# Lamprophyres, F-Sn-rhyolites and -explosive breccia pipes and their relationship to Sn-polymetallic mineralization in the Muehlleithen-Gottesberg district (Germany) - indications for late-Variscan mantle-derived rare metal-enriched fluid pulses

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## Introduction

An important part of the rare metal resources (Sn, W, Mo, In, Sc, Li) in the Saxo-Thuringian Zone is related to the Permo-Carboniferous Sn-W-Li-F-polymetallic association in the Erzgebirge-Slavkovský les-Vogtland metallogenic province (Bolduan 1972; Baumann et al. 2000). There are still about 1 million metric tons Sn metal related to Sn-polymetallic mineralization in greisen-, stringer zone- and skarn-type ore bodies @ 0.15 - 1 wt.% Sn with significant quantities of W, Mo, Bi, In, and Li as byproduct. One of the most important Sn ore fields in the Variscides is the Muehlleithen-Gottesberg old mining district (Sn, U, W, Ba, Ag) which is located at the western contact of the Eibenstock-Nejdek granite massif in the SE part of the Vogtland region. Characteristic are subvolcanic, postgranitic pipe- and dike-shaped felsic intrusions, explosive breccia pipes and lamprophyre dikes which are hosted by the Eibenstock granite and contact metamorphic schists (Kaemmel 1961; Baumann and Gorny 1964; Gottesmann and Kruse 1981; Wasternack et al. 1995; Seifert 2008).

Subeconomic resources of about 47 million metric tons greisen ore of the Gottesberg deposit with an average grade of 0.26 wt.% Sn, 0.015 wt.% Bi, and 0.015 wt.% $WO_3$ are concentrated in pipe-shaped greisen bodies (with impregnative cassiterite mineralization) with a maximum known size of about 150 m in diameter and about 900 m at depth (Sippel et al. 1983; Gottesmann and Kruse 1991). The cassiterite-bearing greisen orebodies of the Mühlleithen Sn(-W) deposit were mined from c. 1500 to 1964. The greisen bodies are located in the main intrusive phase of the Eibenstock granite and are structurally controlled by the granite / phyllite (hornfels) contact (Donath 1964; Kaemmel 1961).

## Geology and geochemistry of post-collisional lamprophyric and rhyolithic/microgranitic intrusions with post-Eibenstock granite age

The post-collisional evolution shows an increase of mantle influence which is indicated by NW-SE, ENE-WSW and N-S striking lamprophyric dikes which crosscut the Eibenstock granite and the Ordovician schists. Two distinct episodes of lamprophyric intrusions have been documented: a pre- and post-granitic type in relation to the main intrusion stage of the Eibenstock granite. The pre-granitic lamprophyres (LD1) show exclusively a kersantitic composition, whereas the post-granitic lamprophyres (LD2) are predominantly mica-minettes to mica-kersantites (Ačejev and Harlass 1968; Kramer 1974; Seifert 2008). The studied ENE-WSW striking lamprophyre dike (type LD2) is located in the +835 m level (Tannenberg adit) of the Mühlleithen Sn mine at the endocontact zone of the Eibenstock granite and crosscut the porphyric medium-grained monzogranite of the main stage. Significant contents of mantle-compatible elements (275 ppm Cr, 145 ppm V, 20 ppm Sc) and a mg# of 67 measured from dike LDT1a verify a mantle-related magmatism corresponding with worldwide data from Rock (1991) and data from the Mid-European Variscides (Seifert 2008). The relatively low contents of Ni (39 ppm) and Co (17 ppm) are caused by the replacement of phlogopites and olivines by greisen fluids. Chromium-spinel is stable, explaining that the high Cr-content (Fig. 1) is consistent with the Cr-contents of the 'primary magmas' field from Rock (1991). High contents of incompatible LILE and HFSE and $\varepsilon Nd_i$ = -0.2 indicate mantle metasomatic processes similar to those found in earlier studies of different lamprophyre intrusions in the Saxo-Thuringian (Kramer 1988; Seifert 2008) and a world-wide database from Rock (1991).

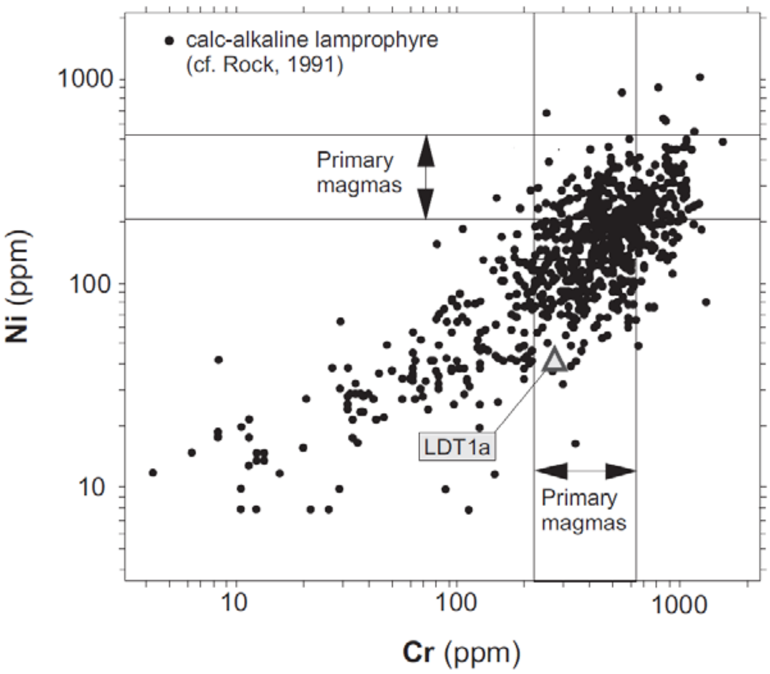


**Figure 1:** Cr-Ni ratios of lamprophyre dike LDT1a (highlighted by triangle) in comparison to primary Ni and Cr contents of calc-alkaline lamprophyres worldwide compiled by Rock (1991)

Two groups of felsic (sub)volcanic rocks are described in Wasternack et al. (1995): porphyritic rhyolites and serialporphyric microgranites. Accessories are apatite, fluorite, topaz, zircon, and sulfides. These (sub)volcanic felsic rocks increase in size and abundance with depth. Their shapes change from dike- to tube- and stock-like intrusions at depth. A representative microgranitic dike from the Sn deposit Gottesberg (sample GRGOT, drill hole TAH 4/77, 1171.5 m - 1174 m depth) was analyzed. Accessory minerals are xenotime-(Y), monazite-(Ce), zircon, thorite, and columbite (Fig. 2). Non-primary albite micro-phenocrysts represent post-microgranitic albitization processes with pre-greisen age. Sample GRGOT shows very high Nb (40 ppm), Th (60 ppm), Y (70 ppm), Zr (150 ppm), F (1050 ppm), and LREE (175 ppm) contents and εNdi = -2.1. Younger sericite in the microgranite (GRGOT) indicates greisenization.

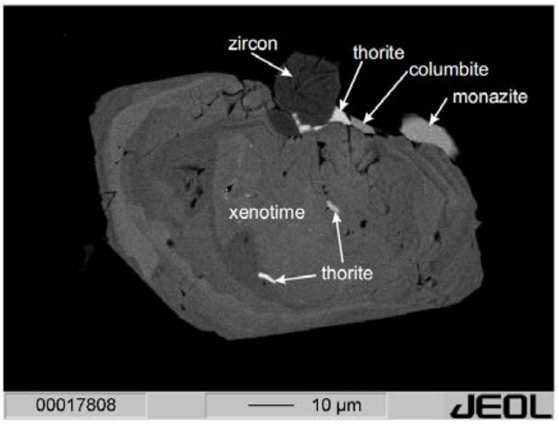


**Figure 2:** Backscattered electron image of xenotime (Y,U,Th)(Gd-Lu)[$PO_4$] intergrowth with zircon, monazite, thorite, and columbite grains in microgranitic dike sample GRGOT. drill hole TAH 4/77, 1171.5 m - 1174 m

**Late-Varsican magmatic stages and related Sn-polymetallic mineralization of the Muehlleithen-Gottesberg Sn-W-U-Ag-Ba district**

The important Sn-ore deposition in the Muehlleithen-Gottesberg district is spatially and temporal related to an intrusion center of the lamprophyric and rhyolitic (sub)volcanic magmatism which is controlled by the intersection of NW-SE, N-S, and NE-SW to ENE-WSW deep-rooted regional fault zones. Based on about 17,000 m of drilling (e.g., bore hole Tah 4/77 with a depth of 1,200 m), and intensive fieldwork, exploration geologists proposed that the pipe-like greisen bodies are controlled by older explosive breccia pipes (Donath 1964; Gottesmann and Kruse 1981; Wasternack et al. 1995). The impregnative cassiterite mineralization (meta-monzogranite Sn-greisen) extended to a depth of 900 m and show a significant positive correlation to the F contents (cassiterite-rich topaz and quartz-topaz greisen).

The Sn-polymetallic mineralization of the Muehlleithen-Gottesberg district is spatial and possibly temporal associated with LD2 (Pb-Pb zircon age: 316±2.7 Ma) and subvolcanic pipe- and dike-shaped felsic intrusions (Pb-Pb zircon age: 312±4.6 Ma) and explosive breccia pipes hosted by 318 – 320 Ma age monzogranites of the Eibenstock massiv (cf. Seifert 2008) and by contact metamorphic schists. The extreme F-enrichment of fluids during the emplacement of explosive breccia pipes is represented by intensive topazization (e.g., schist-quartz-topaz breccia pipe "Schneckenstein mountain"). The lamprophyre dikes show extreme high F (20,450 ppm), Rb (1,100 ppm), Cs (100 ppm), Li (230 ppm), and Sn contents (1,350 ppm), and high W (25 ppm) and In contents (5 ppm) as well as cassiterite-arsenopyrite-sphalerite-quartz-topaz mineralization which clearly show the influence of Sn-polymetallic mineralization and consequently the pre-Sn-polymetallic age of LD2.

The emplacement of lamprophyric melts at the base of the lower crust in the Erzgebirge-Vogtland area and Sub-Erzgebirge basin is probably associated with asthenospheric doming. F-Sn-enriched rhyolitic melts and Sn-polymetallic mineralization were probably produced by small amounts of partial melting of the lower crust and mantle-fluids, resulting from underplating of fluid-enriched proto-lamprophyric melts. Genetic relationships to a mantle plume are in discussion (Seifert 2014).

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