Research Open

Geology, Earth and Marine Sciences
Volume 7 Issue 3

Research Article

The Evolution of Endogenous Uranium Ore Formation in Western Uzbekistan (Central Kyzylkum)

Mirkhodjayev Bakhtiyar Ismailovich*

Deputy Chief Geologist, "Navoiyuran" State Company, Navoi, Uzbekistan

***Corresponding author:** Mirkhodjayev Bakhtiyar Ismailovich, Deputy Chief Geologist, "Navoiyuran" State Company, Navoi, Uzbekistan

Received: April 14, 2025; **Accepted:** April 18, 2025; **Published:** April 22, 2025

Abstract

The article substantiates and schematically shows the vertical zonality in the structure of uranium deposits, as well as the mechanism of "overflow" of basement fractured waters into the aquifers of the platform cover. A geochemical model has been developed for the distribution and concentration of the main useful metals in the earth's crust and the conditions for the formation of various types of endogenous uranium deposits in the Central Asian region.

Keywords: *^{13}C-rich diamond, Supercritical fluid, Strong isotope fractionation, Variscan mineralization, Extensive range of diamond formation*

Introduction

A large number of works are devoted to the problem of the geology of endogenous mineral deposits, at the same time, issues related to the patterns of formation of uranium deposits, in connection with the geochemical evolution of the earth's crust, the development and restructuring of geological structures from the Precambrian to the Cenozoic, are considered in the works of only a number of scientists. Among them, the works of [1-16] who devoted their scientific works to the issues of metallogeny, geochemistry of black shales and the study of hydrothermal uranium deposits.

Metodology

An important, if not decisive, place in uranium ore genesis is given to the last stage of metamorphism, the processes of dynamohydrothermal metamorphism-metasomatosis. According to the time of manifestation, this is the stage of the latest Hercynian processes, in which they are distinguished according to the type of aqueous (hydrothermal) solution - hydrothermal and hydrothermal-metasomatic. The 1st type is characterized by a wide manifestation of postmagmatic processes with the formation of a range of near-ore alterations - greisenization, silicification, albitization with the appearance of brannerite-nasturan and quartz-tourmaline formations. 2nd type - hydrothermal-metasomatic, in which mineral parageneses are also distinguished according to the temperature interval. At the same time, as the temperature of hydrothermal solutions decreases, high-temperature mineral associations of uranium change and separation from magmatic satellites - lanthanides, Ta, Nb, Zr, and rare earths occurs. At the stage of hydrothermal ore formation, the separation of uranium and thorium also occurs. For medium- and low-temperature deposits, ore minerals of uranium are represented by oxides (nasturan, uraninite) and silicates (coffinite) of uranium. The average temperature of hydrothermal-metasomatic solutions forming pitchblende vein deposits is 1500C, and generally does not go beyond 200°C. The formation temperature of hydrothermal ores with uraninite is higher: 250-300°C [17,18]. Having carried out a number of calculations on the temperature and pressure of the formation of mineral paragenesis, taking into account the fact that in hydrothermal solutions the most common form of uranium migration is uranyl-carbonate complex compounds as $Me_4[UO_2(CO_3)_3]$ or $[Me_2UO_2(CO_3)_2(H_2O)_2]$ - the main temperature intervals of migration of uranyl-organometallic complexes in solutions are given below (Table 1). The boundary between these types of solutions is accepted conditionally. The table indicates the most "developed" forms, which depending on the acid-base balance have one or another degree of migration.

Marakushev [7,9] emphasized that the acid-base differentiation of metals is the main factor in ore zoning. During cation transport by acid solutions, metals with more alkaline properties migrate further than acidic ones and ore zoning is formed in the order of increasing alkaline properties of metals: Sn+W–Mo+Cu+Bi–Zn+Pb+Cd–Ca+Ba (cationic migration zoning). During anionic transfer, parageneses of ore metals are located in the reverse order - there is an increase in acidic properties (zoning of anionic migration). At the same time, the anionic form of migration in alkaline or hydrogen sulfide solutions is of primary importance for the transfer of metals over long distances. In particular, at the Dzhantuar deposit in carbonaceous-siliceous shales, we noted the following vertical zonality (Figure 1): the lowest - a zone of oxide pitchblende ores in association with sulfides (pyrite, sphalerite, molybdenite) is replaced upward by a zone of uranyl-vanadate with goethite and molybdenum and further uranyl-phosphate ores with alunite. The appearance of alunite indicates the maximum acidity of hydrothermal solutions. And finally, in the uppermost part of the ore zone, located in the aeration zone, secondary uranium minerals are localized - carnotite, otenite, thuyamunite. Such successive change from bottom to top of earlier mineral associations by later ones indicates the formation of uranium ores from ascending solutions (Figure 1).

Table 1: Distribution and Migration of Uranium in Solutions at Uranium Deposits of Central Kyzylkum.

Type of aqueous solution	Temperature	Ore Formation	Migration Forms	Stages of mineral formation				Mineral parageneses	Ore changes
				Acid Leaching		Carbonate Leaching			
				Acidic pH≤4	Slightly Acidic pH=4-5,5	Subalkaline pH=5,5-6,5	Alkaline pH>6,5		
Hydrothermal	200-300^{0}C	Brannerite-Pitchblende Quartz-Tourmaline	*Uranyl-Phosphate Uranyl-Hydroxyl*	+ + + +	+ + +	+ +	+	crb+ep+amp±gr qz+mu+fl+turm qz+crb+sulf qz+ab+mu	Silicification Skarning Greisenization Albitization Pyritization
Hydrothermal Metasomatic	100-200^{0}C	Fluorite - Pitchblende-Carbonate Sulfide-Nasturan-Coffinite	*Uranyl-Carbonate Uranyl-Fluoride*	+ +	+ + +	+ + + +	+ + + +	qz+ser+nast+mo qz+ap+mu+chl ab+qz+mu+bi+ank	Carbonatization Silicification Beresitization Albitization
	≤100^{0}C	Quartz-Pyrite-Lamprophyr Quartz-Carbonate-Gold-Uranium	*Uranyl-Carbonate Uranyl-Sulfate*	+	+ +	+ + +	+ + + +	crb+ser+qz+kaol qz+pyr+act+chl qz+crb+chl+ser aln+qz+pyr+kaol	Carbonatization Hematitization Sericitization Chloritization Alunitization Argillization

Symbols: The degree of dominance in the solution of certain uranium-containing complexes - ++++ wide, +++ significant, + + in some cases, + rare. Parageneses: qz: Quartz, crb: Carbonate, ep: Epidote, amp: Amphibole, gr: Garnet, mu: Muscovite, ser: Sericite, turm: Tourmaline, sulf: Sulfide, chl: Chlorite, pyr: Pyrite, aln: Alunite, bi: Biotite, nast: Pitchblende, mo: Molybdenite, ap: Apatite, ab: Albite, ank: Ankerite, act: Actinolite, kaol: Kaolin.

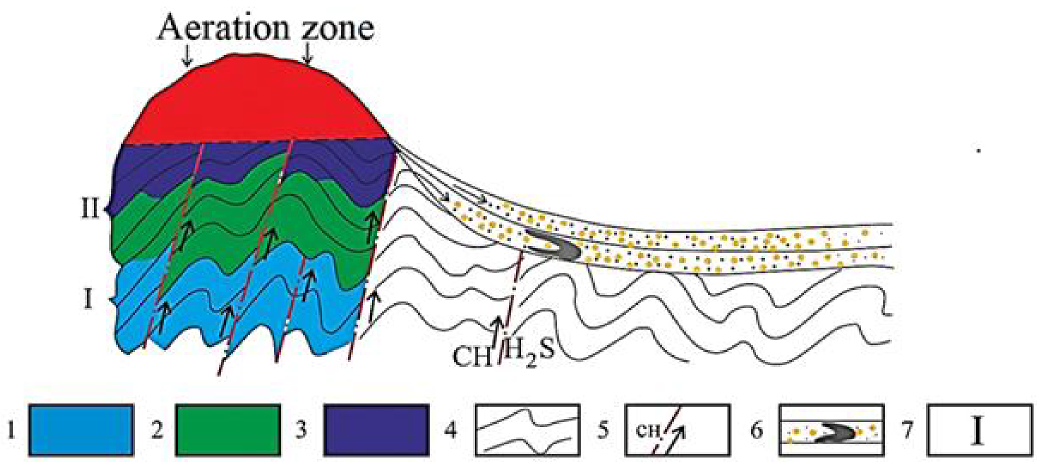

Figure 1: Formation of Ore Zonality at the Jantuar Uranium Deposit.

Legend: Ores - 1. Sulfide, 2. Uranium-phosphate, 3. Uranium-Vanadate. 4. Folding. 5. Faults and direction of solutions. 6. Uranium deposit in the platform cover (Sandstone Type). 7. Ore Zoning: I-Oxide Zone, II-Zone of Oxidized Ores. Minerals of Aeration Zone: Carnotite, Otenite, Thuyamunite, Malachite, Calcite, Barite.

Results and Discussion

The mineralogical composition of uranium ores, paragenetic and mineral associations are always closely related to the nature of hydrothermal solutions and the lithological composition of host rocks. For the most common form of uranium migration, uranyl-carbonate, the temperature of the solution should not exceed 200^{0}C, since its further increase leads to a decrease in the dissociation of carbon dioxide and a decrease in the chemical activity of the latter, which is fixed by the formation of carbonates (primarily ankerite). At temperatures above 200^{0}C (250-300^{0}C) hydrothermal uranium deposits with a high-temperature association - brannerite-nasturan or uraninite-pyrite can be formed. Often, brannerite mineralization is confined to exocontact hydrothermal-metasomatic halos (Kvartsevoe ore occurrence), and sulfide-nasturan mineralization is confined to similar halos located at a distance of up to 1 km from uranium-bearing sources (Madanli and Khodzhaakhmet deposits). An important problem is the vertical migration of ore matter from the depths of the Earth towards the surface, where the gas transport of ore metals is of great importance. In the deep parts, the fluids are strongly reduced, they are dominated by hydrogen and its compounds, but as they rise, the role of oxygen and oxygen compounds increases. [8]. Hydrothermal solutions or fluids migrating to the upper horizons from deeper geospheres are initially rich in halogens, especially chlorine and alkali metals, mainly sodium, copper, nickel and cobalt, silver and gold, platinoids, chromium (metals of the first group). The oxidation of fluids leads to the dispersion of these metals and the concentration of lead and zinc, with an intermediate stage of complex copper-lead-zinc mineralization, molybdenum, tin, beryllium, lanthanides, yttrium, uranium and other metals of the second group. It is these ratios, according to A.A. Marakushev, that determine the differences between the metallogenic features of the femic and sialic zones. A further increase in the oxidizing power of fluids leads to the formation of such metals as vanadium, titanium, yttrium, scandium, lanthanides, actinium, thorium, uranium and others (Figure 2).

At the end of the final stage of tectonomagmatic processes (post-folding stage), hydrothermal solutions, possibly genetically related to already intruded igneous rocks, moving along faults, interact with host rocks, creating fields of wall-rock alterations in them. By the time of formation, these solutions are postmetamorphic and appear locally. At the same time, if the solution does not absorb components that contribute to its dissolution and migration (alkalis, CO_2, O_2, SO_4^{2-}), then uranium migrates in one or another mineral form, otherwise, fields of secondary changes appear in the enclosing regionally metamorphosed rocks , along which hydrothermal-metasomatic uranium mineralization develops. These superimposed processes include beresitization, carbonatization, albitization, sulfidization and silicification. Albitization produces well-known Rare-metal albitites containing Thorium and Uranium. As a rule, the intensity of uranium accumulation increases towards the end of the albitization process. At higher temperature processes, a concentration of uranium mineralization is also observed. During skarning, the forms of uranium occurrence depend on the presence of concentrating minerals, in which it is able to enter as an isomorphic impurity. In the case of high concentrations of rare-earth elements, uranium-rare-earth skarn deposits can even arise at the contact of alkaline rocks with limestones, where ore minerals are represented by accessory ones. At low concentrations of rare earth elements, with

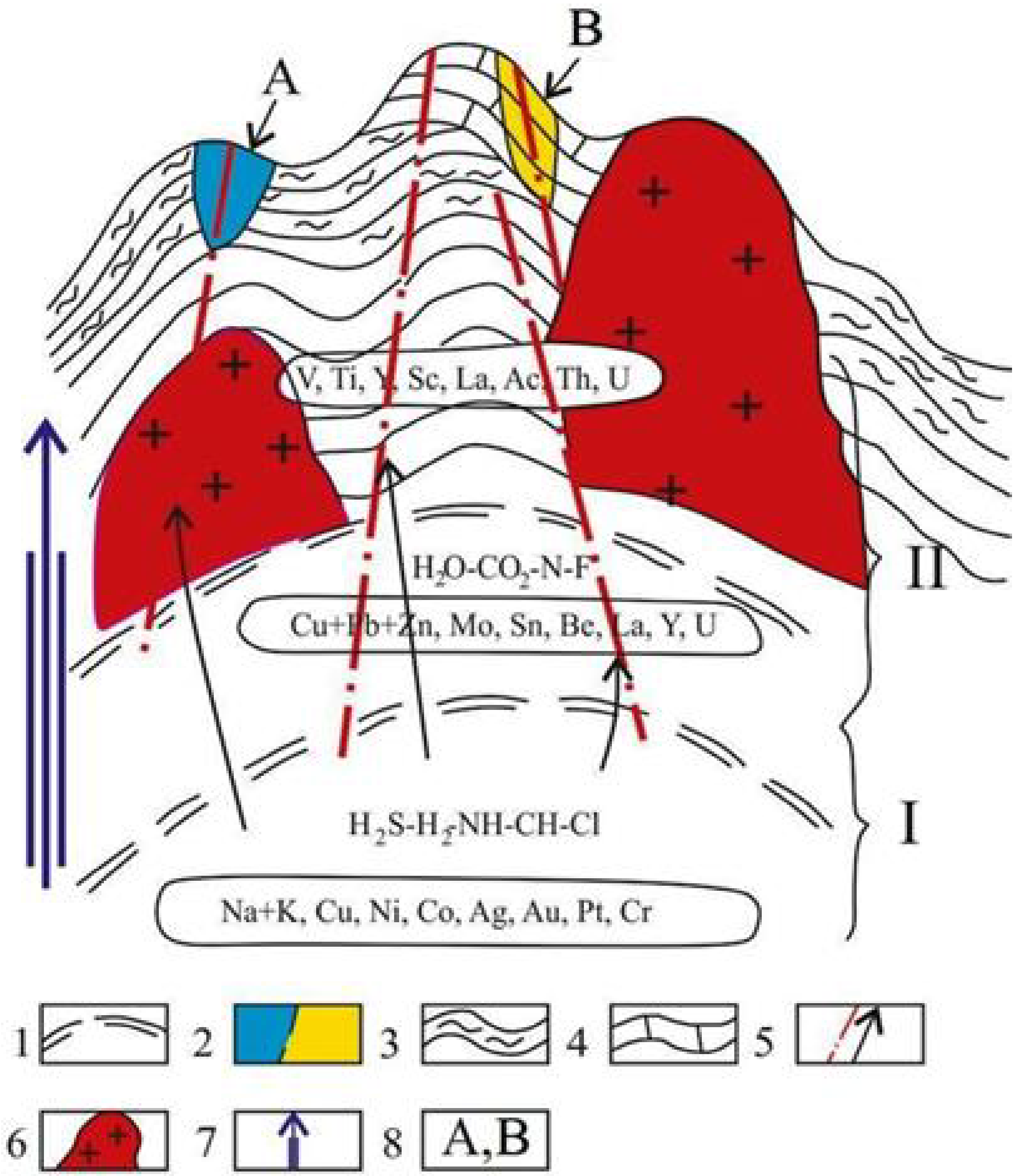

Figure 2: Geochemical model of the distribution and concentration of ore elements and compounds in endogenous uranium deposits.

Legend: 1. Interfaces of the zone of concentration of elements of the 1st (I) and 2nd (II) groups. 2. Near-ore alterations - yellow skarning, blue pyritization. 3. Black Shale Strata, 4. Limestones, Dolomites. 5. Faults and directions of ascending fluids. 6. Granitoids. 7. Direction of growth of the oxidizing abilities of fluids. 8. A - Sulfide-Pitchblende Ores, B - Uranium-Rare Earth Ores.

which uranium isomorphism is possible, uranium concentrations in skarns are low, and its localization occurs in cracks and intergranular space. Such a close relationship between uranium mineralization and skarnization is widely observed in the Zirabulak-Ziaetda SVK and, in part, in Auminzinsky and Vostochno-Bukantausky. In the processes of greisenization, an increased content of uranium in greisens is noted. Its main mass is deposited at the late stages of the greisen process in intergranular seams and microcracks. High concentrations of uranium (up to hundredths of a percent) were noted in gas-liquid inclusions [19]. This may indicate the enrichment of greisenizing solutions with uranium, as is observed at the Khodzhaakhmet ore occurrence in the Bukantau mountains.

Apparently, the first reason for this is the high temperatures of hydrothermal solutions (above 200^0C), which makes uranyl-carbonate complexes easily soluble, although as the temperature decreases and carbon dioxide is simultaneously consumed for the formation of carbonates, supersaturation of solutions with uranium may occur with the formation of uranium-bearing carbonate metasomatites. The second reason is the blockage of porous permeable spaces when solutions move through them and an increase in the partial pressure of carbon dioxide, which also leads to an increase in the solubility of carbonate complexes. On the other hand, at high temperatures, the most common complexes will be uranyl-phosphate and uranyl-hydroxyl, creating the corresponding mineral paragenesis and ore formations. In the hydrothermal-metasomatic type of solutions, medium-temperature (fluorite-nasturanium-carbonate and sulfide-nasturanium-coffinite) and low-temperature (quartz-pyrite-lamprophyre and quartz-carbonate-gold-uranium) ore formations are formed with the corresponding parageneses and large-scale near-ore changes in host rocks. We note the almost complete prevalence of uranyl-carbonate complexes in this type of solution under neutral and subalkaline conditions. When hydrothermal solutions are separated from a magmatogenic source containing uranium, the latter can be carried out in the form of UF_6 and form the UO_2F_2 compound, from which fluorite is formed, and part of the uranium in the composition of the uranyl-carbonate complex migrates to other favorable conditions for precipitation. The isolation of the quartz-pyrite-lamprophyre formation in endogenous uranium deposits is explained by the paragenetic relationship of uranium and the quartz-pyrite association in lamprophyre dikes, which often contain uranium mineralization (Dzhantuar, Kaskyr, Ingichke, etc.). H.M. Abdullaev noted that diabase and lamprophyre dikes can contain such syngenetic ore and accessory minerals as magnetite, pyrite, chalcopyrite, sphene, apatite, etc., paying attention to the nature of low-temperature hydrothermal alterations in dikes - epidotization and chloritization. The reason for this, apparently, is volatile lamprophyres in the dikes themselves, as pointed out by [1]. We noted that in the contact zone with alkaline lamprophyre dikes, uranium mineralization becomes more intense, and the thickness of the ore deposit increases.

Conclusion

1. The petrological and geochemical study of the pre-Mesozoic basement rocks of Western Uzbekistan showed the evolution of metamorphic processes in stages with the manifestation of progressive and regressive stages. An analysis of the development of epigenetic processes indicates that the most favorable criteria for the formation of endogenous uranium ore concentrations is a sharp change in the physicochemical and structural conditions for the formation of basement rocks in the final stages of the Hercynian tectonic-magmatic activation stage with the manifestation of regional and local metamorphism processes. The latter plays an important role in the formation of industrial gold and uranium mineralization.
2. The evolution of uranium ore genesis in the parent rocks of the basement has been studied in detail. Acid-alkaline differentiation is the main factor in ore zoning, which is determined by the change of reducing solutions with Ni, Co, Cu, Cr, Pt, Ag, Au, and other conditions of dominance of oxygen fluids with Pb, Zn, Mo, V, Sc, Be, La , It, U etc. The successive change from bottom to top of earlier (uraninite, coffinite, pyrite, sphalerite) mineral associations by later ones (carnotite, otenite, tuyamunite) indicates the formation of uranium ores from ascending solutions, as is traced in carbonaceous-siliceous shales at the Jantuar deposit.
3. Endogenous migration and localization of uranium occurred in the process of formation of zones of near-ore changes such as beresitization, sulfidization, silicification and others at relatively low temperatures of hydrothermal transformations ($150 – 250^0$). Uranium in solutions migrated predominantly in the hexavalent form.
4. The mineral forms of localization of basic metals - uranium, vanadium, selenium, rare earths, polymetals, etc. were studied. The ores of the deposits are very highly complex, which are characterized by the presence of colloidal, amorphous and amorphous minerals, which are excellent sorbents. Therefore, the latter contain significant amounts of metals that can be valuable for their industrial development.

References

1. Abdullaev HM (1954) Genetic connection of mineralization with granitoid intrusions. Gosgeoltekhizdat.
2. Betekhtin A.G. (1955). On the causes of the movement of hydrothermal solutions, their nature and processes of ore formation. In: Main problems in the theory of magmatogenic ore deposits. *Publishing House of the Academy of Sciences*.
3. Domarev VS (1973) The role of metamorphism in the distribution of ore deposits. Problems of regional geology – Leningrad. *VSEGEI*. 191: 136-151.
4. Rundqvist DV (1968) The pulsation hypothesis of S.S. Smirnov in the light of new data on the processes of ore formation - L. *VSEGEI*. 55: 46-66.
5. Smirnov VI (1982) Geology of minerals. *Nedra*.
6. Smirnov SS (1955) On the issue of zoning of ore deposits. Selected works. *Publishing House of the Academy of Sciences*.
7. Marakushev AA (2005) Metamorphic petrology. *Publishing house of Moscow State University*. Pg: 256.
8. Marakushev AA (2004) New model of formation of platform depressions // Problems of Ore Geology, Petrology. Mineralogy and Geochemistry - M. IGEM RAN.
9. Marakushev AA (1979) Petrogenesis and ore formation. Nedra.
10. Tugarinov AI (1983) Evolution of the earth's crust and processes of ore formation. *Nauka*.

11. Laverov NL (1986) Fundamentals of forecasting uranium ore provinces. *Nedra*.

12. Lindgren W (1925) The Gel-Replacement – a new aspect of metasomatism. *Proc. Nat. Acad. Sci. USA*. 11.

13. Bowie SHU, Some geological concepts for consideration in the search for uranium provinces and major uranium deposits. In uranium exploration geology (Vienna: IAEA, 1970). Pg: 285-300.

14. Rich RA, Holland HD, Peterson U (1977) Hydrotermal uranium deposits. (*Amsterdam: Elsevier*).

15. Routhier P. Les disements metalliferes, volume 2 (Paris: Masson, 1963).

16. Swanson VE (1961) Geology and geochemistry of uranium in marine black shales, a review. *Prof. Pap. U.S. geol. Surv*. 356-C: 67-112.

17. Kotov EI, Timofeev AV, Khoteev AD (1970) Formation temperature of some hydrothermal uranium deposits. In: "Essays on geology and geochemistry of ore deposits". *Nauka*.

18. Naumov GB (1978) Fundamentals of the physical and chemical model of uranium ore formation. *Atomizdat*.

19. Omelyanenko BI, Kozlova PS, Eliseeva OP, Simonova LI (1983) Local distribution of uranium in rocks and minerals as an indicator of its geochemical history. *Nauka*. 140-163.

Citation:

Ismailovich MB (2025) The Evolution of Endogenous Uranium Ore Formation in Western Uzbekistan (Central Kyzylkum). *Geol Earth Mar Sci* Volume 7(3): 1-5.