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Characteristics of highly differentiated granite and metallization of tungsten-tin, rare and rare earth metal in the eastern Nanling region, China

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1 Introduction

Massive tungsten-tin, rare and rare earth metals ore deposits were formed with the widespread granite magmatic activity in early Yanshanian period in the eastern Nanling region. Recent studies indicate that the Yanshanian highly differentiated-granite formation is closely related to the deposits of tungsten and tin, rare and rare earth metals mineralization in the region（Xiao Huiliang et al., 2011）. The Yanshanian granite is mainly composed of small rock mass. The related ore-forming magmatic rocks are acidic (SiO_2 content: 72~78%), F-rich, with more than 74% super acid granite and middle-to-excessive-aluminum basic granite. The magmatic rocks include three major types of granites:muscovite, dimicaceous and garnetiferous. The formation age of the magmatic rocks is ~150-165Ma.

2 The characteristics of highly differentiated granite

2.1 The formation of muscovite type ore deposits (“muscovite” type)

The formation of muscovite type ore deposits is related to tungsten-tin-molybdenum-bismuth and rare metals, with a major mineral assemblage of plagioclase, K-feldspar, quartz and muscovite. The petrochemical characteristics are described as weight percentages below: SiO_2>74% (74-78%) with an average of 75.05%; high Na_2O+K_2O, within the range of 3.25-7.54%, averaged 5.45%, K_2O/Na_2O>1 (1.41-3.51); Al_2O_3<15%

low MgO, TFeO and TiO_2; Alkalinity ratio (AR) within 1.64-3.19, averaged 2.33; (A/CNK)=1.22-2.67; ΣREE=（66.39-204.98）×10^{-6}, suggesting weak enrichment of moderately differentiated, heavy rare earth elements; negative anomalies of Eu with a “seagull” pattern for the rare earth element coordination curve. The trace element spider diagram indicates that the formation has a Rb concentration of (582-1195)×10^{-6}, rich in U, Ta, Th, Nb and poor in Ba, Sr, Ti.

2.2 The formation of muscovite and mica type ore deposits (“dimicaceous” type)

The formation of muscovite and mica type ore deposits (“dimicaceous” type) is mainly related to tungsten-tin, rare and rare earth metal ore deposits. The major mineral assemblage is plagioclase, K-feldspar, quartz, muscovite and biotite. The petrochemistry is characterized by: SiO_2>72% (72.27-77.76%); Al_2O_3 < 14% (11.8913.49%); high Na_2O+K_2O, generally within 6.92-8.45%, K_2O /Na_2O > 1; low MgO, TFeO and TiO_2; ASI (Al_2O_3/Na_2O+K_2O+CaO molecular ratio)>1.1; (A/CNK)=1.02-1.35 (mainly ~1.06-1.17); ΣREE=(40-120)×10^{-6}, suggesting weak enrichment of moderately differentiated heavy rare earth elements. The formation shows negative anomaly of Eu, whereas the coordination curve of the rare earth elements shows a “seagull” pattern. Most samples are highly differentiated and have high contents of rare earth elements, as well as moderate negative Eu anomalies (δEu mainly around 0.64 - 0.21). The trace elements spider diagram shows that the formations has a Rb concentration of (430-995)×10^{-6}, being rich in U, Ta, Th, Nb and poor in Ba, Sr, Ti.

2.3 The formation of garnet type ore deposits (“garnetiferous” type)

The formation of garnetiferous type ore deposits is

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mainly related to tungsten and molybdenum ore deposits. Major minerals include quartz, plagioclase, K-feldspar, biotite, garnet and tourmaline. The petrochemical characteristics are: SiO_2>76% (76.02-77.12%); Al_2O_3>12% (12.05-13.28%); high Na_2O+K_2O, generally around 8.0% (7.52-8.45%); K_2O/Na_2O =0.84-1.06; low MgO, TFeO and TiO_2; (A/CNK)=1.06-1.08. ΣREE=(332.14- 477.03)$\times 10^{-6}$, indicating medium fractionation and HREE enrichment type, together with Eu negative anomalies and "seagull " rare earth coordination curve. The trace element spider diagrams show the formation has a Rb concentration of (523-681)$\times 10^{-6}$, rich in U,Th, Ta, Hf, Y, Yb, Lu and poor in Ba, Sr, Ti.

3 Mineralization

In the eastern Nanling region, the differentiation process of the granite during the Yanshanian period produced the ore deposits of tungsten-tin, rare and rare earth metals, with three major types: granite, quartz vein and skarn. Tungsten-tin, rare elements and rare earth metals are mainly sourced from the ore-bearing granite body (stage II and III) during the early Yanshan period Granite-type tungsten-molybdenum, niobium-tantalum-rubidium rare metal and rare earth metal ore deposits are from different stages of the product during the magma differentiation process. Quartz vein and skarn type tungsten-tin polymetallic ore deposits are the products of the late magmatic hydrothermal activities.

After the formation of the Yanshanian granite melt in the deep source area, the melt rose to the surface under the driving force of regional tectonic activities. During the rising process, the gradual changes in environmental conditions and physical and chemical parameters caused the rock mass to evolve and differentiate.

As the granite evolved from $\gamma_5{}^{2-1}$ to $\gamma_5{}^{2-2}$ and $\gamma_5{}^{2-3}$, the granite gradually differentiated during crystallization. The abundance of tungsten, tin, rare-metals, rare earth-metals and other metal materials of the granite magma is further enhanced. During the rising and cooling of the granite magma, the low grade tungsten-molybdenum polymetallic ore deposits are formed directly in garnet granite and dimicaceous granite. This further proved the theory of "ore body in rock body-typed tungsten-molybdenum polymetallic ore deposits". This process continued until the end of the magma crystallization(Xiao Huiliang et al.2008, 2011, 2012, 2013).

If the top of the granite a good closed environment, the metasomatism differentiation could occurr in the granite and stratigraphic contact belt. Inside the granite, a self-metamorphic action could occur facilitated by vapor and volatile matter. These processes likely caused the formation of the muscovite granite type of tungsten-tin-molybdenum-bismuth, niobium-tantalum-rubidium and lithium polymetallic ore deposits at the top of the granite body. The skarn-type layered tungsten-tin ore deposits were formed by the ore-forming, high-differentiation granites goes into the limestone and calcareous siltstone of the upper and middle Devonian system in the region.

During the later Steaming hydrothermal metallogenic stage, the quartz vein type tungsten ore deposits likely formed as the highly differentiated granite melt rose up to the sand and siltstone strata.

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