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CLINOPTILOLITE WEST OF CUCHILLO NEGRO CREEK, NEW MEXICO—ZEOLITE AUTHIGENESIS OF THE TUFF OF LITTLE MINERAL CREEK

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Abstract—The Tertiary tuff of Little Mineral Creek crops out in the southern end of the Winston graben about 6.5 km south of Winston, Sierra County. The unit consists of thin to massive, partly silty to sandy, zeolitic tuff interbedded with mudstone, siltstone, and conglomerate. The tuff contains approximately 50% clinoptilolite. The clinoptilolite formed as a diagenetic-alteration product most likely via reaction of alkaline/saline meteoric and/or low-temperature hydrothermal fluids with vitric tuff in an open hydrologic system.

INTRODUCTION

The Tertiary tuff of Little Mineral Creek (Harrison in this guidebook) was altered to clinoptilolite (a zeolite) most likely by alkaline/saline meteoric and/or low-temperature hydrothermal fluids in an open hydrologic system. The zeolitic unit includes the clinoptilolitic tuff and conglomerate unit of Maxwell & Heyl (1976) and was termed the Cuchillo Negro clinoptilolite deposit by Bowie et al. (in press). It is exposed in the southern end of the Winston graben and at numerous localities in the adjacent Black Range and Sierra Cuchillo. The clinoptilolite deposit is about 6.5 km south of Winston (Fig. 1) and is accessible via County Road 6 and Forest Route 157. The central area of the Cuchillo Negro deposit is at the junction of Forest Route 157 and the road to the St. Cloud Mining Company mill, about 3 km northwest.

The purpose of this paper is to describe field relationships and mineralogical and chemical characteristics bearing on the economic potential of the zeolitized tuff of Little Mineral Creek. The nature and possible origins of fluids responsible for the zeolitic alteration are also examined.

Leonard Minerals Company and Todilto Exploration and Development Corporation, both headquartered in Albuquerque, investigated the Cuchillo Negro clinoptilolite resource, but no production occurred. Both companies held leases on the property in the late 1970's and early 1980's but have since cancelled them. No active leases are now held on the deposit. Leonard Minerals did some reconnaissance drilling to assess the gross quality and extent of the clinoptilolitic tuff. The resource base remains largely untested in detail.

STRATIGRAPHY

The tuff of Little Mineral Creek (Fig. 2) is part of a rhyolite–trachyte sequence interbedded within a complex Tertiary volcanic and sedimentary sequence that is at least 762 m thick in the Sierra Cuchillo. The rhyolite–trachyte sequence ranges from 91 to 213 m in thickness on the west side of the Sierra Cuchillo. The rhyolitic material is often porphyritic, with phenocrysts of broken or corroded quartz and smaller fragments of crystals of orthoclase, plagioclase, and lesser biotite. The groundmass is predominantly glassy with minor crystalline constituents (Harley 1934, Jahns et al. 1978).

The rhyolite–trachyte sequence includes zeolitized tuff of Little Mineral Creek, and consist of flows, crystal tuff, pumiceous tuff, and tuff breccia, with interbedded tuffaceous sandstone and conglomerate (Jahns et al. 1955). The sequence contains small to moderately large flow domes, in addition to scattered dikes, small plugs, and vent accumulations associated with several local eruptive centers. The source of the tuff of Little Mineral Creek may be a rhyolite flow–dome complex about 5 km southwest of the Cuchillo Negro deposit (R. Harrison, oral comm. 1986). In the Winston graben, the Tertiary volcanic and sedimentary sequence is unconformably overlain by a thick section of Tertiary and Quaternary fine- to coarse-grained basin fill of the Santa Fe Group (Maxwell & Heyl 1976). The northernmost outcrop of the tuff of Little Mineral Creek on Fig. 1 is conglomeratic and probably represents Santa Fe sediments overlying the tuff. To the south, Santa Fe units contain zeolitized clasts of the tuff.

MINERALOGY AND CHEMISTRY

The units of the tuff of Little Mineral Creek range from zeolitically altered, light-buff to chalk-white, thin-bedded to massive tuff interbedded with silty to sandy altered tuff, mudstone, siltstone, sandstone, and conglomerate (Fig. 2). In spite of this variety, all tuffaceous units sampled were altered, in part, to clinoptilolite. Empirical indicators such as color, texture, and induration are not a measure of the zeolite abundance. Limited x-ray diffraction (XRD) analysis of powder-press mounts returned an average of about 50% clinoptilolite per sample. Varying amounts of unaltered volcanic glass, quartz, calcite, feldspar, cristobalite, smectite, kaolinite, illite, and mixed-layer clay minerals also occur. Chabazite, dolomite, pyrite, magnetite, biotite, and manganese minerals are present in trace amounts.

The paragenetic sequence of authigenic mineralization, based on scanning electron microscopy, is unaltered volcanic glass $\longrightarrow$ early smectite $\longrightarrow$ cristobalite(?) $\longrightarrow$ clinoptilolite $\longrightarrow$ late smectite (Fig. 3). Smectite has displacively overgrown the glass and occurs as leafy, interconnected ridges forming a honeycomb texture. Clinoptilolite has grown at the expense of both volcanic glass and smectite. It occurs as small, subhedral to euhedral, coffin-shaped, monoclinic laths, either isolated or in clusters (Fig. 3). The laths are up to 10 microns long and wide and up to 3 microns thick. Second-generation smectite locally coats clinoptilolite.

X-ray diffraction analysis of tuff samples from vertical section A of the tuff of Little Mineral Creek exposed along the northern side of South Fork Arroyo (Fig. 1) shows little vertical variation in zeolite content. Similar analysis of vertical section B to the northwest (Fig. 1), reveals a tendency toward increased zeolitization up-section and in fault zones. Fault zones were, therefore, at least local conduits for some of the fluids responsible for zeolitic alteration.

A single major-oxide chemical analysis of an unbeneficiated zeolitic sample from the tuff of Little Mineral Creek returned the following composition (in wt% oxide):

SiO_2	64.72
Al_2O_3	12.65
Fe_2O_3	1.85
FeO	<0.04
MgO	1.04
CaO	3.32
Na_2O	0.88
K_2O	3.31
TiO_2	0.24
P_2O_5	0.04
MnO	0.048
SrO	0.053
BaO	0.078
$H_2O^{(+)} + CO_2$	8.77
$H_2O^{(-)}$	2.81
Total	99.81

The notably high calcium and potassium content of Cuchillo Negro

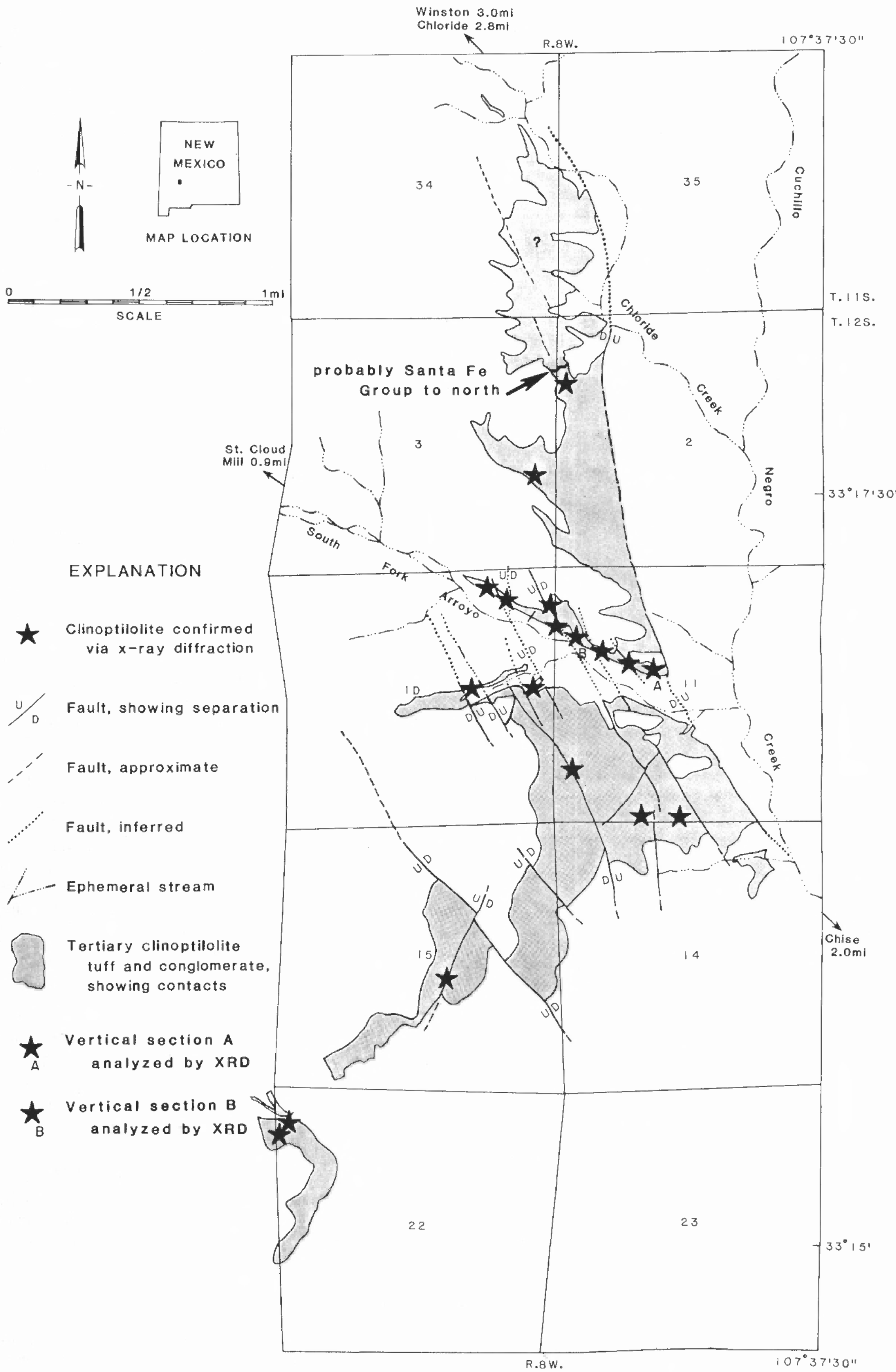

FIGURE 1—Outcrop pattern (shaded) of tuff of Little Mineral Creek in southern end of Winston Graben. Starred sample localities contain clinoptilolite confirmed by XRD. Two vertical sections (A, B) of tuff were analyzed by XRD to investigate vertical trends in mineralogy (modified from Maxwell & Heyl 1976 and Bowie et al. in press).

FIGURE 2—Prominent exposure of about 6 m of white, massive, zeolitic tuff of Little Mineral Creek along the St. Cloud road. View is northwest, about 1.6 km southeast of the St. Cloud mill. The tuff is overlain by poorly indurated, tuffaceous sandstone and conglomerate of the Santa Fe Group.

clinoptilolitic tuff was also confirmed by energy-dispersive spectroscopic analysis.

DISCUSSION AND SUMMARY

The timing of the zeolitization of the tuff of Little Mineral Creek cannot be completely bracketed by the data in hand. The zeolitization postdates the age of the tuff, which is tightly constrained between 28.9 and 28.46 my (Harrison in this guidebook). The tuff of Little Mineral Creek was pervasively altered by alkaline/saline fluids during one or more diagenetic events. The most likely mechanisms are alteration by: (1) immersion in a shallow lake (or playa) system; (2) meteoric alkaline/saline fluids percolating downward into the tuff from a shallow lacustrine (or playa) system; (3) infiltrating fresh meteoric water made alkaline and saline by reaction within the tuff itself; and (4) late-stage, low-temperature hydrothermal fluids related to nearby vent complexes.

The latter three proposed mechanisms are open hydrologic systems in contrast to the closed-hydrologic, shallow-lake mechanism. More than one of the four mechanisms may have affected the tuff mineralogy, but their relative contribution cannot yet be determined. We conjecture that percolation of alkaline/saline waters from a shallow lake was responsible for most of the zeolitization.

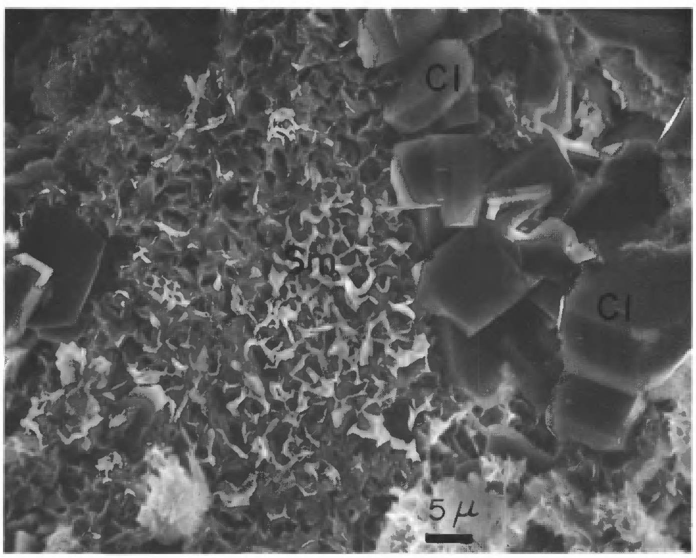

FIGURE 3—Scanning electron photomicrograph of zeolitized tuff of Little Mineral Creek. Honeycomb smectite (Sm) and coffin-shaped laths of clinoptilolite (Cl) have grown at expense of a volcanic glass shard. Clinoptilolite has also grown from the smectite.

A shallow-lake system can generate the fluids described in (1) and (2) above. The tuff of Little Mineral Creek could have been altered directly in alkaline/saline lake waters or by alkaline/saline lake fluids percolating downward into the tuff in the subsurface. The presence of conglomerate and coarse sandstone interbedded with water-laid tuff indicates that some of the tuff has been reworked, perhaps in a shallow-lake complex. The age of the tuff of Little Mineral Creek places it early in the period encompassing Rio Grande rift initiation. One characteristic of an early rifting phase is a poorly integrated drainage favorable to widespread ponding. Percolation of alkaline/saline lake water through the tuff of Little Mineral Creek would cause pervasive zeolitization. A similar mechanism was possibly active in the rift near Socorro over a period of nearly 20 my (Chapin & Lindley 1985). Time of this magnitude coupled with migration of playa/lacustrine centers around a basin following episodes of tectonism could yield widespread, pervasive alteration of reactive rhyolitic tuff in the subsurface.

Alkaline/saline fluids can be generated internally (Hay & Sheppard 1977) as fresh meteoric water percolates through a reactive unit such as the tuff of Little Mineral Creek. However, this mechanism generally produces increasing zeolitization downward, the reverse of the relationship seen in vertical section B. Downward percolation of alkaline/saline fluids would produce decreasing zeolitization with depth or pervasive alteration. Thus, the data in hand support an external source of diagenetic fluids.

Zeolitic alteration of the tuff of Little Mineral Creek may have been produced, in part, by late-stage, low-temperature hydrothermal solutions emanating from several rhyolite-porphyry vent complexes and acting in concert with meteoric waters. This is supported by the increase in zeolitization near some faults and by the possibility of age-equivalent hydrothermal activity at the nearby St. Cloud base- and precious-metal deposit. Eggleston & Norman (1985) examined the paragenesis of rhyolite-hosted tin deposits in the Black Range and Sierra Cuchillo by calculating fluid-inclusion homogenization temperatures of the authigenic mineral assemblage. The fluids responsible for vapor-phase alteration and tin mineralization of the rhyolite were probably magmatic fluids evolved during ascent and cooling of the magma. Low calculated salinities and low $\delta^{18}O$ values of the mineralizing fluids suggest that the magmatic fluid mixed with, and was eventually replaced by, meteoric water. Fluid-inclusion homogenization temperatures suggest that zeolite alteration to heulandite group minerals (including clinoptilolite) occurred over a 100–160°C temperature range (T. Eggleston, oral comm. 1986, Eggleston & Norman 1985).

Understanding the facies and hydrogeochemical history of the Santa Fe Group above the tuff of Little Mineral Creek is critical to clarifying the process of tuff diagenesis. The presence of a lacustrine facies must be demonstrated if a dominantly shallow-lake contribution is proposed. Rapid erosion of the margins of the narrow graben tends to mask this facies. Further work is underway to investigate the extent of lacustrine systems in the Santa Fe Group and their influence in altering the underlying tuff of Little Mineral Creek.

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