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Post-collisional lamprophyres – exploration tools for rare metal deposits

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Introduction

The link between Large Igneous Provinces (LIPs), mantle plumes and rare metal deposits has been discussed for more than 40 years. In this context lamprophyre dikes in metallogenic provinces are of special interest (cf. Seifert 2009). Based on a worldwide database of lamprophyres, N.M.S. Rock (1991, p. 155) noted that "...lamprophyres are a missing element in the traditional 'granites + mineralization' maxim which should no longer be ignored; it may be at least as reasonable to attribute certain components of mineralizing fluids to deep, mantle-derived, lamprophyric melts as to shallower granitic magmatism ...". Many years of study have not resulted in a general agreement concerning the petrogenesis and metallogenic importance of subvolcanic lamprophyric intrusions and shoshonites. (e.g., Kerrich and Fyfe 1981, Rock 1987, 1991, Rock and Groves 1988, Kerrich and Wyman 1994, Mitchell 1994, Seifert and Baumann 1994, Seifert 1997, 2008, Müller and Groves 1995, Wyman et al. 1995, Sillitoe 2002, Kenworthy and Hagemann 2005, Štemprok and Seifert 2011, Smithies et al. 2018, Mathieu et al. 2018, Witt et al. 2020). However, lamprophyres and shoshonitic/ultrapotassic volcanic rocks are important for the reconstruction of the tectonic setting and exploration of mantle-derived magmatic processes and associated deposition of rare metals (Au, Sn-W-Mo-Li, Ag-In-polymetallic sulfide, Ag-Sb, U) in different metallogenic provinces.

Au-lamprophyre association

A genetic link between gold deposits and lamprophyres was proposed in the 1980s and 90s (cf. Rock and Groves 1988, cf. Rock 1991). Lamprophyres in Au-bearing districts show Archean to Tertiary ages (e.g., ca 2.6-2.7 Ga: Eastern Goldfields and Murchison provinces in the Yilgarn Block (Western Australia), Superior Province; 1.8 Ga: Woods Point (Australia); 400 Ma: Caledonides (Scotland), Pine Creek (Australia); Permo-Carboniferous: Bohemian Massif (Czech Republic, Germany); Jurassic-Tertiary: Sierra Nevada and Klamath Mountains (CA), Tonopah and Goldfield (NV), Rossland (BC), Kreuzeck Mountains/Alps (Austria), Cripple Creek (CO), Porgera (P.N.G.) (cf. Rock 1991 and references therein).

In agreement with Rock (1991), it can be postulated that the gold-lamprophyre association represents a deep-seated magmatism which can transport Au ligandes from Au-rich sources in the deeper mantle. These volatile-enriched, hot lamprophyric melts then undergo an extensive crustal interaction, generating felsic magmas and releasing their Au into hydrothermal systems. The persistent and widespread association in both space and time between hydrothermal Au(-polymetallic) mineralization and lamprophyric intrusions (especially calc-alkaline lamprophyres/CAL) is an important metallogenetic factor for genetic models of post-magmatic Au mineralization and for their exploration in different geotectonic environments: continental arc, oceanic island arc, post-collisional orogenic and anorogenic intracontinental rifting (e.g., McLennan 1915, Fyles et al. 1973, Boyle 1979, Rock and Groves 1988, Wyman and Kerrich 1989, Rock

1991, Perring and McNaughton 1992, Müller and Groves 1995, 2019, Štemprok and Seifert 2011, Manning and Hofstra 2017, Mathieu et al. 2018, Smithies et al. 2018, Choi et al. 2020, Witt et al. 2020).

Lamprophyre dikes occur in many of the mining camps of the West Kootenay district in British Columbia, commonly occurring in swarms following northerly trending fractures and local fracture systems (cf. Fyles et al. 1973). The Cu-Au vein-type mineralization in the Rossland district consists of Au-bearing sulfides (pyrrhotite, chalcopyrite), quartz and minor carbonates. The main veins have been mined at depths of up to 730 m below the surface (cf. Fyles et al. 1973). The Cu-Au sulfide veins crosscut the lamprophyre dikes and the MoS_2-bearing breccia complex. The K-Ar age of the lamprophyres (46.4 ± 1.5 Ma to 49.2 ± 1.4 Ma; biotite: n=5, hornblende: n=1) overlap with the K-Ar ages of monzonite and syenite stock intrusions and the quartz-diorite of the Rainy Day Stock (Fyles et al. 1973). Samples of three lamprophyre dikes and Au-sulfide mineralization in the old underground Au-Cu mine "Midnight Mine" were taken in 1993 (Fig. 1). The relatively fresh dark grey-black lamprophyre samples plot in the Cr-Ni diagram in the field of primary CAL magmas (cf. Rock 1991) with high contents of Cr (avg. 587 ppm, 310 - 790 ppm, n = 4) and Ni (avg. 285 ppm, 79 - 423 ppm, n = 4; cf. Seifert 2008, p. 70, Fig. 32). Two samples show an slightly overprint by Au-enriched hydrothermal fluids: L-2M with 14 ppb Au and L-3M with 12 ppb Au. This confirms that the CAL have a pre-Au-mineralization age. Molybdenum contents < 1 ppm (n = 4) confirm Fyles et al. (1973) that the CAL are younger than the Mo mineralization. Considering the K-Ar ages of the magmatic pulses (cf. Fyles et al 1973) a metallogenic relationship between CAL intrusions and the Au mineralization is not unlikely. However, lamprophyre dikes with slightly increased Au contents are an important indicator in the exploration of hydrothermal gold deposits.

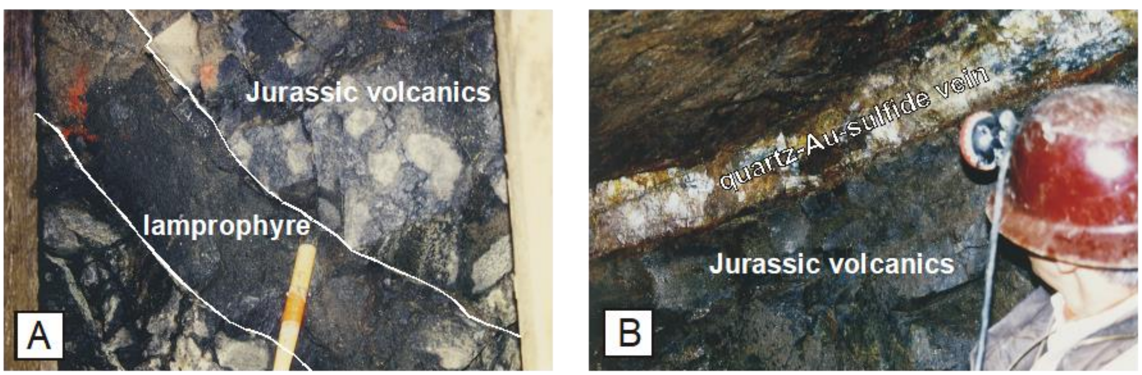

Figure 1: Spatial relationship between calc-alkaline lamprophyric dikes (CAL) and Au-sulfide-quartz vein-type mineralization, Au-Cu-Mo district Rossland (B.C., Canada), Midnight Mine. **A.** CAL (pre-Au mineralization age; K-Ar age of CAL c. 48 Ma, Fyles et al. 1973) crosscut Jurassic volcanics. **B.** Au-sulfide-quartz vein crosscut Jurassic volcanics and crosscut CAL (after Fyles et al. 1973 and own data); in October 1993 the tunnel was broken in this part. Pictures: T. Seifert 10/1993.

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