JURASSIC MAGMATIC-TECTONIC-METALLOGENIC EVOLUTIONARY PROCESSES IN THE CENTRAL NANLING REGION, SOUTH CHINA : A CASE STUDY FROM THE HUANGSHAPING POLYMETALLIC DEPOSIT

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（中国南部中央ナンリン地域のジュラ紀マグマ・構造運動・鉱化過程の進化に関する研究：フアンシャピン多金属鉱床におけるケーススタディ）

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論　文　内　容　の　要　旨

The intra-continental magmatism in South China is characterized by huge volumes of Phanerozoic granitoids, which indicate a widespread episodic crustal reworking. The complex Jurassic tectonic setting and crustal evolution of the Nanling region has been a subject of wide interest. This dissertation aims to reveal the Jurassic magmatic–tectonic–metallogenic processes in the central Nanling region, based on the case study of the Huangshaping deposit. The dissertation consists of 8 chapters that discuss the different aspects of the research.

Chapter 1 introduces the background of this study and the geology of the Nanling region and South China. Based on reviews of previous research, the problems are identified and the objectives of this study are proposed.

Chapter 2 reviews the geological settings of the Nanling region in South China. First, it describes the characteristics of two blocks of South China, and the collision process between them. This is followed by a comprehensive review on the tectonic setting, Early Yanshanian (Jurassic) granitoids and endogenous metallogenic series of the Nanling tectono–magmatic belt.

Chapter 3 focuses on the geology outline of the Huangshaping deposit. Based on the field investigation, the stratigraphic correlation, structural characteristics, magmatism and associated mineralization are interpreted.

Chapter 4 discusses the petrology and geochemistry of the Huangshaping granites. Petrographically, three types of granites have been identified to be associated to mineralization: quartz porphyry, granophyre, and granite porphyry. Whole rock geochemistry suggests that the Huangshaping granites, especially the granite porphyry, exhibit typical A-type granite characteristics with enrichment in Si, Rb, U, Th, and Nb and significant depletion in Ba, Sr, Ti, Eu, and P. Based on the Al, Y and Zr contents as well as the REE patterns of the rocks investigated, the quartz porphyry and the granophyre are classified as A_1 type alkaline granites whereas the granite porphyry is considered as A_2 type aluminous granite. The O–Pb–Sr–Nd isotopic analysis on the whole rock, quartz and/or feldspar samples reveal that the Huangshaping granites are within-plate granites mainly derived from a felsic infracrustal source related to continental extension. The magma sources of the quartz porphyry and the granophyre may have been generated at deeper depths, and then rapidly ascended with limited water content and low oxygen fugacity, which contributed to Cu, Pb and Zn mineralization. On the other hand, the magma that generated the granite porphyry may have ascended relatively slower and experienced pronounced crystal fractionation, upper-crustal basement rock contamination (assimilation) and wall-rock interaction, producing the Sn- and W-rich granite porphyry.

Chapter 5 interprets the zircon morphology, geochronology and trace element geochemistry of the Huangshaping granites. Hundred zircon separates from different intrusive stages of the pluton have been analyzed for trace element contents and U–Pb isotopic concentrations. The zircons from the Huangshaping granitoids are enriched in Th, U, Hf, Ti, REE and other trace elements, indicating hydrothermal fluid alteration and transformation. Compared to

the zircons from the quartz porphyry and the granophyre, zircons from the granite porphyry are more enriched in Th, U, Hf, Ti, and P, whilst strongly depleted in Eu. This suggests that the magma that formed the granite porphyry possessed higher temperatures, possibly experiencing stronger crystal fractionation and originating from a more evolved, complex magmatic source region with higher degree of crustal maturity. Combined with characteristics of crystal morphology and internal texture, hydrothermal zircons were distinguished from magmatic zircons in each granitoid to reveal the processes of mineralization. The U–Pb geochronology results show that there are two major stages of mineralization: ~190 Ma weak Cu (Pb, Zn) mineralization related to the quartz porphyry and the granophyre, and ~155 Ma strong W, Sn (Mo, Pb, Zn) mineralization associated with the granite porphyry. The compositions of these hydrothermal zircons suggest that the earlier stage mineralization could be close to single, relatively cool, reduced and quickly ascended fluids, whereas the later stage might be related to oxidized, strongly fractionated and highly evolved, mixed fluids. Study on the zircon morphology, geochronology and trace element geochemistry of the Huangshaping granites also indicates that hydrothermal zircons from typical composite granitic plutons could be a good tool to reveal the multi-stage magmatic and mineralization process in middle to late Jurassic South China.

Chapter 6 presents the ore trace element geochemistry and fluid inclusion analytical data. The relatively low REE concentrations, positive (or slightly negative) Eu anomalies and depletion of large ion lithophile elements in the quartz porphyry- and granophyre-associated ore minerals suggest the relatively univocal, deep-sourced magmatic fluids under a reducing environment. In contrast, the highest REE concentrations, pronounced negative Eu anomalies, distinct lanthanide tetrad effects, and relative enrichment of the high field strength elements of the ore minerals from the granite porphyry are ascribed to a highly oxidizing environment and the contribution of metallogenic substances derived from crustal basement rocks. The relatively high abundances of SO_4^{2-}, Na^+, K^+ in the quartz porphyry-associated ore minerals and F^-, Cl^- in the granophyre-associated ore minerals suggest magmatic fluids under high pressure and low water content during the Cu (Pb–Zn) mineralization process. On the contrary, the poor covariation relations in gaseous abundances and the high CO_2, H_2O and Ca^{2+} contents of the inclusions of ore minerals from the granite porphyry imply that the W–Sn mineralization was formed in a high temperature environment with complicated fluid sources.

Chapter 7 deals with the systematically collected data on element geochemistry, age determination and Sr–Nd–Hf isotope for each stage of the Early Yanshanian granitic intrusions in the central Nanling region. These Jurassic granites have been classified into two groups based on their age and geochemical variations: Group 1 (180–165 Ma) and Group 2 (165–150 Ma). Group 1 granitoids are classified as A_1 type alkaline rocks with faster cooling and uplift rates, indicating influence from crust–mantle interaction. Group 2 granites experienced more intense magmatic evolution and differentiation and are considered as A_2 type aluminous rocks with slower cooling and ascent rates, suggesting stronger upper crustal contamination or assimilation. Consequently, a new conceptual model of "mantle plume generated triple junction rifts" is proposed to explain the distribution of major deposits in the central Nanling region and the different cooling-uplift rates, geochemical compositions, and evolutionary processes of these granite composites. The Group 1 granitoids are envisaged to be closely related to the rising mantle plume head which is located in the center of the rift system. The older, rapidly ascended magmas underwent crust–mantle interaction and resulted in the Cu (Mo–Au, or Pb–Zn) mineralization. On the contrary, the slowly cooled and ascended Group 2 magmas experienced more intense crustal contamination (or assimilation) and crystal fractionation, contributing to the large W–Sn mineralization in the central Nanling region. The Early Mesoproterozoic (1.4–1.6 Ga) crustal basement of the Cathaysia Block in South China is the ore source bed for the world-famous Nanling W–Sn polymetallic mineralization.

Finally, Chapter 8 concludes the major findings and achievements of this study that were reported and discussed in the previous chapters. Based on the case study from the Huangshaping deposit, this research yields important insights into the complex Jurassic magmatic–tectonic– metallogenic processes in the central Nanling region.