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Spatial-temporal collocation and genetic relationship among uranium, coal, and hydrocarbons and its significance for uranium prospecting: A case from the Mesozoic–Cenozoic uraniferous basins, North China

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Abstract

The fact that uranium, coal, oil, and other ores occur in the same sedimentary basin has been extensively recognized. By comparing the spatial and temporal relationships among uranium, coal, and hydrocarbons, we found that the ore-bearing uranium and coal layers within the same basin are commonly interbedded or adjacent to each other. In general, however, uranium deposits are spatially distant from oilfields. We analyzed the genetic relationship among oil, coal, and uranium by compiling numerous geological surveys, test analyses, and previous studies of the Ili, Songliao, and other basins in North China. It is considered that the mild and humid paleoclimate should be an important factor affecting the formation of coal reservoir, mudstone as the upper and lower aquifuges, and the host rocks with rich organic matters. Thus, these coal-mining areas occurring at the edges of basins deserve to be studied in detail for uranium exploration. In addition, the metallogenic epochs are roughly similar to the epochs of hydrocarbon migration and tectonic events. These existing data of oil exploration can be used to unravel the regional and local tectonic evolutions of the basin related to uranium mineralization. Finally, a rough relationship between uranium mineralization and hydrocarbons was presented. Note that hydrocarbon is not just beneficial for the formation of uranium deposits but may also inhibit the transportation and mineralization of uranium-bearing materials. Regions with shallow hydrocarbon fields or large quantities of hydrocarbon dissipation are not the ideal exploration locations for uranium.

Keywords: hydrocarbon-coal-uranium; energy basin; spatiotemporal allocation; uranium mineralization; genetic relationship

1. Introduction

In North China, a series of sandstone-hosted uranium deposits have been discovered in the Ili, Ordos, Erlian, and Songliao basins (Bonnetti et al., 2014, 2015; Cai et al., 2007; Dai et al., 2015; Gao et al., 2008; Li et al., 2009; Min et al., 2007; Wu et al., 2009b; Yue and Wang, 2011; Zhang et al., 2005, 2017; Zheng et al., 2015). So far, the type of uranium deposits accounts for more than 50% of known uranium resources in China (OECD-NEA/IAEA, 2014). The coexistence of uranium deposits, hydrocarbons, and coal fields within the same basin is a common feature in North China, even in the Central-east Asia metallogenetic domain (Li et al., 2009; Liu et al., 2006, 2007a). The idea of comprehensive multienergy mineral exploration has been recently put forward in China (Dai et al., 2015; Liu et al., 2008; Wang et al., 2014). This phenomenon has previously attracted the attention of many scholars (Chi and Xue, 2011, 2014; Deng et al., 2005; Liu et al., 2006, 2007a). The Dongsheng uranium deposit related to hydrocarbon and coal in the Ordos Basin represents the most interesting uraniferous area (Cai et al., 2007; Fan et al., 2007; Li and Li, 2011; Li et al., 2006; Liu et al., 2007b; Sun et al., 2007; Tuo et al., 2010; Xue et al., 2010, 2011; Yang et al., 2009; Zhang et al., 2017). Liu et al. (2008) suggested that coal and hydrocarbon generally exhibit a close association with uranium due to a specific geological background and similar geochemical behaviors. In addition, a large amount of research efforts related to the methods of photomicrographs, fluid inclusion oil biomarkers, X-ray diffraction,

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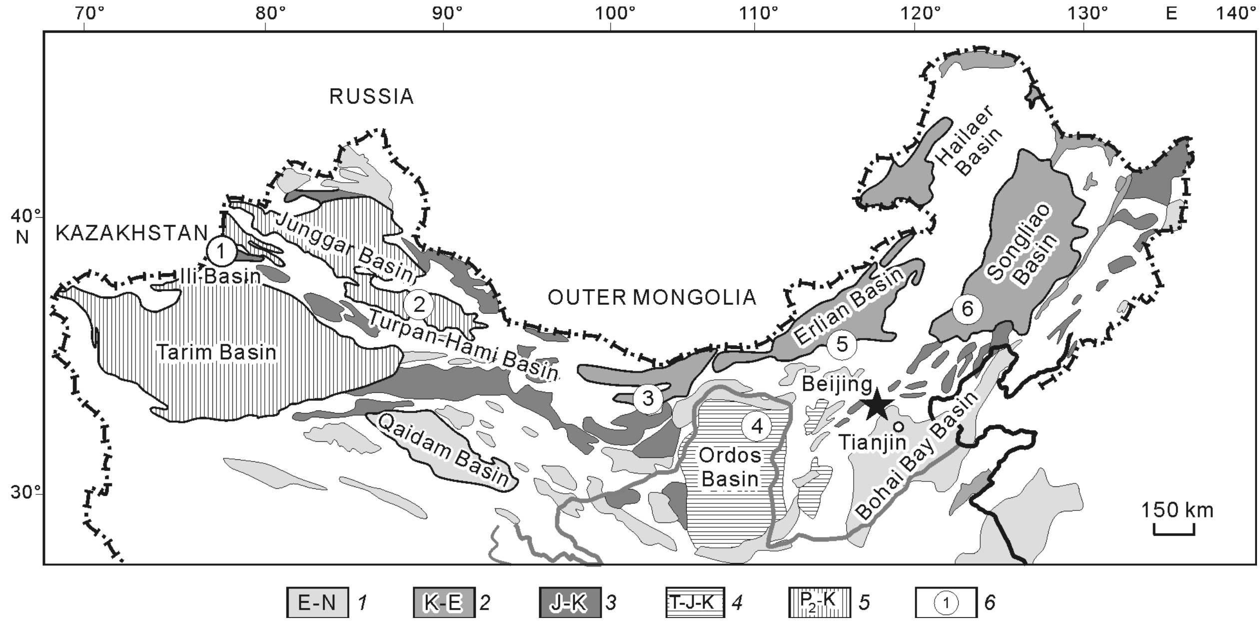

Fig. 1. Distribution map of the major Meso-Cenozoic uranium-bearing basins in North China. *1*, Paleogene–Neogene basins; *2*, Mesozoic–Cenozoic basins; *3*, Jurassic–Cretaceous basins; *4*, Triassic–Cretaceous basins; *5*, Late Permian–Cretaceous basins; *6*, sandstone-hosted uranium deposits. Circled numbers: 1, Ili uranium deposits; 2, Shihongtan uranium deposit; 3, Tamusu uranium deposit; 4, Dongsheng uranium deposit; 5, Bayanwula uranium deposit; 6, Qianjiadian–Baixingtu uranium deposits.

electron microprobe, as well as scanning electron microscopy, had been conducted to try to understand the relationship among hydrocarbon, coal, and uranium (Cai et al., 2007; Deng et al., 2005; Fan et al., 2007; Li et al., 2007; Wu et al., 2009a; Yang and Zhang, 2007). Many of them suggested that hydrocarbon is favorable for the formation of uranium deposits (Cai et al., 2007; Fan et al., 2007; Li et al., 2006; Li et al., 2007; Liu et al., 2006; Wu et al., 2007; Xue et al., 2011). However, we argue that the magnitude of the influence from hydrocarbon is limited in the Ili and Turpan–Hami basins. Moreover, hydrocarbon may inhibit uranium mineralization under particular unified conditions, but related research is still rare.

Here the spatial and temporal relationship among uranium, coal, and hydrocarbons in North China are elucidated by compiling numerous geological surveys, a few test analyses, and previous studies of the Ili, Songliao, and other basins of China. Then we present a brief comparative analysis of factors which may have controlled the formation of uranium deposits or anomalies within the Ili and Songliao basins. In addition, we provide detailed discussions of the relationships among uranium, hydrocarbons and coal and finally present a pattern regarding the relationship among uranium mineralization and hydrocarbons.

2. Spatio-temporal collocation among oil, gas, coal, and uranium

2.1. Spatial distribution among uranium, coal, and hydrocarbons

2.1.1. Lateral distribution. The Central–East Asia metallogenetic domain, more than 6000 km long from the western Caspian Sea to the Songliao Basin in Northeast China, is one of the most important hydrocarbon-producing areas in the world, and also contains abundant other natural resources (Liu et al., 2007a). The exogenic uranium deposit is the major of uranium ore-forming types across the metallogenic domain, especially the sandstone-hosted uranium deposit (Dai et al., 2015).

In Central Asia, resources of the Koldzhatsk and Nizhneillisk deposits are as large as 37,000 t, and 60,000 t of uranium, respectively (Kislyakov and Shchetochkin, 2000). A number of smaller uranium deposits were found in the Kansk–Achinsk basin, Primorskii Krai, southern Urals, and Transbaikalia (Seredin and Finkelman, 2008; Yudovich and Ketris, 2001, 2006). These deposits mentioned above occur in the coal bearing basins (Dai et al., 2015; Seredin and Finkelman, 2008). In China, the known sandstone-hosted uranium deposits are mainly discovered in the Meso-Cenozoic sedimentary basins in North China (Fig. 1; Bonnetti et al., 2014, 2015; Cai et al., 2007; Dai et al., 2015; Gao et al., 2008; Li et al., 2009; Min et al., 2007; Wu et al., 2009b; Yue et al., 2011; Zhang et al., 2005, 2017; Zheng et al., 2015). These uraniferous basins have the features of varied sizes and shapes. Amongst them are a number of large-scale uraniferous basins (e.g., Ordos, Songliao basins), and several smaller uraniferous basins (e.g., Erlian, Ili, Turpan–Hami basins) (Fig. 1). Additionally, massive uranium anomalies have been discovered in the Tarim, Junggar, Qaidam, and Hailaer basins, and hence have significant outlooks for prospecting in these basins (Liu et al., 2007a). Likewise, these uranium deposits found in North China had also normally been discovered in the coal bearing basins (Wu et al., 2007). In turn, some uraniferous and proven abnormally radioactive basins, the large-scale basins like Ordos, Tarim, and Junggar basins, have annual output of