Application of Source-to-Sink System in the Prospect Analysis in Early Stage of Sandstone Uranium Exploration

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Abstract. In-situ leaching sandstone uranium deposit has the advantages of low mining cost and environmentally friendly. The research ideas from "source" to "sink" are applied to the study of the mineralization of sandstone-hosted uranium deposits. Prospect areas are predicted by studying the source-sink system of sandstone uranium deposits. Soil radon survey is carried out in prospect areas to delineate the abnormal range of soil radon and to reduce the scope of the favorable exploration area. Accurately determining the exploration area is conducive to reduce the damage to vegetation and environment in the exploration area, and to achieve the goal of green exploration.

1. Introduction

The study of the dynamic process of a "source-to-sink" system on the earth's surface has become one of the focuses in the international field of geoscience. The "source-to-sink" system is a full process of formation of the source in denuded zone, and transportation to deposition of sediments in basins through river runoffs [1, 2]. It is composed of three parts: the erosion landforms, the sedimentary landforms and the sediments runoff systems which connect the first two parts [3].

With the transformation of China's energy mix, clean, safe and efficient energy will be the main requirements of the future development. The rapid development of nuclear power has put forward a long-term and significant demand for the uranium resources. Sandstone uranium deposits are also products of source-sink process. The uranium-rich materials are released by chemical weathering and physical denudation from the bedrocks in source area, via transportation of water flow, to mineralize in basin. The metallogenesis of sandstone uranium deposits, including the activation, migration, enrichment and precipitation of uranium, is mainly controlled by factors such as uranium source, sedimentary formation, structure and interlayer oxidation zone in the basin [4 - 6]. It is one of the present scientific focuses. This paper attempts to predict the prospect sandstone uranium areas by studying the source-sink system. Radon survey in soil is carried out to narrow the target in a way of reducing the damage to environment and achieving the goal of green exploration.
2. Source-to-Sink System

The physical and chemical processes of the whole uranium metallogenesis, from denudation of source material to confluence and enrichment, are considered as a complete source-to-deposit system which does favour to study the enrichment mechanism of sandstone uranium deposits. The source-to-sink system of sandstone uranium deposit is composed of three parts: uranium source, uranium confluence system and uranium mineralization.

Taking the Southern Yili Basin as an example, a series of granite intrusions occurred in Hercynian Period, and large-scaled volcanic activities occurred in Carboniferous and Permian, forming a set of uranium-rich intermediate-acid volcanic rocks, pyroclastic rocks and tuff formations in the southern part of the basin. The average uranium content of the source rocks are from $3.91 \times 10^{-6}$ to $4.07 \times 10^{-6}$. Weathering and erosion of these uranium-rich bed rocks provided the sufficient uranium source for the uranium-rich formations and the later transformation of uranium deposition in the basin.

Uranium confluence system is divided into two stages: the synsedimentation and the late metallogenesis. Pre-concentration of uranium deposits occurred mainly in the synsedimentation stage, and the uranium content of sedimentary rocks are relatively high, which provided uranium-bearing materials for later uranium mineralization. The transportation of uranium during this period mainly went through the distributary channels during the sedimentary period. At the metallogenic stage, the strata were uplifted by structure and eroded to expose on the surface. Oxygen- and uranium-bearing water flowed due to gravity through valley and penetrated through well permeable and porous sandbodies in the distributary channels (Fig.1).

Under the continuous reaction of uranium- and oxygen-bearing surface water, a large-scaled interlayer oxidation zone formed in the target layer of the Middle and Lower Jurassic. Groundwater carrying active uranium migrated continuously along interlayer sand bodies to the interior of the basin, which led to alternative formations and destructions of uranium mineralization in permeable gray sandstone beds and finally resulted in the uranium mineralization in the redox transitional zone by superposition of multi-staged transformations (Fig.1).

![Figure 1. Source-to-sink System (J2x) of Sandstone-hosted Uranium Deposits in the south of Yili Basin, China.](image-url)
3. Application of Source-to-Sink System to Forecast the Prospect Area

Huahai Basin is located in the west of the corridor area of Gansu Province, China. The uranium geological work has rarely been carried out in the Huahai Basin. Based on the analysis of source-deposit system of sandstone uranium deposit, it is taken into account the metallogenic potential in the northern Huahai Basin. A large area of Hercynian uranium-rich granitic body is developed in the north and west of the basin. The uranium source is abundant, and gamma-ray spectrometric measurements show that the highest uranium content reaches $57.45 \times 10^{-6}$ (Fig.2).

![Geological Map of Huahai Basin in the Hexi Corridor, China](image)

*Figure 2. Geological Map of Huahai Basin in the Hexi Corridor, China.*

Uranium confluence system in the north of the basin is well developing. The tectonic slope zone developed in the north of the basin has been in a slowly uplifting stage for a long time. The development of stream delta plain and front sand is favorable for ore-bearing sandbodies. All these factors are conducive to the migration and confluence of uranium (Fig.3).

The uranium metallogenic conditions in the north are favorable. Oxygen-reduction zone is developed in the north, and the center of the basin is rich in reductant such as organic matters and oil and gas. Soil radon measurements which has little destructive to the environment, were carried out in the overlapping areas of favorable tectonic belts and sedimentary facies belts in the north of Huahai Basin to delineate the radon anomalies. The overlapping area of favorable structural slope zone, favorable sand body and soil radon anomaly is the prospect area for uranium mineralization (Fig.3). Uranium mineralization was verified by a drill hole (ZKH3-1) in the early stage of exploration, which further proves the sandstone-hosted uranium potential in the working area.
4. Conclusion

The method of prospect analysis with source-to-sink system is effective in early stage of sandstone uranium exploration. This method effectively saves drilling and geological work and is less destructive to the environment. It is a green exploration technique and worth to be popularized.

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