THE HAGENDORF-PLEYSTEIN PHOSPHATE PEGMATITES (NE BAVARIA, GERMANY) - A MINERALOGICAL, CHRONOLOGICAL AND SEDIMENTOLOGICAL OVERVIEW

H. G. Dill *

* Institute of Geosciences, Gem-Materials Research & Economic Geology, Johannes-Gutenberg University, D-55099 Mainz Becherweg 21, Germany
haralddill@web.de; http://www.hgeodill.de

Keywords: phosphate pegmatite, Hagendorf-Pleystein, Germany

INTRODUCTION

Pegmatites and aplites in the NE Bavarian basement are an important source of feldspar, quartz and of rare metals such as Li contained in a wide range of phosphates. The Hagendorf pegmatite was one of the biggest feldspar-quartz pegmatite deposits in Europe, totaling 4.4. Ma tons of ore (Forster et al. 1967). The phosphates have also attracted the attention of mineralogists who found among others the mineral hagendorfite and only recently a new aplitic body hosting Sc minerals some of which not identified elsewhere (Forster & Kummer 1974, Strunz et al.1975, Mücke 1981, 2000, Dill et al. 2007a, 2008, 2009). In the succeeding sections the evolution and lateral facies variation of the pegmatite and aplites is discussed. The geomorphological and sedimentological evolution in the environs of Pleystein-Hagendorf is dealt with to contribute to the unroofing story of the pegmatites and provide a tool for the exploration of this type of pegmatites using placer-type accumulations of "nigrine" in the Cenozoic alluvial-fluvial drainage system.

GEOLOGICAL SETTING

Upper Proterozoic basement rocks (amphibolites, metabiolites, marbles, calcsilicates), forming part of the Moldanubian core zone of the Bohemian Massif, were folded during the Variscan convergence in mid-Carboniferous times and succeeded by the emplacement of synorogenic granites, pegmatites and aplites. During the Cenozoic the basement was uplifted placer deposits of "nigrine" were deposited in the drainage system.

THE METAMORPHIC-MAGMATIC STAGE AND ITS RELATED PHOSPHATES

The aplitic mobilizates and aplitic granites at W and E boundary of the pegmatite province

The estimated P–T conditions in the meta-psammopelitic rocks are compatible with those of the low-P facies series, considering the prevalence of cordierite in medium-grade schists. The area under study is typical of the cordierite-K-feldspar zone (temperature: approx. 650°C, pressure: 3

to 4 kbar). Structural adjustments in the Oberpfalz is constrained to the period 450 to 330 Ma by Weber and Vollbrecht (1989). A more precise date can be obtained by the dating of columbite-(Fe), which provides evidence of a thermal event at 376 ± 14 Ma. NW-SE striking garnet- and tourmaline-bearing aplitic dykes- P/T regime : 400 to 500 °C, < 3 kbar- and quartz veins evolved during the waning stages of metamorphic and structural overprinting of the psammopelitic country rocks west of Pleystein. During the early magmatic stage (302.1±3.3 Ma), Mn apatite, triplite, wolfeite, triploidite, monazite are most widespread and unnamed Zr-Sc phosphate-silicates and K-Sc-Zr-Ba phosphate are marker minerals for this aplitic mobilizates. East of Hagendorf, the aplitic granite at Silbergrube Waidhaus, the only operating mine at present, gave an age of formation of 302.8±1.9 Ma. There is little or no zonation as to the feldspar-quartz distribution and the aplite is interpreted to have been emplaced by a single stage process. The Silbergrube aplite contains neither anomalously high Ti nor Sc values and is only host to Fe-Mn phosphates.

The quartz aplites and quartz dykes

Aggregates of rutile-ilmenite intergrowths (“nigrine”) are typical of the quartz dykes at the NW edge of the pegmatite province. Tracing these sheet-liked quartz bodies further south leads to the rose quartz pegmatite at Pleystein which is surrounded by an aplitic border zone structurally and texturally quite similar to what has been described from the Trutzhofmühle aplite. Apart from the Fe-Mn phosphates common to all aplites and phosphates of the Hagendorf pegmatite province, Ti-Zn-Bi phosphate mineralization composed of benyacarite, parahopeite, schoonerite and xemingite was detected.

The feldspar-quartz pegmatites

Plugs with a conspicuous zonation of feldspar-quartz distribution were exploited at Hagendorf North and Hagendorf South pegmatite deposits. These peraluminous intrusives emplaced around 299.6±1.9 Ma show only a random orientation of rock-forming minerals and resulted from a multistage-emplacement after the main granite at Flossenbürg formed (311.9±2.7 Ma). Minable concentrations of Li phosphate mainly triphylite were encountered at the boundary between the siliceous core and the rim zone made up of K feldspar. Based upon U/Pb dating of columbite-(Fe) this huge Li-phosphate feldspar plug was intruded at 299.6±1.9 Ma.

THE HYDROTHERMAL/ EPITHERMAL STAGE AND ITS RELATED PHOSPHATES

Excluding the quartz dykes in the NW of the pegmatite province, a group of variegated Fe-Mn-Ca-Zn-Sc-Li phosphates evolved in the various aplitic mobilizates and pegmatite plugs from the primary phosphates under hydrothermal conditions (< 200°C) and strongly fluctuating redox conditions, controlled by the composition of the primary mineralization. Kolbeckite formed from primary Sc phosphates , Li phosphates gave rise to ferrosicklerite and tavoite and sphalerite decomposed to form keckite. Many phosphates containing bivalent and trivalent Fe are intimately intergrown with each other and accommodate iron of different valences in their structure, e.g., rockbridgeite, reflecting contrasting physical and chemical conditions. Opposed to the zonation where mineral assemblages in pegmatites and aplites are separated in space and time these minerals developed side-by-side at low temperature and by a hydrothermal system emplaced at shallow depths of less than1 km similar to an epithermal system ("telescoping"). This mineralization can only chronologically be constrained by minero-stratigraphic correlation with similar phosphate mineralization in neighboring platform sediments in the foreland of the uplifted basement. The epithermal phosphate mineralization is post-Coniacian in age and bridges the gap between hypogene and supergene mineralization.

THE SUPERGENE CHEMICAL ALTERATION AND THEIR RELATED PHOSPHATES

The presence of autunite and torbernite accompanied by wavellite, beraunite, cacoxenite, churchite and kaolinite allows for a precise determination of the chemical weathering at 4.55±0.02 Ma (Dill et al. 2007b). This Neogene process marks subtropical weathering and the formation of a vast peneplain similar to modern-day (sub)tropical morphoclimatic zones in Central Africa.

THE SUPERGENE PHYSICAL ALTERATION AND PLACER FORMATION

The trap placer deposits formed from the Late Cretaceous to the Neogene on a vast peneplain under subtropical conditions. Towards the Quaternary acidic meteoric fluids became more alkaline and linear erosion gradually replaced peneplanation as the main process of shaping the landscape. Alluvial-fluvial Ti ("nigrine") and Sn (cassiterite) heavy mineral accumulations derived from these geomorphological and sedimentological processes. The "black" sands may help to reconstruct that part of the "white" rocks when they were unroofed. Inclusions in "nigrine" (e.g., columbite, pyrochlore, aeschynite, pseudobrookite) may help draw picture of the apical parts of the pegmatites and aplites now eroded, twinned cassiterite aggregates have "internal sediments", e.g., plumbogummite, florencite, goyazite which are of assistance when it comes to the description of the chemical weathering during the late Mesozoic and Cenozoic. Both "black" heavy minerals may be used as an ore guide to "white" phosphate pegmatites/aplites which in general are very poor in minerals stable under pervasive chemical weathering.

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