimasha, Bortovaya, Zhantanat (Well 2), Ala-Tyube, Akkar, Atambai, Severnoe Karagie, and others. The studied rocks consist of metasandstones, metasiltstones, marbleized limestones, and slates.

Secondary postsedimentary processes are clearly manifested in these rocks. First of all, this is expressed in the intense stylolitization of rocks, which are crosscut by numerous thin veinlets of quartzites and carbonates. Clastic grains are corroded and surrounded by regeneration rims. The cement of clastic rocks is recrystallized and silicified. However, the altered Upper Paleozoic rocks retain the clastic and aleuropelitic texture typical of sedimentary rocks. Blastic texture, which is a distinctive feature of metamorphic rocks, is not observed or very poorly expressed in these rocks. The cleavage structure is prominent in shales.

Shales from the studied sequences consist of chlorite and sericite. Albite, epidote, and prehnite are observed as secondary admixture. Specific features of rock texture and paragenesis of secondary minerals testify that the studied Paleozoic rocks are weakly metamorphosed and located at the metagenetic stage.

In the South Mangyshlak Block, typical metamorphic rocks are found in the Oimasha and Severnoe Karagie prospecting areas.

In the Severnoe Karagie area, Well 3 recovered amphibolite schists at a depth of 4010 m. According to Bakirov (1970), the schists have pre-Cambrian age. However, wood remnants later found in the schists disproved this viewpoint.

According to Kuprin (1985), crystalline schists are intruded by Variscan granites in the Oimasha area. They are characterized by the presence of numerous fractures, quartz veins and slickensides, steep dips of layers (50°–90°), partial mylonitization, and other indicators of disjunctive dislocations.

At the upper structural stage of the basement, the sandy–shaly sequence (350–500 m) has been recovered by numerous wells in the Peschanyi Mys–Rakushechnoe Uplift, Segendyk Depression, and Zhetybai–Uzen Terrace.

They are represented by metamorphosed sandy–clayey rocks of the chlorite–muscovite subfacies and crosscut by diabase and dacite dikes and sills.

Thus, deep wells have recovered in the Peschanyi Mys–Rakushechnoe Uplift initially terrigenous rocks metamorphosed to the chlorite–sericite subfacies of regional metamorphism and intruded by magmatic bodies of different compositions.

Similar metamorphic rocks were recovered in the northeastern part of the Segendyk Depression (Karagie, Alatyube, Atambai, and Bortovaya areas) at a depth of 3902–4450 m. These rocks are noticeably dislocated (dip angle up to 45°).

Rocks of the upper structural stage of the basement contain abundant wood remnants. Sandstones, siltstones, and mudstones with a high content of strongly coalified plant remnants were initial rocks of the basement. According to the vitrinite reflectance, these rocks are at the stage of apocatagenesis. The 1000-m-thick shaly sequence recovered in the Zhantanat area (Well 2, depth 3550 m) consists of silky black and greenish gray chlorite schists. Starting with a depth of 3950 m, the schists include numerous stylolites and quartz veinlets. The schists are strongly fractured. The fractures are filled with coarse-crystalline calcite and dolomite.

In general, paragenesis of secondary minerals in the rocks corresponds to the metagenetic stage. We consider these rocks as Hercynides developed at the upper structural stage of the basement in southern Mangyshlak.

Stratigraphic Position and Petrographic Features of Granitoids in the Bortovaya Area

It is known that buried granites of the Oimasha and Bortovaya areas belong to Upper Paleozoic rocks of southern Mangyshlak.

Results of the additional stratigraphic, mineralogical–petrographic, and spectrographic investigations of cores from a granite massif in the Bortovaya area are presented below.

The Bortovaya Uplift is composed of two independent equant domes located along a single NE–SW axis.

Well 1 recovered the thick Jurassic–Triassic sedimentary and the Paleozoic volcanosedimentary and metamorphic rocks. Starting with a depth of 4215 m, the well penetrated granitoids. They were studied by microscopic and petrochemical methods. Their absolute age was also determined (Fig. 1).

The studied light gray granitoids are macroscopically indiscernible. They contain small inclusions of dark minerals (mica and hornblende). The rocks have massive structure and holocrystalline texture. They locally contain tiny fractures filled with secondary quartz and less common acid plagioclase.

However, the detailed microscopic study of samples allowed us to subdivide the granitoids into the micaceous–hornblende, micaceous, and hornblende–micaceous, cataclastic, and greisenized varieties. The petrographic features of the granite massif are shown in Fig. 2.

The micaceous–hornblende granites consist of quartz, orthoclase, plagioclase, hornblende, biotite, and several accessory minerals. They are marked by the hypidiomorphic-granular texture, local development of silicification, sericitization, and chloritization, the fracture-type open porosity equal to 3.5–4.0%, and the permeability equal to 0.001×10^{-12} m^2.

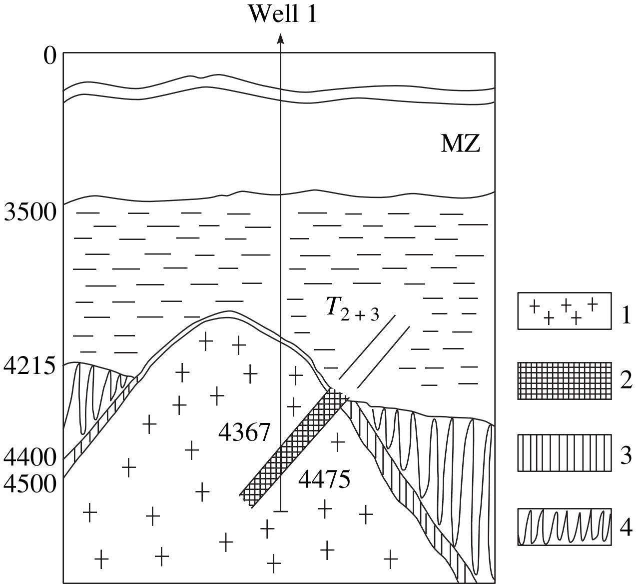
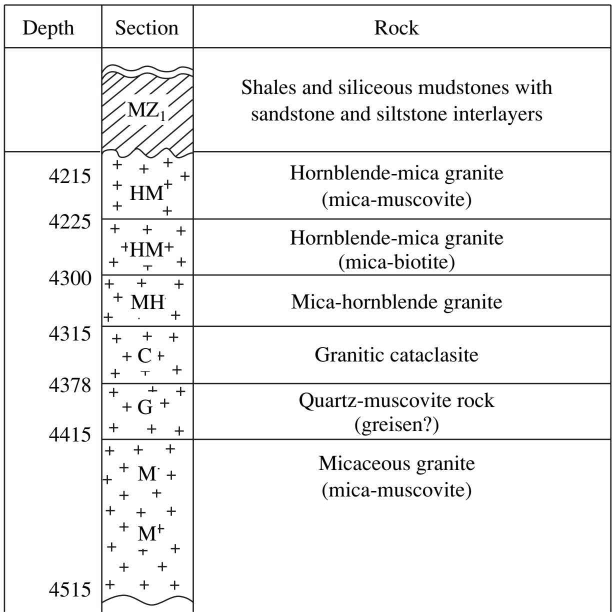


Fig. 1. Schematic geological cross section of granite massif in the Bortovaya area. (1) Variscan granites; (2) catagenesis and greisenization zone; (3) assumed hornfels zone; (4) basement schists.



Depth	Section	Rock
	MZ_1	Shales and siliceous mudstones with sandstone and siltstone interlayers
4215	HM	Hornblende-mica granite (mica-muscovite)
4225	HM	Hornblende-mica granite (mica-biotite)
4300	MH	Mica-hornblende granite
4315	C	Granitic cataclasite
4378	G	Quartz-muscovite rock (greisen?)
4415	M M	Micaceous granite (mica-muscovite)
4515		

Fig. 2. Schematic petrographic cross section of granitoid massif in the Bortovaya area.

Hornblende granitoids are close to granodiorites in terms of the quantitative ratio of orthoclase and quartz and the hornblende content therein. At a depth of 4300–4315 m, the hornblende granitoids give way to massive micaceous–hornblende granites with the open porosity up to 3.2–3.4% and the permeability equal to 0.003×10^{-12} m^2.

The cataclastic and greisenized granites recovered at depths of 4367–4378 and 4400–4415 m, respectively, are of certain interest. The occurrence of cataclastic granites within this depth range suggests the presence of a local fault. These granites are characterized by a distinct cataclastic texture. They are composed of oxygonal clasts of quartz, orthoclase, and plagioclase, as well as muscovite flakes, cemented by a fine clayey material. Microfractures are observed. The open porosity is as much as 5–6% and the permeability varies from 0.0003×10^{-12} m^2 to 0.003×10^{-12} m^2.

Quartz–muscovite varieties (greisens or greisenized granites) appear at a depth of 4400–4415 m. They are characterized by the heterogranoblastic texture. The presence of these rocks seems to be related to the impact of stress on the local fault zone.

Despite the scarcity of the studied core material, we tried to draw some petrochemical conclusions.

Data points of analyzed rocks on the SiO_2–(Na_2O + K_2O) diagram fall on the granite–leucogranite line with some affinity toward the low-alkaline and subalkaline granites and leucogranites. The silica content varies from 70 to 76% (Table 1). In terms of the alumina coefficient (Al^1), these rocks belong to the high-aluminous series.

The alumina coefficient correlates well with the relative quantitative composition of the rock-forming minerals (potash feldspars, micas, and others).

The K–Ar dating of two granite samples (Table 2) yielded 140 and 141 Ma, respectively, corresponding to the Late Jurassic (Kimmeridgian).

However, there is no doubt that the Bortovaya granites belong to the Variscan cycle. The underestimation of absolute age in the studied rocks seems to be related to their metamorphism and greisenization.

Lithology and Structure of the Granite Massif in the Oimasha Area

It is known that hydrocarbon accumulations in the buried granitoid massifs of southern Mangyshlak, which yielded commercial oil inflows, are related to the rock weathering zone within a ring-shaped morphostructure broken into blocks.

The Oimasha area is linked to a sublatitudinal fold clearly expressed in the Mesozoic sedimentary cover. The crushing of rocks is probably related to the circular fault system in the basement reactivated by the recent tectonic movements.

Granitoids confined to the uplifted part of the block are related to a large batholith. This is evidenced by porphyry texture of the granitoids with orthoclase inclusions up to 5 cm in size. Traces of contact metamorphism are also observed in the rocks.

The age of the granitoids in the Oimasha area is 250–340 Ma.

Table 1. Chemical composition of granites in the Bortovaya area

Components	Sample no. and sampling depth 18 4215–4225	19 4300–4314	21 4400–4415	22 4500–4519	23 4540–4550	16 4290–4300	20 4367–4378	Average
SiO_2	76.05	72.63	75.59	75.32	73.43	73.43	69.66	73.75
TiO_2	0.07	0.30	0.01	0.03	0.31	0.36	0.35	0.25
Al_2O_3	13.05	14.16	13.43	13.79	14.24	13.90	16.62	14.17
Fe_2O_3	0.01	0.04	0.39	0.89	0.62	0.81	0.91	0.67
FeO	1.59	2.60	0.72	0.72	1.30	0.58	2.02	1.36
MnO	0.05	0.06	0.08	0.04	0.04	0.04	0.05	0.05
MgO	0.02	0.05	0.01	0.01	0.06	0.04	0.07	0.04
CaO	0.20	0.25	0.20	0.40	0.36	1.29	0.57	0.47
Na_2O	3.49	3.17	2.74	4.63	3.35	2.91	2.88	3.31
K_2O	4.53	4.83	4.01	3.07	4.94	5.28	5.08	4.54
P_2O_5	0.06	0.17	0.11	0.12	0.14	0.07	0.32	0.14
L.O.I.	1.33	2.27	1.45	1.13	1.61	1.55	1.80	1.59
Total	100.44	100.58	99.74	100.53	100.29	100.26	100.56	100.34
$Na_2O + K_2O$	8.02	8.05	6.75	7.70	8.29	8.19	7.96	7.85
Na_2O/K_2O	0.77	0.65	0.68	1.51	0.68	0.55	0.57	0.73
Al^1	8.20	5.26	6.33	8.51	7.19	9.72	5.54	6.85

Table 2. Absolute age of granites

Sample no.	Sampling depth	Rock	K, %	AR/K	Age, Ma	Geological age
18	4215–4225	granite	3.92	0.008493	140	I_3 km
20	4367–4379	granite	3.92	0.008573	141	I_3 km

Note: Analyses were carried out in the Laboratory of Physicochemical Methods of the Study of Material (Geological Institute, National Academy of Sciences of Azerbaijan).

The detailed macro- and microscopic study of granitoid samples from the Oimasha area made it possible to distinguish unaltered, altered and strongly altered varieties.

The unaltered granitoids are most widespread in both time and space. Such rocks were recovered by Well 22 below 3600 m. They are represented by light gray granites and granosyenites.

Middle Triassic rocks are underlain by altered granitoids noted for the intense weathering of feldspars and fracturing with signs of the cataclasis of quartz and other minerals.

In the depth interval of 3725–3800 m, the well penetrated a zone of intense crushing and alteration of granitoids up to the point of the formation of cataclasites and mylonites.

The unaltered granites are mainly composed of fine- and medium-grained varieties. They are observed as leucocratic, gray and light gray rocks including quartz, potash feldspars (orthoclase and orthoclase–perthite), plagioclase (mainly, oligoclase), and rare biotite flakes and plates. Orthoclase is mostly replaced by perthite. Oligoclase is slightly pelitized. Biotite is encountered as different-sized plates. The unaltered granitoids are characterized by microfracturing. Their collector capacity and filtration properties are governed by the presence of open fractures. Fracture porosity of the unaltered granitoids varies from 0.01 to 1.11%.

The altered and intensely altered granitoids are marked by the pore-fracture type of collectors. The altered granitoids have an open porosity from 4 to 9% and permeability of 0.003×10^{-12} m^2.

Lithological Features and Composition of Triassic Rocks. Subdivision and Correlation of Triassic Rocks of Southern Mangyshlak Based on Mineralogical–Petrographic Peculiarities

At present, despite a large volume of geological–geophysical and lithostratigraphic works, the structure of the Triassic rocks of southern Mangyshlak remains unclear and needs the use of advanced methods of investigation. The complexity of structure of the Triassic rocks is, first of all, conditioned by abundance of regional–intraformational erosion surfaces and tectonostratigraphic unconformities. This was responsible for the restricted development of separate Triassic series and significant thickness gradients of the Triassic rocks in the major structural elements of southern Mangyshlak. Uncertainty of the pre-Jurassic erosion depth in the northern regions (Beke–Bashkuduk Swell and Zhetybai–Uzen Terrace) also hampers the correlation.

Results of previous works and our investigations show that the South Mangyshlak Depression incorporates four (Uzen, South Zhetybai, Peschanyi Mys, and Temir-Baba) types of Triassic sequences that reflect structural-facies conditions of the formation and development of the Triassic complex of southern Mangyshlak. The estimation of oil and gas potential of the Triassic rocks is partially related to the analysis of these sequence types.

The Uzen type is characterized by a significant thickness of the Lower Triassic rocks and complete denudation of Upper–Middle Triassic rocks as result of the pre-Early Jurassic washout. This sequence is developed north of the Kokumbai–Uzen–Shalva anticlinal profile.

The South Zhetybai type is observed in the Tenge–Tasbulat anticlinal profile and Zhetybai–Uzen Terrace, where the Triassic rocks are represented by all series yielded commercial-grade inflows of oil and gas. In this zone, the Lower Triassic complex is significantly reduced in thickness (250–300 m).

The Peschanyi Mys–Rakushechnoe zone of blocks is marked by the reduction of all Triassic series. Moreover, the Lower Triassic sequence is absent or it lacks the terrigenous–carbonate and varicolored gritstone–sandstone unit in many local structures (Oimasha, Tashkum, Ashisor, Atambai, Alatyube, and others). The boundary between the Olenekian sandy–clayey sequence and the underlying weakly metamorphosed Carboniferous–Permian complex (upper molasse) is marked by a stratigraphic unconformity.

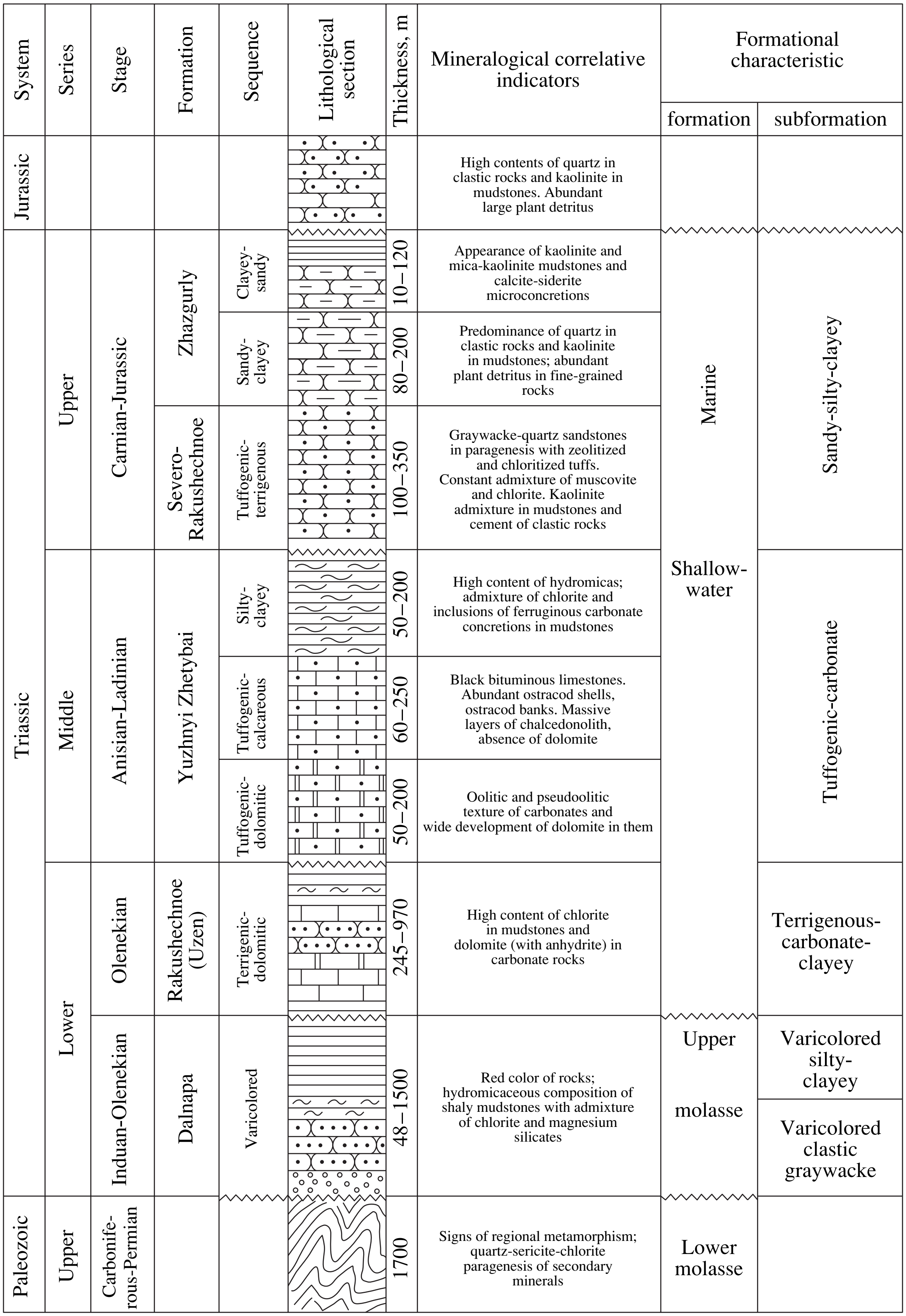
The Triassic rocks are represented by all series in reduced form in the Temir-Baba type. This type is developed on the Akhsu–Kinderla Terrace, where the Triassic rocks gradually pinchout in the southwest. This sequence is absent in the Kara Bogaz Arch.

The Zhetybai–Uzen type is subordinate and confined to the Zhetybai–Tasbulat–Tengiz anticlinal system. All Triassic series of this type are oil- and gas-bearing rocks. The Triassic section in the Yuzhnyi Zhetybai area can be considered a stratotype of the Zhetybai–Tasbulat–Tengiz anticlinal system. This sequence was lithologically scrutinized by Cherbyakova *et al.* (1984). Rocks of all Triassic series are widespread in the Zhetybai–Uzen type. The Lower Triassic sequence includes ammonite fauna that makes it possible not only to refine the stratigraphic range of the Olenekian, but also to distinguish different faunal zones with this stage. The Zhetybai–Uzen type includes all of the nine variants of the Triassic lithostratigraphic sequence identified in our works, suggesting stable subsidence of the Zhetybai–Uzen Terrace in the Triassic.

The Peschanyi Mys type of the Triassic sequence is even more widespread and developed in the Peschanyi Mys–Rakushechnoe Uplift and Karagie Saddle. The Triassic rocks are absent or sharply reduced in this type. For example, the lowermost part of the Triassic sequence is composed of coarse-grained rocks in the Rakushechnoe, Severo-Rakushechnoe, and Rakushechnoe-More areas (wells 5 and 8) (Khalifa-zade *et al.*, 1990). The reduced Middle Triassic sequence overlies schists of the folded basement in the northwestern part of the Rakushechnoe Uplift (Oimasha, Zhantanat, Zhaga, and Zapadnyi Zhantanat areas) and structures of the Karagie Saddle. The Middle Triassic carbonate–clayey sequence unconformably overlies the weathered Variscan granites. In the Peschanyi Mys sequence, the upper part of Upper Triassic rocks is locally eroded by the pre-Early Jurassic hypergene weathering. The denudation also affected the lower section of the Upper Triassic volcanogenic-terrigenous sequence and even the middle section of the Middle Triassic volcanic–calcareous sequence (Akkar, Ala-Tyube, and Bortovaya areas).

Following V.I. Popkov, we subdivide the Triassic sandy–clayey and terrigenous–tuffogenic–carbonate sequence of southern Mangyshlak into nine homogeneous (varicolored gritstone-sandstone, silty–clayey, sandy–carbonate–clayey, tuffogenic–dolomitic, tuffogenic–calcareous, clayey–silty, volcanogenic–terrigenous, sandy–clayey, and clayey–sandy) lithological types (Fig. 3). Some of these lithological sequences often correspond to the Triassic regional series. The sequences show more or less clear boundaries and reflect transgressive or regressive stages of the development of southern Mangyshlak during the Triassic. They can frequently be traced in electrometric and radiometric logs of rock sections in large or adjoining structures. However, as noted above, the study of the Triassic section is strongly hampered as a result of facies replacements, intraformational and regional erosions, thickness reduction in different structures, and the consequent disturbance of the boundaries and combination of rock sequences. In this case, logging methods are inefficient and more reliable criteria should be used.

We resolved this problem with the help of the combination of mineralogical and logging data. This made it possible to more reliably define the boundaries and volumes of rock sequences and correlate them over a large distance. We carried out the mineralogical correlation of Triassic rocks in different areas (Tarly-Kuidzhak, Yuzhnaya Karamanata, Severnoe Karagie, Ala-Tyube, Akkar, Bortovaya, Kamenistaya, Tashkum, Uilyuk, Severo-Rakushechnoe, Zharta, Makhat-Pribrezhnaya, Kokbakhty, Dolinnaya, and Vostochnyi Chakyrgan). The lithostratigraphic section based on these investigations is shown in Fig. 3.



System	Series	Stage	Formation	Sequence	Lithological section	Thickness, m	Mineralogical correlative indicators	Formational characteristic	
								formation	subformation
Jurassic							High contents of quartz in clastic rocks and kaolinite in mudstones. Abundant large plant detritus		
Triassic	Upper	Carnian-Jurassic	Zhazgurly	Clayey-sandy		10–120	Appearance of kaolinite and mica-kaolinite mudstones and calcite-siderite microconcretions	Marine	Sandy-silty-clayey
				Sandy-clayey		80–200	Predominance of quartz in clastic rocks and kaolinite in mudstones; abundant plant detritus in fine-grained rocks		
			Severo-Rakushechnoe	Tuffogenic-terrigenous		100–350	Graywacke-quartz sandstones in paragenesis with zeolitized and chloritized tuffs. Constant admixture of muscovite and chlorite. Kaolinite admixture in mudstones and cement of clastic rocks		
	Middle	Anisian-Ladinian	Yuzhnyi Zhetybai	Silty-clayey		50–200	High content of hydromicas; admixture of chlorite and inclusions of ferruginous carbonate concretions in mudstones	Shallow-water	Tuffogenic-carbonate
				Tuffogenic-calcareous		60–250	Black bituminous limestones. Abundant ostracod shells, ostracod banks. Massive layers of chalcedonolith, absence of dolomite		
				Tuffogenic-dolomitic		50–200	Oolitic and pseudoolitic texture of carbonates and wide development of dolomite in them		
	Lower	Olenekian	Rakushechnoe (Uzen)	Terrigenic-dolomitic		245–970	High content of chlorite in mudstones and dolomite (with anhydrite) in carbonate rocks		Terrigenous-carbonate-clayey
		Induan-Olenekian	Dalnapa	Varicolored		48–1500	Red color of rocks; hydromicaceous composition of shaly mudstones with admixture of chlorite and magnesium silicates	Upper molasse	Varicolored silty-clayey
									Varicolored clastic graywacke
Paleozoic	Upper	Carboniferous-Permian				1700	Signs of regional metamorphism; quartz-sericite-chlorite paragenesis of secondary minerals	Lower molasse	

Fig. 3. Summary lithostratigraphic column of Triassic rocks of southern Mangyshlak.

Characteristic of Lithostratigraphic Subdivisions of the Lower Triassic

We studied the Lower Triassic varicolored gritstone–sandstone and silty–clayey sequences in the Tarly-Kuidzhak, Severnoe Karagie, and Pridorozhnaya areas, but the mineralogical analysis was not carried out. However, this gap was filled up by the study of core material from the Vostochnyi Chakyrgan parametric well and new prospecting areas of the Tenge–Tasbulat–Zhetybai anticlinal zone. The Lower Triassic sequence consists of three parts in the Zhetybai–Uzen Terrace. Its most complete sequence has been established in the Uzen area (Well 115) and the Vostochnyi Chakyrgan parametric well. We can recognize here the following units (from bottom to top): varicolored gritstone–sandstone (T_1^1); silty–clayey sequence (T_1^2); and terrigenous–carbonate sequence (T_1^3). Subsequently, we united the second and third sequences into the sandy–carbonate–clayey sequence.

The varicolored gritstone–sandstone sequence includes coarse-grained rocks of the poorly sorted arkosic graywacke composition and alluvial–proluvial–lacustrine origin. On the basis of lithological composition, V.V. Lipatova correlated this sequence with the Dolnapa Formation of the Mangyshlak Mountains.

On the basis of ammonite and pelecypod fauna, Lipatova analyzed the stratigraphic position of the silty–clayey and terrigenous–carbonate sequences, which are the youngest Lower Triassic units, confirmed their belonging to the Olenekian (Kolubit and Prokhumgarit) units.

The sandy–clayey and terrigenous–carbonate sequences probably match the Uzen Formation of the Mangyshlak Mountains. The Lower Triassic silty–clayey sequence is noted for a high content of muscovite and chlorite.

Characteristic of Lithostratigraphic Subdivisions of the Middle Triassic

The complete Middle Triassic sequence is encountered in the Zhetybai–Uzen Terrace, zone of block structures, and Akhsu–Kenderla Terrace of southern Mangyshlak. We studied the Middle Triassic rocks in the Severnoe Karagie, Vostochnaya Karamanata, Tarly-Kuidzhak, Kamenistaya, Ala-Tyube, Akkar, Tashkum, Uilyuk, Severo-Rakushechnoe, and Kokbakhty areas. The volcanogenic–carbonate composition of the Middle Triassic makes it possible to easily distinguish them in logs of deep wells. However, the identification of more detailed lithostratigraphic units and their regional correlation need the use of additional lithological criteria. Therefore, we subdivided the Middle Triassic rocks into the tuffogenic–dolomitic (T_2^1), tuffogenic–calcareous (T_2^2), and silty–clayey (T_2^3) lithological sequences. All of these sequences are united into the South Zhetybai Formation and entirely fall within the Middle Triassic.

The tuffogenic–dolomite sequence is difficult to distinguish in logs. However, its range and boundaries are reliably determined by the lithological indicators. This sequence is characterized by abundance of dolomites and their calcareous and siliceous varieties. The sequence also contains intercalations of the pelitomorphic and oolitic dolomites with the tuffaceous sandstones and mudstones and the less common siliceous rocks (chalcedony). In the Tenge–Tasbulat and Severnoe Karagie folded zones, the high orthoclase content (40–55%) is also an important mineralogical criterion for distinguishing this sequence from the underlying Lower Triassic layers.

The tuffogenic–calcareous sequence occupies the upper part of the Middle Triassic sequence in all studied structures of southern Mangyshlak. The sequence is composed of intercalations of the pelitomorphic and fractured limestones with the oolitic and pseudoolitic organogenic-detrital limestones containing a large amount of ostracod shells. It is distinguished in the Middle Triassic section by the association of ostracod limestones, arkosic sandstones, and chalcedony interlayers. In the Karagie Saddle, this sequence is represented by black bituminous limestones. The tuffogenic–calcareous sequence is easily recognized by its black color in wells of the Akkar, Ala-Tyube, Atambai, and Dolinnaya areas.

The silty–clayey sequence, 25–40 m thick, is well defined from geophysical data in all structures of southern Mangyshlak. In fact, this sequence separates the two natural (tuffogenic—calcareous and volcanogenic-terrigenous) reservoirs. The silty–clayey sequence serves as a regional seal for the first reservoir. The silty–clayey sequence is weakly studied in petrographic aspect because of the scarcity of core material and can only be defined based on the high clay content coefficient of the sequence (0.6–0.7) and the abundance of hydromicas in mudstones.

Characteristic of Lithostratigraphic Subdivisions of the Upper Triassic

The Upper Triassic rocks are only retained in the Tenge–Tasbulat–Zhetybai fold zone of the Zhetybai–Uzen Terrace. V.V. Lipatova and V.I. Popkov studied rocks of this series in materials from prospecting wells of the southern Zhetybai and Tasbulat areas.

Our petrographic investigations were carried out in the Kamenistaya, Akkar, Pridorozhnaya, Bortovaya, Tarly-Kuidzhak, Severnoe Karagie, Tashkum, Makhat-Pribrezhnaya, and Zharty areas situated in different structural-facies zones. The Upper Triassic section has a three-member structure and can be subdivided into three (volcanogenic–terrigenous, sandy–clayey, and clayey–sandy) lithological sequences (from bottom to up). A significant part of the two upper sequences was

Table 3. Grain size composition of Triassic clastic rocks (Kuidzhak area)

Sampling interval	Clastic rock	Fraction content, %				
		0.5–0.25	0.25–0.1	0.1–0.05	0.05–0.01	<0.01
3720–3726	Fine-grained sandstone	25.0	51.6	13.0	6.4	4.6
3795–3826	Medium- to fine-grained sandstone	31.0	50.0	11.0	5.0	3.0
3892–3900	Fine-grained siltstone	–	5.0	38.0	47.0	10.0
3941–3947	Medium- to fine-grained arkosic sandstone	35.0	49.0	8.0	5.0	3.0
4005–4010	Coarse- to medium-grained arkosic sandstone	40.0	50.0	6.0	3.0	1.0
3935–3941	Fine-grained silty sandstone	2.0	54.0	35.0	4.0	5.0
3991–3995	Medium-grained arkosic sandstone	55.0	29.0	10.0	7.0	–

destroyed by the pre-Jurassic erosion in the linear structure zone. According to our data, the volcanogenic–terrigenous sequence corresponds to the Severo-Rakushechnoe Formation, whereas the sandy–clayey and clayey–sandy sequences correspond to the Zhazgurly Formation (Fig. 3).

The volcanogenic–terrigenous sequence develops in the framework of the Zhetybai–Uzen Terrace and Peschanyi Mys–Rakushechnoe Swell. Commercial oil and gas inflows were obtained in the linear structure zone from the volcanogenic–terrigenous sequence in the Tasbulat, Pionerskaya, Yuzhnyi Zhetybai, Severnoe Karagie, Ala-Tyube, and Akkar areas. This sequence unconformably overlies the silty–clayey or tuffogenic–calcareous sequences of the Middle Triassic. The sequence is characterized by the development of graywacke–quartz sandstones and siltstones, which alternate with tuffogenic clastic rocks. Graywacke–quartz sandstones with an admixture of tuffs and siliceous rocks are present in the composition of the volcanogenic–terrigenous sequence.

The Zhazgurly Formation (Upper Triassic sandy–clayey rocks) is completely retained in the Tenge–Tasbulat–Zhetybai fold zone. In the northern regions and Kokumbai Terrace, these rocks are annihilated by the pre-Jurassic denudation.

The sequence is composed of graywacke–quartz sandstones separated by mudstone interlayers. They are enriched in moderate- and well-preserved plant remnants and chorophite algae. The high content of hydromica (up to 70–100%) and considerable admixture of kaolinite in mudstones is a characteristic feature. Boundaries of the Lower Jurassic rocks are outlined by the high concentration of well-preserved plant remnants and kaolinite. In the Tarly-Kuidzhak area, the sandy–clayey sequence includes mudstones mainly composed of kaolinite (80–90%) at a depth of 3320–3395 m. However, this unit has not been established in other areas because of the absence of core material. After the detection of kaolinite mudstones in other prospecting areas, this unit can be used as a reference horizon of the Zhazgurly Formation.

Mineral Composition of the Triassic–Paleozoic Clastic Rocks of Southern Mangyshlak

Clastic and carbonate rocks, the principal lithological types of the Triassic complex, play the role of industrial hydrocarbon reservoirs in the Middle–Upper Triassic sequences.

Clastic rocks are widespread in all Triassic series in southern Mangyshlak. These rocks are most common in the Lower Triassic terrigenous–carbonate sequence and the Upper Triassic volcanogenic-terrigenous (sandy–clayey and clayey–sandy) sequences (Severo-Rakushechnoe and Zhazgurly formations). Their sand content coefficient is 0.6–0.8.

The clastic rocks are represented by fine- and medium-grained sandstones and coarse- and fine-grained siltstones. The coarse-grained sandstones and gritstones are locally encountered at the base of transgressive cycles. The grain size spectrum of the clastic rocks is dominated by 0.25–0.1 mm fraction (Table 3). Sorting coefficient of the clastic rocks is 3.5–3.8.

The Triassic clastic rocks are marked by dark or light gray color, massive structure, and occasional low-carbonate composition.

Some issues of the lithology of the Triassic clastic rocks of southern Mangyshlak are elucidated in works by Popkov *et al.* (1986) and Orudzheva *et al.* (1984).

We studied the core material from new prospecting areas of southern Mangyshlak (Severnoe Karagie, Ala-Tyube, Akkar, Atambai, Dolinnaya, Karamanata, Kamenistaya, Tarly-Kuidzhak, Bortovaya, Tashkum, Uilyuk, Zhilanda, Makhat, Zharta, and Kokbakhty). We also studied core material from the Vostochnyi Chakyrgan parametric well. The Middle Triassic clastic rocks contain an effusive admixture.

In terms of mineral composition, the Triassic clastic rocks can be subdivided into the graywacke–quartz, arkose–quartz, and graywacke–arkose sandstones and siltstones and less common feldspar–graywacke varieties. The graywacke–quartz sandstones are most widespread and encountered in all structural units of southern Mangyshlak (Zhetybai–Uzen Terrace, Karagie Saddle, Peschanyi Mys–Rakushechnoe zone, and Akhsu–

Table 4. Average mineral composition of Middle Triassic sandy–silty rocks of southern Mangyshlak (%)

Minerals and rocks	Studied sections of deep wells							
	Bortovaya (3)	Pridorozhnaya (5)	Severnoe Karagie (4)	Kamenistaya (3)	Yuzhnaya Karamanata (3)	Tarly-Kuidzhak (12)	Uilyuk (8)	Makhat-Pribrezhnaya (10)
Quartz	35.0	25.0	21.0	21.0	33.1	12.5	32.0	24.0
Orthoclase–microcline	4.6	22.0	30.0	23.0	11.5	49.0	10.0	11.0
Albite–oligoclase	–	4.0	8.0	2.5	2.6	7.0	3.0	3.5
Quartzite fragments	0.8	1.8	–	1.0	–	2.0	–	1.5
Fragments of siliceous rocks and schists	46.0	30.8	36.0	36.0	30.7	26.5	53.0	32.0
Shale fragments	13.8	17.0	6.0	11.0	16.7	2.4	2.0	12.5
Effusive rock fragments	–	–	–	–	2.6	1.2	–	–
Muscovite–chlorite	–	–	–	–	1.1	–	–	–
Accessory minerals	0.8	–	–	0.5	0.3	–	0.7	–

Note: Number of the studied samples is given in parentheses. (–) Not detected.

Kinderla Terrace). The graywacke–quartz sandstones serve as reservoirs in the Triassic oil pools of the Yuzhnyi Zhetybai, Kamenistaya, Tasbulat, Ala-Tyube, Akkar, and other areas. The content of quartz minerals in these sandstones is more than 50%. Metamorphic, magmatic, and sedimentary quartz is present among grains of this mineral. The metamorphic and sedimentary quartz grains dominate in the total content of quartz grains of the graywacke–quartz sandstones. The content of graywacke material (quartzite and siliceous rock fragments) in these sandstones is 30–45%. The graywacke material of these sandstones is mainly composed of shale fragments (Table 4) in some areas (e.g., Kamenistaya and Tarly-Kuidzhak). The Upper Triassic sandy–silty rocks of southern Mangyshlak are often enriched in coalified plant detritus and complicated by vitrain interlayers and veinlets. The Middle–Upper Triassic sandy–silty rocks are characterized by lumpy texture and heterogeneity related to the activity of fucoids. The mineral composition of clastic rocks usually bears important genetic and paleogeographic information. Therefore, they were carefully examined for the distribution of clastic minerals, their composition, and structure of the cement.

The average mineral composition of the Middle–Upper Triassic and Lower Jurassic clastic rocks is shown in Tables 4–6.

The determination of petrographic families and classes of clastic rocks is essential for the genetic analysis. Therefore, the mineral composition of the clastic rocks is illustrated in the ternary diagram (Fig. 4). It is evident from the diagram that the Triassic–Lower Jurassic clastic rocks are localized in two petrographic families (quartz and graywacke sandstones).

A few samples of the Middle Triassic clastic rocks are related to the arkose family (Fig. 4). In general, the Middle Triassic clastic rocks are dominated by graywackes and arkoses, whereas the Upper–Lower Jurassic clastic rocks are mainly represented by quartz sandstones.

Family of quartz sandstones. As noted above, representatives of this family are established in the Upper Triassic–Lower Jurassic clastic rocks. They have not been found in rocks of other Triassic stratigraphic series.

The Upper Triassic rocks include three representatives of the quartz sandstone family (oligomictic quartz, graywacke–quartz, and arkose-quartz). Among them, graywacke–quartz clastic rocks are most widespread and encountered in all structural elements of southern Mangyshlak (Zhetybai–Uzen Terrace, Karagie Saddle, Peschanyi Mys–Rakushechnoe zone, and Akhsu–Kenderla Terrace). The graywacke–quartz sandstones compose reservoirs of oil pools in the Yuzhnyi Zhetybai, Kamenistaya, Tasbulat, Ala-Tyube, Akkar, and other areas.

The oligomictic quartz sandstones are relatively rare in the Upper Triassic rocks and mainly found in the sandy–clayey sequence. The quartz content in them reaches 65–70%. The feldspars (3–5%) are represented by orthoclase. Quartzite and siliceous schist fragments are also found. The cement is composed of the clayey–siliceous material. The clayey material of the cement is mainly composed of kaolinite. Zircon and tourmaline are the accessory minerals.

Evolution of the Mineral Composition of Clastic Rocks during the Late Paleozoic and Early Mesozoic History of Southern Mangyshlak

The composition of clastic rocks bears important information about provenances, petrographic composi-

Table 5. Average mineralogical composition of Upper Triassic sandy–silty rocks of southern Mangyshlak

Minerals and rocks	Studied sections of deep wells					
	Bortovaya (5)	Pridorozhnaya (6)	Tarly-Kuidzhak (12)	Makhat-Pribrezhnaya (14)	Zharta (10)	Tashkum (12)
Quartz	43.0	31.0	47.0	52.0	52.4	60.0
Orthoclase–microcline	4.3	20.4	6.9	6.6	15.0	15.0
Albite–oligoclase	–	3.4	1.3	–	–	10.0
Quartzite fragments	1.0	2.0	2.2	3.1	1.8	–
Siliceous shale fragments	40.0	34.0	12.0	18.1	17.0	8.0
Shale fragments	12.0	11.36	25.6	10.3	12.3	5.0
Effusive rock fragments	–	–	0.98	1.3	0.95	–
Muscovite–chlorite	–	–	–	1.2	–	–
Accessory minerals	0.8	–	–	–	–	–

Note: See Table 4.

Table 6. Average mineralogical composition of Lower Jurassic sandy–silty rocks of southern Mangyshlak

Minerals and rocks	Bortovaya (3)	Pridorozhnaya (2)	Akkar (4)	Makhat (5)	Uilyuk (4)
Quartz	45.0	41.0	65.0	56.0	52.0
Orthoclase–microcline	20.5	5.5	8.0	3.5	5.0
Albite–oligoclase	1.5	0.9	2.0	0.8	0.5
Quartzite fragments	3.5	3.6	5.6	4.5	2.5
Siliceous shale fragments	14.0	12.0	15.0	16.0	25.0
Shale fragments	20.0	40.0	5.0	9.5	15.0
Effusive rock fragments	–	–	–	1.4	–
Muscovite–chlorite	0.5	–	0.5	–	0.6
Accessory minerals	0.1	0.3	–	–	0.5

Note: See Table 4.

tions of denudation areas, and physiogeographic and climatic conditions of ancient landscape. The ternary classification diagram provides insights into the genesis of clastic rocks and their spatiotemporal changes. Application of this method by Kossovskaya (1959) in the Verkhoyansk region and Khalifa-zade *et al.*, (1982) in the Caucasus gave interesting results.

In order to elucidate the aforesaid specific features of clastic rocks, we examined results of the study of more than 300 petrographic analyses of the Triassic and, partially, Lower Jurassic and Upper Paleozoic rocks of southern Mangyshlak. Results of the analysis are summarized in Table 7 and Fig. 5.

In Table 7, we introduced the monomineral coefficient (maturity coefficient) of clastic rocks calculated on the basis of the following formula:

$$Q_{\text{mat}} = \frac{\text{Q}}{\text{Fs} + \text{Fr}},$$

where Q_{mat} is the maturity coefficient proposed by Dapples *et al.* (1953), Q is the quartz content, Fs is the feldspar content, and Fr is rock fragment content.

It is clear from Table 6 that the maturity coefficient is less than unity for the Triassic clastic rocks, testifying their formation in a single sedimentation cycle. Moreover, in addition to sedimentary rocks, metamorphic and magmatic rocks also played a significant role in the formation of clastic rocks.

The table and diagram demonstrate the variation trend of quartz, orthoclase, and albite–oligoclase contents and the maturity coefficient of clastic rocks in the Triassic history of southern Mangyshlak.

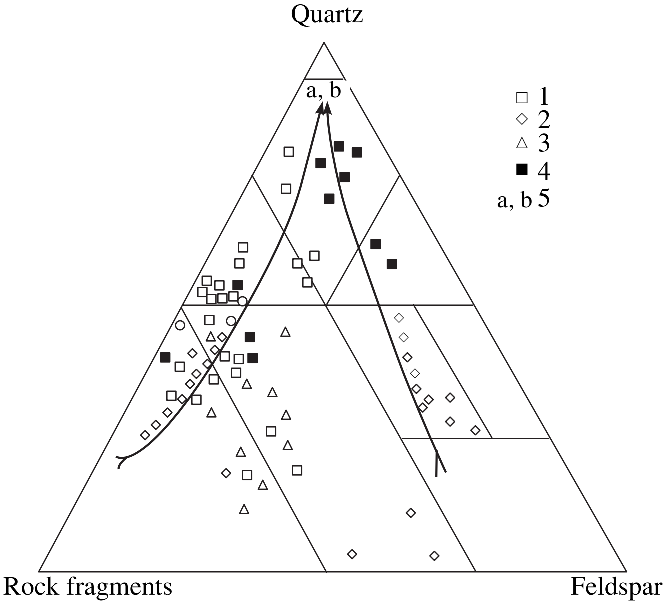


Fig. 4. Diagram of the mineral composition of Triassic clastic rocks of southern Mangyshlak. (1) Upper Triassic clastic rocks; (2) Middle Triassic clastic rocks; (3) Lower Triassic clastic rocks; (4) Lower Jurassic clastic rocks; (5) trend of the maturation of mineral composition of clastic concentrate.

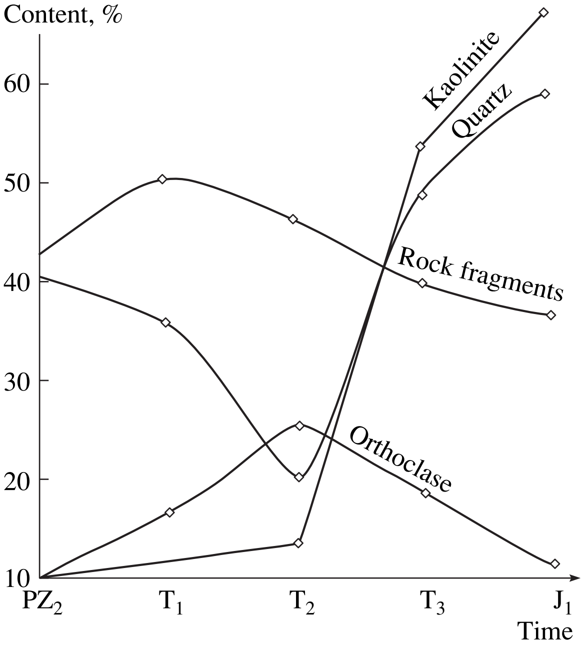


Fig. 5. Evolution of the mineral composition of Triassic clastic rocks of southern Mangyshlak.

The quartz content is 40% in the Upper Paleozoic clastic rocks, diminishes to 24% in the Middle Triassic rocks, and sharply increases to 48–52% in the Upper Triassic–Lower Jurassic rocks.

The inverse trend is observed in changes of orthoclase and acid plagioclase contents in the clastic rocks during the Triassic–Early Jurassic history of southern Mangyshlak. This is graphically illustrated in the variation diagram, where changes in the quartz and feldspar contents have a mirror-image pattern (Fig. 5).

Such spatiotemporal relations in changes of the mineral composition are not incidental. They are dictated by the influence of climate and tectonics on sedimentation. In particular, the Early Triassic tectonic reactivation of the territory (the Kimmerian orogenic phase) promoted an intense denudation of bedrocks under arid and subarid climatic conditions. Therefore, only different representatives of graywacke clastic rocks are found in the Early Triassic varicolored sequence.

The content of quartz material in these rocks is negligible due to a weak chemical weathering of the initial

Table 7. Average mineral composition of Lower Jurassic and Triassic–Paleozoic sandy–silty rocks of southern Mangyshlak

Stratigraphic subdivision	Minerals and rocks										
	Quartz	Orthoclase, microcline	Albite, oligoclase	Quartzite fragments	Siliceous shale fragments	Shale fragments	Effusive rock fragments	Accessory minerals	Muscovite, chlorite	Monomineral coefficient	Number of analyses
Lower Jurassic	51.8	9.3	1.1	3.8	16.4	18.0	0.3	0.1	0.2	1.06	29
Upper Triassic	48.5	11.3	2.5	1.6	21.6	14.3	0.5	–	–	0.93	56
Middle Triassic	24.0	20.1	3.7	0.8	36.2	10.0	1.5	0.4	0.45	0.34	50
Lower Triassic	35.0	15.0	6.1	1.2	37.0	13.0	0.5	0.3	0.9	0.50	15
Upper Paleozoic	40.0	8.0	8.2	–	39	50	–	0.9	1.2	0.70	16

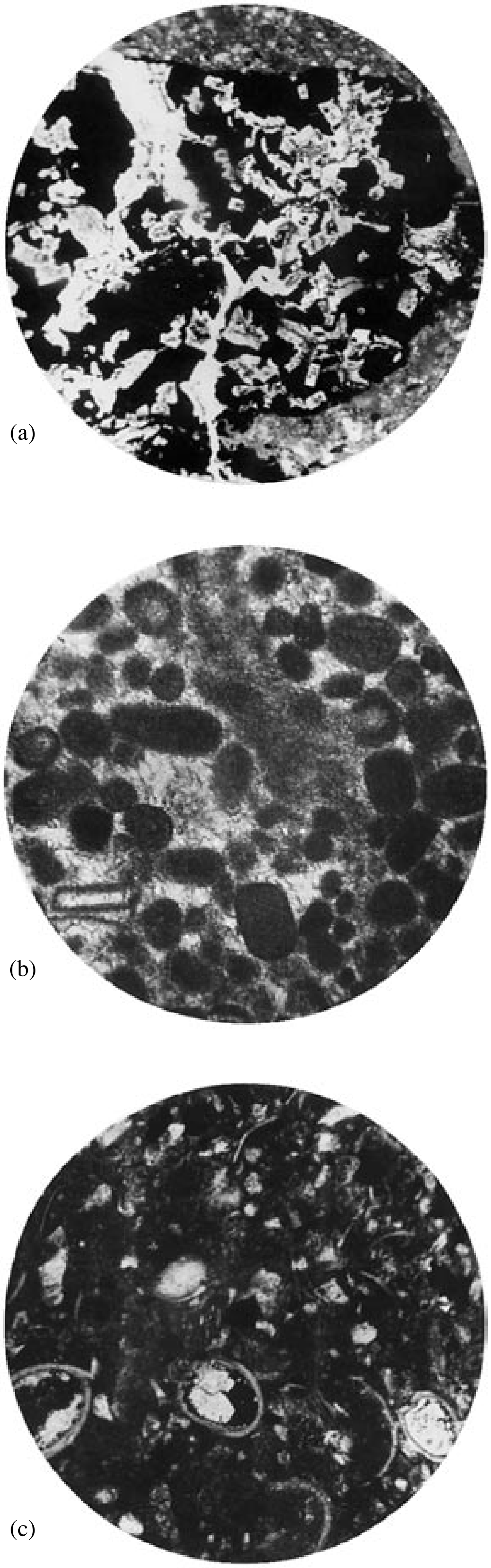


Fig. 6. The Tarly-Kuidzhak area, Well 1. (a) Naphthide spot with pyrite (depth interval 4078–4085 m, parallel nicols, magn. 64); (b) microstructure of oolitic limestones (4147–4252 m, parallel nicols, magn. 64); (c) accumulation of ostracod shells (4088–4092 m, parallel nicols, magn. 64).

rocks under conditions of arid climate. The Early Triassic environment was characterized by the intense denudation of bedrocks and differentiation of relief on land. The bedrocks consisted of the major metamorphic and the subordinate magmatic rocks.

In the Middle Triassic, the average quartz concentration in the composition of clastic rocks continued to diminish as a result of increase of the graywacke and arkosic material. In the northwestern areas with the abundance of the buried Variscan granites, the clastic rocks were transformed into arkosic graywackes, suggesting a high tectonic activity and significant humidity in southern Mangyshlak in the Middle Triassic. This is supported by the abundance of explosive volcanic products and remnants of mesophytic flora in the Middle Triassic rocks.

In the Upper Triassic, the clastic rocks were transformed into the graywacke–quartz variety as a result of twofold increase of the quartz content and the subsequent reduction of graywacke and arkosic material.

Analysis of the lithology of the Upper Triassic rocks, in combination with the study of plant and faunal remnants in them, indicates strong decrease of tectonic activity in the Mangyshlak Basin in the Late Triassic, flattening of the adjoining land, and gradual humidification of climate. Under these conditions, the bedrocks underwent an intense chemical weathering. The stabilization of tectonic regime favored the attenuation of volcanic activity. Volcanic rocks are only observed at the lowermost parts of the Upper Triassic. Traces of explosive and other types of volcanism completely disappeared by the end of the Late Triassic and in the Jurassic. The tectonic, physiographic, and climatic conditions noted above stipulated the accumulation of quartz sandstones in the Late Triassic.

We also analyzed the average mineral composition of the Lower Jurassic clastic rocks of southern Mangyshlak (Figs. 4, 5; Table 7). The results show that the Lower Jurassic clastic rocks contain even more quartz (up to 52%), and the maturity coefficient is more than unity. There is no doubt that it was conditioned by the further stabilization of tectonic regime in the Early Jurassic in Mangyshlak. The South Mangyshlak sedimentary basin was transformed into the typical platformal (epicontinental) structure. Under conditions of stable tectonics and humid climate, the parental rocks underwent a strong chemical weathering, possibly, with the formation of kaolin crust. The factual material indicates the predominance of quartz and kaolinite in the products of denudation and transportation in these conditions. Thus, the Early Triassic–Early Jurassic interval was marked by intense mineralogical changes in the clastic rocks of southern Mangyshlak under the influence of tectonic and physiographic factors. The clastic rocks were transformed into the more mature and oligomictic varieties. Thus, the evolution of the mineral composition of clastic rocks reflects the influence of tectonics, climate, and volcanism on sedimentary processes.

Lithology of Carbonate Rocks

The chemical and mineral compositions of Triassic carbonate rocks are partly described in works by Popkov *et al.* (1986) and Khalifa-zade *et al.* (1982, 1990).

We studied the Middle Triassic carbonate rocks in the Yuzhnaya Karamanata, Severnoe Karagie, Ala-Tyube, Akkar, Atambai, Pridorozhnaya, Tarly-Kuidzhak, Kamenistaya, Tashkum, Uilyuk, and Kokbakhty areas. These rocks locally serve as porous-fractured and fractured-cavernous reservoirs that contain commercial reserves of oil and gas in southern Mangyshlak. Two types of carbonate rocks are developed in the Middle Triassic. The lower part of the Middle Triassic is composed of dolomites and dolomitized limestones, whereas the upper part consists of the organogenic, detrital, ostracod, clayey, and tuffogenic limestones.

The dolomitic rocks include the coarse-crystalline dolomites, oolitic dolomites, dolomitized limestones, and sandy dolomites. The oolitic dolomites are developed in the Middle Triassic rocks of the Severnoe Karagie area. These rocks consist of dolomitic oolites and pseudoolites cemented by calcite and the less common chalcedony. The cryptocrystalline oolites range from 0.1 to 0.3 mm in size (generally, 0.15 mm) and reveal concentric structure. In some cases, their central part is composed of coarse-crystalline dolomite. In the dolomitized limestone, the dolomite constituent is observed as separate clusters (2.0–3.5 mm) of large rhomboids 0.15 mm in size. Oolites and pseudoolites in this rock are also partially or completely replaced by dolomite. Fractures and caverns are locally filled with solid naphthides. In some hybrid (limestone–dolomite) rocks, the bulk mass contains sand particles (10–12%) of the quartz–feldspar composition and vitroclastic tuffs. The dolomite mass includes microfractures and caverns 0.75–1.5 mm in size. Dolomite is irregularly distributed as sedimentary-diagenetic and diagenetic patches (Strakhov, 1960). It is possible that the fracturing and cavernosity of the Middle Triassic carbonate rocks are mainly related to processes of secondary dolomitization of the oolitic and organogenic limestones. Dolomitization is also observed in the cement of sandy rocks (Uilyuk area, 4097–4170 m).

As noted above, the limestones are concentrated in the tuffogenic–calcareous sequence in the upper part of the Middle Triassic. The limestones are subdivided into the pelitomorphic (micrites), clayey, oolitic, organogenic-oolitic, ostracod, and detrital varieties. Ostracod shells are also encountered in the composition of clayey and oolitic limestones (Fig 6c). The clayey limestones consist of thin-crystalline calcite with an admixture of ostracod shells (Fig. 6c). The rock is fractured and marked by a weak development of stylolites. The microfractures (0.05–0.08 mm) are filled with coarser-crystalline calcite. The thin-crystalline calcareous matrix of the organogenic limestone is locally saturated with ostracod shells. One can also see rare large oolites consisting of coarse-crystalline calcite with polysynthetic twins. The rock is fractured and cavernous. The caverns locally reach 1.5 mm in size. Among the limestones, ostracod limestones are of great stratigraphic importance, because they are abundant within a narrow stratigraphic range in all large structures of southern Mangyshlak. Therefore, we recognize the ostracod limestones as a petrographic reference level for the determination of the volume and boundaries of the Middle Triassic tuffogenic–calcareous sequence.

CONCLUSIONS

Based on the study of lithology, stratigraphy, mineralogy, and petrography of Triassic and, partially Jurassic–Paleozoic, rocks of southern Mangyshlak, these rocks were subdivided into several natural lithological sequences that correspond to crucial stages in the tectonic development of the studied region.

The stratigraphic position of the lithological sequences was determined with the help of ammonite and ostracod fauna studied in these rocks by previous geologists.

On the basis of mineralogical indicators, the lithological sequences were traced in the quasi-platform complex in different structural-facies zones of southern Mangyshlak.

Trends revealed in our works make it possible to outline perspective oil- and gas-bearing rocks in the Triassic–Paleozoic rocks of southern Mangyshlak.

REFERENCES

Bakirov, A.A., Rykov, R.M., *et al.*, *Fundament i osnovnye razlomy Turanskoi plity v svyazi s ee neftegazonosnost'yu* (Basement and Main Faults of the Turan Plate: Implications for Oil and Gas Potential), Moscow: Nedra, 1970.

Cherbyakova, L.F., Popkov, V.I., and Pronyakov, V.A., Lithological Features of the Triassic Volcanogenic–Carbonate Rocks in Southern Mangyshlak, *Geol. Nefti Gaza*, 1984, no. 11, pp. 23–28.

Dapples, E.C., Krumbein, W.C., and Sloss, L.L., Petrographic and Lithologic Attributes of Sandstones, *J. Geol.*, 1953, vol. 61, pp. 291–317.

Khalifa-Zade, Ch.M., Gurbanov, V.Sh., *et al.*, Catagenesis Model of Clastic and Carbonate Reservoirs in the Triassic–Paleozoic Sequence of Southern Mangyshlak, *Izv. Vuzov, Ser. Neft' Gaz*, 1990, no. 3, pp. 22–26.

Khalifa-Zade, Ch.M. and Magomedov, A.M., *Sredneyurskie otlozheniya vostochnoi chasti Bol'shogo Kavkaza* (Middle Jurassic Rocks of the Eastern Greater Caucasus), Moscow: Nauka, 1982.

Kossovskaya, A.G., Factors Governing the Clay Mineral Composition in Cratonic and Geosynclinal Environments, *Dokl. Akad. Nauk SSSR*, 1959, vol. 129, no. 6, pp. 21–28.

Krylov, N.A., Orudzheva, L.S., Yuferov, Yu.K., *et al.*, Permian–Triassic Rocks with Gas Potential in the Mangyshlak Region, *Nauchno-tekhnicheskii obzor. Seriya geologiya i razvedka gazovykh i gazokondensatnykh mestorozhdenii* (Scentific-Technic Review: Geology and Exploration Gas and Gas-Condensate Fields), Moscow: Vses. Nauchn. Issled. Inst. Gazprom, 1975, pp. 52–64.

Kuprin, P.N., Junction of Granites and Schists in the Oimasha Area (Southern Mangyshlak), *Vest. Mos. Univ., Ser. Geol.*, 1985, no. 1, pp. 33–42.

Orudzheva, D.S., Danilin, A.N., Edrenkin, S.S., Krymov, V.P., *et al.*, *Litofizika i neftegazonosnost' triasovykh otlozhenii zapada Turanskoi plity* (Lithophysics and Petroleum Potential of Triassic Rocks in the Western Turan Plate), Moscow: Nauka, 1984.

Popkov, V.I., Yapaskurt, O.V., and Demidov, A.A., Specific Features of Basement Structure in the Mangyshlak Region, *Izv. Akad. Nauk SSSR, Ser. Geol.*, 1986, no. 5, pp. 135–142.

Strakhov, N.M., *Osnovnye teorii litogeneza* (Fundamentals of the Theory of Lithogenesis), Moscow: Akad. Nauk SSSR, vol. 1, 1960.