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Zeolite-group minerals in phonolite-hosted deposits of the Kaiserstuhl Volcanic Complex, Germany

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Abstract

Subvolcanic phonolite intrusions of the Kaiserstuhl Volcanic Complex (Germany) show variable degrees of alteration. Their secondary mineralogy has been characterized by petrographic textural observations, bulk-rock powder X-ray diffraction, thermogravimetry, differential thermal analysis, and electron probe microanalysis. The alteration assemblage is dominated by various zeolites that occur in fissures, vugs, and as replacement products of primary phases within the phonolite matrix. Phonolites in the eastern Kaiserstuhl were emplaced into a sedimentary sequence and are characterized by high zeolite contents (Endhalden: 48 wt%, Fohberg: 45 wt%) with the temporal sequence: ± thomsonite-Ca ± mesolite – gonnardite – natrolite – analcime. In the western Kaiserstuhl zeolite contents are lower (Kirchberg: 26 wt% or less) and the crystallization sequence is: ± thomsonite-Ca – gonnardite – natrolite – chabazite-Ca. Pseudomorphic replacement textures and barite inclusions in secondary aggregates suggest that zeolites grew at the expense of a sulfate-bearing sodalite-group mineral, i.e., haüyne. Fresh grains of sodalite-haüyne are only found at Kirchberg, whereas the pervasive alteration at Fohberg and Endhalden transformed feldspathoid minerals completely to zeolites.

Zeolites formed in a continuously cooling hydrothermal regime after emplacement and solidification of phonolitic magmas. The common paragenetic sequence corresponds to a decrease in the Ca/Na ratio, as well as an increase in the Si/Al ratio with time. The shift from Ca-Na- to pure Na-zeolites is an expression of closed-system behavior in a water-rich environment at Fohberg and Endhalden, which both intruded an Oligocene pre-volcanic sedimentary unit. The late crystallization of K-bearing chabazite-Ca points to a progressively more open hydrothermal system in the Kirchberg phonolite, which was emplaced in a subaerial volcanic succession and was influenced by K-enriched fluid from leucite-bearing country rock. Therefore, the geological setting and nature of emplacement are important factors that control the degree of zeolitization of intrusive feldspathoid minerals-bearing rocks and whether a zeolite occurrence can be used as mineral deposit.

Keywords: Natrolite, gonnardite, analcime, zeolite, alkaline rocks, phonolite, Kaiserstuhl; Microporous materials: Crystal-chemistry, properties, and utilizations