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Magmatic Oxygen Fugacity and Significance of the Pulang Ore-bearing Prophyry, in Yunnan Province, China

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1 Introduction

The oxygen fugacity of a magma is a very important physicochemical parameter which plays a decisive role in mineralization. Generally, at low oxygen fugacity, sulfur in the magma exists mainly as S^{2-}, whereas at high oxygen fugacity, it exists mainly as SO_4^{2-}. The transition of S^{2-} to SO_4^{2-} may prevent the saturation of an immiscible sulfide phase that scavenges Cu from the fractionating melt. Copper in the magma with high oxygen fugacity will become enriched during differentia- tion and partition into a magmatic–hydrothermal fluid, this is favourable for mineralization (Sun *et al.,* 2004).

2 Geological Setting

The Pulang porphyry copper deposit is located in the Zhongdian island arc belt of the Southwest Sanjiang region in China, which belongs to the south segment of the Yidun island arc belt. And it is one of the typical representatives of Sanjiang region. Pulang porphyry copper deposit is usually thought to be formed in late Triassic during westward subduction of the Garze- Litang oceanic plate.

3 Geochemistry of Pulang Porphyries

As porphyries from island arc and continental margin arc, Pulang porphyries rich in large ion lithophile elements (Rb, K) and depleted in high field strength elements (Nb, Ta, P, Ti). They also show the essential characteristics of adakites associated with ocean floor subduction with high Sr (648.58×10^{-6}-897.54×10^{-6}, average=750.38×10^{-6}), Sr/Y (33.21-117.88) and La/Yb (average=13.75) ratios but low Y and Yb contents without significant Eu anomalies.

4 Magmatic Oxygen Fugacity

The zircon Ce^{4+}/Ce^{3+} ratios (Ballard *et al.,* 2002) and δCe calibration (Trail *et al.,* 2012) provide useful tools to infer relative oxidation state in a wide range of intermediate to felsic igneous rocks. Zircon grains from ore-bearing porphyries have higher Ce^{4+}/Ce^{3+} ratios, higher fO_2 and lower Ti-in-zircon temperatures (Ferry and Watson 2007) than those of barren porphyries. The ore-bearing porphyry, quartz monzonite, with zircon U-Pb age of 214Ma in Pulang deposit have higher zircon Ce^{4+}/Ce^{3+} ratios, average is 487.36 (Fig.1a) and fO_2 (average=15.87, FMQ+9.2, T=810.94℃, Fig.1d) than ore-bearing porphyries (average=268.90, FMQ+8.0, T=835.83℃, Fig.1d) and barren porphyries (FMQ+0.61, T=928.47℃, Fig.1d) from Xuejiping porphyry deposit in the same region (Zhongdian island arc belt) with Pulang deposit, implying that the Pulang ore-bearing porphyries have crystallized from more oxidized and cooler magmas than the barren magmas. This square with the fact: whatever scale or grade, Pulang deposit is all above Xuejiping deposit. Perhaps this suggests that more higher magmatic oxygen fugacity develop along with more enriched mineralization. And it is also coincident with previous researches (Mungall, 2002).

In addition, what is more noteworthy is that the magmatic oxygen fugacities of ore-bearing porphyries from Pulang and Xuejiping, measured by zircon Ce anomalie calibration are very high, fO_2 up to 9.2 and 8.0 orders of magnitude higher than the FMQ buffer (Fig.1d). And about 7.2 and 6.0 orders of magnitude higher than the previously recognized lower limit of copper porphyries (Mungall, 2002). Similar deposits as Pulang and Xuejiping with such high oxygen fugacities have never been reported in the world.

Arc magmas with high potential to generate Au and Cu deposits, they will have fO_2 more than two log units above

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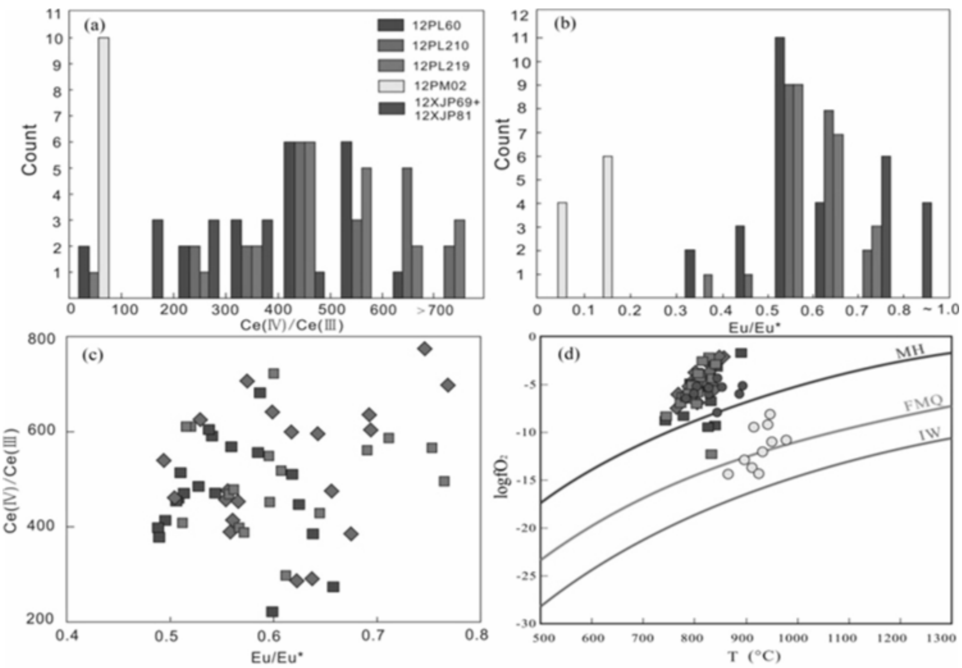

Fig.1. Magma oxygen fugacities diagrams. (a)Zircon Ce^{4+}/Ce^{3+} ratio histogram. (b)Zircon Eu_N/Eu_N^* ratio histogram. (c) Zircon Ce^{4+}/Ce^{3+} vs. Eu_N/Eu_N^*. (d) Magma oxygen fugacities ore-bearing and barren porphyries of Pulang and Xuejiping deposit.

FMQ and they will have either adakitic, sodic- alkaline or potassic-ultrapotassic affinities (Mungall, 2002). Pulang ore-bearing porphyries show the charac- teristics of adakite and very high magmatic oxygen fuga- city. Moreover, zircon Ce^{4+}/Ce^{3+} ratios are similar to the ratios of Chuquicamata-El Abra porphyry (Ce^{4+}/Ce^{3+} > 300, Ballard *et al.,* 2002). Zircons Ce^{4+}/Ce^{3+} of three ore-bearing porphyries from Red River–Ailaoshan fault system in eastern Tibet, Yulong, Malasongduo and Duoxiasongduo, also show higher ratios, range from 204 to 258 (Liang *et al.,* 2006). They are all large-superlarge porphyry deposits and all display high magmatic oxygen fugacity. It suggests that the magmatic oxygen fugacity has a close relationship with mineralization.

5 Conclusion

Pulang ore-bearing porphyries (U-Pb age is 214Ma) show the essential characteristics of adakites associated with ocean floor subduction. The zircon Ce^{4+}/Ce^{3+} ratios of Pulang quartz monzonite are higher than Xuejiping ore-bearing porphyry and barren porphyry. Magmatic oxygen fugacity of Pulang ore-bearing porphyry average is FMQ+9.2 (T=809.72℃), also higher than ore-bearing (FMQ+8.0, T=835.83℃) and barren porphyries (FMQ +0.61, T=928.47℃) from Xuejiping. It suggests that magmatic oxygen fugacity of ore-bearing porphyry is higher than barren porphyry, but temperature is lower than barren porphyry, implying that higher magmatic oxygen fugacity along with more enriched mineralization.

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