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Age and mineralogy of supergene uranium minerals — Tools to unravel geomorphological and palaeohydrological processes in granitic terrains (Bohemian Massif, SE Germany)

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ABSTRACT

Uranyl phosphates (torbernite, autunite, uranocircite, saleeite) and hydrated uranyl silicates (normal and beta-uranophane) found in various erosion levels and structures in the Late Variscan granites at the western edge of the Bohemian Massif, Germany, were the target of mineralogical investigations and age dating, using conventional and more advanced techniques such as Laser-Ablation-Inductive-Coupled-Plasma Mass Spectrometry (LA-ICP-MS). Supergene U minerals have an edge over other rock-forming minerals for such studies, because of their inherent 'clock' and their swift response to chemical and physical environmental changes on different scales. Uraniferous phoscretes and silcretes, can be used to characterize the alkalinity/acidity of meteoric/*per descensum* fluids and to constrain the redox conditions during geomorphic processes. This study aims to decipher the geomorphological and palaeohydrological regime that granitic rocks of the Central European Variscides (Moldanubian and Saxothuringian zones) went through during the Neogene and Quaternary in the foreland of the rising Alpine mobile fold belt. The study provides an amendment to the current sub-division of the regolith by introducing the term "hydraulith", made up of percolation and infiltration zones, for the supergene alteration zone in granitic terrains. It undercuts the regolith at the brink of the phreatic to vadose hydrological zones. Based upon the present geomorphological and mineralogical studies a four-stage model is proposed for the evolution of the landscape in a granitic terrain which might also be applicable to other regions of the European Variscides, considering the hydrological facies changes along with paleocurrent and paleoslope in the basement and the development of the fluvial drainage system in the foreland.

Stage I (U mineralization in the infiltration zone) is a mirror image of the relic granitic landscape with high-altitude divides and alluvial–fluvial terraces. Its characteristic features are preserved in the uplifted hinterland of a peneplain which in this case is tilted towards a lacustrine basin. Stage II (U mineralization in the infiltration zone, regolith and saprock) includes two sub process, planation and exposure, resultant in the exposure of inselbergs and quartz ridges in front of the hinterland (stage I). Stages III and IV (U mineralization in percolation zone and saprock) are controlled by the base level lowering in the foreland. Rapid incision caused pinnacle-like tors and large granitic land forms to form, whereas a slow-down of fluvial incision favored its destruction and the development of weathering pits of different kinds. A full blown cycle of planation and incision lasted for approx. 10 Ma, a stage which covers planation and exposure, resulting in the formation of domal structures which lasted for as much as 2 Ma. Climate is an important factor but the most important factors for the geomorphological processes shaping the granitic landscape in the study area are uplift and erosion. The study area is located within the stress field of an ancient Variscan craton (Mesoeurope) and a highly mobile Alpine fold belt (Neoeurope). The rate of vertical displacement in the mobile parts of the crust had a long-distance effect also on the granitic terrains in the rigid parts of the crust.

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1. Introduction

Establishing landform chronologies, dating depositional processes and determining the rate of vertical movements of rock series during a certain period of time play an ever-increasing part for geomorphological applications dealing with the most recent periods of the Earth's history. Apart from biologically-based methods like lichenometry and dendrochronology successfully used for dating Quaternary materials and landforms, there are two main physical methods, radiocarbon dating and the application of luminescence dating (OSL) which are widely used to date modern geological and geomorphological processes (Geyh and Schleicher, 1990; Wagner, 1995; Dill and Techmer, 2009). Other isotope

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couples, e.g. U/Pb, have found little application during interpretation of geomorphological process despite the fact that these methods may cover the gap between the late Pleistocene and the Neogene, a gray zone that cannot be handled by the aforementioned techniques for physical constraints (Lenz et al., 1962; Carl and Dill, 1983, 1985; Dill, 1985). Supergene uranium mineralization has gained little attention so far as a tool for chronologically constraining young geological and geomorphological process (Onac, 2000–2001). In this study, LA-ICP-MS data together with data from conventional U/Pb dating are discussed for resolving geomorphological and hydrological processes in SE Germany. Geomorphology and weathering of the granitic landscapes has been studied intensively and numerous comprehensive papers have been published, but little has been done to link these geomorphological processes with hydrological processes in the immediate surroundings of these granitic terrains (Linton, 1955; Ehlen, 1991; Bremer, 1993; André, 2004; Twidale and Vital-Romani, 2005; Migoń, 2006). Special studies focusing on granitic terrains in the region have been published by Czudek et al. (1964) and Demek (1964) for the Czech part of the Bohemian Massif and by Jahn (1974) for the Polish part. In the current study paleohydrological and geomorphological processes shaping the landscape at the western edge of the Bohemian Massif, Germany, have been investigated jointly at various study sites (Fig. 1). Enrichments of supergene U minerals refer to paleoaquifer. Therefore mineralogical aspects concerning supergene U minerals are presented in the current paper in more detail to ease the identification of these paleo water gauges in the field by those geoscientists not fully acquainted with uranium geology, chemistry and mineralogy. Supergene U minerals have an edge over other geogene materials allowing for a modeling of the physical and chemical regime at the time of formation at near-ambient conditions. Dating of secondary/supergene U minerals helps

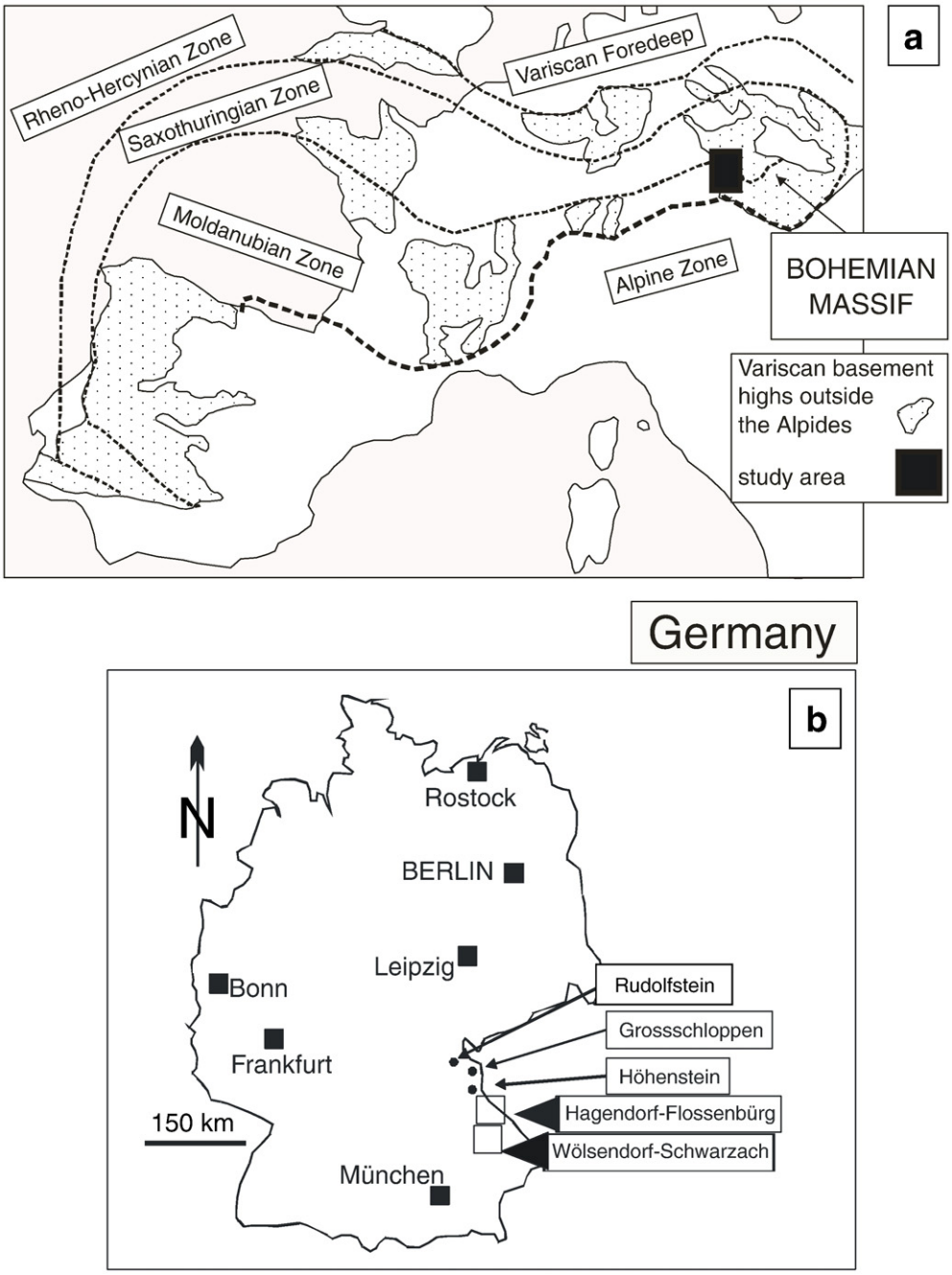

Fig. 1. Index maps to show the geographic position and geological setting of the working areas at the western edge of the Bohemian Massif. a) Geological and geodynamic position of the working area within the Variscides in Europe at the western edge of the Bohemian Massif (geology after Matte, 1991). b) Geographic position of the working areas in SE Germany.

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