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Petrogenesis of Mesozoic Dioritic Rocks and Cu-Au Mineralization in Tongling Region: In-situ Zircon Geochemical Constraints

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1 Introduction

Tongling region in the Lower Yangtze River belt (LYRB) is one of the most important Cu-polymetal producers in China (Fig. 1). Metal deposits are closely associated with and genetically related to the dioritic rocks in the region (e.g., Chang et al., 1991; Mao et al., 2011). The petrogenesis of Early Cretaceous dioritic intrusions and their genetic relation with Cu-Au deposits have been debated in the past decade (Xie et al., 2012 and references therein). This contribution aims to provide firmer constraints on the petrogenesis of the dioritic rocks and Cu-Au mineralization, based on in-situ geochemistry of zircon from ore-forming dioritic intrusions in the Tongling region.

2 Regional Geological Setting

The Tongling region is situated in the Yangtze craton in eastern China (Fig. 1a). Cambrian to middle Triassic sedimentation developed on stable Precambrian basement, forming a thick sedimentary sequence, which became the country rock for the later Cu, Au, and Fe deposits related to the collision event of the Yangtze and Sino-Korean platforms in the middle Triassic (Chang et al., 1991). During the Yanshanian period, this region became active again within an intraplate deformational stage and magmatism. These Yanshanian magmatic rocks consist mainly of pyroxene diorite, quartz diorite, and granodiorite (Fig. 1b), are adakitic in composition (Xie et al., 2012 and references therein). High-precision zircon U-Pb (SHRIMP and LA-ICPMS) results for intrusive rocks in the Tongling region have shown that they formed in the Early Cretaceous (mainly 145–137 Ma; Xie et al., 2012 and references therein).

Three representative samples of Jiguanshi (JGS) pyroxene diorite, Xinqiao (XQ) quartz diorite, and Fenghuangshan (FHS) granodiorite were selected from fresh outcrops and drill cores, and analyzed in-situ geochemistry of zircon in this contribution (Fig. 1b).

3 Analytical Methods

Zircon in-situ trace elements were analyzed at the School of Resources and Environmental Engineering, Hefei University of Technology using LA-ICPMS. Detailed instrumentation and analytic accuracy descriptions are seen in Liu et al. (2010). Zircon Ce^{4+}/Ce^{3+} and Eu/Eu^{*} were calculated using software from the Research School of Earth Sciences, Australian National University (Ballard et al., 2002).

4 Results And Discussion

4.1 Zircon Trace Elements

The Tongling dioritic rocks have typical characteristics of magmatic zircon: consistent REE patterns with HREE enrichment, Ce positive anomalies (δCe: 2 to 209), weak Eu negative anomalies (δEu: 0.42 to 0.85), high Th/U (0.62–7.13) and $(Sm/La)_N$ (mostly > 40) ratios, low La contents.

Zircon in-situ trace elements of the dioritic rocks in Tongling region have a clearly correlation, indicating that they have the genetic relationship. It is noteworthy that these composition points of the Tongling zircon samples are offset to the oceanic crust zircon area with increasing Yb and U, implying important contribution of oceanic crust components in magma source. Hf and most trace elements (e.g., U, Th, Y, P and HREE) of ocean crust zircon vary systematically with Ti, typically becoming enrichment with falling Ti-in-zircon temperature (Grimes

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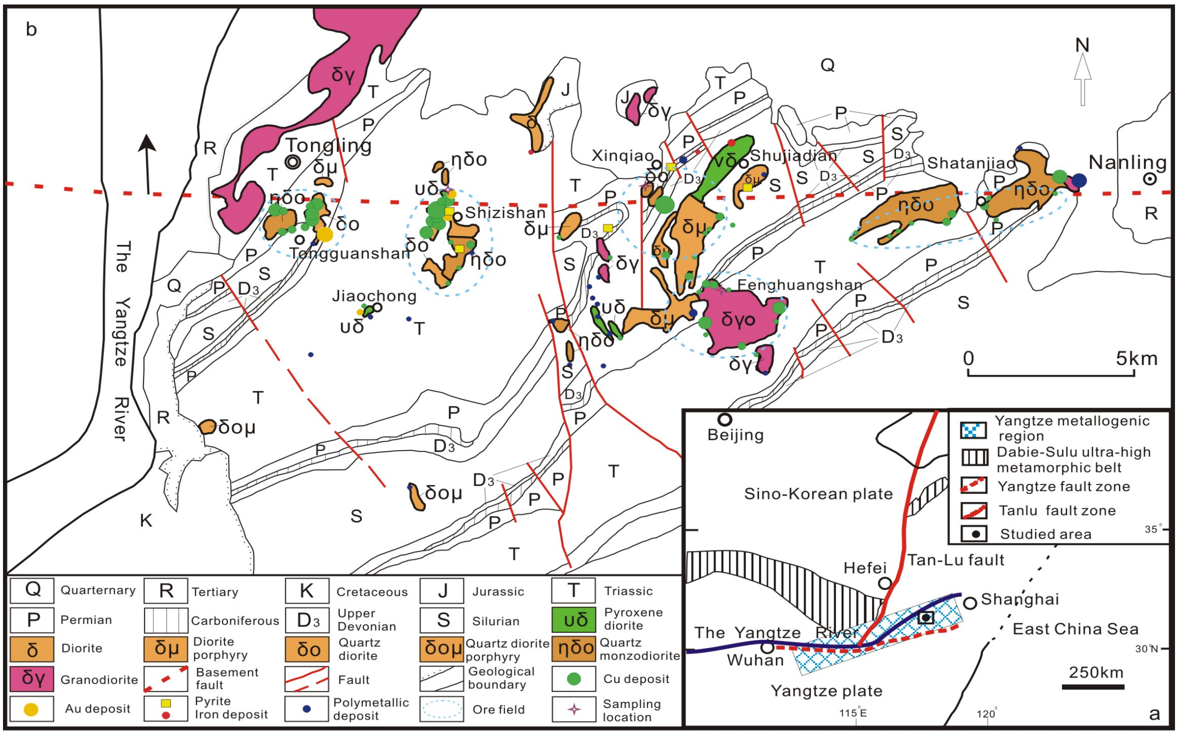

Fig. 1. Geological sketch map of the Tongling metallogenic district, East China (modified from Xie et al., 2009).

et al., 2009). Our samples have the consistent characteristics too. Dioritic rocks of this study have high Zircon Eu/Eu* ratios (0.41–0.87, average 0.64) (Fig. 2) similar to other adakitic rocks from the LYRB, indicating water enrichment in their magma source (Wang et al., 2013).

4.2 Ti-in-zircon temperatures

Based on the calibration of Watson et al. (2006), Ti-in-zircon temperatures vary from 754° to 902°C in JGS sample, from 719° to 903°C in XQ, from 654° to 797°C in FHS, respectively, which are consistent with those of magmatic ocean zircon (1,040–660°C) (Grimes et al., 2009).

4.3 Zircon Ce^{4+}/Ce^{3+} and Eu/Eu*

Qualitative estimate of fO_2 using zircon Ce^{4+}/Ce^{3+} and Eu/Eu* helps to distinguishing the basic difference of fO_2 for the dioritic rocks in Tongling region. Here, we calculate zircon Ce^{4+}/Ce^{3+} and Eu/Eu* by the method of Ballard et al. (2002). The calculated zircon Ce^{4+}/Ce^{3+} values of three samples are 0.3–341 of JGS (avg. 114; n = 23), 78–1204 of XQ (avg. 368; n = 17) and 101-651 of FHS (avg. 366; n = 10), respectively; and Eu/Eu* range from 0.54 to 0.87 (avg. 0.73; n = 23), from 0.41 to 0.65 (avg. 0.56; n = 17) and from 0.47 to 0.73 (avg. 0.59; n = 10) (Fig. 2).

Oxygen fugacity in convergent margin magmas is usually considerably higher than magmas from other geologic settings, likely due to subduction-released fluids (Sun et al., 2007). Ce^{4+}/Ce^{3+} and Eu/Eu* ratios of zircons are good oxygen fugacity indexes of magma that higher Ce^{4+}/Ce^{3+} and Eu/Eu* correspond to higher fO_2 of the magmas. They are also effective indicator to distinguish the ore-forming intrusions from barren ones (Ballard et al.,

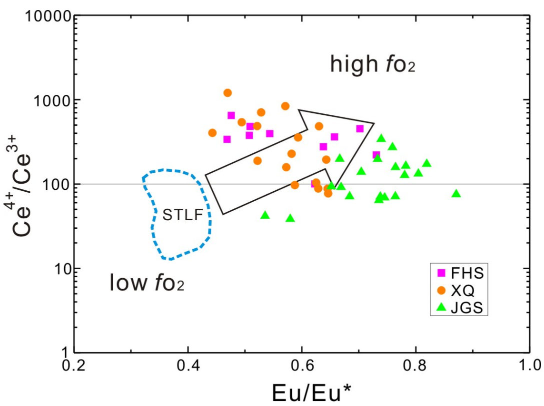

Fig. 2. Correlation between Ce^{+4}/Ce^{+3} and Eu/Eu* of zircons from the Tongling dioritic rocks. Data for adakites from the south Tan-Lu fault (STLF) are from Wang et al. (2013).

2002; Liang et al., 2006), such as, ore-bearing intrusions with zircon Ce^{4+}/Ce^{3+} > 300 and Eu/Eu* > 0.4 from the Chuquicamata-El Abra porphyry copper belt of northern Chile (Ballard et al., 2002), zircon Ce^{4+}/Ce^{3+} boundary value of 120 distinguishing between ore-bearing and barren intrusions in the Yulong copper belt of eastern Tibet, China (Liang et al., 2006). As shown in Fig. 2, Tongling ore-froming dioritic rocks have higher fO_2 with zircon Ce^{4+}/Ce^{3+} (>100) and Eu/Eu^* (>0.41) levels similar to other ore-forming adakitic rocks from the LYRB (Wang et al., 2013), than those for STLF ore-barren adakites, indicating that the Tongling ore-bearing magmas have high oxygen fugacity.

5 Conclusions

The in-situ chemical signatures of zircon show that the dioritic rocks and large-scale Cu-Au metallgenesis in the Tongling and LYRB was formed by partial melting of high oxidized oceanic slab subduction, whereas zircon Ce^{4+}/Ce^{3+} can be an important indicator for Cu-Au deposit exploration.

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