Ore Geology Reviews 65 (2015) 433–456

Contents lists available at ScienceDirect

Ore Geology Reviews

journal homepage: www.elsevier.com/locate/oregeorev

Review

# A review of the intracontinental porphyry deposits in the Middle-Lower Yangtze River Valley metallogenic belt, Eastern China

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ARTICLE INFO

*Article history:*
Received 30 June 2014
Received in revised form 5 October 2014
Accepted 6 October 2014
Available online 15 October 2014

*Keywords:*
Porphyry (-skarn) deposits
Magmatic-metallogenic model
Middle–Lower Yangtze River Valley
Metallogenic Belt
Intracontinental setting

ABSTRACT

The Middle-Lower Yangtze River Valley Metallogenic Belt (MLYB) is one of the most important metallogenic belts in eastern China, and contains many important porphyry deposits. These deposits include the Tongshankou Cu-Mo, Jiguanzui Cu-Au, Chengmengshan Cu-Mo, Wushan Cu-Mo, Fengshandong Cu-Au, Dingjiashan Cu, Yangjishan Au, Shaxi Cu-Au, Dongguashan Cu-Au, Shujiadian Cu and Anjishan Cu deposits, etc. In this review, we summarize the geological characteristics (including the stratigraphy, structure, ore-bearing porphyry types, vein characteristics and wall rock alteration), metallogenic ages and petro-geochemistry of representative porphyry deposits in the MLYB. We conclude that porphyritic magmatism and metallogeny have occurred in three stages. The Early (ca. 149–135 Ma) and Late (ca. 123–105 Ma) stages comprise mainly porphyry-skarn mineralization, whereas the Middle (ca. 133–125 Ma) stage comprises porphyry mineralization. Ore-bearing porphyries in the MLYB are the high-K calc-alkaline to calc-alkaline series, with the majority possess adakitic geochemical signature. The ore-bearing porphyries with adakitic signature may have originated from magma mixing, produced by the delamination of enriched lithospheric mantle and partial melting of the thickened lower crust. The enriched mantle-derived mafic melts component are very important for generating fertile magma, and the $\delta^{34}S$ and $\delta^{18}O$ values suggest that ore-forming materials were magma-derived. Compared with porphyry deposits in typical magmatic arc settings, porphyry deposits in the MLYB do not contain advanced argillic lithocaps or high- to intermediate-sulfidation systems, and the magmatic- and ore-forming material sources are also very different.



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http://dx.doi.org/10.1016/j.oregeorev.2014.10.002
0169-1368/

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## 1. Introduction

Porphyry deposits are responsible for three fourth of the world's copper (Cu) and one fifteenth of the world's gold (Au) (Sillitoe, 2010), with 97% of the giant-large porphyry Cu (Mo-Au) deposits being generated in island- or continental-arc settings (Cooke et al., 2005; Mitchell, 1973; Richards, 2003; Sillitoe, 1972). Nevertheless, recent studies indicate that porphyry deposits may also be formed in non-subduction environments, e.g., along continental collision orogeny and intracontinental setting (Chen, 2013; Hezarkhani, 2006a,b; Hezarkhani and Williams-Jones, 1998; Hou and Yang, 2009; Pirajno and Zhou, in press; Shafiei et al., 2009; Stocklin, 1974; Zarasvandi et al., 2005, 2007).

The Middle- Lower Yangtze Metallogenic Belt (MLYB) is one of the most important Cu-Au-polymetallic metallogenic belts in eastern China, and has been studied extensively in the past. Various hypotheses have been proposed concerning the regional metallogeny, with major ones including the "porphyrite iron deposit[1]" (NW Group, 1978), "stratabound skarn deposits[2]" (Chang and Liu, 1983; Chang et al., 1991) and the "superimposed metallogenic system[3]" (Chang et al., 2012; Zhai et al., 1992). With the discoveries of large porphyry Cu-Au deposits at Shaxi, Shujiadian and Baiyunshan in the recent years, porphyry deposits are becoming important exploration targets in the MLYB. Since there is little systematic regional study on the MLYB porphyry Cu-Au deposits, their nature and origin are still controversial, and are considered to be the products of intracontinental magmatism (Hou and Yang, 2009; Lv et al., 2014) or of the subduction of the Paleo-Pacific Plate (Ling et al., 2009, 2011; Liu et al., 2010a, b; Sun et al., 2010; Xie et al., 2012). Research on ore genesis and modeling are particularly necessary because shallow ore deposits have largely been discovered, while deeper or hidden ore deposits will become future exploration targets in the MLYB.

In this study, we have 1) Described and summarized the geological characteristics, magmatic-metallogenic ages, petrochemistry, ore deposit geochemistry and fluid characteristics of the major porphyry deposits in the MLYB in order to summarize a metallogenic pattern for the MLYB porphyry deposits; 2) Compared the major porphyry deposits in the MLYB with those generated in magmatic arcs in the world with a view construct a new MLYB regional porphyry metallogenic model; 3) To discuss the relationships between the MLYB porphyry metallogeny and the Yanshanian (Jurassic-Cretaceous) tectono-thermal event.

## 2. Geological background

The MLYB is located in the Yangtze tectonic depression along the northern margin of the Yangtze Block. The "V-shaped" MLYB is bounded by the Xiangfan-Guangji- and Tan-Lu faults to the northwest, and by the Yangxin-Changzhou Fault to the southeast (Fig. 1). The basement rocks are a Late Archean to Early Proterozoic metamorphic core complex and a thick flysch sequence intercalated with pelagic volcanic rocks, together with Late Proterozoic granitic rocks (Dong et al., 2011). The basement is overlain by a continuous Sinian (ca. 800–570 Ma)-Lower Triassic passive continental margin sedimentary sequence. The region has undergone intraplate deformation in the Middle Triassic, and has developed thick terrestrial sedimentary and volcanic sequences.

Since the Jinningian Period (ca. 850–800 Ma), the prolonged tectono-magmatic-metallogenic interactions have formed a faulted-uplift and depression tectonic framework and diverse Fe-Cu-Au-polymetallic ore deposits. A total of 200 ore deposits (prospects) have been documented in various ore concentration areas (OCAs). These OCAs, from west to east, are Edongnan, Jiurui, Anqing-Quichi, Lucong, Tongling, Ningwu and Ningzhen. Among these OCAs, Lucong and Ningwu are located in a volcanic rift basin, whereas Tongling, Anqing-Quichi, Jiurui, Ningzhen and Edongnan are located in a secondary uplift area. Rift basins and uplift areas were affected by different kinds of magmatism: Uplift areas (e.g., Tongling) are characterized by high-K calc-alkaline suites (including pyroxene monzodiorite, diorite and granodiorite), whereas rift basins (e.g., Ningwu and Lucong) contains high-Na calc-alkaline plutonic (e.g., pyroxene diorite and monzonite) and volcanic rocks (e.g., trachyandesite, trachyte, andesite and basalt). In addition, alkaline volcanic rocks (e.g., pseudoleucite phonolite and blue phonolite) occur in the late MLYB magmatic stage (Chang et al., 1991; Mao et al., 2004; NW Group, 1978; Xing and Xu, 1999; Zhou et al., 2005, 2008, 2011).

The MLYB contains diverse ore deposit types (Chang et al., 1991). In particular, the porphyry-, skarn- and magnetite-apatite type deposits constitute the majority of the Cu-Fe-Au metallogeny (Fig. 1), and are closely associated with the Yanshanian tectono-thermal events. In this study, we have focused on the major porphyry Cu (Mo-Au) deposits, including the Tongshankou Cu-Mo (Edongnan OCA), Jiguanzui Cu-Au (Edongnan OCA), Chengmengshan Cu-Mo (Jiurui OCA), Wushan Cu-Mo (Jiurui OCA), Fengshandong Cu-Au (Jiurui OCA), Dingjiashan Cu (Jiurui OCA), Yangjishan Au (Jiurui OCA), Shaxi Cu-Au (Lucong OCA), Dongguashan Cu-Au (Tongling OCA), Shujiadian Cu (Tongling OCA) and the Anjishan Cu (Ningzhen OCA) deposits (Fig. 1) .

## 3. Geological and geochemical characteristics of the MLYB porphyry deposits

### 3.1. Tongshankou Cu-Mo deposit

The Tongshankou deposit, located at ca. 20 km southwest of the Daye area, is a large porphyry-skarn deposit with 0.5 Mt Cu and 2000 t Mo (Li et al., 2008). Lithological sequences exposed in the mine include mainly those of Carboniferous, Permian and Triassic, with the Lower Triassic Daye carbonates being the major host rocks (Fig. 2). Orebodies occur mainly in a NNE-trending plunging anticline in the eastern part of the mine. Many faults are recognized in the mine. Among these are, the largely E-W trending ones (located along the anticlinal axis) which crosscut the main lithologies as well as the orebodies and were themselves intruded by later dykes. Minor mineralization has also been developed along these faults.

[1] "Porphyry iron deposit" are associated in time and space with continental volcanic and subvolcanic rocks (Ningwu Research Group, 1978).
[2] "Stratabound skarn deposits" : Orebodies occur as stratiform-like or lensoidal along the strata. They occur commonly along contacts or far away from intrusions. .
[3] "Superimposed metallogenic system": Spatial superimposition of different metallogenic episodes.