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# Tectonic Settings of Palaeoproterozoic Uranium Deposits of the Jiao–Liao–Ji Belt in Eastern Liaoning Province, China

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## 1 Introduction

Columbia is considered as the first coherent supercontinent in Earth history, proposed by Rogers and Santosh (2002). The assembly and breakup of the Palaeo-Mesoproterozoic Columbia supercontinent has been extensively discussed, and shed light on the tectonic settings of major metallic deposits formed during Columbia supercontinent cycle (Kaur and Chaudhri, 2013 and references therein). The North China Craton (NCC), one of the fundamental Precambrian nuclei of Asia, has recently been in focus related to studies on the history of assembly, evolution and breakup of the Paleoproterozoic supercontinent Columbia (Santosh, 2010 and references therein).

The NCC is consists of three major Paleoproterozoic tectonic belts: the Khondalite Belt, Trans-North China Orogen and Jiao-Liao-Ji Belt in the western, central and eastern parts of the craton, respectively (Zhao et al, 2005). The eastern Liaoning province is a part of the Jiao-Liao-Ji Belt in the eastern parts of the NCC. Here, we summarize the geochronological data of the Jiao-Liao-Ji Belt and uranium deposits to discuss the tectonic setting of uranium mineralization related to the Paleoproterozoic orogenisis.

## 2 Geological Background

The Jiao-Liao-Ji Belt lies at the eastern margin of the Eastern Block of the NCC, with its northern segment intervening between the Longgang block and the Nangrim block, and its southern segment extending across the North Yellow Sea into the Eastern Shandong Complex. The major components of the Jiao-Liao-Ji Belt in the Liaodong peninsula are the Paleoproterozoic Liaohe Group and associated granitoid rocks, named the Liaoji granitoids. Conventionally, the Liaohe Group has been divided into the North and South Liaohe Groups, but both are a sedimentary-rich lithostratigraphic assemblage transitional from a lower arkose- and volcanic-rich sequence through a carbonate-rich sequence to an upper arigillaceousrich sequence.

Associated with the Liaohe Group are voluminous Paleoproterozoic Liaoji granitoids and mafic intrusions. Liaoji granitoids are composed predominantly of A-type monzogranites with minor rapakivi granites. The monzogranites in the eastern Liaoning Province were previously interpreted as syn-tectonic granites with respect to the main deformational event (Yang et al., 1988; Liu et al., 1997), but their penetrative foliation and well-developed lineation suggest that they were most likely emplaced prior to the deformation event. The rapakivi granites occur only in local areas and are undeformed, suggesting a post-tectonic origin (Zhang and Yang, 1988; Hao et al., 2004). Mafic intrusions consist of gabbros and dolerites, most of which have been metamorphosed to amphibolite facies, although original igneous textures (gabbroic and ophitic textures) are still preserved in some rocks.

## 3 Temporal Framework of the Jiao-Liao-Ji Belt

The North and South Liaohe Groups have been dated using zircon U-Pb method by SHRIMP and LA-ICP-MS (Luo et al., 2004, 2008; Lu et al., 2006). These zircon U-Pb data of the North and South Liaohe Groups indicated that they both were deposited after ~2.0 Ga.

The ages of the Liaoji granitoids have been dated recently using SHRIMP and LA-ICP-MS U–Pb zircon techniques. Two groups of granitoids can be identified: one group of granites are pre-tectonic and have been deformed, with zircon U–Pb ages of 2.09–2.17 Ga (Li et al., 2003; Lu et al., 2004, 2006); and the other group of granitoids mainly consists of rapakivi granite, syenites and monzogranites without deformation, are post-tectonic and have zircon U-Pb ages of 1.85–1.88 Ga (Li et al., 2003;

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Cai et al., 2002; Lu et al., 2004, 2006; Yang et al., 2007; Li and Zhao, 2007).

Bisides the Liaoji granitoids, minor Paleoproterozoic granitic pegmatite, diabase and diorite dykes without deformation are also present in this belt. Wang et al. (2011) obtained zircon SHRIMP U-Pb ages of meta-diabase at ~1830 Ma and granitic pegmatite at ~1860 Ma, with the later indicated termination of orogenisis and the former indicated the beginning of post orogenic extension.

The zircon U-Pb dating of the North and South Liaohe Groups also show constraints on metmorphrism. Luo et al. (2008) summarized data of Luo et al. (2004), Lu et al. (2006) and concluded that both the North and South Liaohe Groups experienced the 1.93~1.90 Ga metamorphic event, though locally they may have encountered a thermal reworking event at ~1.85 Ga due to post-orogenic/anorogenic extension.

## 4 Tectonic Settings of Uranium Mineralzation

The Palaeoproterozoic uranium deposits in the Jiao-Liao-Ji Belt are distributed from the Gongchangling district of Liaoyang in the west to the Caohekou town of Benxi in the east. Three uranium deposits, named as 3075, 410 and 405, have been discovered and exploited. All of these uranium deposits are hydrothermal vein mineralization controlled by faults.

The age of Palaeoproterozoic uranium deposits was dated previously by conventional U-Pb technique on ores and/or uraninite. Guo (1982) documented that the uranium ore of 3075 deposit in the Langzishan Formation gave a U-Pb age at ~2114 Ma, and the uraninite veins in granitic rocks gave U-Pb ages at ~1891 Ma and ~1829 Ma. Wang (1987) obtained the age of ores of 3075 deposit in the Langzishan Formation at ~2085 Ma, the ages of uraninite at ~2044 Ma and ~1974 Ma. Recently, Xia and Han (2008) documented that the uraninite U-Pb defined upper intercept ages of the 3075 deposit at ~1851 Ma, of the 410 deposit at ~1933 Ma and of several mineral occurrence at ~1876 Ma. Han (2009) obtained uraninite Pb-Pb isochrone ages of 3075 deposit at 1834±30 Ma, 1848±36 Ma and 1892±99 Ma, of 410 deposit at 1889±40Ma, and of several mineral occurrence at 1846±71 Ma. Since the North Liaohe group was dated to form later than ~2.0 Ga and peak metamorphism was at 1.93~1.90 Ga, the uranium mineralzation could not ealier than the North Liaohe group. Therefore, ages documeted in Han (2009) are more acceptable and show a window at 1.83–1.89 Ga.

The uranium mineralzation ages are identical to the zircon U-Pb ages of post-tectonic rapakivi granite, syenites and monzogranites at 1.85–1.88 Ga (Li et al., 2003; Cai et al., 2002; Lu et al., 2004, 2006; Yang et al., 2007; Li and Zhao, 2007), the zircon SHRIMP U-Pb ages of meta-diabase and granitic pegmatite at 1.83~1.86 Ga (Wang et al., 2011) and the thermal reworking event at ~1.85 Ga due to post-orogenic/anorogenic extension (Lu et al., 2006; Luo et al., 2008; Xie et al., 2011). Wang (2011) interpreted the 1.86 Ga granitic pegmatite as the termination of orogenisis and the 1.83 Ga meta-diabase as the beginning of post-orogenic extension. The post-orogenic granites and syenites are also a good indicator of the termination of the orogenic cycle (Bonin et al., 1998; Lu et al., 2006; Li and Zhao, 2007).

In conclusion, the uranium mineralzation event (1.83–1.89 Ga) in the eastern Liaoning Province of the Jiao-Liao-Ji belt are identical to the post-orogenic magmatic rocks (1.83–1.88 Ga). Therefore, the uranium mineralzation event in late Palaeoproterozoic was formed in a post-orogenic transitonal setting from compression to extension.

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