

## **Nb-Ta mineralization in a metaluminous-weakly peraluminous magmatic system: Constraints from the chemical compositions and Hf isotopes of columbite-group minerals in China**

**ZHI-MIN TANG<sup>1,2</sup>, XU-DONG CHE<sup>1,2,\*</sup>, RU-CHENG WANG<sup>1,2,\*</sup>, YUE-HENG YANG<sup>3</sup>, FU-YUAN WU<sup>3</sup>,  
ROBERT L. LINNEN<sup>4</sup>, FEI DENG<sup>5</sup>, HUAN HU<sup>1,2</sup>, AND JIAN-JUN LU<sup>1,2</sup>**

<sup>1</sup>State Key Laboratory for Mineral Deposits Research, School of Earth Sciences and Engineering,  
Nanjing University, Nanjing, 210023, China

<sup>2</sup>Frontiers Science Center for Critical Earth Material Cycling, Nanjing University, Nanjing, 210023, China

<sup>3</sup>State Key Laboratory of Lithospheric Evolution, Institute of Geology and Geophysics, Chinese Academy of Sciences,  
Beijing, 100029, China

<sup>4</sup>Department of Earth Sciences, Western University, 1151 Richmond Street North, London, Ontario N6A 5B7, Canada

<sup>5</sup>Bureau of Foshan Geological Survey, Guangdong Province, Foshan, 528000, China

### **ABSTRACT**

Mineralization of Nb and Ta associated with metaluminous-weakly peraluminous (MWP) magmatic systems has gained increasing attention in recent years, particularly with the recognition of several major Nb-Ta deposits in China originating from MWP granites. Columbite-group minerals (CGMs), the key ore minerals for Nb-Ta, serve as crucial indicators for understanding the mechanisms underlying this mineralization. This study presents a comprehensive analysis of major and trace elements, as well as Hf isotopes, of CGMs from seven Nb-Ta deposits in China, related to MWP systems. We compared these CGMs with those from deposits associated with strongly peraluminous (SP) magmatic systems to uncover the distinctions in their mineralization processes. Statistical analyses, including elemental plots and partial least squares discriminant analysis, revealed significant variations in CGMs between the MWP system and the SP system. The earliest crystallized CGMs from MWP systems exhibit higher Nb<sub>2</sub>O<sub>5</sub> contents resulting from higher Nb concentration in the initial magma and therefore do not need to undergo as high a degree of fractional crystallization as those in SP systems do. Additional geochemical markers further differentiate MWP magma sources, including higher Sc, total REE, and Y contents, as well as Th/U atomic ratios, along with lower Li contents and Y/Ho atomic ratios. As magma evolves, the Zr/Hf atomic ratios and total REE contents decrease, while Ta/(Nb+Ta) atomic ratios increase. Additionally, the influence of melt-crystal-fluid interactions on REE characteristics in late-stage CGMs cannot be ignored. The Hf isotopic compositions of CGMs indicate that the Nb-Ta mineralization in South China during the Early Cretaceous (~140–120 Ma), associated with MWP systems, is attributed to contributions from a deep material source within an extensional tectonic setting. The differences in chemical compositions, U-Pb ages, and Hf isotopes of CGMs between the two systems offer valuable insights for heavy mineral prospecting to locate Nb-Ta deposits related to MWP granites in regional exploration.

**Keywords:** Columbite, Nb-Ta mineralization, metaluminous-weakly peraluminous granite, partial least squares discriminant analysis, Hf isotopes, Nb-Ta magma source