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The role of groundwater testing in uranium exploration in SE Mongolia

Ролята на опробването на подземните води при проучването на уран в ЮИ Монголия

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Many of the uranium deposits of major economic importance are mainly associated with the dispersal of uranium eroded from magmatic or skarn sources and sources are generally related to the ancient craton regions. Primary U deposits which are located within volcanic rocks and skarns usually have small exploitation reserves and have high production costs. There are exceptions such as The Rossing U deposit in Namibia (Basson, Greenway, 2004).

The most significant U deposits have been developed mainly within the sediments rich in organic matter. Ages range from the Middle–Late Paleozoic to younger than the Mesozoic. Deposits are developed in basins, present in the areas of eroded granites and volcanic rocks and filled with its weathered material. Kazakhstan and Mongolia have the potential for the mentioned younger types of deposit.

Roll-front U deposits are characteristic for arid climate and continental environment. They generally require surface-decomposed U-rich sources present in rock outcrops. Dissolved U compounds with water are transported through surface decomposed and oxidized sediments of Tertiary and younger ages. They are moving up to the point/place where the redox geochemical environment is developed, in these places the U concentrates and forms deposits.

Also, pH values, or the natural acidic or alkaline characteristic of surface or groundwater, are some of the significant control factors for the mobility of elements in many environments. This basic property of forming dissolution effects the transport, leaching, and precipitation of the elements, and in the first place, metals in the soils, water, bedrock and affects the processes of surface decomposition. Oxidation of sulfide minerals results in low pH values (high acidity). Under these conditions, many ore metals and other ions become mobile. The mobility of metal ions generally decreases with increasing pH (the environment becomes more alkaline). The elements are more mobile in soils with good drainage and are generally slightly acidic (precipitation has a pH of approximately 5.8). Soils with poor drainage or soils in dry areas are more similar to those with high pH (alkaline) values, so ion mobility in these environments is generally decreased.

The valence or oxidation state of any element also determines to a large extent whether it will go into solution, remain in solution, or be deposited in specific geological environments. The indicator (criteria) of the tendency of oxidation or reduction of a solution is known under the synonym for terms Eh, redox potential, oxidation potential or oxidation-reduction potential. The Eh indicates the voltage generated by the increase or movement of electrons during changes in the valence state of the elements. The necessary energy, created by pH or by Eh and pH together, determines what concentrations of ions will remain in solution, and a change in either of these two conditions can be sufficient reason for their precipitation. The aforementioned parameters are widely used for geochemistry, for explaining low-temperature phenomena in secondary environments and for understanding water chemistry. The utilization of Eh-pH diagrams in applied geochemistry has been widely used to interpret natural water chemistry.

Most groundwater has a pH of 6.0 to 8.5. Water rarely has lower pH values, but, for example, it occurs in areas of thermal sources and drainage areas of oxidized sulfide minerals (such as acidic sulfate soils). The highest pH values of surface waters are generally related to carbonate rich areas. In liquid environments, daily pH amplitudes may occur as a consequence of taking up carbon dioxide for photosynthesis. Many surface environments (e.g. soil, wetlands, ponds) have pH values of about 4 to 9, due to the decomposition of organic components and therefore many chemical reactions occur within this range.

Uranium has two common oxidation states under normal conditions – reduction U^{4+} and oxidation U^{6+} forms. In its oxidizing form, U is highly mobile as uranyl ion (UO_2^{2+}) or it may form soluble complex compounds with carbonates CO_3^{2-}, hydrophosphates HPO_4^{2-}, hydroxides OH^-, fluorites F^- and other anions (Langmuir, 1978). During surface decomposition, U has similar mobility as Mo and As and is more mobile than other base metals such as Cu, Ni, and Pb, so it is common for it to form groundwater anomalies. Mobilized as a uranyl ion, U can be immobilized by adsorption with secondary minerals of iron and Mn or organic matter. Unlike MoO_4^{2-} and AsO_4^{2-}, the adsorption of uranyl ions at low pH is limited by its positive charge. Uranium can be immobilized by reduction, for example, U fluids that are in contact with organic matter or sulfide minerals. Uranium (IV) is much less soluble than uranium (VI) and by the reduction precipitated U minerals. Reduction and precipitation of U from water can lead to economically significant concentrations of U in roll-front deposits.

Only a few elements, for example, alkaline metals (such as Na, K, and Rb), alkaline earth metals (e.g. Ca, Mg, and Sr) and some acidic radicals (e.g. nitrogen and chlorine) are normally soluble throughout the almost hole range of existing pH values. Most metals are soluble solely in acidic environments and tend to precipitate as hydroxide (or alkaline salts) with increasing pH values.

During water sampling procedures for geochemical analyzes, Eh and pH were determined during sampling, or directly in the drill hole/well where it was possible. For the purpose of U exploration in Mongolia, the Dornogovi Region, 2007–2008. In addition to reconnaissance of the terrain and verification of historical anomalies, groundwater sampling was also carried out. As there was no cadastre of hydrogeological objects, it was necessary to georeference topographic maps of 1:100 000 in order to define the position of the existing wells shown on these maps. Thereafter, a database of the location of the facilities needed to be inspected and sampled was established. The objects of interest could generally be classified into 4 groups (Ristic Vakanjac et al., 2014): 1) Hand-dug wells by nomads, for their use and livestock. These shallow wells were mostly located in river beds or on the banks of dry river valleys. In areas that have been permanently abandoned by nomads, existing wells are dry and mostly covered with sand; 2) deep wells drilled by Soviet geologists during decades of exploration. These wells were mostly blocked so that groundwater sampling could not be carried out; 3) recent wells financed by donations from Japan and the Czech

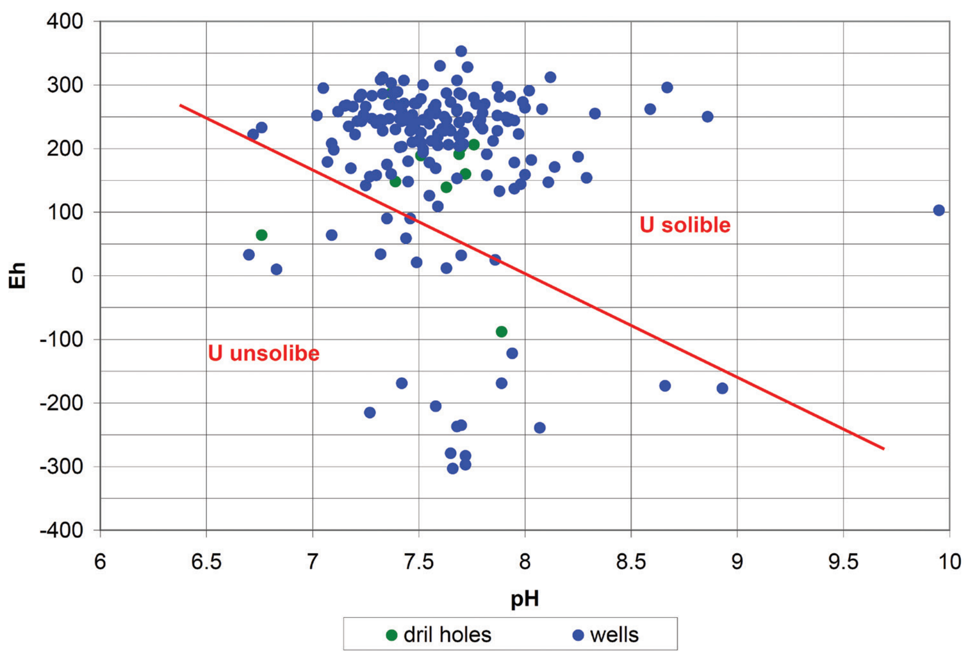

Fig. 1. Eh vs pH diagram

Republic to rural areas of Mongolia; 4) springs, that were very few in SE Mongolia.

Based on the established database of existing hydrogeological sites, from September 2007 to October 2018, 303 sites were visited. On 33 locations wells were not found. On the other 33 locations, wells were covered with sand. 17 wells were blocked (old Soviet wells) or locked (wells from donations). 27 wells were not sampled due to low water level, or close vicinity of other wells where water was sampled. Finally, water sampling was performed at 214 wells (Vakanjac, Ristić Vakanjac, 2012). During the groundwater sampling, water temperature, pH, Eh and conductivity measurements were performed with the HORIBA instrument (Fig. 1). After fieldwork, water samples were sent to an ActLab accredited laboratory in Canada, where 68 elements were analyzed. Based on the results obtained from field measurements, it can be concluded that water temperatures ranged from 2.4 to 21.3 °C. It should be noted that most of the wells from which the water was sampled were of relatively low water level (up to 5 and 10 m respectively) so those groundwater temperatures located at these depths were exposed to the climate (air temperature) characteristic of this part of Mongolia. Summers are extremely warm with temperatures over 40 °C occurring at short intervals of about 15 days and winters extremely cold with temperatures below –30 °C without snow, or if there is any then it is short-term. For this reason, during the winter months, it was impossible to sample water from shallow wells, due to the freezing of water. In terms of pH, it ranged from 6.38 (slightly acidic) to 9.95 (alkaline water). About 85% of samples, had a pH value between 7 and 8. The general conclusion is that with the sampling depth the pH value also changed, samples taken from wells with shallower depths had a slightly acidic to neutral character, whereas samples taken from wells that were of greater depth had a weak to an extremely alkaline character. Electroconductivity ranged from 0.248 to 7 μS/m except for one sample that had a value of 16.78 μS/m. Conductivity results indicate a noticeable increase with sampling depth.

References

Basson, I., G. Greenway. 2004. The Rossing uranium deposit: a product of late-kinematic localization of uraniferous granite in the Central Zone of the Damara Orogen, Namibia. – *J. African Earth Sciences*, *38*, 5, 413–435.

Langmuir, D. 1978. Uranium solution-mineral equilibria at low temperatures with applications to sedimentary ore deposits. – *Geochim. Cosmochim. Acta*, *42*, 6, 547–569.

Ristić Vakanjac, V., B. Vakanjac, R. Kondžulović. 2014: Hidrogeološka prospekcija u jugoistočnoj Mongoliji. – In: Stevanović, Z. (Ed.). *Zbornik Srpskog geološkog društva*, ISSN 0372-9966, 159–172.

Vakanjac, B., V. Ristić Vakanjac. 2012. Uzorkovanje vode kod istraživanja urana u jugoistočnom Mongoliji. – In: *XIV Srpski simpozijum o hidrogeologiji sa međunarodnim učešćem*, 17–20 maja 2012, Zlatibor, Srbija, ISBN 978-86-7352-236-4, 301–308.