ZHOU Taofa, WANG Shiwei, FAN Yu, YUAN Feng, ZHANG Dayu and Noel White, 2014. Characteristics of the Intracontinental Porphyry Deposits in the Middle-Lower Yangtze River Valley Metallogenic Belt, Eastern China. *Acta Geologica Sinica* (English Edition), 88(supp. 2): 667-669.

Characteristics of the Intracontinental Porphyry Deposits in the Middle-Lower Yangtze River Valley Metallogenic Belt, Eastern China

ZHOU Taofa*, WANG Shiwei, FAN Yu, YUAN Feng, ZHANG Dayu and Noel White

School of Resources and Environmental Engineering, Hefei University of Technology, Hefei 230009, China

Porphyry deposit system generates 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 magmatic arc setting (Richards; 2003; Cooke et al., 2005; Sillitoe, 2010). Nevertheless, recent studies indicate that important porphyry deposits may also be formed in subduction-unrelated environments, e.g., along continental collision-related orogeny and intracontinental setting (Hou et al., 2009; Chen, 2013; Zhou et al., 2011).

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 (Zhou et al., 2008). Various models have been proposed concerning the regional metallogeny, with major ones including the "porphyrite iron deposit" (NW Group, 1978), "stratabound skarn deposits" (Chang et al., 1991) and the "superimposed metallogenic system" (Zhai et al., 1992; Chang et al., 2012). With the discoveries of large porphyry Cu-Au deposits at Shaxi and Shujiadian in the recent years addition to the previous discovered porphyry deposits such as Chengmenshan and Fengshandong and other deposits, porphyry deposits are becoming more important exploration targets in the MLYB. Their nature and origin are still controversial, and are attributed variably to be the products of intracontinental magmatism (Hou et al., 2009; Chen, 2013; Zhou et al., 2011) or of the subduction of the Paleo-Pacific Plate (Ling et al., 2009, 2011; Liu et al., 2010; Sun et al., 2010; Xie et al., 2012), and recent study are more and more tend to the former point (Chen et al., 2014; Lv et al., 2014; Wang et al., 2014).

To further illustrate the differences between the porphyry deposits formed in intracontinental setting and magmatic (continental or island) arc setting, we have chosen typical continental margin arc porphyry deposits, i.e., Bingham Canyon (US) and Bajo de la Alumbrera (Central Andes); island arc porphyry deposits, i.e., Panguna (PNG) and Batu Hijau (Indonesia) to compare with the MLYB porphyry deposits. It is summarized that:

1. Distribution of magmatic (continental or island) arc-generated porphyry deposits is commonly linear, and is parallel to the orogeny and perpendicular to the subduction zone (Sillitoe, 2010). The MLYB porphyry deposits are distributed along the Yangtze Fault, oblique to the Paleo-Pacific subduction zone.

2. Magmatic arc-generated porphyry metallogenic systems are commonly preceded by calc-alkaline or alkaline felsic volcanism (Sillitoe, 1973) that occurs ca. 0.5 – 3 Ma prior to the porphyry emplacement, as evidenced at Bingham (Waite et al., 1997), Farallón Negro (Argentina; Sasso and Clark, 1998; Halter et al., 2004), Yerington (Dilles and Wright, 1988; Dilles and Proffett, 1995), Tampakan, Philippines (Rohrlach and Loucks, 2005) and Yanacocha (Longo and Teal, 2005). No coeval (or similar age) volcanism with the porphyry deposits has been documented in the MLYB.

3. Types of wall rocks vary in different deposits, suggesting porphyry Cu deposits are indiscriminative towards their wall rocks. Wall rocks for magmatic arc-generated porphyry deposits are commonly volcaniclastic rocks, whereas wall rocks for the intracontinental MLYB porphyry deposits contain sandstone (e.g., Shaxi) and carbonates (e.g., Tongshankou).

4. Major metal sulfides in the MLYB include chalcopyrite, pyrrhotite, pyrite,and bornite. Pyrrhotite is closely associated with skarn, and may suggest the reducing nature of the wall rocks (Kósaka and Wakita, 1978; Perelló et al., 2003), in accordance with the formation of magmatic arc-generated porphyry deposits (Sillitoe, 2010). The MLYB porphyry deposits contain the same vein types as typical magmatic arc-generated porphyry deposits, but with different vein type proportion:

* Corresponding author. E-mail: tfzhou@hfut.edu.cn

In arc-generated porphyry deposits, veins of the potassic alteration stage have contributed most of the metals for the deposits; whereas in the MLYB porphyry deposits, veins of the potassic-phyllic alteration transition stage have contributed most of the metals for the deposits (Yuan et al., 2012).

5. The MLYB porphyry deposits contain basically the same alteration types and similar zonations as in typical magmatic arc-generated porphyry deposits. Nevertheless, advanced argillic lithocaps and shallow intermediate-high sulfidation alteration do not commonly appear in the MLYB porphyry deposits, which may have been a result of prolonged erosion. Compared with typical magmatic arc-generated porphyry deposits, alteration in the sedimentary strata at the Shaxi- and Shujiadian deposits is less developed, and the ores in these two deposits occur mainly as veins. This may have been caused by the sandstone wall rocks, which are more stable and are thus less likely to be altered. In contrast, wall rocks of typical magmatic arc-generated porphyry deposits (commonly volcanoclastic rocks) are more prone to alteration.

6. In general, magmatic rocks associated with porphyry ore formation are of calc-alkaline series. Ore-bearing porphyries in typical continental arc setting are mainly calc-alkaline and minor high-K calc-alkaline, with rock types include granodiorites and quartz monzonites (Singer et al., 2005); Ore-bearing porphyries in typical island arc setting are typically calc-alkaline, with rock types include granodiorites, quartz monzonites and syenites (Misra, 2000). Compared with these arc-related porphyries, the MLYB ore-bearing porphyries are mainly calc-alkaline to high-K calc-alkaline.

7. Typical magmatic arc-generated ore-bearing porphyries are generally considered to be formed by partial melting of metasomatized mantle wedge (Richards 2003, 2005). As discussed earlier, the MLYB ore-bearing porphyries are better ascribed to be formed by magma mixing between an enriched mantle-derived mafic magma and a magma generated by partial melting of the thickened lower crust.

8. Ore-forming materials for typical magmatic arc-generated porphyry deposits are mainly originated from oceanic plates, when dehydration carries substantial amount of H_2O, S, Cl and metals to the overlying mantle wedge (Tatsumi et al., 1986; De Hoog et al., 2001), which gives good ore-forming potential for mantle wedges. Ore-forming materials for the MLYB porphyry deposits were most likely to be originated from enriched mantle-derived mafic magmas. The ore-forming fluid of the porphyry deposits in the MLYB were magma-derived, and there was late stage meteoric water involvement, similar to typical magmatic arc-generated porphyry deposits (Sillitoe, 2010).

To summarize, the MLYB porphyry deposits contain fundamentally the same geological characteristics as typical magmatic arc-generated porphyry deposits, but their major mineralization vein types are different, and argillic alteration does not occur. The nature of magma source and origin of ore-forming materials are the major differences between the MLYB porphyry deposits and those of typical magmatic arc-generated porphyry deposits.

Acknowledgements

Thanks to fund supported by the National Natural Science Foundation of China (grant no. 41320104003; 41172086; 41172084; 40830426), China Geological Survey (grant no. 1212011121115; 1212011220369; SinoProbe-03-02-05), and Public Welfare Project of Anhui Province (grant no. 2009-g-22), CODES Funding (Project No. P2.B1B.), Centre of Excellence, University of Tasmania.

References

Chang, Y.F., Liu, X.P., Wu, C.Y., 1991. The Copper-Iron Belt of the Lower and Middle Reaches of the Changjiang River. Beijing: Geological Publishing House. 1-379 (in Chinese).

Chang, Y.F., Zhou, T.F., Fan, Y., 2012. Polygenetic compound mineralization and tectonic evolution: Study in the Middle-Lower Yangtze River Valley metallogenic belt. Acta Petrol. Sinica. 28(10): 3067-3075 (in Chinese with English abstract).

Chen, L., Zhao, Z.F., Zheng, Y.F., 2014. Origin of andesitic rocks: Geochemical constraints from Mesozoic volcanics in the Luzong basin, South China. Lithos. (190-191): 220–239.

Chen, Y.J., 2013. The development of continental collision metallogeny and its application. Acta Petrologica Sinica. 29 (1): 1-17 (in Chinese with English abstract).

Cooke, D.R., Hollings, P., Walshe, J.L., 2005. Giant porphyry deposits: characteristics, distribution, and tectonic controls. Econ.Geol. 100: 801-818.

De, Hoog, J.C.M., Mason, P.R.D., Van, Bergen, M.J., 2001. Sulfur and chalcophile element s in subduction zones : Constraints from a laser ablation ICP-MS study of melt inclusions from Galunggung Volcano , Indonesia. Geochim.Cosmochim.Acta. 65: 3147-3164.

Dilles, J.H., and Proffett, J.M., 1995. Metallogenesis of the Yerington batholith, Nevada. Arizona Geological Society Digest. 20: 306-315.

Dilles, J.H., Wright, J.E., 1988. The chronology of early Mesozoic arc magmatism in the Yerington district, Nevada, and its regional implications. Geol.Soc.Am.Bull. 100: 644-652.

Halter, W.E., Bain, N., Becker, K., Heinrich, C.A., Landtwing, M., VonQuadt, A., Clark, A.H., Sasso, A.M., Bissig, T., Tosdal, R.M., 2004, From andesitic volcanism to the formation of a porphyry Cu-Au mineralizing magma chamber: the Farallón Negro Volcanic Complex, northwestern Argentina. J. Volcanol. Geotherm. Res.136: 1-30.

Hou, Z.Q., Yang, Z.M., 2009. Porphyry deposits in continental settings of China: Geological characteristics, magmatic-hydrothermal system, and metallogenic model. Acta Geol.Sinica. 83(12): 1779-1817 (in Chinese with English abstract).

Kósaka, K., and Wakita, K., 1978. Some geological features of the Mamut porphyry copper deposit, Sabah, Malaysia: Econ.Geol. 73: 618-627

Ling, M.X., Wang, F.Y., Ding, X., Hu, Y.H., Zhou, J.B., Zartman, R.E., Yang, X.Y., Sun, W.D., 2009. Cretaceous ridge subduction along the Lower Yangtze River Belt, eastern China. Econ. Geol. 104: 303-321.

Ling, M.X., Wang, F.Y., Ding, X., Zhou, J.B., Sun, W.D., 2011. Different origins of adakites from the Dabie Mountains and the Lower Yangtze River belt in eastern China: Geochemical constraints. Int.Geol.Rev. 53: 727 - 740.

Liu, S.A., Li, S.G., He, Y.S., Huang, F., 2010. Geochemical contrasts between early Cretaceous ore-bearing and ore-barren high-Mg adakites in central-eastern China: Implications for petrogenesis and Cu-Au mineralization. Geochim.Cosmochim.Acta 74: 7160-7178 .

Longo, A.A., and Teal, L., 2005. A summary of the volcanic stratigraphy and the geochronology of magmatism and hydrothermal activity in the Yanacocha gold district, northern Peru, in Rhoden, H.N., Steininger, R.C., and Vikre, P.G., eds., Symposium 2005: Window to the world, v. 2: Reno/Sparks, Geological Society of Nevada. 797-808

Lv, Q.T., Dong, S.W., Shi, D.N., Tang, J.T., Jiang, G.M., Zhang, Y.Q., Xu, T., Sinoprobe-03-CJ Group., 2014. Lithosphere architecture and geodynamic model of Middle and Lower Reaches of Yangtze Belt: A review from SinoProbe. Acta Petrol. Sinica. 30(4). 889-906 (in Chinese with English abstract).

Misra, K.C., 2000. Understanding Miner.Depos.[M]. Kluwer Academic Publishers. 353-413.

Ningwu Project Group., 1978. The porphyrite iron deposit of Ningwu. Beijing: Geological Publishing House. 1-320 (in Chinese).

Perelló, J., Posso, H., Zárate, A., Neyra, C., Caballero, A., and Stein, H., 2003. Syntectonic Ag-rich porphyry copper mineralization at Pachagón, northern Peru [abs.]: Congreso Geológico Chileno, 10th, Concepción, 2003, CD-ROM, 1 p.

Richards, J.P., 2003. Tectono-magmatic precursors for porphyry Cu-(Mo-Au) deposit formation. Econ.Geol. 98: 1515-1533.

Richards, J.P., 2005. Cumulative factors in the generation of giant calc-alkaline porphyry Cu deposits. in Porter, T.M., ed., Super porphyry copper and gold deposits: A global perspective, v. 1: Adelaide, PGC Publishing. 7-25.

Rohrlach, B.D., Loucks, R.R., 2005. Multi-million-year cyclic ramp-up of volatiles in a lower crustal magma reservoir trapped below the Tampakan copper-gold deposit by Mio-Pliocene crustal compression in the southern Philippines, in Porter, T.M., ed., Super porphyry copper and gold deposits: A global perspective. Adelaide, PGC Publishing, 2: 369-407.

Sasso, A.M., and Clark, A.H., 1998. The Farallón Negro Group, northwest Argentina: Magmatic, hydrothermal and tectonic evolution and implication for Cu-Au metallogeny in the Andean back-arc. Soc.Econ.Geol.Newsletter. 34, 1: 8-18.

Sillitoe, R.H., 1973. The tops and bottoms of porphyry copper deposits: Econ.Geol. 68: 799-781.

Sillitoe, R.H., 2010. Porphyry copper systems. Econ. Geol. 105: 3-41.

Singer, D.A., Menzie, W.D., and Berger, B.R., 2005. Porphyry copper deposit density: Econ.Geol.100: 491-514

Sun, W.D., Ling, M.X., Yang, X.Y., Fan, W.M., Ding, X., Liang, H.Y., 2010. Ridge subduction and porphyry copper gold mineralization: An overview. Sci China Earth Sci 40(2): 127-137 (in Chinese with English abstract).

Tatsumi, Y., Hamilton, D.L., Nesbitt, R.W., 1986. Chemical characteristics of fluid phase released from a subducted lithosphere and the origin of arc magmas: evidence from high pressure experiments and natural rocks. J. Volcanol. Geotherm. Res. 29: 293-309.

Wang, S.W., Zhou, T.F., Yuan, F., Fan, Y., Yu, C.H., Ge, L.H., Shi, C., Chi, Y.Y., 2014. Emplacement sequences and geochronology of the Shaxi porphyry copper-gold deposit, Anhui Province, East China. Acta Petrol. Sinica. 30(4): 979-994 (in Chinese with English abstract).

Waite, K.A., Keith, J.D., Christiansen, E.H., Whitney, J.A., Hattori, K., Tingey, D.G., Hook, C.J., 1997, Petrogenesis of the volcanic and intrusive rocks associated with the Bingham Canyon porphyry Cu-Au-Mo deposit, Utah: Soc.Econ.Geol.Guidebook Ser. 29: 69-90

Xie, J.C., Chen, S., Sun, W.D., Yang, X.Y., 2012. Geochemistry of Early Cretaceous adakitic rocks in Tongling region of Anhui Province: Constraints for rock-and ore-forming. Acta Petrol. Sinica. 28(10): 3181-3196 (in Chinese with English abstract).

Yuan, F., Zhou, T.F., Wang, S.W., Fan, Y., Tang, C., Zhang, Q.M., Yu, C.H., Shi, C., 2012. Characteristics of alteration and mineralization of the Shaxi porphyry copper deposit, Luzong area, Anhui Province. Acta Petrol. Sinica. 28(10): 3099-3112 (in Chinese with English abstract).

Zhai, Y.S., Yao, S.Z., Ling, X.D., 1992. Regularities of Metallogenesis for Copper (Gold) Deposits in the Middle and Lower Reaches of the Yangtze River Area. Beijing: Geological Publishing House. 1-120 (in Chinese).

Zhou, T.F., Fan, Y., Yuan, F., 2008. Advances on petrogenesis and metallogeny study of the mineralization belt of the Middle and Lower Reaches of the Yangtze River area. Acta Petrol. Sinica 24(8): 1665-1678 (in Chinese with English abstract).

Zhou, T.F., Fan, Y., Yuan, F., Zhang, L.J., Ma, L., Qian, B., Xie, J., 2011. Petrogenesis and Metallogeny Study of the Volcanic Basins in the Middle and Lower Yangtze Metallogenic Belt. Acta Geol.Sinica 85(5): 712-730 (in Chinese with English abstract).