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THE LEGACY OF ACADEMICIAN K.I. SATPAYEV IN THE STUDY OF URANIUM DEPOSITS OF KAZAKHSTAN

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Abstract. *Relevance*. The geological history of the Semizbai depression, which was formed at the beginning of the Mesozoic and developed during the Cenozoic, has been studied. The relatively stable platform tectonic regime in the Triassic led to the territory peneplanation and the development of an areal weathering crust. The sources of the formation of the terrigenous sequence were the products of physical weathering of the basement granitoids. *Objective*. Uranium-containing products of chemical weathering entered the stratum in the form of solutions and were absorbed by its clayey rocks. During the activation of the tectonic regime at the beginning of the Jurassic, the faults in the basement served as channels for the entry of uranium-bearing hydrothermal solutions into the pore layers of the terrigenous sequence. *Methods*. According to geological studies primary ore bodies were formed from these solutions in sandy layers. When the depression subsided, as deposits accumulated, the thickness of the stratum, consisting of water-bearing

and water-resistant rocks, increased. In the thickness, the conditions of an artesian basin were created, where interstratal and infiltration underground waters circulated. In the elision regime, uranium compounds were squeezed out of clayey rocks, which, together with primary hydrothermal ores, fell into aquifers. *Results and practical significance.* Water flows redeposited uranium compounds and formed the hydrothermal-hydrogen Semizbai uranium deposit. The presented geological model serves as the basis for choosing a rational development technology and effective reagents.

Keywords: Mesozoic depression, terrigenous sequence, hydrothermal solutions, uranium ores, hydrogenic mineralization, geological model for technology selection

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АКАДЕМИК Қ.И. СӘТБАЕВТІҢ ҚАЗАҚСТАН УРАН КЕНОРЫНДАРЫН ЗЕРТТЕУДЕГІ МҰРАСЫ

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Аннотация. Өзектілігі. Семізбай депрессиясының мезозойдың басында қалыптасып, кайнозойда дамыған геологиялық тарихы зерттелді. Қазақ қалқанының тектоникалық белсенділігінен кейін аумақ платформалық тектоникалық режимге енді. Триастағы салыстырмалы тұрақты тектоникалық

режим аумақтың пенеленуіне және аумақтық мору қыртысының дамуына әкелді. Мақсаты. Іргетас гранитоидтарының физикалық мору өнімдері депрессияның терригендік түзімдерінің пайда болу көздері ретінде қызмет етті, ал химиялық морудың уранды өнімдері ерітінділер түрінде сол қабаттарға еніп, оның сазды таужыныстарына адсорбцияланды. Зерттеу әдістері. Кенорын ауданында жүргізілген геологиялық зерттеулер және далалық барлау берген деректер бойынша юраның басында тектоникалық режимнің белсенуі кезінде іргетастағы жарылымдар мен жарықшақтар терригендік кеуек қабаттар құрамына уранды гидротермалық ерітінділердің ену арналары қызметін атқарғаны анықталған. Осы ерітінділерден құмды қабаттарында бастапқы кен денелері пайда болды. Депрессия төмен батқан сайын шөгінділер жиналып, сулы және сутірек қабаттардан тұратын қатқабаттың қалыңдығы артты. Нәтиже және практикалық маңызы. Қатқабатта артезиан алабы жағдайы орнап, қабатаралық және инфильтрациялық жерасты суы айналымға түскен. Элизиялық жағдайда уран қосылыстары саз таужыныстардан сығылып шығып, бастапқы гидротермалық рудамен бірге сулы горизонттарға түскен. Жерасты суы ағындары уран қосылыстарын қайта түзіп, гидротермалық-гидрогендік Семізбай уран кенорны қалыптасты. Тектоникалық, гидротермалық, седиментогендік, палеоклиматтық және гидрогеологиялық факторлардың бірігіп әсер етуінен өзіндік минералдық құрамы, бітімдік және құрылымдық ерекшеліктері бар көп деңгейлі уран жатындары жаралған. Ұсынылған геологиялық модель кенорынды игерудің ұтымды технологиясын және тиімді реагенттерін таңдауға негіз болады.

Түйін сөздер: Мезозой депрессиясы, терригендік қат, гидротермалық ерітінділер, уран рудасы, гидрогендік рудалану, технологияны таңдаудың геологиялық моделі

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НАСЛЕДИЕ АКАДЕМИКА К.И. САТПАЕВА В ИЗУЧЕНИИ УРАНОВЫХ МЕСТОРОЖДЕНИЙ КАЗАХСТАНА

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Аннотация. Актуальность. Изучена геологическая история Семизбайской депрессии, заложенной в начале мезозоя и развивавшейся на протяжении кайнозоя. По завершении тектонической активности Казахского щита территория перешла в платформенный режим. Относительно стабильные тектонические условия в триасе привели к пенепленизации территории и формированию площадной коры выветривания. Цель исследования. Продукты физического выветривания гранитоидов фундамента служили источником формирования терригенной толщи депрессии, тогда как урансодержащие продукты химического выветривания поступали в толщу в виде растворов и адсорбировались её глинистыми породами. При активизации тектонических движений в начале юрского периода оживлённые разрывные нарушения фундамента стали каналами поступления урановосных гидротермальных растворов в пористые слои терригенной толщи, где формировались первичные рудные тела. Методы. На основе данных геологических исследований установлено, что по мере погружения депрессии и накопления осадков возрастала мощность толщи, состоящей из чередующихся водоносных и водоупорных горизонтов. В таких условиях формировался артезианский бассейн, в котором циркулировали межпластовые и инфильтрационные подземные воды. Из глинистых пород выжимались элизионные урановые соединения, которые вместе с первичными гидротермальными рудами поступали в водоносные слои. Потоки подземных вод переотлагали уран и приводили к формированию гидротермально-гидрогенного Семизбайского уранового месторождения. Результаты и практическая значимость. Под воздействием совокупности тектонических, гидротермальных, седиментогенных, палеоклиматических и гидрогеологических факторов происходило формирование многоуровневых урановых залежей со своеобразным минеральным составом, текстурно-структурными особенностями. Представленная геологическая модель служит научной основой для выбора рациональной технологии разработки месторождения и эффективных реагентов.

Ключевые слова: мезозойская депрессия, терригенная толща, гидротермальные растворы, урановые руды, гидрогенное оруденение, геологическая модель для выбора технологии

Introduction. Academician K.I. Satpayev noted (1945) the prospects for using uranium for peaceful purposes as an energy source and the importance of geological

studies of its natural sources long before their systematic study (Sbornik, 2024). During this time, geologists have discovered many endogenous and exogenous uranium deposits. Currently, the leading industrial type is the exogenous group of uranium ore deposits, which are concentrated in the corresponding provinces of Southern, Central, Western and Northern Kazakhstan (Spravochnik, 2015). Kazakhstan has now become the world leader in uranium mining (Figure 1).

A study of the geology of the Semizbai depression in northern Kazakhstan showed that it formed at the beginning of the Mesozoic and developed during the Cenozoic. A relatively stable platform regime in the Triassic led to the leveling of the territory and the development of an area weathering crust. The initial material for the formation of the terrigenous strata were the products of physical weathering of Paleozoic granitoids. Uranium-containing weathering products entered the strata in the form of solutions and were absorbed by clayey rocks. During the period of activation of the tectonic regime at the beginning of the Jurassic, faults in the basement served as channels for the entry of uranium-containing hydrothermal solutions into the pore layers of the terrigenous strata. Primary ore bodies were formed from these solutions in porous sand layers. As the depression sank and sediments accumulated, the thickness of the strata, consisting of aquifers and impermeable layers of rocks, increased. In the thickness, conditions of an artesian basin were created, where interstratal and infiltration underground waters circulated. In the elision mode, uranium and rare element compounds were squeezed out of clay rocks (Baibatsha et al, 2024), which, together with primary hydrothermal ores, entered aquifers. Water flows redeposited uranium compounds and formed the hydrothermal-hydrogenetic uranium deposit Semizbai. The presented geological model serves as a basis for forecasting new promising areas, choosing a rational technology for developing the deposit and effective reagents.

Figure 1 - Location of the main uranium ore deposits of the Republic of Kazakhstan by (Spravochnik, 2015)

The results obtained can serve as a reliable geological basis for choosing a rational development technology and effective reagents (Amirova et al, 2017; JSC «NNC «Kazatomprom», 2023; Aubakirov, 2017; Aubakirov, 2011; Aubakirov, 2018; Bashilova et al, 2022; Bektai et al, 2019).

Materials and methods. To achieve scientific results on the object under study, we used a complex of field geological and laboratory studies in combination with the methods of tectonic, hydrothermal, sedimentogenic, paleogeographic, paleoclimatic and hydrogeological reconstructions, the essence of which is described below in the text in the appropriate places.

According to the leading ore-forming factors and the direction of ore-forming processes, the Semizbai deposit is primarily hydrothermal, and also partially post-sedimentary, infiltration- hydrogenic and is associated with ancient zones of formation oxidation (Amirova et al, 2017; JSC «NNC «Kazatomprom», 2023; Aubakirov, 2017; Aubakirov, 2011; Aubakirov, 2018). The above considerations are confirmed by the data on determining the absolute age of ores of all horizons. Determinations carried out in the laboratory of the Radium Institute V.G. Khlopin (uranium-lead method) age of fresh pitchblende and concentrate of pitchblende and coffinite showed values of 108-114 and 41-49 Ma, respectively. In addition, the values of the absolute age of ores by lead isotopes in the laboratory of the Steppe Expedition (45 samples) showed three main time intervals: 180-140, 120-80 and 60-60 Ma, and the interval of 120-80 Ma is distinguished by the prevailing values. Similar age determinations were obtained from 16 samples (isotope-spectral method) in the laboratory of the Neva Expedition: 56-98 and 140-199 Ma. Determination of the temperature of homogenization of gas-liquid inclusions in calcite cementing sandstones, performed in the laboratory IGEM (Institute of Geology of Ore Deposits, Petrography, Mineralogy and Geochemistry, Moscow), showed its value in the range of 194-216 °C (Kontcepciya, 2023; Pirmatov et al, 2006; Sholakov et al, 2003; Abdikerim, 2020).

It can be concluded that earlier age indicators correspond to the initial primary hydrothermal ore formation. Subsequent age determinations correspond to hydrogenic and postsedimentary processes in the ore-bearing strata of the deposit after relatively tectonic stabilization of the depression area. The history of the formation of the Semizbai depression has passed four important and major stages, which is illustrated by the data in Figure 2.

The first – early stage, covering the period from the Jurassic to the beginning of the Cretaceous, is associated with the formation of the Semizbai depression proper and the formation of the ore-bearing strata that fulfills it. At the same time, in the previous period, the Triassic-Lower Jurassic break in sedimentation was clearly manifested, which is associated with the formation of an areal weathering crust of granitoids in the basement of the depression. This crust could serve as one of the probable sources of uranium mineralization. The Semizbai structure is superimposed on a folded Paleozoic basement and developed as an intermountain erosive-tectonic depression under the conditions of activation of the tectonic regime

in the Mesozoic. As can be seen from the facies-paleogeographic scheme, the Semizbai paleovalley in the northeast had access to the coastal area of the shallow marine basin of the West Siberian Lowland.

The formation of the productive Semizbai Formation took place in the intermountain paleovalley under conditions of a rather active tectonic regime. The semiarid, turning into arid climate of the region, was an important factor in the formation of the sedimentogenic appearance of the depression – the creation of facies zoning in plan and the alternation of permeable and water-resistant horizons in the section. The distinguished facies zones of alluvial gray flowers and deluvial-proluvial variegated flowers simultaneously reflect the primary geochemical and, accordingly, redox conditions, therefore they are facies-geochemical zones. Since alluvial gray flowers are characterized by saturation with organic residues, probable uranium concentrators, already in the process of formation of the deposited Semizbai uranium-bearing suite, favorable lithological and geochemical prerequisites were quite clearly defined.

The final stage of the stage under consideration, during which the upper clay aquiclude was formed (Fig. 2, 1), can be considered the beginning of the formation of the Semizbai depression artesian basin, which obviously had a connection with the Irtysh artesian basin in the east. Aquifer (and ore-bearing) horizons overlain by water-resistant ones, in accordance with the ideas about the evolution of artesian structures, obviously experienced epigenetic transformations of a restorative nature. These processes are associated with early progressive diagenesis under the conditions of an elisional hydrogeological regime with an upward flow of formation recovery waters. These processes can also be associated with hydromica of clay cements, biotite and other femic minerals, the formation of early epigenetic sulfides in areas of accumulation of organic matter, the restoration (gleying) of primary reds in a general increase in the contrast of the reducing environment. Under such conditions, previously created diagenetic uranium accumulations could be buried or partially redistributed and deposited in areas of the most contrasting geochemical environment.

The second stage (Hautherivian-Aptian) is the most important in the formation of industrial uranium mineralization of the deposit. This stage was marked by a general uplift of the territory, a long (15-15 million years) break in sedimentation, which could contribute to the establishment of the most stable infiltration hydrogeological regime of the Semizbai basin. It is with this stage that the maximum opening of the depression in the entire geological history is associated, the dimensions of which, although somewhat exceeding, but generally approaching the modern ones, significant erosion of the ore-bearing stratum and complete cutting of the depression in the west of the upper, and in its upper reaches, of the lower aquicludes (Fig. 2, 2). In the existing situation, the most favorable real conditions were created for the formation of uranium-bearing waters and their infiltration along the layers of permeable (ore-bearing) horizons. Fractured massifs of underlying and surrounding granitoids served as the area of water supply and transit over most of the area.

The most probable penetration of primary uranium-bearing solutions into permeable depression deposits is associated with the revival of faults and the formation of cracks in the basement, which served as channels for the supply of primary hydrothermal ore solutions. The directions of water flows were oriented along the depression to the east, in accordance with the general slope of the bed, and from the sides to its axis. The upper ore-bearing horizon in the west of the depression was open and came to the surface, there were also groundwaters that passed into interstratal waters, while in the lower horizon formation infiltration waters dominated.

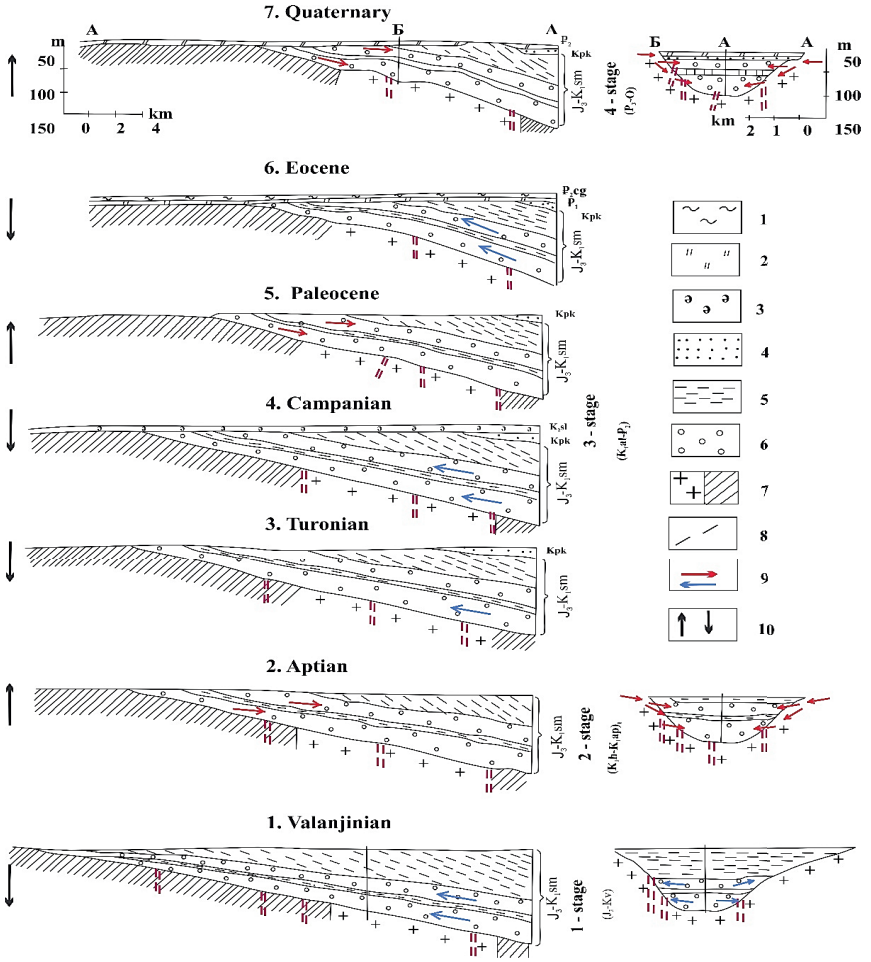

Figure 2 – Geological model of the formation of the Semizbai depression. A, B – longitudinal and transverse sections: 1 – silty-argillaceous deposits of the Shagan Formation (P_2^3*ćg);* 2 – glauconite-quartz deposits of the Lyulinvor Formation (P_2^3ll); 3 – quartz-glauconite sands of the Slavgorod Formation (K_2sl); 4 – gravelstones and quartz sands of the Pokur Formation (K_1pk); sediments of the Semizbai Formation (J_3-K_1sm); 5 – silty-argillaceous aquifers; 6 – conglomerate-sandstone aquifer (ore-bearing) horizons; 7 – Paleozoic granitoids and volcanic-sedimentary rocks of the basement; 8 – faults; 9 – direction of movement of groundwater; 10 – uplift and subsidence of the territory

At the late time of the stage, with the likely predominance of gley formation waters, an additional supply of uranium by hydrogenic flows and its deposition on reduction barriers, as well as partial redeposition of previously created concentrations, is possible. Thus, the described stage seems to be the main one in the formation of commercial ores of the Semizbai deposit.

The third stage (Albian-Eocene) occupies the longest period of time (about 70 Ma) in the geological history of the depression. On the whole, it was characterized by a directed subsidence of the territory under conditions of a predominantly humid climate, by the intermittent development of marine transgression, which reached its maximum at the end of the Eocene. Three main stages can be distinguished within the stage: Albian-Campanian (Fig. 2, 3 and 2, 4), Maastrichtian-Paleocene (Fig. 2, 5), Eocene (Fig. 2, 6). At the beginning of the early stage, tectonic activation appeared, which can be associated with the migration of deep reservoir thermal waters and the formation of epigenetic carbonates.

Further in time, descending tectonic movements dominated, interrupted by a short-term uplift and erosion in the pre-Turonian time, which caused a marine transgression, by the end of which the depression was almost completely covered and buried under marine deposits of the Slavgorod Formation. During the period of Turonian erosion (see Fig. 2, 3), it is possible that ore formation processes resumed or there was a partial redeposition of ores. All the rest of the time, during the subsidence of the territory and the sea transgression, in the Semizbai artesian structure, the elisional hydrogeological regime dominated mainly with rising recovery formation waters. They led to the restoration of previously limonitized rocks and the partial destruction of ancient zones of in-situ oxidation. Ore deposits could either have been mothballed or partially converted and have undergone redeposition of ore matter.

The fourth and final stage covers the latest epoch from the Oligocene to the Quaternary inclusive (Fig. 2, 7). This is the occurance time relatively weak differential tectonic movements against the background of the general uplift of the territory, predominantly arid climate and infiltration hydrogeological regime. At this stage, Eocene marine deposits overlying the Semizbai valley underwent significant erosion. Partial opening of the ore-bearing strata and the formation of the modern appearance of the depression took place in separate windows. At present, the Semizbai artesian structure is characterized by slow infiltration of low-oxidizing formation waters in ore-bearing horizons. The main filtration direction is along the depression from west to east, partly from the sides to its axis. The activity of these waters is obviously related to the processes of the latest pyritization and gleying of rocks, as well as partial redeposition of uranium compounds. The formation of episodically occurring secondary uranium minerals – uranopilite, zippeite, uranophane in association with gypsum and barite can also be attributed to this stage.

The given data show that the Semizbai deposit is a rather complex and peculiar object, on which uranium mineralization was formed over a long period of time in several stages. On this basis, it can be attributed to the polygenetic type.

Results. Sedimentary cover deposits make up the upper structural-formational complex of the region. The formation of the complex took place in three stages, which correspond to three structural floors, separated by regional breaks in sedimentation and distinguished by characteristic sedimentary formations, structural forms and other features.

The lower level was formed at the stage of tectonic activation of the Epipaleozoic platform and is represented by continental deposits of the variegated coal-bearing formation (Lower Jurassic). At the beginning of this stage, in the Lower Triassic, splits of a rigid folded base, block slips along faults, and outpourings of andesite-basalt and liparitic lavas occurred, which manifested themselves in the adjacent Korjynkol-Torgai region. During the Middle Triassic-Early Jurassic, the processes of peneplanization of the relief, chemical weathering of rocks and the formation of the most ancient weathering crust, two diverging in the sub latitudinal direction of the Semizbai and Selety depression zones with a total length of up to 200 km, took place.

Regionally, the Mesozoic intermountain graben-depressions in the northeast of the region, obviously, had access to the foothill plain, passing into the coastal region of the sea basin that existed in the south of the West Siberian Lowland.

The variegated-coal-bearing formation consists of two strata: Early-Middle Jurassic and Upper Jurassic-Lower Cretaceous. The deposits of the first of them are of limited distribution and within the area are known only in the Seletinsk depression, where they occur at the base of the sedimentary cover. The facies-lithological characteristics of this sequence and all subsequent stratigraphic units of the sedimentary cover are given in Table. 1.

Table 1 - Stratigraphic of the Mesozoic-Cenozoic deposits of the Semizbai depression

Structural units	Index – thickness, m	Lithological composition of deposits
Top level N – up to 100 P$_3$ – до 40	Q – up to 30	Quaternary deposits. Sands, sandy loams, loams, clays, gravels, pebbles of deluvial-proluvial and alluvial-lacustrine origin
	Undivided Aral and Pavlodar suites. continental deposits. Clays are red-brown and greenish-gray montmorillonite and beidellite, weakly gypsum with marl nodules; siltstones, sands	
	Undivided Atlym, Shilikta and Shagrai suites. Continental deposits. Gray-colored sands, silts, clays with coalified plant remains	

Middle level	upper storied	P_2^3 – up to 80	Shagan suite. Marine deposits. Clays, greenish-gray, foliose, with sand powders, siltstone interbeds, and siderite lenses
		P_2^{1+3} – up to 60	Lyulinvor suite. Marine and coastal-continental deposits. Greenish-gray glauconite-quartz sands and sandstones, flasks, siliceous sandstones and siltstones, gravelstones with wood fragments
		K_2m+d – up to 35	Gankin suite. Marine deposits. Gray calcareous, silty clays, siltstone interbeds; abundance of shell detritus
		K_2cn-cp – up to 100	Slavgorod suite. Marine deposits. Gray-green glauconite and quartz-glauconite sands and sandstones, clays, siltstones, phosphorite concretions
		K_2t – up to 12	Kuznetsov suite. Marine sediments: micaceous clays, sands, sandstones
	lower storied	K_{1-2}b-ab – up to 120	Pokur suite. Lacustrine-alluvial and swamp deposits. Light gray and gray sands and quartz sandstones, kaolin clays, gravelstones, conglomerates; accumulations of plant detritus and brown coal lenses, bauxite deposits
		J_3-K_1v sm – up to 300	Semizbai suite. continental deposits. Channel-floodplain, predominantly gray-colored inequigranular sandstones, sands, clays, siltstones, conglomerates, gravelstones; abundance of carbonized plant remains - leaves and wood; deluvial-proluvial variegated and red-colored clays, siltstones, sandstones, gruss
Lower level		J_{1-2} – 50	Undivided alluvial and lacustrine-marsh deposits. Gray-colored sandstones, gravelstones, conglomerates, siltstones, carbonaceous mudstones, brown coal seams

Due to block movements along the faults by the beginning of the Upper Jurassic erosion, the Lower-Middle Jurassic deposits of the lower stage were significantly eroded and they were preserved only in the form of separate erosion-tectonic remnants, mainly buried under younger formations.

The data obtained make it possible to confidently date the age of the ore-bearing strata of the region, distinguishing three stages in its formation. The analysis shows that there was a long (10-15 million years) break in the sedimentation of the Hauterivian-Barremian era against the general background of the uplift of the territory at the end of the Valanginian and its subsequent peneplainization. During this epoch, the Jurassic-Lower Cretaceous depression structures were exposed and subjected to erosion. Bearing in mind that by this time, paleodepressions had formed into local artesian basins, in which one can assume the circulation of descending stratal waters, including uranium-bearing waters, which redeposited primary hydrothermal ores. It is this epoch that should be considered as the most productive in epigenetic ore formation in the strata of the Semizbai deposit.

The middle level of the sedimentary cover was formed during the platform stage of development, which was generally characterized by a relatively calm tectonic regime, discrete subsidence of the territory, accompanied by marine transgression. According to the features of the sedimentary stratum and other features, two tiers are distinguished within the storey.

The lower level includes Cretaceous, predominantly marine, partly continental deposits of the Pokur, Kuznetsov, Slavgorod, and Gankin formations. The Pokur suite is represented by continental deposits. They were formed under the conditions of a peculiar tectonic regime, which, according to its features, is transitional from the stage of tectonic activation to the actual platform one. As established by paleogeographical constructions, in the Aptian time, most of the area was uplifted, it was an area of peneplanation and the formation of an areal weathering crust. The Jurassic-Lower Cretaceous depressions still remained open, which could contribute to the continuation of bedding-infiltration processes in them and epigenetic uranium accumulation. The first half of the Albian was marked by tectonic activation, accompanied by a revival of erosional activity and the formation of river valleys. In the Cenomanian, the tectonic regime gradually stabilized, which led to the formation of a vast alluvial-lake-marsh plain, under which most of the Jurassic-Lower Cretaceous depressions were buried, including the eastern part of the Semizbai depression.

The deposits of the next three formations make up most of the lower structural stage and form a gray-colored quartz-glauconite sandy-clayey sequence (Table 1). The formation of these deposits took place under conditions of discontinuous transgression of the sea, which was due to the alternation of uplift and subsidence of the territory. In accordance with this, the Turonian, Maastrichtian, and then the Paleocene epochs of breaks in sedimentation are distinguished, during which sedimentation was localized only in the marginal parts of the area, and the Coniacian-Campanian age of prolonged transgression. Recently, the depression structures of the activation stage have been almost completely covered and buried under the sediments of the Slavgorod Formation. At the same time, during the epochs of breaks in sedimentation, their erosion and partial opening could occur in the marginal western, most elevated part of the region.

The characteristic Upper Cretaceous structures of the area were wide troughs of a typical platform type, the largest of which almost completely occupied the Selety block, and the second one entered the area of the Kyzyltu block in the form of a bay. As paleotectonic constructions show, within the Selety block, the areas of maximum subsidence spatially coincided with the Jurassic-Lower Cretaceous depression zones.

The upper sedimentary level is represented by marine grey-colored glauconite-quartz and argillaceous deposits of the Lyulinvor and Shagan formations of the Eocene. Their formation is associated with a new after a long date-Paleocene break in sedimentation and marine transgression, which covered a vast territory.

At that time, the sea was deeply wedged to the west along the Semizbai and Selety depression zones, the deposits of which were completely buried. The structure formed in the Eocene was a vast trough that occupied the areas of the Selety and Kyzyltu blocks. As in the Upper Cretaceous, within the trough, areas of maximum subsidence were distinguished, the axes of which generally coincided with the ancient depression zones, which indicates their rather high mobility.

The upper level was formed in the Oligocene-Quaternary time at the final stage of the Mesozoic-Cenozoic cycle and characterizes the modern period of the geological history of the area with a general uplift of the territory and differentiated tectonic movements of recent times. The stage is represented by continental deposits of the Oligocene (undivided Atlym, Shilikta and Shagrai suites), Neogene (Aral and Pavlodar suites) and various Quaternary formations.

The period under consideration is associated with the design of the modern relief of the region. Relatively weak recent tectonic activation most intensively manifested itself in the area of the Selety block. Here, differentiated tectonic movements along long-lived fault systems of the northeast and northwest directions led to the formation of longitudinal stepped ledges and transverse dome-shaped uplifts, expressed by positive landforms. Cretaceous deposits, including deposits of the Upper Semizbai subformation, and in some areas, basement rocks are brought to the day surface in their arches. The tectonic movements of that time also led to the lowering of the Semizbai depression, which predetermined the preservation of both the ore-bearing rocks and their top, the Eocene marine deposits, from erosion.

Discussion. Epigenetic uranium deposits associated with the Mesozoic zones of seam oxidation are not uncommon for the Asian part even now. According to the results of many years of comprehensive study, the large uranium-coal deposit Kolzhat was also formed in connection with the processes of soil and seam oxidation, mainly in the Mesozoic, having undergone only a partial infiltration redeposition of ores in the latest stage of tectonic activation. In contrast to the Semizbai deposit, the ore-controlling zones of oxidation at such deposits are quite distinct and show almost no signs of post-ore recovery of rocks.

As a result of regional studies of recent years, it can be considered proven that during the of the Upper Jurassic-Lower Cretaceous aridization, which manifested itself against the background of the general attenuation of the Cimmerian orogeny, the processes of productive oxidative epigenesis in the western part of the Central Asian orogenic belt acquired intensive development.

Ancient filtration uranium mineralization of the Mesozoic era usually does not have a roll morphology. It is characterized mainly by lenticular deposits, often multi-tiered, tending to accumulations of organic matter in sandstones or coal-bearing layers. In this regard, the Semizbai deposit is no exception. According to the morphological features of mineralization, it is quite comparable with such relatively well-studied objects as the Im, deposits of the Kavak group, etc. The indicated features of the morphology of ore bodies are due to the landscape-geochemical specificity of the Mesozoic stage of uranium ore formation.

In the case of ancient infiltration Mesozoic deposits formed under conditions of relatively low uranium content of oxygen underground waters, the decisive role was played by the long duration of ore-forming processes, which continued according to a single plan for many millions and tens of millions of years. This has been largely proven for the Kolzhat and other uranium-coal deposits and can reasonably be assumed for the Semizbai deposit, where the stage of infiltration ore formation, according to geological data, dates back to the Valanginian-Aptian, i.e., has a duration of 25 Ma.

The Semizbai deposit differs from its well-studied counterparts in the presence of a primary ore-redistributing hydrothermal stage and the subsequent stage of hydrogenous ore accumulation. It should be noted that manifestations of post-ore hydrothermal activity due to the latest (Pliocene-Quaternary) orogeny are also known in uranium-coal deposits (Turakavak, Djil, Shang, Garm, etc.). They are represented by calcite and other veins, formed according to the study of gas-liquid inclusions, in the temperature range of 100-300 °C by alkaline sodium chloride (carbonate-free and sulfur-free) solutions. They are comparable in their hydrogeochemical features with the current "nitrogen hot springs" of the Tien Shan. Hydrothermal activity at these sites is separated in time from the ore-forming oxidative epigenesis by hundreds of millions of years. It practically did not affect uranium mineralization, both due to the lithification of ore-bearing rocks at the stage of hydrothermal ore and vein formation, and due to the weak aggressiveness of ascending carbonate-free waters in relation to uranium concentrations.

At the Semizbai deposit, the picture is significantly different. The hydrothermal stage, caused by the tectonic activation of the North Kazakhstan province in the Jurassic-Early Cretaceous, manifested itself in the ore-bearing stratum, which had not yet passed the stage of diagenesis. This made it possible for ascending thermal solutions to spread from the basement supply structures along the porous layers of the Semizbai Formation and for the formation of sheet-like zones of epigenetic sulfidization and carbonatization. The solutions, apparently, had a high carbonate content and, in terms of their aggressiveness towards uranium, had similarities with tar-forming hydrotherms. As shown, in places of contact with the previously formed seam-hydrogenous mineralization, they made its partial processing. This led to the appearance at the deposit of a new mineralogical and chemical variety of ores – coffinite-tar with uranium titanates. At the same time, the role of this superimposed process did not go beyond the local redistribution of ore matter. The assessment of the role of hydrothermal transformations at the Semizbai deposit is generally close to that usually given to manifestations of the post-ore ("calcite", "pyrite-calcite", etc.) stage at many endogenous deposits. At the Semizbai deposit, the hydrothermal process was associated with the splitting of its basement by long-lived faults and fracture zones, which served as ore supply channels for the penetration of ore hydrothermal fluids into rocks with sufficient reservoir properties. Subsequently, a hydrogenous redistribution occurred in the section and laterally.

Productive diagenesis was superimposed both on the already formed zones of seam limonitization and on the uranium ore bodies associated with their boundaries.

Conclusion. In the described region, the end of the Paleozoic is marked by the completion of the formation of various tectonic blocks, limited by large long-lived faults, tectonic stabilization of the region and the dominance of denudation processes, which led to the general peneplanation of the territory with the formation of an areal weathering crust. At the end of the Triassic - beginning of the Jurassic, the entire territory was covered by the formation of an areal weathering crust. At the beginning of the Jurassic, tectonic revival occurs with the formation of graben and horst structures limited by faults and alternating vertical movements. Grabens served as sedimentary basins for the accumulation of terrigenous strata, and horsts - areas of removal of terrigenous material with products of chemical weathering of mainly Paleozoic basement granitoids. The established favorable climate at the beginning of the Jurassic contributed to the accumulation of coal-bearing strata in grabens with industrial coal deposits known in Kazakhstan. In the Mesozoic-Cenozoic, as a result of regional subsidence, the territories were covered by relatively short-term shallow-water marine transgressions.

By the end of the Jurassic, in the territory of the Semizbai depression, where accumulation of terrigenous predominantly sandy-clayey strata occurred, there was a revival of faults and fracture zones in the basement. These tectonic structures served as channels for the entry of primary hydrothermal ore solutions into the accumulated terrigenous strata and their penetration into rocks with the corresponding reservoir properties. Determination of the homogenization temperature of gas-liquid inclusions in calcite cementing sandstones, carried out at IGEM, showed its value in the range of 194-216 °C.

The formation of the artesian basin in the Semizbai depression led to hydrogenic processes of change in the primary hydrothermal uranium mineralization and the formation of hydrogenic-elision (infiltration-sedimentation) deposits of uranium ores. Uranium mineralization does not have a roll morphology. It is characterized mainly by lenticular deposits, often multi-tiered, possibly gravitating toward accumulations of organic matter in sandy-clayey deposits. Based on the presented geological model, a rational technology for developing the deposit and reagents that increase the extractability of metals from ores were selected (Bashilova et al, 2022; Kontsepsiya, 2023; Pirmatov et al, 2006; Sholakov et al, 2003; Abdikerim et al, 2020; Kenzhaliyev et al, 2020; Cuney et al, 2015; Shiderin, 2020).

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