Study on Associated Rare Earth Minerals in Huayang Chuan Uranium Polymetallic Mine

Dequan Wang¹ *, Jianguo Wang¹, Yizhong Wang²

¹Sino Shaanxi Nuclear Industry Group, Shaanxi province, China
²Sino Shaanxi Nuclear Industry Group 214 Brigade Co., Ltd. China.

*Corresponding author e-mail: wdq0013@163.com

Abstract. Huayangchuan uranium polymetallic deposit is located in Huaxian County, Huayin City, Shaanxi Province. The geotectonic location belongs to the Xiaoqinling intracontinental orogenic belt on the southern margin of the North China block. The average content of rare earth in uranium ore reaches $740 \times 10^{-6}$. Rare earth minerals in ores have been studied by means of microscopic identification and scanning electron microscopic energy spectrum analysis. We believe that the rare earth minerals in Huayangchuan uranium polymetallic ore are mainly brown epidote, bastnaesite, gadolinite, monazite and ancylite. Among them, the most important rare earth mineral is epidote.

1. Introduction

Huayangchuan uranium polymetallic deposit is located in Huaxian County, Huayin City, Shaanxi Province. The geotectonic location belongs to the Xiaoqinling intracontinental orogenic belt on the southern margin of the North China block. The outcropped strata in the mining area are mainly Archaean Taihua Group and Mesoproterozoic Middle-Upper Xionger Group. The mineralization-related alterations in the area are mainly hydrothermal alterations such as silicification, biotitization, aegirine and carbonation. The uranium polymetallic deposit is associated with rare earth minerals. The average content of rare earth in uranium ore reaches $740 \times 10^{-6}$. In order to utilize mineral resources efficiently, rare earth minerals in ores were studied by means of microscopic identification and scanning electron microscopic energy spectrum analysis.

2. Characteristics of Rare Earth Minerals

Rare earth minerals in Huayangchuan uranium polymetallic ore are mainly brown epidote, monazite, bastnaesite, yttrium silicate, strontium cerium ore. The mineral characteristics are summarized as follows.
2.1. Characteristics of epidote
Epidote occurs in gneiss, pegmatite and carbonate rocks. In carbonate rocks, epidote is associated with monazite, which can be seen to encapsulate monazite. In pegmatite, the granules of epidote are larger, some of which are several centimeters in diameter. Under a single light microscope, the size of automorphic granules of brown epidote ranges from 200 microns to several centimeters. It is black-yellowish-brown with high protuberance and obvious polychromatism (Figure 1a,b,c). The interference color of epidote under orthogonal polarizing mirror is often disturbed by its own color. Scanning electron...
microscopy (SEM) energy dispersive spectroscopy (EDS) analysis showed that the brown epidote was obviously rich in light rare earth elements. Among them, the content of $\text{La}_2\text{O}_3$ was 5.53%-7.70%, the content of $\text{Ce}_2\text{O}_3$ was slightly higher (9.68%-13.67%). $\sum\text{REO}$ was 36.19%-49.66%.

2.2. Characteristics of monazite
Monazite is the main rare earth mineral in Huayangchuan mining area. Monazite occurs mainly in gneiss surrounding rocks, granite porphyry, pegmatite and carbonate rocks. It is closely related to niobium-titanium-uranium ore, epidote and mica. Monazite is usually wrapped in calcite and potassium feldspar in fine grains. Sometimes it can be seen that it coexists closely with brown epidote and apatite. Monazite in hand specimens is yellowish, showing a fine aggregate of particles, often with a circle of brown epidote "black halo" at the edge (Figure 1d). Monazite is colorless, highly protuberant and rough under transmission single polarizing mirror (Figure 1e). The particle size is usually 50-100 micron, and often appears as aggregates (Figure 1f). Under orthogonal polarization, the interference color is bright, three-level to high-level white. Gray under reflected light, low reflectivity. From the energy spectrum analysis results of monazite, it can be seen that monazite is obviously rich in light rare earth. Some monazites contain Th and U. $\sum\text{REO}$ ranged from 57.43% to 69.09%.

2.3. Characteristics of bastnasite
Bastnasite occurs mainly in automorphic, semi-automorphic columnar or plate shape, and its particle size is very fine, mainly wrapped in calcite minerals (Figure 2a). A small amount is embedded in quartz. The results of energy spectrum analysis of bastnasite show that bastnasite is obviously rich in light rare earth elements. Among them, $\text{Ce}_2\text{O}_3$ content is 36.71%-39.67%, which is relatively stable. $\text{La}_2\text{O}_3$ content is 21.65%-29.03%. $\text{Nd}_2\text{O}_3$ content is 6.79%-12.00% (Figure 2b). Other rare earth elements content is less. $\sum\text{REO}$ content is 72.23%-77.42%.

2.4. Characteristics of gadolinite
Gadolinite are mainly semi-automorphic and granular (Figure 2c). They are closely related to the distribution of epidote and are mostly enclosed in fine grains in the epidote. A small amount is also embedded in calcite. Energy spectrum analysis of yttrium silicate shows that the content of $\text{Y}_2\text{O}_3$ in minerals is 38.05%-42.99% (Figure 2d). The content of other rare earths is relatively low.

2.5. Characteristics of ancylite
The content of strontium carbide in the ore is very small, and most of them are semi-automorphic and granular, mainly distributed in calcite, and closely coexist with quartz, apatite and other minerals (Figure 2e). The results of energy spectrum analysis show that Ce and Nd are the main rare earth elements in the ancylite (Figure 2f).

3. Distribution of Rare Earth in Different Minerals
In this paper, the average content of different rare earth minerals in uranium ore and the rare earth content of the mineral are multiplied. The distribution of rare earth in different minerals is calculated. The results are shown in Table 1.

| Mineral name | Minerals | Rare Earth Content in Minerals | Rare earth metals | REE Distribution Rate |
|--------------|----------|-------------------------------|-------------------|----------------------|
| epidote      | 0.22     | 19.77                         | 0.04349           | 73.19                |
| bastnasite   | 0.0106   | 63.38                         | 0.00672           | 11.31                |
| gadolinite   | 0.0102   | 50.02                         | 0.0051            | 8.58                 |
| monazite     | 0.0058   | 59.2                          | 0.00343           | 5.77                 |
| ancylite     | 0.0018   | 37.53                         | 0.00068           | 1.14                 |
| Total        |          |                               | 0.05942           | 100                  |
From Table 1, it can be seen that the rare earth content of epidote accounts for 73.19% of the total rare earth content. Bastnaesite accounts for 11.31% of the total rare earth. Gadolinite accounts for 8.58% of the total rare earth content. Monazite accounts for 5.77% of the total rare earth content. Ancylite accounts for 1.14% of the total rare earth content.

4. Conclusion
Based on the above analysis, we believe that the rare earth minerals in Huayangchuan uranium polymetallic ore are mainly brown epidote, bastnaesite, gadolinite, monazite and ancylite. Among them, the most important rare earth mineral is epidote. The total amount of rare earth in epidote accounts for 73.19% of the total amount of rare earth in the deposit.

References
[1] HUI Xiao-chao, LI Zi-ying, FENG Zhang-sheng. Research on the Occurrence State of U in the Huayangchuan U-Polymetallic Deposit, Shanxi Province. ACTA MIRALOGICA SINICA, 2014, PP.573-580.
[2] GUO Wei, ZHOU Ding-wu, REN Jun-feng. Characteristics of the Huayangchuan ductile shear zones in the Xiaoqinling Mountains, Shaanxi, China, and its regional tectonic significance. Geological Bulletin of China. GEOLOGICAL BULLETIN OF CHINA, 2008, PP.823-828.
[3] ZHANG Zhen-yue, HE Zheng-yan, XU Zhi-gao. Rare Earth Partitioning Characteristics of China Rare Earth Ore[J]. Chinese Rare Earths, 2016, PP.121-127.
[4] ZHAO Zhi, WANG Denghong, CHEN Zhenyu. Metallogenic Specialization of Rare Earth Mineralized Igneous Rocks in the Eastern Nanling Region[J]. Geotectonica et Metallogenia, 2013, PP.255-263.
[5] YU XiaoCan, WANG ChunLian, LIU ChengLin. REE geochemical characteristics of sedimentary rocks in Jiangling Depression and their geological significance [J]. MINERAL DEPOSITS, 2014, PP.1057-1068.