Introduction to the Middle-Lower Yangtze River Valley Metallogenic Belt

The Middle-Lower Yangtze River Valley metallogenic belt (MLYB) has been a cradle of modern metallogeny in China. In the MLYB, there are numerous stratabound sulfide deposits and polymetallic skarn-porphry and magnetite-apatite deposits, together constituting a significant mineralogic exploration belt on the northern margin of the Yangtze craton. The deposit metallogenic series (Cheng et al., 1979), the metallogenic system (Zhai, 1999), a porphyritic iron metallogenic model (Ningwu Iron Ore Research Group, 1978), the continental fault depression belt in a syngenetic submarine copper deposit (Gu and Xu, 1986), stratabound skarn (Chang et al., 1991) and the Mesozoic large-scale metallogenic explosion (Pan and Dong, 1999; Mao et al., 1999) in the MLYB have been described and reviewed in detail. The Middle to Lower Yangtze region has been one of the main targets of research and exploration since the early period of geological work in China since the middle 20th century, Chang et al. (1991), Zhai et al. (1992), Tang et al. (1998) and other researchers have made a full review of the achievements before the 1990s. In the 21st century, much further research work has been carried out in the MLYB. Chang et al. (2012, 2017, 2019), Mao et al. (2011, 2012), Pirajno and Zhou (2015), Xie et al. (2019), Zhou et al. (2008, 2011, 2017, 2019) and Fan et al. (2019) have conducted excellent research and have summarized the geochronology, metallogenic regularity and provided ore deposit models.

The MLYB, known as the Yangtze region’s ‘industrial corridor’ in the eastern China, plays an important role in the economic development of eastern China. In recent years, with the discovery and exploration of new deposits, such as the Yaojialing, Huangtun, Heshuashan and Dongguashan deposits, exploration in the MLYB has aroused increasing attention. In the mid-1980s, Academician Chang Yinfo put forward the concept of "deep geological surveys and three-dimensional (3D) mapping" in the Tongling and Daye ore clusters in the MLYB, and predicted the ore prospecting potential. Later, the discovery of the Dongguashan, Yaojialing and other deposits have proved this prediction. More than 30 years later, China is now facing a shortage of resources. A strategic choice has been made to explore deep resources for China’s sustainable economic and social development. The breakthrough of deep exploration has become the central task of the current geological work in the metallogenic belt.

Main Achievements of Academician Chang Yinfo

Academician Chang Yinfo, well-known and important ore deposit geologist and exploration expert, was born in July 1931 in Taixing, Jiangsu Province, China. He graduated from the Department of Geology, Tsinghua University, Beijing, in 1952. He served as chief engineer of Anhui 321 Geological Team, deputy director and chief engineer of Anhui Provincial Bureau of Geology and Mineral Resources, President of School of Earth and Space Science of China University of Science and Technology, and special term professor of Hefei University of Technology. He has won the national prize for scientific and technological progress, the provincial
award of science and technology and the science and technology progress award of He Liang He Li Foundation. He was elected a member of the academic department of the Chinese Academy of Sciences in 1991 and was selected as one of the first members of the Chinese Academy of Engineering in 1994.

Academician Chang Yinbo has been engaged in exploration and research for much of his life and has mainly focused on the Middle-Lower Yangtze River Valley metallogenic belt, including the tectonic background, metallogenic models, exploration guides and ore-hunting indicators. His research has developed the theory of intracontinental mineralization. He has put forward the classification metallogenic model of stratabound skarn deposits, which has significantly helped to develop the skarn metallogenic theory. He led the second round of general geological survey and 3D mapping of metallogenic belt and achieved so much to provide abundant mineral resources for the development of the Tongling City and the regional economic in east China.

Mineral exploration research

In 1952, Academician Chang Yinbo started his geological career at Tongguanshan Copper Mine in Tongling, Anhui Province. Then he worked with academicians Guo Wenkai and Chen Qingxuan in Geology Team 321. During that time, he took part in the exploration of the Tongshan copper deposit and the Huangshanling lead–zinc deposit. Then he participated the
exploration of Tongguanshan in 1953 and was responsible for the exploration of the copper deposits in Tongling ore district in 1955.

After 1957, Academician Chang Yinfo was responsible for the technical work of the geological exploration project around Tongguanshan for several years. The project systematically carried out regional geological survey, prospecting, exploration and geological research, and discovered several large-scale copper deposits, such as Shizishan and Fenghuangshan, which greatly increased copper reserves and opened up new prospecting prospects for the Tongling ore district. At the same time, through the joint efforts of geologists in various provinces along the Yangtze River, the Middle-Lower Yangtze River Valley metallogenic belt have become one of the largest copper belts in China. During this period, he also organized the implementation of the earliest Geological Survey at 1:50000 scale (Tongling) in China, which greatly improved the geological research level of the metallogenic belt.

Ore deposit research

Stratabound ore bodies are common in skarn deposits in the Tongling ore district, which was interpreted by classical metallogenic theory as caused by magmatic-hydrothermal metasomatism. Academician Chang Yinfo regarded all these layered ore bodies as a system and introduced the concept of stratabound mineralization, which represents a transitional deposit series between the two end members of typical sedimentary and magmatic-hydrothermal deposits. Therefore, in 1980, he proposed the establishment of a new type or subtype of ‘stratabound skarn type deposit’, which is defined as ‘within the scope of magmatic thermal influence, the hydrothermal system forms and emplaces the stratoid and layered deposits in the layered rocks through the mechanism of metasomatism, superposition and transformation while forming skarn and subsequent altered rocks’. This study has greatly developed the skarn metallogenic theory. As this kind of ore body is generally large and stable in skarn deposits, it has always been an important exploration target.

Regional metallogeny research

In 1963, based on the analysis of geological and geophysical data, Academician Chang Yinfo proposed that the nearly East–West Tongling–Daihui basement fault zone is the main ore-controlling structure in the area. This is one of the early achievements in the research on the ore control of the basement fault (and deep faults) in China, and it has been recognized by follow-up exploration and scientific research work and plays a guiding role in ore prospecting. Since the 1980s, Academician Chang Yinfo and his colleagues have demonstrated that the main part of the metallogenic belt lies at the junction of the north and the south basement. Under the action of Yanshanian intraplate deformation, a network fault system, the Yangtze River fault zone, was developed along this structural ‘weak zone’, which can cut down to the interface between the middle and lower crust. In the Tongling ore district, high K calc-alkaline magmatic rocks are widely developed, accompanied by copper-gold-skarn deposits, especially stratabound skarn type deposits. In the Luzong and Ningwu volcanic basin, there was intense magmatic activity of the shoshonite series, accompanied by large-scale enrichment of magnetite–apatite deposits.

Field investigation of Prof. Chang (the third from left) in the Beiya gold ore deposit
Based on the above analysis, Academician Chang Yinfo established a metallogenic model for an intracontinental metallogenic belt.

Academician Chang Yinfo continues to pay attention to the scientific research in metallogenic belts, and has put forward a new understanding of the theory of the composite structural system of the Middle-Lower Yangtze River Valley metallogenic belt (Chang et al., 2019). Based on project of “Geology of mineral resources in China” from China Geological Survey (Grant No. DD20160346, DD20190379), Academician Chang Yinfo has summarized the research results of the metallogenic belt in the past several decades, systematically expounding the structural pattern and composite structural system of the metallogenic belt, and discussed the age of the combination of the Dongling/Gucheng basement and the Jiangnan basement, putting forward the concept of the North–South confrontation zone that defines the connotation of the Jiangnan transitional zone, and makes a new contribution to the study of the MLYB.

Congratulations to Academician Chang Yinfo

Academician Chang Yinfo is a celebrated exploration geologist in China, and he has long been committed to the comprehensive study of regional geological surveys, metallogenic theory and exploration of deposits, especially in the MLYB.

This year marks his 90th birthday and the 70th anniversary of the start of his career in geology, and so, with this special issue, we would like to take the opportunity to express our heartfelt gratitude to him for his sustained leadership and important contributions to the Ore Deposit Geology of China. We all wish him a long and healthy life to make an even greater contribution to the geological sciences of China.

Introduction to the Special Issue

In this special issue of Acta Geologica Sinica (English Edition), we have assembled 24 papers that contribute to a better understanding of the metallogeny and geotectonic setting of the MLYB as well as the adjacent areas in South China. Of these, 14 Papers are focused on the latest progress on the tectonic background, metallogenesis, prospecting and geophysics in the Middle-Lower Yangtze River Valley metallogenic belt.

Rare metals found, including Lithium (Li), Beryllium (Be), Rubidium (Rb), Cesium (Cs), Zirconium (Zr), Hafnium (Hf), Niobium (Nb), Tantalum (Ta), Tungsten (W) and Tin (Sn), are important critical mineral resources. Jiang et al. (2020–this issue) suggest that major ore-forming epochs include Indosinian and the Yanshanian. They put forward several most important controlling factors for rare metal mineral deposits including geochemical behaviors, sources of the rare metals, highly evolved magmatic fractionation, and structural controls, with a revised conceptual model in this paper.

South China is endowed with copious wolframite–quartz vein-type W deposits that provide a significant contribution to the world’s tungsten production. Ni et al. (2020–this issue) summarize the published geology, geochronology, fluid-inclusion and isotope data from these W deposits mainly in South China. Their comprehensive studies on spatial variation of fluid inclusions show that both the steeply and gently dipping veins are consistent with the ‘five floors’ model that may have broader applications to exploration of wolframite–quartz vein-type deposits. Further studies on wolframite–quartz vein-type W deposits will bring a deeper understanding on ore-forming fluids and the metallogenic mechanism involved.

Xie et al. (2020–this issue) review the principal geological characteristics of some Cu–Fe, Fe, Cu–Au and Au–Cu skarn, and distal Au deposits. They propose a new mineral deposit model of the Cu–Fe–Au skarn system to illustrate the relationship between the skarn Cu–Fe–Au mineralization, the evaporitic sedimentary rocks, and the distal Au–Tl deposits. Their new proposed model will have important implications for the exploration for carbonate-hosted Au–Tl deposits in the more distal parts of Cu–Fe–Au skarn systems, and skarn Fe deposits with the occurrence of gypsum-bearing sedimentary rocks in the MLYB, and possibly elsewhere.

Xu et al. (2020–this issue) collected colloform pyrite (CPy) from Xinqiao stratabound sulfide deposit. Based on X-ray diffraction (XRD), field-emission scanning electron microscopy (SEM), and high-resolution transmission electron microscopy (TEM), they suggest that CPy is of sedimentary origin rather than hydrothermal origin, which is associated with Yanshanian magmatism. Moreover, the coexistence of CPy and stratabound sulfide orebodies in the MLYB suggests a causal link between the two. It is considered that CPy might have served as a Cu mineralization geochemical barrier for the Cu-bearing ore-forming fluids, which originated from the Mesozoic magma in the MLYB.

Yin et al. (2020–this issue) indicate that the Pengshan Sn-polymetallic ore field originated at approximately 128 Main compressional-extensional tectonic transformation and that the granites in Pengshan are characterized by a high silicon content and are rich in alkalis, based on studies of LA-ICP-MS zircon U-Pb chronology and petrogeochemistry of Early Cretaceous acid granites from Pengshan. This paper provides new evidence allowing a deeper understanding of the metallogenic dynamic background of the field and the Early Cretaceous tectonic deformation at the junction of the northern edge MLYB.

South China as an amalgamation of the Yangtze and Cathaysia blocks is composed of an Archean to Mesoproterozoic basement overlain by Neoproterozoic and younger cover. Wang K. et al. (2020–this issue) provide a summary of the geochronological, petrological, isotopic, geochemical, and geophysical features of the Archean to Mesoproterozoic crust in South China. By synthesizing the available data from the literature, this paper discussing the spatial and temporal framework for the formation and evolution of the pre-Neoproterozoic continental crust in South China.

Yan et al. (2020–this issue) focus on the gravity data (1:50000) and aeromagnetic data (1:50000), which were obtained through the latest geophysical survey, establishing a 3D geological model of the Zhuxi tungsten deposit. They obtained the spatial shape of intrusions and stratum with a depth of 5 km underground, as well as
preliminarily realizing the ‘transparency’ for main orecontrolling bodies. Based on the analysis of the 3D model and geological information, five new prospecting targets have been predicted surrounding the Zhuxi deposit.

Chen et al. (2020–this issue) compiled and analyzed 69310 P-wave travel-time data from 6639 earthquake events. Their work provides a 1-D crustal velocity model from the Lixin (Anhui)-to-Yixing (Jiangsu) wide-angle seismic profile as the initial model, and uses the tomo DD program to perform 3D velocity structure inversion and earthquake relocation. Checkerboard resolution tests were conducted to assess the merit of the different grid size models. The optimal velocity model results were integrated with geological/geophysical data to constrain the MLYB deep-seated structure and basement architecture.

Intensive mid-Neoproterozoic magmatism is the salient feature of the Yangtze Block, preserving abundant information about crustal reworking and growth. Niu et al. (2020–this issue) conducted work on zircon U–Pb dating and Lu–Hf isotope analyses in the mid-Neoproterozoic igneous and sedimentary rocks from the Zhangbaling Group (ZBLG) and the Feidong Complex (FDC), indicating that the provenance of the metasiltstone is primarily the underlying Xileng Formation. The transition from ancient to juvenile crustal sources for felsic magmatic rocks is attributed to gradually increased crustal extension during continental rifting.

Based on the geological conditions and characteristics of mineralization in the Tongling ore district and using 3D geological modelling combined with previous deep research results, Wan et al. (2020–this issue) summarize the metallogenic model of ‘coupling of layers’ in the Tongling ore district, and establisha ‘one body, two belts and multilayer metallogenic system’, which is significant for the direction of deep prospecting in the Tongling area.

Shi K. et al. (2020–this issue) study the geochronology, geochemistry and Hf isotopes of the magmatic rocks of the Jiangshan Au deposit. Their results show that the rock-forming age of the quartz diorite porphyry in the Jiangshan gold mine is 111.5 ± 1.8 Ma, which corresponds to a rock-forming and metallogenic event in the late Early Cretaceous in the Bengbu Uplift. The quartz-diorite porphyry in the Jiangshan gold mine has a high temperature and oxygen fugacity, which not only brought some metallogenic materials, but also provided copious heat for the convection circulation of groundwater.

An increasing number of tungsten deposits and scheelite in Fe–Cu deposits have been discovered in the MLYB during the recent decades. Nie et al. (2020–this issue) analyze cathodoluminescence and trace-element compositions of scheelite from tungsten deposits to reveal the variations in ore-forming fluid evolution and volatile components between different tungsten deposits and mineralization. A plot of (La/Lu)_N versus Mo/6Eu is used to distinguish quartz vein type, porphyry and skarn tungsten deposits. This study demonstrates that scheelite grains give implication of tungsten mineralization and are effective in identifying magmatic types of tungsten deposits in prospective mine sites.

Xiong et al. (2020–this issue) carried out a comprehensive study of field core logging and indoor petrographic observation of the Yaojialing deposit, using whole rock main micro testing and LA-ICP MS zircon U–Pb dating analysis to investigate the geochemical characteristics, diagenetic age and genetic model of Yaojialing deposit. The Yaojialing deposit shows the mineralization characteristics of proximal skarn and distal skarn, and has the common characteristics of the ‘multi-storey’ and ‘Trinity’ metallogenic model.

Fu et al. (2020–this issue) carried out research on two representative granitoid intrusions in the Feidong district and propose a model for the origin of the granites and discuss their petrogenesis, regarding the subduction of the Pacific Plate beneath eastern China in the Jurassic, when the NCC lithosphere became thickened, followed by large-scale lithospheric thinning. The upwelling asthenosphere caused partial melting of NCC lower crust, and produced large amounts of magma along the TLFZ including the Xishanyi and Jiangsan intrusions.

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References


