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Anticorrelated Rb-Sr and K-Ar age discordances, Leuchtenberg granite, NE Bavaria, Germany

Abstract The Leuchtenberg granite (Oberpfalz, NE Bavaria) displays a continuous differentiation trend ranging from mildly peraluminous, coarse-grained, porphyritic biotite granites (BG) to strongly peraluminous, medium- to fine-grained, garnet-bearing muscovite granites (GMG). The Rb-Sr and K-Ar age determinations of whole-rock and mineral samples from the granite and associated intermediate rocks (redwitzites) have revealed two divergent age gradients: Rb-Sr whole-rock dates decrease and initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratios increase for successively more evolved subsets of the granite. All BG samples ($^{87}\text{Rb}/^{86}\text{Sr} = 2-16$) yield a date of $326 \pm 2$ Ma with a low initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratio of $0.70778 \pm 0.00013$ (1σ), while all GMG samples ($^{87}\text{Rb}/^{86}\text{Sr} = 70$ to $1000$) yield a younger date of $317 \pm 2$ Ma with an enhanced initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratio of $0.7146 \pm 0.0039$. The K-Ar measurements on biotites and muscovites give closely concordant dates for the GMG (326-323 Ma) and the southern lobe of the BG (324-320 Ma). The northern lobe of the BG, including the redwitzites, shows a well-defined trend of decreasing K-Ar dates from 320 Ma to 300 Ma towards the northwest. Critical consideration of both isotope systems leads to the conclusion that the Rb-Sr system of the GMG was disturbed by a later hydrothermal event. The ca. 326 Ma whole-rock Rb-Sr date for the BG is not in conflict with any of the K-Ar mineral dates and is taken as approaching the crystallization age of the Leuchtenberg granite. The K-Ar age progression within the northern lobe of the BG indicates that this part either cooled down over a protracted period of some 20 Ma or experienced reheating at ca. 300 Ma. The study highlights the potential of combined Rb-Sr and K-Ar dating in deciphering detailed chronology on the scale of a single igneous intrusion.

Introduction and aims of investigation

Isotopic studies have demonstrated that plutonic rocks can show rather complex age patterns. Regional variation of apparent age information is attributed to: (1) thermal gradients due to the proximity to an orogenic front (Wanless et al. 1970); (2) sequential cooling due to regional uplift (Krummenacher et al. 1975; Criss et al. 1982; Hess et al. 1993); (3) meteoric-hydrothermal convection (Criss et al. 1982; Kwan et al. 1992); (4) rejuvenation caused by subsequent intrusions (Kwan and Yap 1986); (5) faulting or tilting processes modifying the relative elevations of adjacent subregions (Kwan et al. 1992) (6) crustal propagation due to plate tectonic movement (Stille et al. 1986). However, with some exceptions, close-mesh geochronological data sets for discrete intrusions are rare, which limits the possibility for testing hypotheses bearing on the interpretation of small-scale age zoning. The causes of such age gradients can remain equivocal if only one dating method were used. A comparative study of two or more independent chronometers is advantageous because coupling of methods permits a better interpretation of the geochronological data. Monitoring the behaviour of two independent isotope systems such as $^{87}\text{Rb}-^{87}\text{Sr}$ and $^{40}\text{K}-^{40}\text{Ar}$ should provide clues for distinguishing between primary magmatic, heat- and fluid-related, or tectonically controlled age gradients.

In this study, the Rb-Sr and K-Ar dating methods are used to constrain the age distribution pattern within the Leuchtenberg granite, NE Bavaria. This intrusion has already been investigated for its compositional variation and revealed a well-marked textural and compositional zonal pattern. Intermediate rocks, locally known as redwitzites, form a minor component within the Leuchtenberg massif and are included in
this investigation. Special attention is drawn to the identification of the areal distribution of isotope variations within the rocks. By combining the results of this study with relevant age information available from other studies, hypotheses about the mechanisms of the spatial age patterns are discussed.

**Geological framework**

The general geology of the study area, and the sampling sites are shown in Fig. 1. The Leuchtenberg granite is located south of the German Continental Deep Drilling site (Kontinentales Tiefbohr-Programm, KTB) at the western marginal zone of the Bohemian Massif. The granite has a regional SSE–NNW elongation and covers an outcrop area of about 70 km². According to Madel (1975) the granite forms a plate-like, steeply dipping body which was intruded by fault induced emplacement mechanisms into pre-existing NNW-trending structures, parallel to the Franconian Line. A gravity survey has shown that the granite dips to the east (Bücker and Soffel 1986). In the northeast, the Leuchtenberg granite is contiguous to the Falkenberg and Liebenstein granites, whereas in the south it is terminated by the Luhe Line. An elongated body of dioritic rock types, known as redwitzites (sensu Willmann 1920), is located within the axial zone of the northern granite (Fig. 1). Redwitzites account for volumetrically minor amounts within NE Bavaria. In worldwide comparison, they share distinctive compositional features with rocks of the appinite suite (see review in Wright and Bowes 1979). All these intrusions form part of a larger plutonic mass, which is referred to as NE Bavarian Pluton (cf. Blümel 1990). Granites of this pluton are products of Late Hercynian igneous activity.

Mutual relationship and rock texture attests to the existence of the redwitzites before the intrusion of the Leuchtenberg granite (compare Fischer 1965). Judging from the areal geochemical zonation pattern and the different stages of crystal fractionation, Madel (1975) considered the Leuchtenberg granite to be older than Falkenberg and Liebenstein. Combining field evidence and geochemical data, the relative intrusion sequence is: redwitzites → Leuchtenberg granite → Falkenberg–Liebenstein granites.

Petrographic characteristics of the Leuchtenberg granite have been outlined by Voll (1960) and Strunz and Mütke (1975), and only a brief description is given here. The most abundant rock type is a feldspar-porphyritic biotite granite (BG), which becomes poorly porphyritic to equigranular on the western limb. It grades into a tongue of fine- to medium-grained, aphyric garnet-bearing muscovite granite (GMG), which forms the southwesternmost marginal facies. The lack of sharp contacts between the BG and the GMG indicates