SUN Xiang, ZHENG Youye, WU Song, LI Miao, Ouyang Haitao and GENG Ruirui 2013. Mafic enclaves at Jiru porphyry Cu deposit, southern Tibet: Implication for the Eocene magmatic-hydrothermal Cu mineralization *Acta Geologica Sinica* (English Edition), 87(supp.): 778-782.

Mafic enclaves at Jiru porphyry Cu deposit, southern Tibet: Implication for the Eocene magmatic-hydrothermal Cu mineralization

SUN Xiang[1,2*], ZHENG Youye[1,3], WU Song[1], LI Miao[1], Ouyang Haitao[1] and GENG Ruirui[1]

1 *State Key Laboratory of Geological Processes and Mineral Resources, and School of Earth Science and Resources, China University of Geosciences, Beijing, 100083, China*
2 *Key Laboratory of Continental Collision and Plateau Uplift, Institute of Tibet Plateau Research, Chinese Academy of Sciences, Beijing, 100085, China*
3 *State Key Laboratory of Geological Processes and Mineral Resources, China University of Geosciences, Wuhan, 430074,*

The Jiru porphyry Cu deposit in the Gangdese porphyry Cu belt, southern Tibet, is characterized by two magmatic-hydrothermal mineralization caused by the Eocene monzogranite and Miocene monzogranite porphyry, respectively. Compared to the widespread Miocene porphyry Cu mineralization during 12~18 Ma, the Eocene Cu mineralization in the southern Tibet receives much less attention. This paper aims to the mafic enclaves hosted in the monzogranite which were suggested to form by melting of subducted Tethyan oceanic slab. The mixing between the mafic and felsic pluton magmas could provide contribution for the magmatic-hydrothermal Cu mineralization in the Jiru Eocene monzogranite.

Key words: mafic enclave; porphyry deposit; magmas mixing; southern Tibet; Jiru

1 Introduction

Porphyry Cu deposits are characterized by their large tonnages and relatively low grades, the disseminated, quartz veins and stockworks, and breccia type ores, large scale hydrothermal alteration, and occurrence in and around felsic porphyritic intrusions. These felsic porphyries are intrusive complexes typically composed of multiple stocks, pipes, dykes and breccias, which are located within or near the precursor plutons. The precursor pluton is often equigranular intrusive rocks and composed of early dioritic rocks and late felsic rocks. Meanwhile, the porphyritic intrusions and porphyry Cu deposits are often located within the late felsic rocks (Sillitoe, 2010). Therefore, the precursor pluton can be considered the host rocks of fertile porphyries.

The Gangdese Porphyry Copper Belt (GPCB) is located in the southern Tibet and contains the largest porphyry Cu deposit in China, at Qulong with >10 Mt (metal) Cu reserves, as well as many other large and medium sized deposits associated with 18-12 Ma felsic porphyritic intrusions (Rui et al., 2003; Zheng et al., 2004; Hou et al., 2009). The Jiru porphyry Cu deposit is located in the western Namling area, where monzogranitic pluton and monzogranite porphyry exposed. Once we considered that the monzogranite was the precursor pluton without potential mineralization and the intruded monzogranite porphyries were the prospecting target, similar to other large porphyry Cu deposits in the eastern GPCB (Fig. 1). However, the zircon SHRIMP U-Pb data show that the monzogranite was formed at 48.6 ±0.8 Ma, different from the monzogranite porphyry generated at 16.0 ±0.4 Ma (Zheng et al., 2013). Furthermore, it is amazing that the monzogranitic pluton at Jiru deposit is associated with early magmatic-hydrothermal Cu mineralization event, with age of 44.9 Ma based on molybdenite Re–Os data, and the monzogranite porphyry is also associated with the late porphyry Cu mineralization event at ca. 15.2 Ma (Zheng et al., 2013). These data indicate that the pluton in the porphyry ore area also should be studied to evaluate its mineralization potential. In this paper, we present geochronological and geochemical data of mafic enclaves hosted in the monzogranitic pluton and analyze its contribution to the Eocene magmatic-hydrothermal Cu mineralization.

2 Geologic Setting

The Himalayan Tibetan Plateau consists of four terranes including the Himalaya, Lhasa, Qiangtang, and Songpan-Ganzi from south to north. The Lhasa terrane is bounded

* Corresponding author. E-mail: sunxiang8003@sina.com

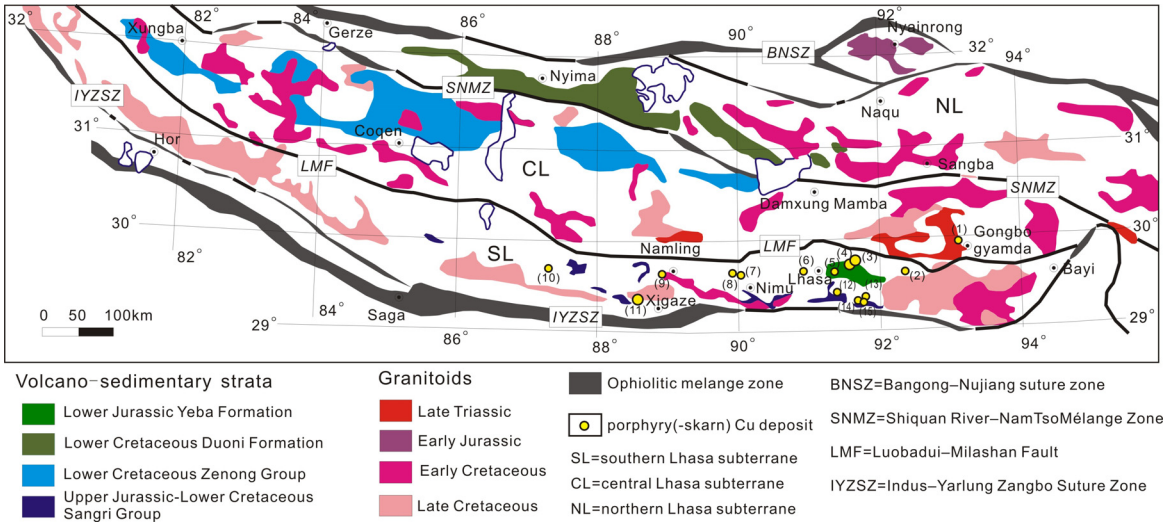

Fig. 1 Simplified geologic map of the Gangdese porphyry Cu belt (after Zheng et al., 2013).
The numbers denoting the deposits are as follows: (1) Tangbula, (2) Cuibaizi, (3) Jiama, (4) Qulong, (5) Lakange, (6) Dabu, (7) Tinggong, (8) Chongjiang, (9) Jiru, (10) Zhunuo, (11) Xiongcun, (12) Kelu, (13) Chongmuda, (14) Nuri, (15) Mingze.

by the Bangong – Nujiang suture zone to the north and by the Indus – Yarlung Zangbo suture zone to the south and is subdivided into the northern, central, and southern subterranes by the Shiquan River – Nam Tso Mélange Zone and Luobadui –Milashan Fault, respectively (Fig. 1). The GPCB is located in the southern Lhasa subterrane and experienced a complex tectonic history from the Early Jurassic subduction of the Neo-Tethyan Ocean to the Cenozoic India-Asian continental collision, resulting four epochs of magmatism, i.e., 205–175 Ma, 100–80 Ma, 65-41, and 33–13 Ma (Ji et al., 2009). The 33–13 Ma granitic porphyries were associated with the widespread Miocene porphyry Cu mineralization in the southern Tibet.

3. Deposit Geology of Jiru Porphyry Cu Deposit

The Jiru porphyry Cu deposit has three distinct orebodies containing 0.18 Mt of Cu metal, with an average grade of 0.43%, as well as 2400t of Mo metal, with an average grade of 0.09%. Orebodies I and II are exposed at the surface, and Orebody III is located at depths of 160-280 m below the surface between Bore ZK101 and Bore ZK201 (Fig. 2). The orebodies are mainly hosted in the monzogranite, but to a lesser extent in the monzogranite porphyry and diorite porphyry. Rhenium-Os ages of molybdenite from the monzogranite and monzogranite porphyry are 44.9±2.6 Ma and 15.2±0.4 Ma, slightly younger than ages of the host rocks (i.e., 48.6 ±0.8 Ma, 16.0 ±0.4 Ma), respectively (Zheng et al., 2013). These geochronological data indicate that there are two mineralization events at the Jiru deposit, in contrast to other porphyry deposits in the eastern part of the GPCB that are only Miocene in age.

Recently, we found that abundant mafic enclaves are hosted in both the

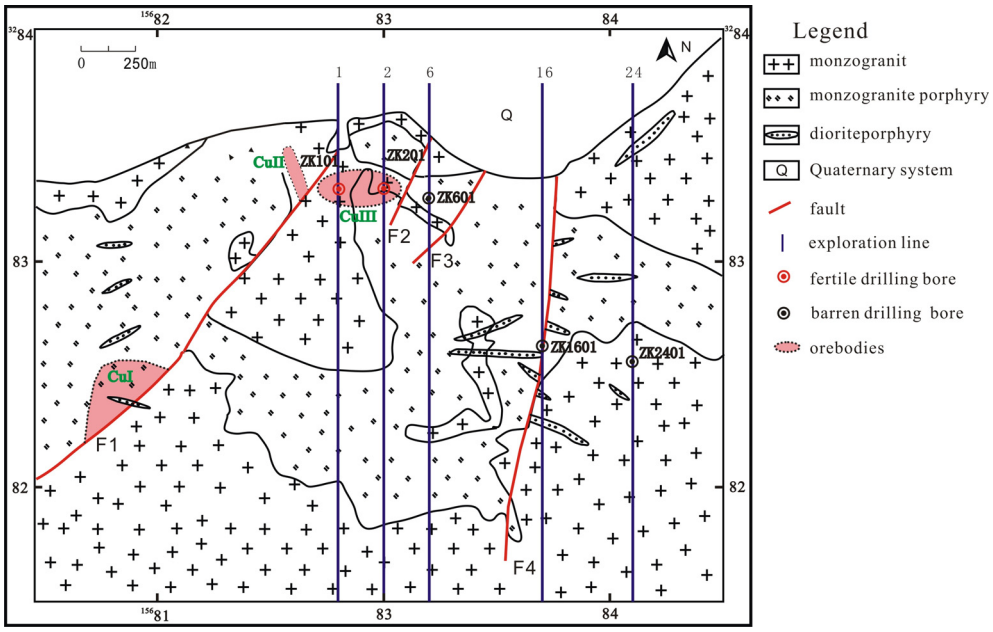

Fig. 2 Sketch geologic map of the Jiru porphyry copper deposit (after Zheng et al., 2013).

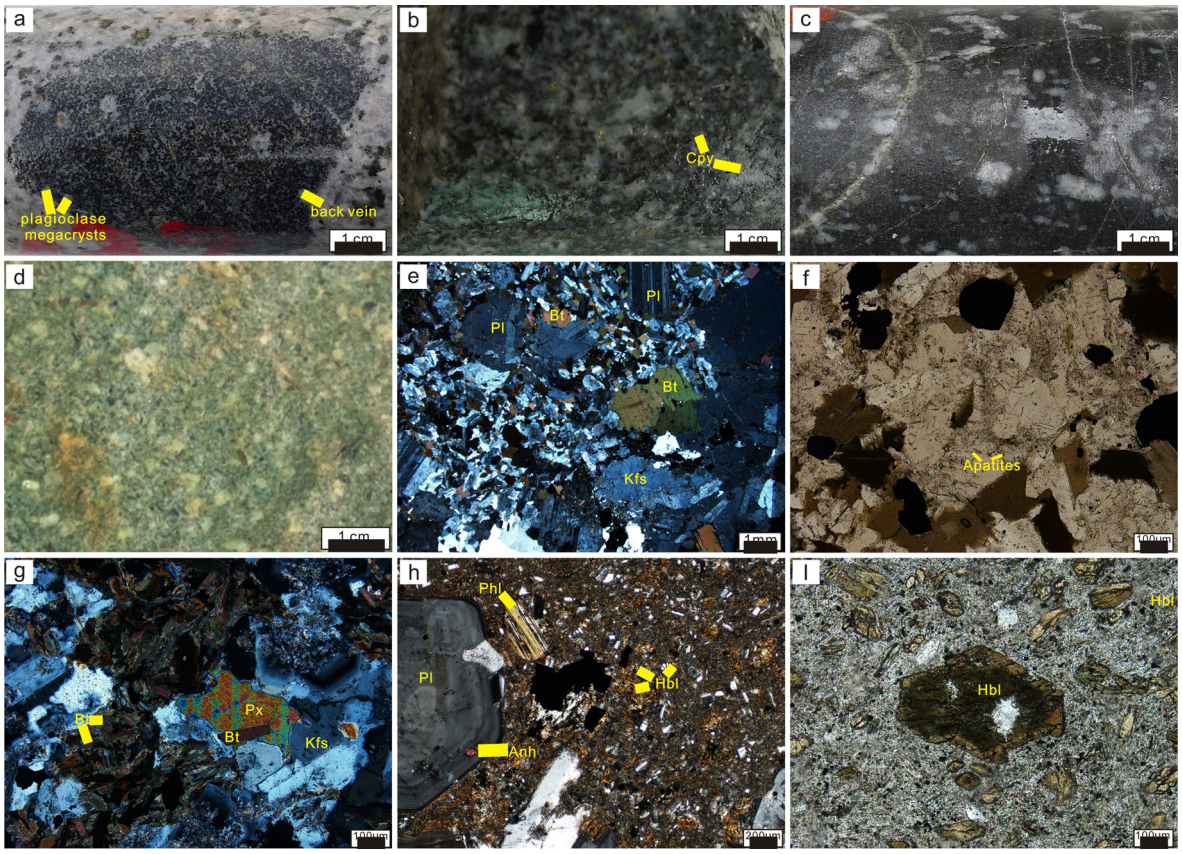

Fig. 3. Representative field and petrographic photographs at Jiru porphyry Cu deposit.
(a) mafic enclave is present in the Eocene monzogranite and show typical back vein and plagioclase megacrysts; (b) mafic enclave with disseminated chalcopyrite are present in the Miocene monzogranite porphyry; (c) early dioritic porphyry containing quartz-pyrite veinlets; (d) late dioritic porphyry; (e) plagioclase megacrysts in Eocene mafic enclave; (f) acicular apatites in Eocene mafic enclave; (g) euhedral pyroxene and fascicular phenocryst of secondary biotites in the Miocene mafic enclave; (h) phlogopite and plagioclase phenocrysts with inclusion of anhydrite in the early dioritic porphyry. The matrix experienced intensive sericitization; (i) euhedral hornblende phenocrysts in late dioritic porphyry.

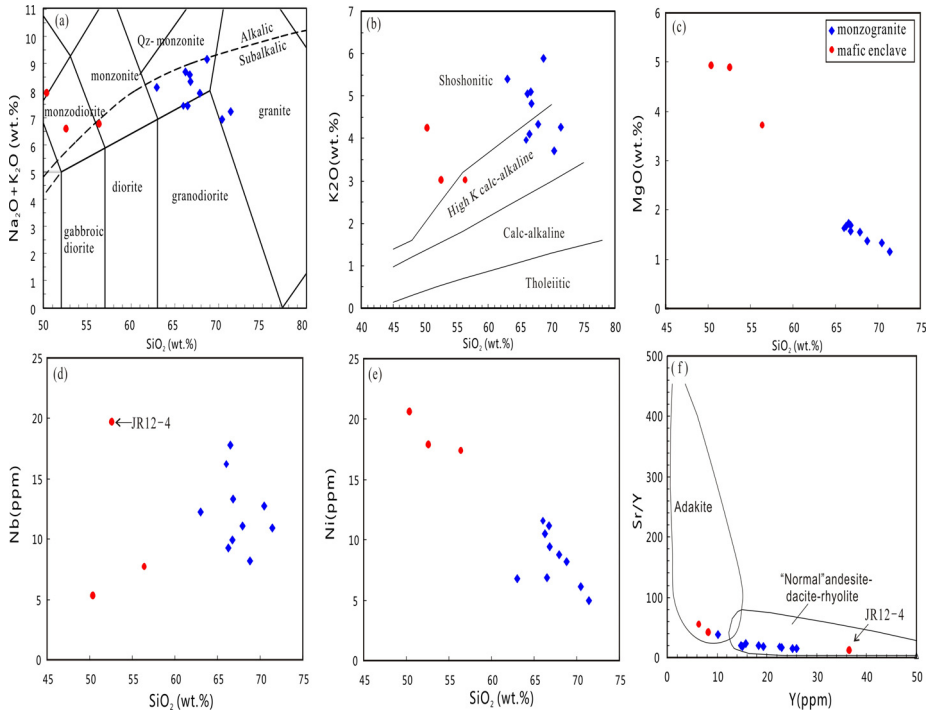

Fig.4. Discrimination diagrams for the Eocene monzogranite and hosted mafic enclave in Jiru porphyry Cu deposit.
(a) SiO_2 against K_2O+Na_2O; (b) SiO_2 against K_2O; (c) SiO_2 against MgO; (d) SiO_2 against Nb; (e) SiO_2 against Ni; (f) Y against Sr/Y ratios.

monzogranite and the monzogranite porphyry (Figs. 3a, b). The early mafic enclave and the host monzogranite have zircon U-Pb ages of 48.8Ma and 48.2 Ma, respectively. The late mafic enclave and the host monzogranite porphyry have zircon U-Pb ages of 15.3 Ma and 15.2 Ma, respectively. The diorite porphyry at the Jiru deposit can be divided into early and late phases (Figs. 3c, d) with zircon U-Pb ages of 14.9 Ma and 14.7 Ma, respectively. The early diorite porphyry shows intensive hydrothermal alteration (Fig. 3h) with high Cu concentrations (141~385 ppm), while the late exhibits no hydrothermal alteration (Fig. 3i) with Cu concentrations only ranging from 71 ppm to 99 ppm.

4 Magmas mixing and its contribution to the Jiru Eocene magmatic-hydrothermal mineralization

The Eocene mafic enclaves hosted in the Eocene monzogranitic pluton are randomly distributed with the size ranging from centimeters to tens of centimeters. They are ellipsoidal and noticeably finer-grained than the host felsic rocks. Their typical igneous textures, acicular apatites, back-veining, quenched margins, and identical emplacement ages to the host rocks indicate that the Jiru Eocene mafic enclaves are magmatic in origin. Some enclaves have a sharp edge at the contact with host rocks, while others have a light-color transitional zone indicative of hybridization between the mafic and felsic magmas. Many irregular patches rich in fine-grained mafic material are present in the host monzogranite, suggesting disaggregation of mafic enclaves as a result of magma mingling with host magma.

The Eocene mafic enclaves are characterized by higher contents of TiO_2, total FeO, MgO, P_2O_5, Zr, Hf, Li, Sc, V, Co, and Ni, and lower contents of Sr, Ba than the host monzogranite. Note that the enclaves have variable Y and Nb concentrations compared to the host monzogranite (Fig. 4). One enclave sample (JR12-4) with high Y (36.5 ppm) and Nb (19.7 ppm) concentrations, together with their low La_N/Yb_N (11.6), Sr/Y (11), Nb/Ta (14.7) ratios, is similar to those of the host monzogranite (Y: 10.2~25.9 ppm; Nb: 8.2~17.8 ppm; La_N/Yb_N: 9.2~20.4; Sr/Y: 14.4~38.8; Nb/Ta: 8.3~10.3), indicating chemical transfer at the boundary of mafic-felsic magmas (Johnston and Wyllie, 1988). Another two enclave samples, however, have low Y (6.4~8.3 ppm) and Nb (5.3~7.7 ppm) concentrations, and high La/Yb_N (21.8~59.1) and Nb/Ta (18.5~23.4) ratios. The relatively low values of siderophile elements (Co: 19.1~27.0 ppm; Cr: 23.8~154 ppm; Ni: 17.4~20.6 ppm; V: 80.9~95.9 ppm) and MgO (3.7% ~4.9%) suggest that most of the mafic enclaves are significantly evolved. But their high Nb/Ta ratios, together with low SiO_2 (50.4% ~56.4%) concentrations, are indicative of a depleted mantle source for their origin. Furthermore, the Eocene mafic enclaves show geochemical affinity with adakite, i.e., low Y and Yb contents and high Sr/Y ratios, suggesting an origin from melting of subducted Tethyan oceanic slab, which is consistent with the tectonic settings at ca. 50 Ma in the southern Tibet (Lee et al., 2009).

As is well known, the adakites formed by oceanic slab melting are favorable for porphyry Cu mineralization. Modeling experiment also indicates that Cu-enriched slab melts are likely to be closely associated with Cu ore formation (Sun et al., 2011). Therefore, the Jiru Eocene magmatic-hydrothermal Cu mineralization in the felsic pluton was probably associated with the injection of Eocene mafic magma and their magmas mixing.

5 Conclusions

1) Mafic enclaves hosted in the Eocene monzogranitic pluton at Jiru porphyry Cu deposit were generated at ca. 48.8 Ma.

2) Mafic enclaves characterized by high Mg, Cr, Ni concentrations and high Nb/Ta and Sr/Y ratios were probably originated from melting of oceanic slab, which provides contribution to the Eocene magmatic-hydrothermal Cu mineralization in the felsic pluton.

Acknowledgments

This paper was supported by the Program of the China Geological Survey (1212011220927), Program for Changjiang Scholars and Innovative Research Team in University (IRT1083), National Key Project for Basic Research of China (2011CB403106), Project for Key Laboratory of Continental Collision and Plateau Uplift (LCPU2010003), and the Fundamental Research Funds for the Central Universities.

References

Sillitoe, R.H., 2010. Porphyry Copper Systems. *Economic Geology*, 105(1), 3-41.

Rui, Z.Y., Hou, Z.Q., Qu, X.M., Zhang, L.S., Wang, L.S., and Liu, Y.L., 2003. Metallogenetic epoch of Gangdese porphyry copper belt and uplift of Qinghai_Tibet Plateau. *Mineral deposits*, 22(3), 217–225 (in Chinese with English abstract).

Zheng, Y.Y., Xue, Y.X., Cheng, L.J., Fang, Z.H., and Gao, S.B., 2004. Finding, characteristics and significances of Qulong superlarge porphyry copper (molybdenum) deposit, Tibet. *Earth Science*, 29, 103–108 (in Chinese with English Abstract)

Hou, Z. Q., Yang, Z. M., Qu, X. M., Meng, X. J., Li, Z. Q., Beaudoin, G., Rui, Z. Y., Gao, Y. F., and Zaw, K. 2009. The

Miocene Gangdese porphyry copper belt generated during post-collisional extension in the Tibetan Orogen. *Ore Geology Reviews*, 36(1-3): 25-51.

Zheng, Y.Y., Sun, X., Gao, S.B., Zhao, Z.D., Zhang, G.Y., Wu, S., You, Z.M., and Li, J.D., 2013. Multiple mineralization events at the Jiru porphyry copper deposit, southern Tibet: Implicati ons for Eo-cene and Miocene magma sources and resource potential. *Journal of Asian Earth Sciences*, http://dx.doi.org/10.1016/j.jseaes.2013.03.029

Ji, W.Q., Wu, F.Y., Liu, C.Z., and Chung, S.L., 2009. Geochronology and petrogenesis of granitic rocks in Gangdese batholith, southern Tibet. *Sci. China D*, 52, 1240–1261.

Lee, H.Y., Chung, S.L., Lo, C.H., Ji, J., Lee, T.Y., Qian, Q., and Zhang, Q., 2009. Eocene Neotethyan slab breakoff in southern Tibet inferred from the Linzizong volcanic record. *Tectonophysics*, 477, 20–35.

Johnston, A.D., and Wyllie, P.J., 1988. Interaction of granitic and basaltic magmas: experimental observations on contamination processes at 10 kbar with H_2O. *Contributions to Mineralogy and Petrology,* 98, 352–362.

Sun, W.D., Zhang, H., Ling, M.X., Ding, X., Chung, S.L., Zhou, J.B., Yang, X.Y., and Fan, W.M. 2011. The genetic association of adakites and Cu-Au ore deposits. *International Geology Review*, 53(5-6), 691-703.