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Uranium Provinces of the World

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INTRODUCTION

Uranium deposits in continental blocks of the Earth are distributed rather randomly and form uranium provinces and districts. Under the uranium ore province we mean crust block characterized by occurrence of uranium deposits of a certain type (or types), main features of which are resulted from specific ore-forming processes and peculiar geotectonic position. When systematizing uranium targets, great importance was attached to the ore-hosting environment and geotectonic conditions of ore formation at early stages of the crust evolution, and for particular areas, their relation to main typomorphic structures (arcogenic, taphrogenic, orogenic, epeirogenic) and derivatives of their activation of different age was considered to be the controlling factor. The analysis of extensive material is aimed at the identification of new patterns and prognostic criteria of commercial uranium mineralization location in various regions of the world.

METHODOLOGY AND RESULTS

The research is based on the historical-geological approach, which made it possible to systematize data on uranium geology, geochemistry, geophysics and metallogeny in various countries and continents and develop a unified research base. Most of known uranium and complex ore deposits and numerous (95) ore areas in the rank of provinces and regions on five continents were analyzed [1, 2, 3, 4].

Results of original paleotectonic and palinspastic reconstructions were used for analyzing uraniferous areas. It is shown that geological structures of arcogenic (dome) and taphrogenic (rift) origin played a leading role in the uranium metallogeny since the Early Precambrian. Two global generations of gigantic ore-bearing dome structures of different age have been identified: the Archean (3.2 to 2.5 Ma) generation of domes –nuclears and the Paleoproterozoic (2.5 to 1.6 Ma) generation of granite-gneiss domes. The identified generations of dome structures differ in internal structure and metallogeny mainly due to the structure and evolution of the granitized substrate. The metallogenic uranium zoning of the continents made it possible to identify transcontinental marginal and intracontinental ore-bearing megabelts and giant ore clusters in areas of megabelts'telescoping [1].

Totally, 12 megabelts have been identified on the continents, including marginal continental: 1 –East Pacific with Cordilleran and Andean fragments, II –West Pacific; and inland: III –East African, IV –Damara-Katanga, V –Karpinsky, VI –Baltic-Carpathian, VII –West Siberian-Central Asian, VIII –East Siberian-Gobi, IX –Chara-Aldan, X –Central Australian, XI –Wollaston, XII –Grenvillian. In areas of megabelts'telescoping (Middle European, Middle Asian, Mongolian-Transbaikalian), uranium resources reach 500,000-1,500,000 tons, but similar amounts are sometimes also typical of some provinces inside the megabelts (Athabasca, Colorado-Wyoming, Arnhemland, Olympic Dam).

Two large groups, distinguished based on the degree of lithification of uranium-bearing rock complexes corresponding to main geological structures and genetic classes of uranium deposits are high-order elements in typification of uranium areas.

The first group consists of ore provinces and regions with ore deposits in lithified rock complexes in the basement of old and young platforms, median massifs, fold areas, old epicraton depressions and in areas of continental volcanism and granitoid magmatism (endogenic and polygenic classes of deposits). Among them, ore provinces are distinguished in typomorphic proto-structures of nuclears and structures of activation of different age.

Commercial uranium concentrations in the nuclears appear at the final orogenic stage of their formation and are often clastogenic formations resulted from the accumulation in placers of accessory uranium-bearing minerals from Late Archean potassium granite and pegmatite. Such metamorphosed placers in quartz-pebble conglomerate are typical of proto-orogenic depressions, occurring as spots along the periphery of the nuclears of mainly antiform (uninverted) type: Superior, East Brazilian, South African and other megaprovinces. With some epochs of activation of nuclears of different age, a number of provinces and regions with deposits of various types are associated: carbonatite (U-TR) in alkaline ring tubes of different ages (Ilimaussaq, Palabora, Khibiny, etc.); black shale type in superimposed foreland basins (South China, Carpathian and other provinces); leucogranite type in fault zones among the Mesozoic highly radioactive rocks in association with rare metal mineralization (Gan-Hang, Kerulen-Argun ore belts) [1, 2, 3].

Uranium mineralization accompanies all stages of the formation and transformation of dome structures of second generation (dome rise stages). The formation of typomorphic structures of domes of this generation started at the stage of compensatory destruction, subsidence, and collapse of the roof. Provinces in the fault-contact metasomatite (alaskite) (Rossing), albitite (Kirovograd) and glimmerite (Padma) types are associated with similar structures.

Ore provinces in protostructures of Riphean granite-gneiss domes near zones of structural-stratigraphic unconformities at the base of epicratonic basins belong to polygenic ones (Canadian and Australian subtypes). In the Riphean-Phanerozoic, in some provinces (Franceville, Czech, Katanga), epigenetic regeneration of ore deposits occurred near the unconformity surfaces with a change in their morphology and scale of mineralization [4].

The second group includes ore provinces and areas with deposits in weakly lithified or unlithified rock complexes, in sedimentary basins of covers and young platforms (exogenous class of deposits).

This group includes provinces with syngenetic concentrations of uranium of sorption nature (surficial, with carbonized residues, phosphate, black shale types) and provinces with epigenetic sandstone-type hydrogenous deposits represented by stratal, roll and paleovalley types. Ore provinces were formed in sedimentary basins in central (destroyed) parts of dome structures and in the inter-dome space within riftogenic structures.

Syngenetic-type provinces are characterized by constant relationship between uranium and phosphorous and carbonaceous matter (Phosphoria, Chattanooga and other provinces) [3, 4]. For most of the epigenetic provinces with hydrogenous deposits in suborogenic depressions and platform covers, overlapping old dome structures, the role of linear, linear-arc faults in sedimentary basin deposits (cis-Tian Shan Province, Colorado Plateau, etc.) is emphasized. Faults play an important role in the localization of hydrogenous uranium mineralization near or in flanks of petroliferous areas, which are sources of gas-liquid reducing agents (South Texas, Central Kyzyl-Kum province) [1, 4].

The identified patterns and spatial position of ore districts and provinces allow drawing several conclusions concerning predicting the ore grade within their limits. The relation of uranium ore districts to similar geological structures does not always means a similar level of possible ore grade. The authors have established that the parameter called the “maturity”of the crust can serve as a regional criterion for predicting rich endogenous ores. The level of “maturity”clearly correlates with the level of medium uranium concentrations in granitoid formations of dome structures. Besides, there are ore formation types of uranium mineralization, which differ significantly in the ore grade. So, there is a group of ore formations characterized by low-grade ores but with huge reserves: Lower Proterozoic quartz-pebble conglomerate (Witwatersrand, South Africa), uranium-bearing black shale (southwestern Sweden), phosphorite (Morocco), pegmatite (Charlebois, Canada), nepheline syenite (Ilimaussaq, Greenland), anatectoid alaskite granite (Rossing, Namibia), carbonatite (Palabora, South Africa), calcrete (Yeelirrie, Western Australia), uranium-coal deposits (Nizhneiliyskoe, Kazakhstan). However, the formation type of mineralization also does not guarantee that the ore grade will be similar. Features of ore-hosting rocks do not always affect significantly the degree of concentration of uranium mineralization. The role of lithological factors as well as structural factors in the localization of rich mineralization cannot be considered separately from the nature of metasomatic transformations. Extensive areas of pre-ore metasomatism testifies to relative openness of hydrodynamic systems and is evidence of the dilution of ore-forming solutions. Closed hydrodynamic systems that ensure the presence of high metal concentrations in the solution and local, contrast zones of wall-rock alterations are more favorable for the formation of rich ores. Probably, the alkaline solution containing H2, H2S, S-2, CH4, hydrocarbons, Fe+2, and other reducing agents is initially most suitable for the formation of a large volume of rich ores. Highly concentrated brine of salt complexes is one of the sources of heated subalkaline waters. The ore grade of hydrogen deposits is also controlled by several ways of ore deposition. If the reduction barrier contains only syngenetic reducing agents (primary grey color), the ores are usually poor and lean. The epigenetic preparation of the barrier to ore deposition can be a result of the action of ascending reducing thermal waters and lateral migration of hydrocarbons from neighboring oil and gas basins.

CONCLUSIONS

When analyzing the huge factual material, a number of important planetary factors of uranium geology and metallogeny were discovered: linear-geoblock divisibility of the continental crust as the basis of metallogenic zoning on global and regional scales; factor of irreversible geological time in ore genesis; factor of tectono-physical correspondence of global and local geotectonic settings in the forecast of giant deposits; important conditions for the formation of rich ores are shown.

Many of the discussed problems are beyond the scope uranium metallogeny and allow the discussion of a number of basic factors of the metallogenic school as a whole from a new viewpoint.

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