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Geochemistry of lamprophyres at the Daping gold deposit, Yunnan Province, China: Constraints on the timing of gold mineralization and evidence for mantle convection in the eastern Tibetan Plateau

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ABSTRACT

Cenozoic lamprophyre dykes occur widely along the Ailao-Shan-Red-River (ASRR) shear zone related to the Indian–Eurasian collision. Two generations of lamprophyres have been found at the Daping gold deposit in the southern part of the ASRR shear zone and have been investigated by using phlogopite $^{40}Ar/^{39}Ar$ dating and whole-rock major and trace element as well as Sr and Nd isotope geochemical analyses. The $^{40}Ar/^{39}Ar$ plateau ages of phlogopite from the two generations of lamprophyres bracket the emplacement of auriferous quartz veins in the Daping deposit between 36.8 ± 0.2 Ma and 29.6 ± 0.2 Ma, consistent with the timing of gold mineralization in other parts of the ASRR shear zone. Geochemical data suggest that these lamprophyres most likely originated from a subduction-modified mantle source consisting of phlogopite-bearing spinel lherzolite, which underwent partial melting with contributions from crust materials. In particular, the second generation lamprophyres are characterized by more primitive geochemical features than the first, suggesting that secular source evolution probably resulted from post-collisional slab break-off mantle convection and remelting from ascending asthenosphere after subducted lithosphere break-off. Widespread and episodic occurrences of lamprophyres and other potassic volcanism in the eastern Tibetan Plateau were probably related to the onset of transtensional tectonics along the ASRR shear zone during Oligocene. A genetic model involving transtensional tectonics has been proposed for lamprophyres and gold mineralization in the ASRR shear zone.

1. Introduction

The discovery of intimate temporal and spatial relationships between gold deposits and lamprophyres (Kerrich and Wyman, 1990; Richards and Kerrich, 1993; Richards, 1995; Rock and Groves, 1988; Turpin et al., 1988; Wyman and Kerrich, 1989a,b) prompted hypotheses and debates about possible genetic linkages between gold mineralization and lamprophyre magmatism or whether they were just derived from similar tectonic setting or source region. In this context, widely distributed Cenozoic gold mineralization associated with lamprophyres and potassic volcanic complexes along the Ailao-Shan-Red-River (ASRR) shear zone in the eastern Tibetan Plateau, Yunnan Province, China (Chung et al., 1997; Huang et al., 2002; Kerrich et al., 2000; Wang et al., 2000; Zhou et al., 2002), provides an excellent opportunity to investigate their relationships.

Previous geochronological studies (e.g., Bi et al., 1996; Zhu et al., 2011; Sun et al., 2007b) suggested three episodes of gold and nickel mineralization in the ASRR shear zone (Yang et al., 2010), but temporal relationships between gold mineralization and the emplacement of lamprophyres remain unclear. Also, contributions from interactions between continental crust and lithospheric mantle to both gold mineralization and lamprophyres have been suggested by Sun et al. (2009), but debates about the petrogenesis and geodynamic processes of lamprophyres continue. Potassic magmatism in and around the Tibetan Plateau as well as the ASRR shear zone has been attributed to crustal thickening and subsequent delamination of lithospheric mantle (Chung et al., 1997; Davies and von Blanckenburg, 1995; Turner et al., 1996). With respect to the source region, partial melting of a fertile mantle relative to subduction processes has been emphasized by several authors (Huang et al., 2002; Guan et al., 2005). Nevertheless, few lines of evidence for mantle convection have been provided. Therefore, we are particularly interested in whether the processes of convective removal of lithospheric mantle developed in the study

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of post-collision transtensional tectonics could be extended to the origin of lamprophyres in the ASRR shear zone.

Accordingly, we have investigated lamprophyre dykes in close spatial association with auriferous quartz veins at the Daping gold deposit in the ASRR shear zone. Phlogopite $^{40}Ar/^{39}Ar$ geochronological analyses coupled with whole-rock geochemical analyses of major, trace elements as well as Sr and Nd isotopes have been employed to place constraints on the petrogenesis and source region of lamprophyres. In particular, geochemical divergences between two generations of lamprophyres documented herein provide an opportunity to evaluate the secular evolution of the source region.

2. Geological setting and description of samples

The ASRR shear zone in Yunnan Province, Southwest China, is distributed in a narrow southeast-trending metamorphic zone that extends more than 1000 km from the eastern side of the Tibetan Plateau to the South China Sea. It is the most remarkable geophysical and geological discontinuity between South China and Indochina plates. This shear zone has been proposed to have originated from the collision between India and Eurasia plates at ~58 Ma (Lee and Lawver, 1995) and consists of two metamorphic sequences, high-grade in the north and low-grade in the south (Fig. 1). The high-grade metamorphic sequence is composed of mainly Proterozoic Ailao Shan gneisses and anatexites, which display a strongly mylonitic fabric, indicative of an intensive left-lateral shear. Pressure–temperature determinations yielded amphibolite-facies metamorphic conditions (3–7 kbar and 550–780 °C). The low-grade zone comprises mainly of Paleozoic covers and granitoids (Leloup et al., 1995; Leloup and Kienast, 1993; Zhang et al., 2006).

Four NW-trending major faults (i.e., Honghe Fault, Ailao Shan Fault, Jiujia-Anding Fault and Amojiang Fault) occur in the ASRR shear zone. These faults extend more than 100 km with a narrow width of 1–3 km each, commonly dipping 60–80°NE. For example, the Ailao Shan Fault separates the Proterozoic basement from the Paleozoic metasedimentary rocks and magmatic rocks, and hosts numerous gold deposits (Fig. 1).

The western boundary of the South China block has been proposed as an oceanic collision suture of Tethys (e.g., the Devonian-Carboniferous ophiolitic zone near Mojiang; Fig. 1; Jian et al., 1998; Zhang et al., 1988). Jian et al. (1998) reported zircon U–Pb ages of 362 ± 41 Ma and 328 ± 16 Ma from gabbros and plagiogranites in the ophiolites. Zhang et al. (1991) investigated the geochemical compositions of the ophiolitic suite and suggested it to represent the remnants of Paleotethys oceanic suture zone. The suture was reactivated after the closure of Tethys and Cenozoic collision between Indochina and South China. The ASRR shear zone has experienced two episodes of sinistral movements, including a left-lateral ductile deformation during Oligo-Miocene (27–22 Ma; Leloup et al., 1995; Zhang et al., 2006) and a greenschist-facies mylonitic deformation at ~13–12 Ma (Zhang et al., 2006). Finally,

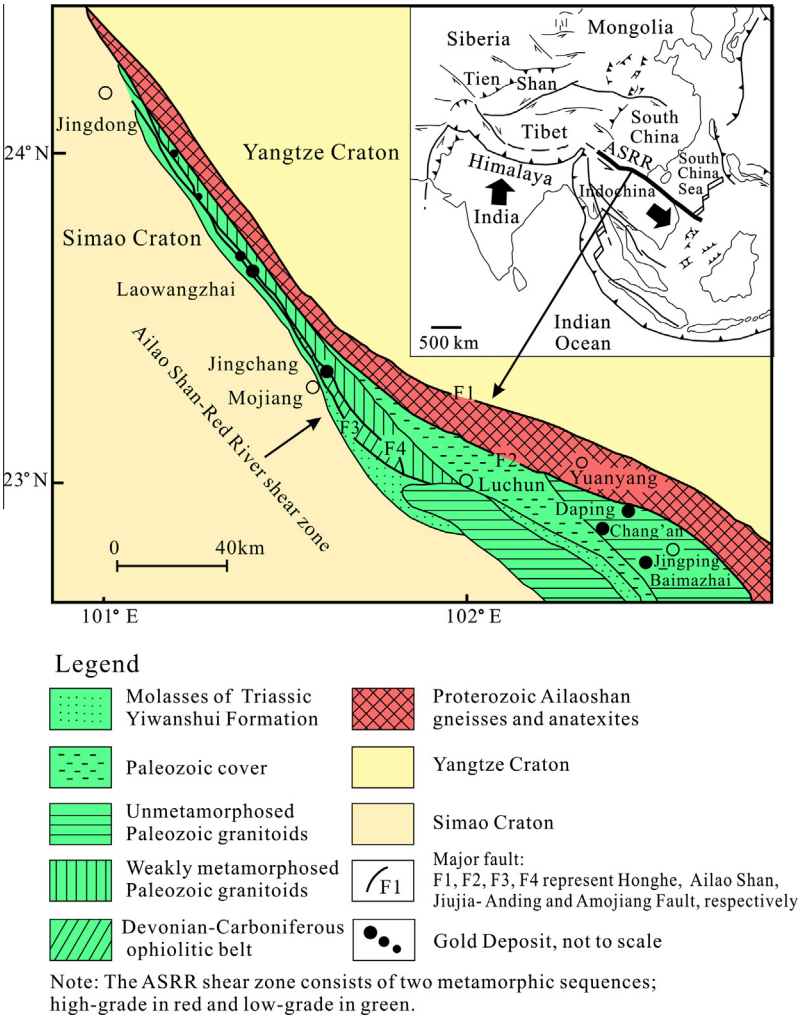

Fig. 1. Geological map showing the ASRR shear zone and the distribution of gold deposits (modified from Ying et al. (2005)).