The spodumene deposit at “Weinebene”, Koralpe, Austria

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Abstract. The Weinebene spodumene deposit is located in Carinthia, about 270 km southwest of Vienna. It is hosted by the medium- to high-grade metamorphic rocks of the Koralpe. The spodumene-bearing pegmatites form unzoned, dikelike bodies in eclogitic amphibolites and kyanite-bearing micaschists with concordant foliations. Their late-orogenic emplacement is probably of Variscan age. A younger, probably Alpine metamorphic event affected the pegmatites; it caused extensive recrystallization of the micaschist-hosted pegmatites, but had only a minor impact on the amphibolite-hosted ones. The spodumene-bearing pegmatites have been traced over a length of 1.5 km along strike and to about 450 m down dip. Their average thickness is 2 m, with a maximum of 5.5 m. Emplacement of the pegmatites caused an alteration halo of several dm in the host- ing amphibolites, characterized by biotitization and formation of holmquistite. An aplitic spodumene-free seam of about 10 cm symmetrically borders the pegmatites. No contact phenomena are observed along the micaschist-hosted dikes. Spodumene is the only lithium-bearing mineral. Its average content is 22 vol % (equivalent to 1.68 wt % Li_2O) in the amphibolite-hosted pegmatites and 15 vol % (equiva- lent to 1.13 wt % Li_2O) in the micaschist-hosted dikes. Such a significant difference is also shown by rubidium (1,100 ppm vs 880 ppm) and cesium (60 ppm vs 25 ppm). Beryllium and tin are the only other significant trace elements. They show average contents of about 100 ppm and 120 ppm, respectively, with maxima of 1,690 ppm beryllium and 1,500 ppm tin. No correlation is found between lithium, tin, and beryllium. Niobium and tantalum are very low. A Na/K ratio of 1.2 emphasizes the predominance of albite over microcline. There is no discernable correlation between spodumene and albite contents, or between lithium and any other alkalies. The average K/Rb ratio is 20, pointing to the high degree of fractionation. Spodumene contains 7.4% Li_2O and 0.45% FeO. There is no difference in the spodumene chemistry between the amphibolite-hosted and the micaschist-hosted pegmatites. Strong structural and textu- ral evidence, mineral zoning, bulk composition corre- sponding to thermal minima in relevant experimental sys- tems, and trace-element signature support an igneous derivation of the pegmatites. However, no granitic intrusion is exposed in the area, and the pegmatites could have been displaced from their source by tectonic events.

A synoptic study of lithium mineral showings and their paragenesis in the Austrian Alps carried out by the author led to the discovery and exploration of the largest lithium deposit known to date in Europe. The potential of the investi- gated area was originally indicated by the occurrence of pegmatitic boulders (Beck-Mannagetta 1951), mineralized with spodumene, beryl (Meixner 1966), and pyrochlore (Postl and Golob 1979). A preliminary note on the spodumene pegmatite has been published recently (Göd 1989). Description of the geology, mineralogy, and geochemistry of the deposit is the object of this paper. 1

Geology

Regional geology

Situated about 270 km southwest of Vienna (Fig. 1), the area under investigation belongs to the Koralpe, a NS-trending mountain ridge about 25 km in length. Being part of the eastern Alpine crystalline basement, the Koralpe is predominantly composed of meso- to katazonal metamorphic rocks and is interpreted as a Variscan nappe. The crys- talline complex comprises a great variety of paragneisses and micaschists as well as eclogites, amphibolites, and mar- bles. A regional outline of the geology of the Koralpe and its geotectonic framework has been given by Tollmann (1977) and Beck-Mannagetta (1980a); a geological map of the Koralpe has been published by Beck-Mannagetta (1980b). The only rock of granitic composition, a granitic gneiss, is situated about 20 km west of the area (Fig. 2). Being part of a window it therefore does not belong to the Koralpe crystalline complex sensu stricto. A schematized profile through the central part of the Koralpe indicating stratigraphic position of the deposit is given in Fig. 2. The metamorphic event causing the formation of the meso- to katazonal rocks is of Variscan age (Beck-Mannagetta 1980a, Tollmann 1980, Frank et al. 1979, 1983). A younger, probably early-Alpine metamorphic overprint is well docu- mented geologically (Wimmer-Frey 1984) and by mica ages 1

1 As this paper was going to press, a technical description of the deposit with emphasis on the exploration technique and eco- nomic parameters has been published by I. Cerny, P. Moser and P. Nedell: Das Projekt “Lithium Koralpe”; Berg- und Hüttenmännische Monatshefte, 134. Jg., Heft 6, 1989. The ge- ological and mineralogical part of this publication is based on unpublished reports by R. Göd
of about 80 Ma (Morauf 1980, 1981). This younger metamorphic event gave rise to the regional, EW striking, gently undulating, syncline-anticline structure of the Koralpe crystalline complex. One of these regional anticlines passes closely by the southern margin of the deposit (Fig. 1).

Local geology

The study area is characterized by a sequence of more or less quartzitic, locally kyanite-bearing micaschists and of eclogitic amphibolites. Due to its position at the northern slope of the anticline, the strata uniformly strike WNW-ESE (average 120°) and dip moderately to the NNE at an average angle of 60° (Figs. 1, 3).

The amphibolites are finely laminated, greenish rocks, mainly composed of amphibole, plagioclase, plus/minus garnet, and minor quartz. Locally they contain abundant calcite as a primary component. The eclogitic parts, occurring as dm up to a few m thick strata, are characterized by symplectic pyroxenes (Jawetzki, personal communication); regional petrographic studies (cited above) and local microscopic observations clearly indicate these eclogitic amphibolites experienced retrograde metamorphism (e.g., pyroxene is extensively replaced by hornblende). Stratigraphically about 1 m below dike 2.1 (see below), the amphibolites bear minor strata-bound scheelite; no scheelite has been found in the pegmatites.

The micaschists, predominantly quartzitic and mainly composed of muscovite, quartz, garnet, and biotite, bear kyanite paramorphs after andalusite up to a few centimeters in size ("Paramorphosenschiefer").

Both the eclogitic amphibolites as well as the micaschists occasionally contain graphite-rich layers, ranging from several cm to a few dm in thickness. As shown in Fig. 3, micaschist layers up to a few meters thick intercalate the amphibolites. These intercalations, the primary carbonate content of the amphibolites, the graphite content, and minor marble layers (a few dm thick, not shown in Fig. 3) in both rock types support a sedimentological interpretation of the eclogitic amphibolites. The bulk chemistries of both rock types are given in Table 1.

The spodumene-bearing pegmatites occur as unzoned, dikelike bodies in eclogitic amphibolites and kyanite-bearing micaschists, strictly concordant with their foliation. They have been traced over a distance of approximately 1.5 km and to a depth of about 450 m. The amphibolite-hosted (AH) pegmatites lie stratigraphically in the hanging wall position relative to the micaschist-hosted (MH) ones,