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Editorial

Molybdenum deposits in China

China is unique for the development of three global tectonic-metallogenic domains, i.e., the Tethys, Paleo-Asia and Circum-Pacific (Chen et al. 2009; Pirajno 2013 and references therein), and also for the Mesozoic reactivation or de-cratonization/destruction of the North China Craton (Zhu et al. 2015 and references therein). The China mainland tectonically consists of the North China, Tarim and Yangtze cratons and their surrounding orogenic belts or plateau (e.g. Tibet). The Central Asia Orogenic Belt (CAOB) along the north border of China, comprising ophiolite suites, magmatic arcs, Precambrian massifs and accretionary terranes, is an orogenic collage resulted from the collision between the Siberia and Tarim-North China continents along the Solonker Suture, following the termination of the Paleo-Asia Ocean that progressively closed eastward from the mid-Carboniferous to the Permian-Triassic transition (Chen et al. 2007, 2009). The Central China Orogenic Belt (CCOB), including West Kunlun, Altyn, East Kunlun, Qinling, Dabie Shan and Su-Lu orogenic belts, constituting the tectonic and geographic backbone of mainland China, was formed from the evolution and closure of the northernmost Paleo-Tethys Ocean that closed in a westward scissor-like fashion in the Triassic, followed by collision between the North China-Tarim continent and South China Block and other continental segments that separated from the Gondwana Land (Chen and Santosh 2014). The southern branch of the Paleo-Tethys Ocean closed along the Jinshajiang Suture in Triassic, followed by the Jurassic collision between the Qiangtang-Indochina Block and South China Block. After the termination of the Paleo-Tethys Ocean, the Siberia Craton, North China Craton, Tarim Craton, South China Block, Qiangtang-Indochina Block, were amalgamated into a huge pre-Cretaceous Eurasian continent. The Eurasian continent further collided with the Lhasa Block along the Bangong-Nujiang Suture since mid-Cretaceous (ca. 98 Ma), and then with the Indian plate along the Indus–Yarlung Suture since 65–52 Ma, resulting in the uplifting of the Tibet Plateau. Since the Jurassic-Cretaceous transition, the Pacific plate began to subduct westward beneath the pre-Cretaceous Eurasian continent, causing widespread Early Cretaceous granitic magmatism in eastern mainland China.

The unique tectonic setting and multistage orogenies accommodated intensive Mo-mineralization all over the China mainland, particularly in continental collision orogens. Systematic geological exploration and scientific research of Mo deposits in China commenced in the 1950s.

China has a proven reserve of >25 Mt Mo metal (mined is included), with ~6 Mt in Qinling Orogen (Li et al. 2007), ~3 Mt in Dabie Shan (Chen et al. 2016a-this volume), >10.5 Mt in Northeast China (Chen et al. 2016b-this volume), 2 Mt in Northwest China (Wu et al. 2016b-this volume), 2.5 Mt in Southwest China (Yang and Wang 2016-this volume), and 1.8 Mt in South China (Zhong et al. 2016-this volume). Mo reserve in China is more than two times the global total (China is not included) that was estimated ~10.7 Mt, including 5.4 Mt in the USA, 2.5 Mt in Chile, 0.91 Mt in Canada, 0.36 Mt in Russia, and 1.67 Mt in other countries (Singer et al. 2002).

China is a ***geological history museum*** recording the multi-episodic Mo-mineralization covering an age span from 1850 Ma (Li et al. 2011b, 2015) to 10 Ma. Available isotope age data show that Mo mineralization mainly occurred in Mesozoic, followed by the Late Paleozoic and Cenozoic, with a few deposits being formed before the Devonian. Each mineralization epoch can be related to a significant tectonic event in the long-time evolving history. China is also an ***exhibition hall*** of various Mo-mineral systems types, which comprise porphyry, porphyry-skarn, skarn, quartz vein, fluorite vein and carbonatite dyke, as well as porphyry-carbonatite combination. Economic porphyry-type orebodies can occur in the causative porphyry stocks as traditionally considered, but also unusually distal to the porphyry stocks, such as Donggou (Yang et al. 2015). In addition to magmatic hydrothermal systems, the structurally-controlled orogenic-type Mo-bearing quartz veins also show economic significance (Ni et al. 2012, 2014; Deng et al. 2016-this volume; Cao et al., 2016a, b-this volume).

In China, Mo deposits are classified into giant (>0.5 Mt), large (0.1–0.5 Mt), medium (0.01–0.1 Mt) and small (<0.01 Mt) in Mo metal tonnages. All the proven giant Mo deposits in China are associated with porphyry or porphyry-skarn systems. In addition to the Endako-type that commonly developed in subduction-related continental arcs, and the Climax-type that developed in rift or rifting back-arc settings, the Dabie-type porphyry Mo systems formed in continental collision regime (Chen et al. 2016a-this volume) are more common and important in China. These three types of porphyry Mo deposits show contrasting geological and geochemical characteristics resulted from distinctive tectonic settings, and thus can be employed as a useful indicator of tectonic settings and associated evolutionary trends (Chen et al. 2016b-this volume).

The majority of the Mo deposits in China have been well studied in their geology, geochemistry and geochronology, leading to major achievements in the understanding of their formation, occurrences and tectonic settings, as well as controversial issues. The research results have been published mainly in Chinese, less so in English, which impedes the knowledge for international geologists who cannot read Chinese literature.

In this special issue, we assemble contributions that provide a broad overview of the spatial distribution and main geological and metallogenic features of major Mo provinces or belts in China, together with detailed case deposit studies. The geological and geochemical characteristics of the Mo deposits are well addressed, and the key issues related to mineralization type, ore genesis and tectonic settings are discussed, which will provide important insights into the understanding

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of Mo mineralization in China, as well as world-wide. This special issue includes four sections, i.e., (1) Central China Orogenic Belt, (2) Central Asia Orogenic Belt, (3) South China Block and (4) Southwest China (Tibet Plateau), focusing on Mo mineralization in different tectonic settings or units. Each section is headed by one or two review articles, followed with papers on individual case deposit studies.

The first section is on the Central China Orogenic Belt, especially on the Qinling and Dabie Shan. The first paper is an overview of the Dabie-type porphyry Mo deposits in Dabie Shan, central China (Chen et al. 2016a-this volume). The geological, geochemical and geochronological characteristics of the Yanshanian Mo deposits and their associated granitic porphyries in Dabie Shan are summarized, which show that the mineralization occurred in *syn-* to post-collision tectonic setting during 156–110 Ma. The authors proposed that the causative porphyries were mainly crust-sourced high-K calc-alkaline granites, which is fully supported by a review of the Yanshanian granitic rocks in the Qinling and Dabie orogenic areas by Bao et al. (2016-this volume) who suggested that the magmas mainly originated from partial melting of the subducted continental crust during continental collision. Chen et al. (2016a-this volume) also proposed that the Dabie-type porphyry systems are characterized by the ore-fluids enriched in K, F and CO_2, as indicated by the observation of pure CO_2 inclusions and daughter crystals of sylvite and fluorite in fluid inclusions. All these geological and geochemical characteristics and genetic understandings of the Dabie-type porphyry or porphyry-skarn Mo systems are consistent with the studies of individual deposits formed in continental collision regime, such as the Tangjiaping (Wang et al. 2016e-this volume), Tianmugou (Yang et al. 2016c-this volume) and Huajiangou (Q.Z. Chen et al. 2016a–this volume) deposits in Dabie Shan; the Shangfanggou deposit in Qinling Orogen (Yang et al. 2016b-this volume); the Xiaoliugou W—Mo deposit in Qilian Orogen (Zheng et al. 2016-this volume); Donggebie Mo deposit in Tianshan (Wu et al. 2014, 2016c-this volume); the Baituyingzi (Sun et al. 2016b-this volume) and Gaogangshan (Zhang et al. 2016-this volume) deposits in NE China; the Tongchanggou deposit in the eastern margin of the Tibet Plateau (Yang et al. 2016a-this volume).

The second paper of the first section is a review article on the Early Mesozoic (Indosinian) Mo deposits in Qinling Orogen (Li and Pirajno 2016-this volume). In this contribution, the Indosinian Mo mineralization is classified into three types, i.e., porphyry(-skarn), carbonatite dykes and structurally-controlled quartz veins. The carbonatite dyke-type Mo deposits are suggested to have developed in a back-arc rift or an extensional region comparable with the tectonic setting of the Climax-type porphyry systems. The structurally-controlled Mo-containing quartz veins, exemplified by those in Waifangshan area (Deng et al. 2016-this volume) and the Dahu Au—Mo deposit (Li et al. 2011a; Ni et al. 2012, 2014), occurring in the northernmost Qinling Orogen, are considered to be the orogenic-type systems formed in the transition zone between the continental arc and back-arc basin (Chen and Santosh 2014). The porphyry-type Mo systems are represented by the Wenquan (Zhu et al. 2011), Liyuantang (Xiao et al. 2014), Yanzhiba and Lanbandeng deposits, associated with highly-fractionated I-type granitoids (Xiao et al., 2016-this volume) developed in the Southern Qinling magmatic arc, and thus assigned to Endako-type. The Endako-type porphyry or porphyry-skarn Mo deposits also developed in the Early Paleozoic in Altyn, such as the Kaladawan Fe-Mo deposit (Wang et al. 2016a-this volume), in Late Paleozoic in Northwest China (Central Asia Orogenic Belt), as exemplified by Suyunhe and Hongyuan (Shen et al. 2016-this volume), and in Middle Jurassic-Early Cretaceous in Northeast China, represented by the Chalukou (Zhang and Li 2016-this volume) and Diyanqin'amu deposits (Wang et al. 2016d-this volume).

The second section is also led by two review articles on the Mo deposits in the eastern (NE China; Chen et al. 2016b-this volume) and western (NW China; Wu et al. 2016b-this volume) sectors of the Central Asia Orogenic Belt. Chen et al. (2016b) divided NE China into three Mo belts, i.e., the Northern North China Craton, Great Hingan Range and Ji-Hei Fold Belt, classified the porphyry Mo deposits into Dabie-, Climax- and Endako-types, and attempted to setup a linkage between the genetic types of porphyry Mo deposits and tectonic settings including continental collision, rift settings and magmatic arc. According to the ages and spatial distribution of the Mo deposits of different types, they suggested that the Indosinian and Early Yanshanian Mo deposits were formed in *syn-* to post-collisional orogeny following the closure of the Paleo-Asia Ocean, the Mid-Yanshanian Mo mineralization (160–130 Ma) in Great Hingan Range was related to the southeastward subduction of the Mongol-Okhotsk oceanic plate, and the Late Yanshanian mineralization in the easternmost China was caused by the westward subduction of the Paleo-Pacific plate. Hence they conclude that the mineral systems are a powerful indicator of tectonic settings, and that the eastern sector of Central Asia Orogenic Belt has been strongly modified during the interaction with Mongol-Okhotsk and Paleo-Pacific oceanic plates, as well as the interaction with the Siberia Craton. Compared to the Northeast China, the tectono-thermal and mineralization events in the western part of the Central Asia Orogenic Belt (Northwest China) are somewhat simpler. Wu et al. (2016b) related the Mo deposits in NW China to the Paleozoic accretionary and Triassic collisional orogenies, and assigned the porphyry Mo deposits to Endako- and Dabie-types, respectively. In the Central Asia Orogenic Belt, the Shabutai (Zhou et al. 2016) and giant Caosiyao (Wang et al. 2016c–this volume; Wu et al. 2016a-this volume) porphyry have been convincingly classified as Climax-type. The Donggebi (Wu et al. 2016c-this volume), Baituyingzi (Sun et al. 2016b-this volume) and Gaogangshan (Zhang et al. 2016-this volume) deposits have been proven to be Dabie-type, whilst the Chalukou (Zhang and Li 2016-this volume), Diyanqin'amu (Wang et al. 2016d-this volume) and Suyunhe (Shen et al. 2016-this volume) giant porphyry Mo deposits are assigned Endako-type.

Zhong et al. (2016-this volume) contribute a review of the Mo mineralization in South China Block (Yangtze Craton + Huanan Orogen), based on a collection and synthesis of the available data obtained from 46 Mo-dominated and Mo-containing deposits, including porphyry and skarn types, followed by quartz-vein and greisen types. They elucidate that the deposits occur mainly in (1) Lower Yangtze River Belt, (2) northern Jiangnan Orogenic Belt, (3) Wuyi-Yunkai Orogenic Belt, and (4) Southeast Coastal Volcanic Belt. Ore ages cluster mainly in the period of 170–134 Ma (Early Yanshanian), followed by the span of 110–92 Ma (Late Yanshanian), with only a few in the span of 450–410 Ma (Caledonian). The Late Yanshanian mineralization mainly occurs in the Southeast Coastal Volcanic Belt and is characterized by coeval andesitic to felsic volcanic rocks related to the Paleo-Pacific plate subduction, whereas, the Early Yanshanian and Caledonian deposits are related to continental collision orogenies. They also address that the granites of S- and A-types commonly associated with Mo or W mineralization, whilst the I-type granitoids are usually associated with Cu-Mo systems. The understanding of Mo mineralization in South China Block is generally consistent with the results from case studies, such as the Tongcun (Ni et al. 2016a-this volume), Shizitou (Ni et al. 2016b-this volume), Dabaoshan (Huang et al. 2016a-this volume), Yuntoujie (Huang et al. 2016b-this volume), Huangcunnan (Cao et al. 2016b-this volume), Fujiawu (Li et al. 2016-this volume), Zhilingtou (Wang et al. 2016b-this volume) and Sanzhishu (Wang et al., 2016f-this volume). However, as commented by Zhong et al. (2016), these authors still prefer to interpret the early Yanshanian tectonic setting of the South China Block using the model mainly related to the westward subduction of the Pacific plate, or related to the continental collision of the South China Block with the North China Craton, Qiangtang-Indochina Block or the hypothesized Dongnanya continent.

Yang and Wang (2016-this volume) present an exciting summary and review of the Mo deposits in Southwest China, i.e. the Tibet Plateau and its marginal orogenic belt. They show that Mo mineralization in this area episodically occurred in the periods of 258–214 Ma, 73–88 Ma and 63–14 Ma, obviously associated with the significant terrane amalgamation or continental collision events. Yang et al. (2016a-this volume)