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Distribution of porphyry deposits in the Eurasian continent and their corresponding tectonic settings

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ABSTRACT

In the Eurasian continent there are three huge metallogenic belts of Cu and Mo porphyry deposits, comprising the Paleozoic Central Asian Ore Belt in the north, the Tethyan Eurasian Ore Belt of Jurassic to Cenozoic age in the southwest, and the East Margin Ore Belt of the Eurasian Continent of Jurassic to Cretaceous age in the east. The latter is considered to be part of the vast Circum-Pacific ore belt. Some of the main features of the spatial–temporal distribution of Cu and Mo porphyry systems and related geodynamic processes of the three metallogenic belts are described. In particular, the key role of post-subduction – related porphyry ore systems is emphasized, comprising collisional and post-collisional Cu–Mo porphyry deposits during the geological history of the Eurasian continent. The recurrent feature of these ore systems and related felsic rocks is their derivation from partial melting of stagnant or residual oceanic slabs, and mixing with a variable amount of crustal material during magma ascent to shallower levels.

1. Introduction

Porphyry deposits constitute one of the world's major sources of Cu and Au and are a major exploration target due to the high demand for these resources (Sillitoe, 2010). In the past 40 years geoscientific research has been mostly directed at the western continental margins of North and South America, and the Southwest Pacific Islands. Indeed, our knowledge and understanding of genetic models for porphyry systems is largely from the research focus on the Circum-Pacific continental and oceanic margins.

In contrast, many porphyry deposits in the Eurasian continent are less known and do not enjoy the benefit of the same intensive research as those of the Circum-Pacific belts. The porphyry systems in the Eurasian continent are distributed throughout a large span of geological history, from the Mesoproterozoic to the Cenozoic. In the Phanerozoic, there are three large orogenic belts in which porphyry deposits are found (Fig. 1), namely: the Paleozoic Central Asian Orogenic Belt (CAOB), the Tethyan Eurasian Orogenic Belt (TEOB) (or Meso-Neotethys orogenic belt) of Jurassic to Cenozoic age, and the East Margin of the Eurasian Continent (EMEC) of Jurassic to Cretaceous, which is considered part of the Circum-Pacific continental margin belt.

2. Porphyry deposits in the Central Asian Orogenic Belt (CAOB)

Major Cu–Au and Cu–Mo porphyry deposits are distributed over an interval of almost 5000 km across central Eurasia, from the Urals Mountains in Russia in the west, though the Central Asian countries, Mongolia, Xinjiang (NW China), Inner Mongolia and Northeast China to the east (Seltmann et al., 2013, 2014; Yakubchuk et al., 2012; Yang et al., 2012; Goldfarb et al., 2013). These deposits formed in magmatic arcs within the extensive subduction-accretion complex of the Central Asian Orogenic Belt (CAOB; or Altaids) and Transbaikal-Mongolian Orogens, from the late Neoproterozoic, through the Paleozoic to the Jurassic. These arcs were predominantly located on the Paleo-Tethys Ocean margin of the proto-Asian continent, but are also associated with the closure of two back-arc basins behind the ocean-facing margin. During the mid-Paleozoic, the two main cratonic components of the proto-Asian continent, the Siberian and Eastern European cratons (Fig. 2), began to rotate relative to each other, "drawing-in" the two sets of parallel arcs to form the Kazakh Orocline between the two cratons. In the Late Devonian and the Early Carboniferous, the Khanty-Mansi back-arc basin began subducting beneath the oroclinally infolded outer island arc mass to form the Valerianov-Beltau-Kurama arc. At the same time, the Paleo-Pacific Ocean began subducting beneath the Siberian craton to form the Sayan-Transbaikal arc, which by the Permian expanded to become the Selanga-Gobi-Khanka arc, and for a period was continuous with the

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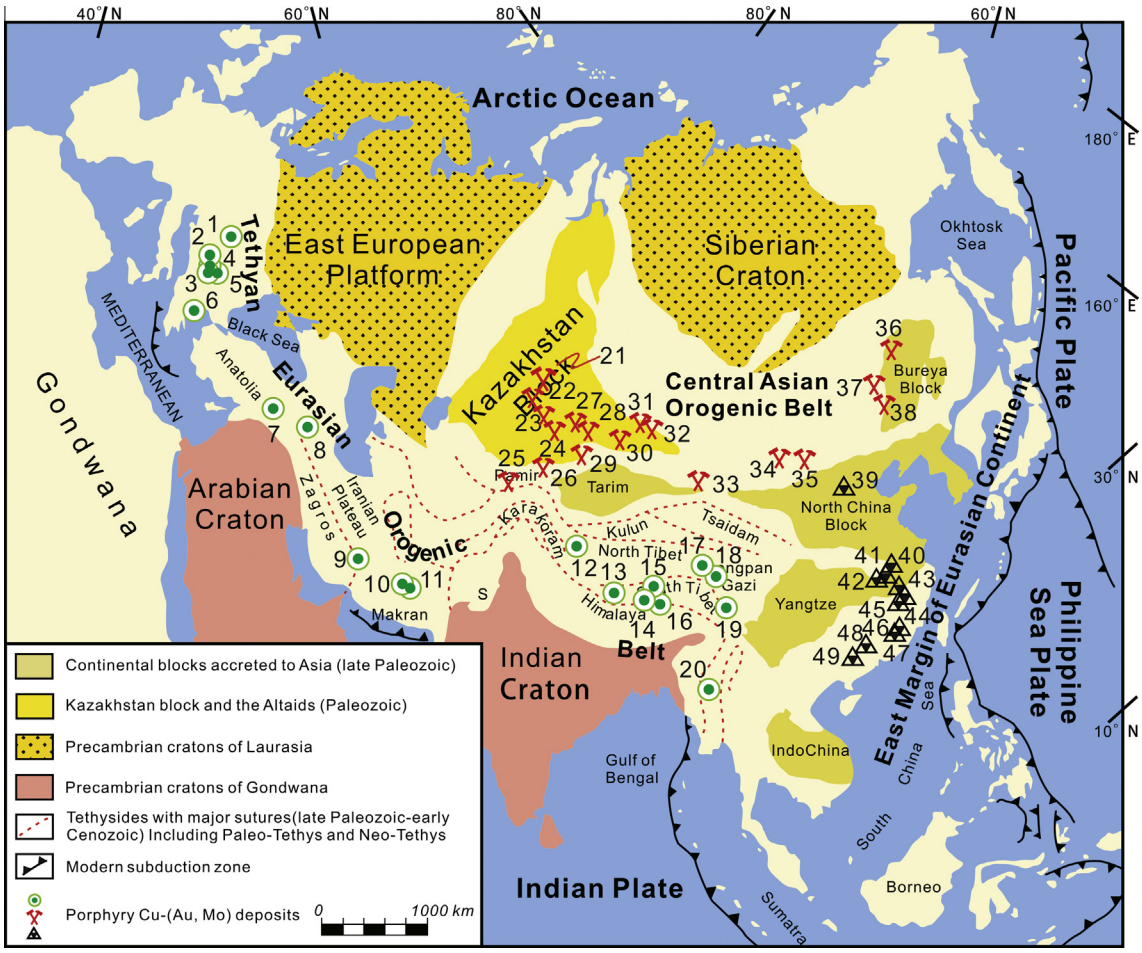

Fig. 1. Map showing distribution of the porphyry copper deposits in the Eurasian continent (modified after Sengor (1987) and Sorkhabi and Heydari (2008); deposit data collected from Singer et al. (2005), Shen et al. (2010) and Mao et al. (2013)) Name of deposits: 1-Resck, 2-Rosia Poieni, 3-Bor, 4-Majdanpek, 5-Veliki Kvivelj, 6-Skouries, 7-Copler, 8-Sar Cheshmeh, 9-Sungun, 10-Saindak, 11-Reko Diq, 12-Duobuzha, 13-Xiongcun, 14-Qulong, 15-Jiama, 16-Nuri, 17-Yulong, 18-Malasongduo, 19-Pulang, 20-Monywa, 21-Bozshakol, 22-Samarsk, 23-Borly, 24-Balkash, 25-Kal' makyr, 26-Taldy Bulak, 27-Sayak, 28-Aktogai, 29-Koksai, 30-Baogutu, 31-Xilekuduke, 32-Yulekenhalasu, 33-Tuwu, 34-Oyu-Tolgoi, 35-Bainaimiao, 36-Duobaoshan, 37-Wunugetushan, 38-Budunhua, 39-Mujicun, 40-Dongguashan, 41-Chengmenshan, 42-Fengshandong, 43-Dexing, 44-Yinshan, 45-Yongping, 46-Luoboling, 47-Zijinshan, 48-Dabaoshan, 49-Yuanzhuding.

Kazakh-Mongol arc. By the Mid to Late Permian, as the Kazakh Orocline had continued to develop, both the Sakmara and Khanty-Mansi back-arc basins closed and the collage of cratons and arcs was sutured by accretionary complexes. During the Permian and Triassic, the North China craton approached and docked with the Siberian plate, closing the Mongol-Okhotsk sea (an embayment on the Paleo-Pacific margin) to form the Mongolian Orocline. Subduction and arc building activity on the Paleo-Pacific Ocean margin continued to the Mid Mesozoic as the Indo-Sinian and Yanshanian orogenic cycles (Seltmann and Porter, 2005, and references cited therein).

The most important porphyry Cu–Au–Mo and Au–Cu porphyry as well as epithermal Au systems (Fig. 2) are, according to age:

(1) *Ordovician*: The Kipchak arc (e.g., Bozshakol Cu–Au in Kazakhstan, Taldy Bulak porphyry Au–Cu in Kyrgyzstan); the Duobaoshan island arc in Northeast China (e.g., Duobaoshan and Tongshan porphyry Cu–Au–Mo); the Bainaimiao island arc in East Inner Mongolia (e.g., Bainaimiao Cu–Au).
(2) *Silurian to Devonian*: The Kazakh-Mongol arc (e.g., Nurkazgan Cu–Au in Kazakhstan; Taldy Bulak–Levoberezhny Au in Kyrgyzstan); the Urals-Zharma arc (e.g., Yubileinoe Au–Cu in Russia); the Kazakh-Mongol arc (e.g., Oyu Tolgoi Cu–Au, and Tsagaan Suvarga Cu–Au, both in Mongolia).
(3) *Carboniferous*: The Kazakh-Mongol arc (e.g., Kharmagtai Au–Cu in Mongolia, Tuwu-Yandong Cu–Mo in Xinjiang, China; Koksai Cu–Au, Sayak skarn Cu–Au, Kounrad Cu–Au and the Aktogai group of Cu–Au deposits, all in Kazakhstan); the Valerianov-Beltau-Kurama arc (e.g., Kal'makyr-Dalnee Cu–Au and Kochbulak epithermal Au, both in Uzbekistan; Benqala Cu–Au in the southeast Urals of Kazakhstan; Baogutu Cu–Au–Mo, and Halasu porphyry Cu–Mo in Xinjiang, China).
(4) *Triassic*: The Selanga-Gobi-Khanka arc (e.g., Erdenet Cu–Mo in Mongolia, Badaguan and Taipingchuan porphyry Cu–Mo in Inner Mongolia, China).
(5) *Jurassic*: The Selanga-Gobi-Khanka arc (e.g., Wulugetushan Cu–Mo in Inner Mongolia, China).

Precise age data indicate that the ages of the porphyry Cu mineralization in the CAOB shift from east to west and from north to south from Ordovician to Late Carboniferous (Fig. 2), following the magmatic fronts of the accretionary orogen (Sengor et al., 1993). Most porphyry Mo deposits occurred in post-collisional settings along the Urals, Tianshan to Xilamulun sutures. The representative porphyry Mo deposits are Shameika in the Urals (molybdenite Re–Os ages of 273 ± 5 and 282 ± 6 Ma; Mao et al., 2003a), Baishan and Gebitan in East Tianshan, China (Re–Os ages of 224.8 ± 4.5 Ma, Zhang et al., 2005, and 231.9 ± 6.5 Ma, Wu