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Thorium resources in China: Spatial distribution, genetic type and geological characteristics

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INTRODUCTION

Thorium is a radioactive element and widely distributed in nature with average content of 10.5 ppm in the upper crust of the earth [1]. The thorium resource has been regarded as a potential energy source nowadays as more nations are looking for more clear energies to reduce carbon dioxide emissions caused by the traditional oil, gas and coal power plants. Several test reactors designed in the United States, Europe, Japan, Russia, and India has successfully generated electricity using thorium fuel sources [2], although till now it is still in experimental stage.

The specialized and systematic exploration and evaluation of thorium resource have not been carried out in China yet. However, at least 90 Th-bearing deposits or occurrences have already been reported till now during the exploration of other resources (e.g. U, REE, Nb). In recent years, some reconnaissance work for the thorium resource have been carried out in China, and by the literature research, comprehensive analyses as well as geological investigation for some representative deposits, we have roughly summarized the spatial distribution, genetic type and geological characteristics of the thorium deposits in China.

SPATIAL DISTRIBUTION

The thorium deposits have been recognized in all the first-level tectonic units in China, from north to south, including the Central Asian Orogenic Belt, North China Craton and Tarim Block, Central China Orogen (Kunlun-Qilian-Qinling-Dabie Orogenic Belt), Yangtze Craton, South China Block as well as the Tibet-Sanjiang Orogenic Belt. Most of these Th deposits or occurrences are concentrated in the following tectonic subunits:

(1) the northern margin of the North China Craton, represented by the well-known Bayan Obo Th-Fe-REE deposit [3], and the Saima U-Th-Nb-REE deposit [4];
(2) the Central Asian Orogenic Belt, represented by the Ba'erzhe (or Balingyao) U-Th-REE-Nb deposit [5];
(3) Central China Orogenic Belt, represented by the Huayangchuan U-Th-Nb deposit [6];
(4) South China (including Yangtze Craton and South China Block), including a series of placer Th deposits and several hydrothermal type Th deposits (e.g., Xiangshan U-Th ore field);
(5) Mian'ning-Dechang metallogenic belt in Southwestern China, represented by the Maoniuping, Muluozhai and other similar Th-REE deposits [7].

GENETIC TYPE

Most of the Th deposits in China have other commodities, including uranium, rare earth elements, high-field strength elements (Nb, Ta, Zr). According to the geological and geochemical features, the major genetic types of the Th deposits identified in China so far mainly include: (1) the magmatic type, (2) hydrothermal type, and (3) placer type, which have different ore element assemblages.

The magmatic type deposits can be further divided into: (a) alkaline silica-undersaturated nepheline syenite-related Th-U-Nb-REE mineralization system, as exemplified by the Saima deposit in northeastern China at the northern margin of the North China Craton [4]; (b) alkaline silica-oversaturated granite-related Th-U-Nb-REE deposit, Ba'erzhe deposit in the eastern Central Asian Orogenic Belt [5] and Boziguo'er [8] in Xinjiang Province at the southwestern margin of the Central Asian Orogenic Belt are both examples of this type; (c) carbonatite-related Th-U-REE deposit, represented by the world-known Bayan Obo Th-Fe-REE deposit (first largest REE and Th deposit in the world [4]) and a series of Th-REE deposits (including Maoniuping, the third largest REE deposit in the world) in the Mian'ning-Dechang metallogenic belt in southwestern China [7].

The hydrothermal type Th deposits are those typically related to hydrothermal fluid activities and are relatively uncommon as compared to the magmatic type Th mineralization systems. This is consistent to the relatively stable geochemical behavior of the thorium element but still some hydrothermal type Th deposits have been recognized, including the Zoujiashan U-Th deposit in the Xiangshan ore field, South China [9] and Xinshuijing U-Th deposit in the Longshoushan metallogenic belt in northwestern China [10].

The placer type monazite deposit is the most common Th deposit type not only in the world but also in China. The placer monazite deposits are widespread in South China (in both the Yangtze Craton and South China Block) where the river systems are well developed, which is favorable for the formation of this type of Th mineralization. The exact examples of the placer type Th deposits include the Juanshui monazite placer in the Mufushan area in Central Yangtze Craton and several similar ones along the southeastern coastal areas.

SUMMARIZED GEOLOGICAL FEATURES OF EACH TH DEPOSIT TYPE

For the magmatic type Th deposits, main summarized geological features include: (1) they all show intimate spatial-temporal and genetical relationship with the host magmatic rocks, no matter they are peralkaline nepheline syenite (Saima), peralkaline granite (Ba'erzhe) or carbonatites (Bayan Obo); (2) the mineralization are commonly controlled by the morphology of the causative plutons or the contact zone between the magmatic rocks and host rocks, although local fracture zones or faults are also favorable locations for ore mineral precipitation. For instance, the Th-U-REE orebodies are mostly concentrated along the contacts between the nepheline syenite and host marbles in the Saima deposit [4]; (3) the major ore minerals are commonly refractory accessory minerals, including zircon, thorite, pyrochlore, monazite, xenotime, F-, CO32−bearing REE minerals (bastnaesite, synchysite, parisite), etc.; (4) although the mineralization are mostly related to the magmatic fractionation crystallization process, the enrichment and overprint of volatile-rich fluids sometimes also play an important role in the formation of the polymetallic mineralization. For example, the mineralization stage of the Saima deposit includes the magmatic crystallization stage, skarn mineralization stage and later hydrothermal type pitchblende vein stage [4]; (5) they were mostly formed in post-collisional or within-plate extensional tectonic settings, although the formation age can be varied form Neoproterozoic (Bayan Obo), Late Paleozoic (Boziguo'er), Mesozoic (Saima and Ba'erzhe) or Cenozoic (Maoniuping).

The representative geological characteristics of the hydrothermal type Th deposits mainly are: (1) they are strictly controlled by liner structures including faults or fracture zones; (2) most of these systems are intimately related to the alkali metasomatism, with the typical alteration assemblage of albite + hematite + chlorite + carbonate, such as in the Xiangshan and Xinshuijing deposits; (3) the major Th minerals are thorite, uranothorite, but some fine-grained Th-phosphate aggregates have also been recognized in certain deposits, suggesting the low-temperature conditions [10].

The placer type Th deposits in China have the following features: (1) they can be further divided into the river/stream placer, beach placer or off-shore placer subtypes according to different sedimentary environments; (2) the major ore minerals are dominated by monazite, together with other heavy minerals including ilmenite, rutile, magnetite, xenotime, zircon, et al. resulting from weathering of the solid source rocks, which are mostly granites.

CONCLUSIONS

1. Thorium deposits have been recognized in all the first-level tectonic units in China but are mostly concentrated in the northern margin of the North China Craton, the Central Asian Orogenic Belt, South China and Mian'ning-Dechang metallogenic belt.
2. The major genetical types of the Th mineralization systems recognized in China are magmatic type, hydrothermal type and placer type.
3. The magmatic type Th deposits are mostly located at the craton margins or in the collision belts, and are genetically related to alkaline syenite, alkaline granite or carbonatite magmatic activities during different geological times, and sometimes overprinted by the post-magmatic hydrothermal fluid processes. The hydrothermal type ones are commonly controlled by faults, fractures or breccias, while the placer Th deposits are mostly located in South China in both the coastal areas and inland river systems.

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Country or International Organization

China

Primary author: Dr ZHONG, Jun (Beijing Research Institute of Uranium Geology)

Co-authors: Prof. FAN, Honghai (Beijing Research Institute of Uranium Geology); Dr CHEN, Jinyong (Beijing Research Institute of Uranium Geology); Dr MENG, Yanning (Beijing Research Institute of Uranium Geology)

Presenter: Dr ZHONG, Jun (Beijing Research Institute of Uranium Geology)

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