Diagenesis of Miocene vitric tuffs to zeolites, Mexican Highlands, Mexico

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Introduction

Volcanism during the Late Oligocene-Miocene in Mexico produced extensive deposits of rhyolitic and rhyodacitic pyroclastics which in cases resulted in potentially economic deposits of non-metallic minerals, including zeolites (De Pablo-Galán, 1979). Zeolitic tuffs have been reported previously in the states Oaxaca (Mumpton, 1973; De Pablo-Galán, 1986) and Sonora. Recent interest on the application of mineral zeolites to environmental control and dietary needs has spurred their interest. This paper attempts to add to the knowledge on zeolites, reporting a new locality in Mexico, discussing the mineralogy, geochemistry, petrology, and diagenetic reactions associated with their formation.

The zeolitic tuffs discussed here are exposed in outcrops extending over an area between 20°52′–21°01′ N latitude and 101°01′–101°19′ W longitude, SE of the city of Guanajuato. They represent the upper unit of the 400 m thick rhyolitic flows and tuffs of the Miocene Chichindaro Formation, overlaid by Quaternary basalts and underlay by andesitic and trachiandesitic lavas of the Oligocene Cedros Formation and the Late Eocene-Oligocene rhyolitic pyroclastics of the La Bufa Formation. The area is located in the limits between the Mexican Volcanic Belt to the south and the Mexican Highlands to the north. The dominant lithology is the altered vitric tuff which is fine-grained, light, soldered, and contains minor phenocrysts of K-feldspar, quartz, and biotite in a glass matrix substantially altered to zeolite. It is exposed at elevations from 1995 to 2048 m, 53 m thick, overlaid by 7 m of partially zeolitized vitric tuff, sectioned by 13 km of the highway between the cities of Guanajuato and J. Rosas (Dirección de Estudios del Territorio Nacional, 1978, 1978*a*, 1978*b*).

Methods

The tuffs were sampled along the highway Juventino Rosas-Guanajuato, SE of Guanajuato. From the several samples collected at various locations and elevations, 28 were selected to illustrate the mineralogy, geochemistry, petrology, and diagenetic reactions. Optical microscopy of thin sections and oil-immersed fragments was applied to study the minerals and their textural relationships. X-ray diffraction (XRD) using Cu-*Kα* radiation in a Siemens D5000 diffractometer allowed the identification of the minerals particularly the authigenic ones and their abundance. To differentiate clinoptilolite from heulandite the samples were heated to 500°C in steps of 100°C and analyzed by XRD (Mumpton, 1960; Minato *et al.*, 1985). The chemical composition of the tuffs was determined by X-ray fluorescence (XRF) and by wet chemistry procedures for H_2O, Na, K, and Mg; total Fe is reported as Fe_2O_3. Microtextural relations, crystallization, composition of minerals and glasses and their relative contents of Si/Al, and the nature of the diagenetic processes were determined by scanning electron microscopy (SEM) coupled to a Kevex energy dispersive spectrometer. Infrared analyses (IR) of material dried at 60°C, mixed with KBr and pressed to thin wafers, were done in a single-beam Perkin-Elmer 783 spectrometer at wavelengths from 4000 to 300 cm^{-1}.

Results

The Chichindaro Formation is about 400 m thick and consists of rhyolitic flows and tuffs. In the sections studied, the parent vitric tuff is light gray to pink, coarse-grain, dense, soldered, hard, containing coarse glass shards and bubbles, euhedral quartz and sanidine phenocrysts, some intermediate plagioclase, minor augite, magnetite, and slightly weathered biotite in a matrix of glass partially altered to opal-CT, at elevations of 1772 m. At higher elevations of 1860 m the tuff is fine-grained, denser and more compact, phenocrysts of quartz, intermediate plagioclase, and sanidine, minor biotite, in a glass matrix largely transformed to quartz.

The zeolitic tuffs crop at elevations from 1995 to 2048 m. The mineralogy is characterized by clinoptilolite in rosettes formed from completely weathered glass bubbles. Some shards were transformed to heulandite. The microtexture is hyaline. At the elevation of 1995 m clinoptilolite is associated with opal-CT and smectite, overlaid at 2010 m by a tuff characterized by essentially pure clinoptilolite, minor opal-CT, very low glass, free of smectite. At 2055 m are observed phenocrysts of euhedral to subeuhedral quartz in a glass matrix partially altered to clinoptilolite and opal-CT. As the elevation increases, weathering decreases and so the abundance of zeolite. The silicified tuff overlying the zeolitic tuff is typified by euhedral phenocrysts of quartz, intermediate plagioclase, and sanidine in a hyaline matrix devitrified to quartz. On top of the sequence, Tertiary andesite and Quaternary basalt.

The authigenic minerals in the zeolite tuffs are clinoptilolite, mordenite, heulandite, smectite, K-feldspar, quartz, and opal-CT. The three zeolites are characterized by their morphology, thermal stability, and Si/Al ratios. Smectite is noted in minor amounts associated with clinoptilolite and also as a very minor alteration in the andesite overlying the upper vitric tuff; it is characterized by the typical 14.0–15.0 A reflection. Authigenic K-feldspar is observed by XRD and microscopically in the form of slightly yellow birefringence patches filling in between the zeolite crystals, easily distinguished from the large sanidine phenocrysts. Quartz occurs in the tuffs underlying and overlying the zeolitic tuffs, from the devitrification of the rhyolitic glass, characterized by its undulatory extintion, easily differentiated from the pyrogenic quartz. Opal-CT is associated with clinoptilolite and smectite in the zeolitic tuffs and also with glass of the vitric tuffs.

The evidence presented indicates that rhyolitic vitric tuffs were diagenetically altered through the sequence: (1), devitrification of glass to opal-CT; (2), transformation to quartz; (3), glass-quartz-smectite; (4), opal CT-smectite-clinoptilolite; (5), clinoptilolite-opal CT. The environment was lacustrine, similar to those described for other locations (Altaner and Grim, 1990; Bowers and Burns, 1990; Lander and Hay, 1993; Panayota and Katagas, 1989; Sheppard, 1991).The deposit has economic potential. Its location substantiates the formation of zeolites in the Mexican Highlands on North Central Mexico.

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