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Zeolites in Tertiary tuffs along the Little Humboldt River,
Humboldt and Elko Counties, Nevada

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INTRODUCTION

Zeolites are important rock-forming constituents in various sedimentary rocks (Hay, 1966). Most zeolites in sedimentary deposits formed after burial of the enclosing sediments by the reaction of aluminosilicate materials with the interstitial water. Silicic volcanic glass is the aluminosilicate material that most commonly served as a precursor for the zeolites, although materials such as clay minerals, feldspars, feldspathoids, and gels have also reacted locally to form zeolites. Zeolitic tuffs generally are white, or pastel shades of green, yellow, orange, or brown, relatively hard, and dull or earthy. The zeolitic tuffs commonly break with a blocky or conchoidal fracture. Unlike fresh volcanic ash, the zeolitic tuffs are resistant and ledge forming, particularly in arid areas. Most zeolitic tuffs consist of two or more zeolites as well as authigenic clay minerals, silica minerals, or feldspar, relict glass, and crystal and rock fragments. Extensive and relatively pure beds of zeolite, however, occur in Cenozoic deposits of the Western United States.

The wide diversity of applications and potential applications of natural zeolites is due to a unique set of properties, some of which were recognized more than a century ago. These properties include reversible dehydration, cation exchange, adsorption, and thermal and acid stability. The commercial utilization of natural zeolites in the United States is in its infancy, but the seemingly useful physical and chemical properties of zeolites, the high grade of many deposits, and the probably low cost of mining suggest greatly increased utilization in many industrial and agricultural processes in the near future (Mumpton, 1978).

Zeolites in sedimentary deposits along the Little Humboldt River in Humboldt County were recognized by us in 1975 during a search for Magadi-type chert in lacustrine rocks of Cenozoic age. Our brief reconnaissance showed the presence of clinoptilolite and erionite near the Chimney Reservoir on the South Fork of the Little Humboldt River and clinoptilolite at Spring Creek (fig. 1). Unknown to us at the time, however, was the unpublished discovery of clinoptilolite and minor erionite at Spring Creek in 1959 by the Union Carbide Corporation (F. A. Mumpton, oral commun., 1983). The only published occurrences of zeolites in sedimentary rocks of Humboldt County are clinoptilolite, erionite, mordenite, and analcime in volcanoclastic rocks associated with the McDermitt caldera complex of Oregon and Nevada (Rytuba, 1977; Glanzman and others, 1978; Glanzman and Rytuba, 1978). This present report is based on samples collected in 1980 from upper Tertiary tuffaceous rocks along the Little Humboldt River east of Paradise Valley.

GEOLOGIC SETTING

The zeolitic tuffaceous rocks are part of an unnamed lacustrine and fluviatile unit that crops out along the Little Humboldt River and its tributaries east of Paradise Valley (fig. 1). Willden (1964) mapped these upper Tertiary sedimentary rocks during his study of the geology and mineral deposits of Humboldt County. In addition to tuffaceous rocks, the Tertiary sedimentary unit of Willden (1964) consists of conglomerate, sandstone, shale, mudstone, diatomite, and chert and is as much as about 240 m thick. This sedimentary unit is nearly flat lying and is locally intercalated with basaltic volcanic rocks or is overlain by silicic flows and welded ash-flow tuffs. Stewart and Carlson (1976) assigned a Miocene age to both the sedimentary and volcanic rocks.

DESCRIPTION OF SAMPLED LOCALITIES

Tuffs were sampled at the seven localities shown on figure 1. The localities are grouped in two areas: (1) an eastern area along the South Fork of the Little Humboldt River, and (2) a western area along Spring Creek north of the Little Humboldt River. The western area along Spring Creek is about 60 km northeast of Winnemucca. Access to the localities along the Little Humboldt River is by a gravel road that intersects Nevada State Route 290 about 10 km south of the town of Paradise Valley. The stratigraphic relationships of the tuffs among the localities are unknown. With the exception of locality 3, some tuffs at each locality are zeolitic.

Locality 1 (NW1/4SE1/4 sec. 17, T. 41 N., R. 43 E.) is in a steep gully near the north end of an east-facing cliff, just west of Chimney Reservoir on the South Fork of the Little Humboldt River. The lower, gentler slope of the cliff consists mainly of gray, soft, unaltered tuffs that are poorly exposed. The upper part of the cliff consists chiefly of yellow, resistant, ledge-forming tuffs that are completely altered to clay minerals, zeolites, potassium feldspar, and (or) quartz. Some tuffs in the lower part of the ledge-forming unit are white to grayish yellow and are especially rich in authigenic potassium feldspar. Several layers of brown, gray, or white platy or nodular chert also crop out in the upper, resistant part of the cliff. The nodular chert and at least some of the platy chert are Magadi type (Surdam and others, 1972) that is generally characteristic of saline, alkaline-lake depositional environments. The zeolitic tuffs are thin to thick bedded, locally laminated, and locally crossbedded, and they break with a blocky to subconchoidal fracture.

Locality 2 (SE1/4SW1/4 sec. 17, T. 41 N., R. 43 E.) is at several small prospects on the south slope of a small hill west of the Chimney Reservoir on the South Fork of the Little Humboldt River. The exposed section consists mainly of white to light-gray tuffaceous sandstone and tuff. Much of the tuffaceous material is unaltered, but some is altered to clay minerals and zeolites. The tuffaceous sandstone contains local concentrations of silicified plant debris.

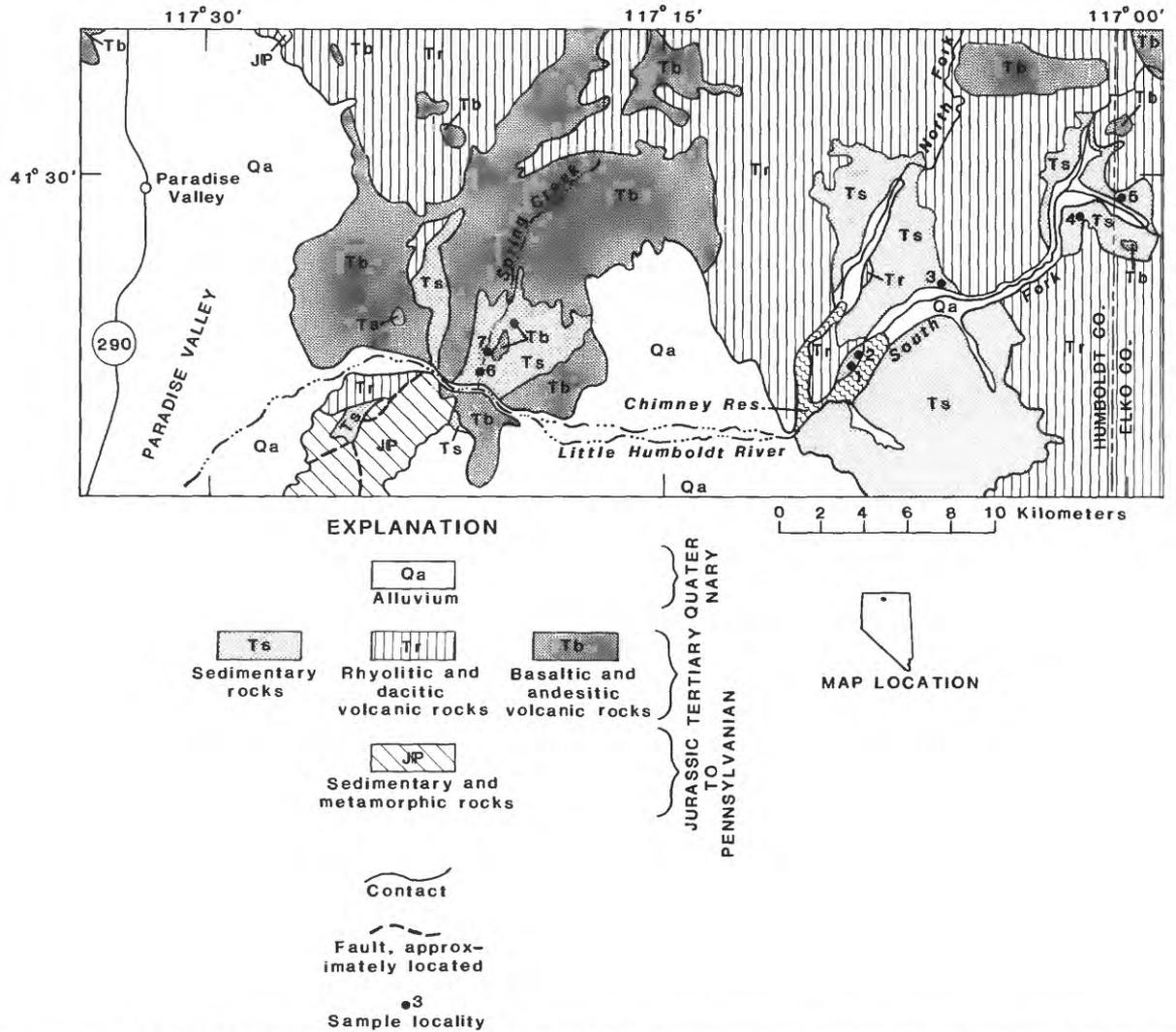


Figure 1.--Generalized geologic map along the Little Humboldt River, showing the sampled localities, modified from Willden (1964).

Locality 3 (SE1/4SW1/4 sec. 3, T. 41 N., R. 43 E.) is at a conspicuous natural exposure of tuffs on the south slope of a small hill north of the South Fork of the Little Humboldt River. The thin- to thick-bedded tuffs are gray, white, yellow, and brownish gray and are mostly soft and unaltered. Some tuffs have large-scale crossbedding. Only those tuffs that appeared altered were sampled, but even these contain some unaltered glass. No zeolites were recognized in the altered tuffs; only authigenic clay minerals and opal were identified.

Locality 4 (SW1/4NW1/4 sec. 2, T. 41 N., R. 44 E.) is at a poor natural exposure of tuffs on the south slope of a hill just north of a small tributary to the South Fork of the Little Humboldt River. The lower part of the hill is underlain by poorly exposed, fresh, gray tuffs and was not sampled. The upper part of the hill is underlain by relatively resistant, yellow- to yellowish-gray zeolitic tuffs.

Locality 5 (NW1/4NE1/4 sec. 1, T. 41 N., R. 44 E.) is at a well-exposed section of zeolitic tuffs that crop out in the lower part of a hillside just north of the South Fork of the Little Humboldt River. The tuffs are yellow to yellowish gray, thin to thick bedded, and completely altered to chiefly zeolites. Some of the tuffs are rich in detrital quartz and (or) plagioclase.

Locality 6 (SW1/4NE1/4 sec. 21, T. 41 N., R. 41 E.) is at the eastern cut bank of Spring Creek, about 0.8 km north of the junction of Spring Creek with the Little Humboldt River. The well-exposed sequence of yellow to light-gray zeolitic tuffs is thin to medium bedded and resistant. Some tuffs are laminated, and several show ripple marks or convoluted bedding.

Locality 7 (NW1/4NE1/4 sec. 21, T. 41 N., R. 41 E.) is on the hillside east of Spring Creek, about 1.4 km north of the junction of Spring Creek with the Little Humboldt River. Several bulldozer cuts expose white and yellow zeolitic tuffs. Additional yellow and orange, ledge-forming zeolitic tuffs crop out farther down the hillside from the bulldozer cuts. The tuffs are thin to thick bedded. Some tuffs, particularly those lower in the sequence, contain megascopic, irregular segregations of white, acicular, silky erionite.

MINERALOGIC COMPOSITION OF TUFFS

The mineralogic composition of the tuffs was determined by study of X-ray diffractometer patterns of powdered samples. The samples were first ground to a powder, packed in aluminum sample holders, and then exposed to copper radiation. Relative abundance of the zeolites and other constituents were estimated from the diffractometer patterns by using peak intensities and the procedure described by Sheppard and Gude (1973). These results are given in tables 1 and 2 where the abundance is expressed as "parts of ten." Inasmuch as no numerical value was assigned to trace amounts of constituents, some samples total 10 plus traces.

Altered silicic tuffs of the Little Humboldt River area commonly contain zeolites and clay minerals and less commonly contain potassium feldspar, all of authigenic origin. Clinoptilolite and erionite are the most common zeolites, and these are followed in abundance by phillipsite. Chabazite is a rare constituent in the zeolitic tuffs. Although nearly monomineralic beds of clinoptilolite and erionite have been recognized, these two zeolites are

generally associated. Nearly monomineralic tuffs of erionite occur at locality 1 (table 1), and nearly monomineralic tuffs of clinoptilolite occur at localities 6 and 7 (table 2). Phillipsite is commonly associated with clinoptilolite or with clinoptilolite and erionite. Trace to minor amounts of smectite are generally present in the zeolitic tuffs, and some tuffs, such as those at localities 2 and 3 (table 2), contain a major amount of smectite. Authigenic potassium feldspar was identified in tuffs at localities 1 and 7.

CHEMICAL COMPOSITION OF TUFFS

The major-element chemistry of an unaltered tuff, four zeolitic tuffs, and a potassium feldspar-rich tuff was determined by X-ray spectrographic analysis in the laboratories of the U.S. Geological Survey in Denver. Results of the analyses are given in table 3 in weight percent of the oxides. The loss on ignition (LOI) was determined at 900°C and is chiefly H₂O. Most of the analyzed tuffs contain impurities of quartz, plagioclase, and smectite in trace amounts. The analysis of the unaltered tuff from locality 1 indicates that the shards of this tuff are silicic and hydrated.

Analyses of three clinoptilolite-rich tuffs and an erionite-rich tuff are given in table 3. Analyses of the clinoptilolite-rich tuffs indicate that all are alkali rich. The erionite-rich tuff seems to have higher MgO and Fe₂O₃ contents and a lower K₂O content than most erionite-rich tuffs (Sheppard and Gude, 1982). Perhaps the analyzed sample has a higher content of impurities than that estimated from X-ray diffractometer data.

The analysis of tuff rich in authigenic potassium feldspar shows a predictably high K₂O content. This K₂O content (12.5 weight percent) is lower, however, than that anticipated from an examination of the X-ray diffractometer data. The relatively low K₂O content and the high contents of Fe₂O₃, MgO, and H₂O (loss on ignition) indicates a higher amount of impurities, probably clay minerals, than that estimated from the X-ray diffractometer data.

GENESIS OF THE ZEOLITES

The zeolites and associated silicate minerals in the tuffs and tuffaceous sedimentary rocks along the Little Humboldt River formed during diagenesis by reaction of silicic glass with pore waters of various compositions. The original composition of the volcanic glass was probably similar to that listed for sample No. 10-1 in table 3. Pore water trapped with the silicic vitric material in a lacustrine depositional environment probably varied from dilute and near-neutral pH to saline, alkaline brine having a pH of 9 or higher. Both high pH and high salinity of the pore water favor rapid solution of silicic vitric material. Surdam and Sheppard (1978) indicated that the important chemical parameters of the pore water in lacustrine deposits during the reaction of glass to zeolites are cation ratios, Si:Al ratio, and activity of H₂O. These parameters are, of course, affected by changes in the salinity and (or) alkalinity. The pH, in particular, influences the Si:Al ratio of the pore water and, thus, influences the Si:Al ratio of the zeolite that crystallizes from the pore water. A high pH favors the crystallization of the zeolite that has a low Si:Al ratio. Thus, a pH of 9 or higher favors the formation of phillipsite or erionite, but a pH of 7 to 9 favors the crystallization of clinoptilolite.

Table 1--Mineralogic composition of samples from locality 1, Little Humboldt River, as estimated from X-ray

diffractometer patterns of bulk samples.

[Locality: NW1/4SE1/4 sec. 17, T. 41 N., R. 43 E. Samples are listed in descending stratigraphic order. Tr., trace; --, looked for but not found. Clay, 10A: authigenic illite, pyrogenic and detrital biotite, and detrital muscovite]

Unit No.	Unit thickness in meters	Sample No.	Sample position in meters above base of unit	Lithology	X-ray diffractometer analysis in parts of ten									
					Glass	Clay, 10A	Clay, 14A	Clinoptilolite	Erionite	Phillipsite	Potassium feldspar	Quartz	Plagioclase	Calcite
17	2.20	10-17B	2.10	Tuff, yellow	--	2	1	5	1	--	--	1	--	--
		10-17A	0.40	Tuff, yellow	--	1	2	3	Tr.	1	--	3	--	--
16	4.10	10-16C	3.90	Tuff, yellow	--	--	Tr.	5	2	3	--	--	--	--
		10-16B	2.50	Tuff, yellow	--	--	Tr.	5	3	2	--	--	--	--
		10-16A	0.30	Tuff, yellow	--	Tr.	Tr.	--	10	--	--	--	--	--
15	0.12	10-15	0.05	Chert, lobate	--	--	--	--	--	--	--	10	--	--
14	1.15	10-14	0.50	Tuff, yellow, vuggy	--	1	1	2	Tr.	--	--	6	--	--
13	0.20	10-13	0.10	Chert, lobate	--	Tr.	Tr.	--	Tr.	--	--	9	--	1
12	3.15	10-12B	1.95	Tuff, yellow	--	--	--	--	10	--	--	--	--	--
		10-12A	1.05	Tuff, yellow	--	--	--	--	10	--	--	--	--	--
11	0.01	10-11	0.01	Chert, white and gray	--	--	--	--	--	--	--	10	--	--
10	1.02	10-10	0.50	Tuff, yellow, vuggy	--	--	Tr.	--	10	--	--	--	--	--
9	1.00	10-9B	0.70	Tuff, yellow	--	--	1	8	1	--	--	--	--	--
		10-9A	0.25	Tuff, yellow	--	Tr.	--	7	--	--	--	--	3	--
8	7.65	10-8D	6.75	Tuff, yellow	--	--	1	6	2	--	--	--	1	--
		10-8C	3.25	Tuff, yellow	--	--	Tr.	7	2	1	--	--	--	--
		10-8B	1.50	Tuff, orange	--	--	--	8	2	--	--	--	--	--
		10-8A	1.00	Tuff, yellow	--	--	2	5	2	--	--	--	1	--
7	0.40	10-7	0.10	Tuff, white, calcareous	--	--	Tr.	--	--	--	4	--	--	6
6	0.18	10-6	0.10	Chert, brown and gray	--	--	--	--	--	--	--	10	--	--
5	0.03	10-5	0.02	Tuff, white	--	Tr.	Tr.	--	--	--	10	--	--	--
4	1.00	10-4	0.50	Tuff, yellow	--	--	--	5	Tr.	5	--	--	--	--
3	0.15	10-3	0.12	Chert, white and brown	--	--	--	--	--	--	--	10	--	--
2	0.25	10-2	0.10	Tuff, white, calcareous	--	--	Tr.	--	--	--	9	--	--	1
1	3.75	10-1	0.10	Tuff, gray, unaltered	10	--	--	--	--	--	--	--	Tr.	--

Table 2--Mineralogic composition of tuffs from localities 2-7, Little Humboldt River, as estimated

from X-ray diffractometer patterns of bulk samples

[Samples at each locality are listed in descending stratigraphic order. Tr., trace; --, looked for but not found. Clay, 10A: authigenic illite, pyrogenic and detrital biotite, and detrital muscovite]

Sample No	Description	X-ray diffractometer analysis in parts of ten										
		Glass	Clay, 10A	Clay, 14A	Chabazite	Clinoptilolite	Erionite	Phillipsite	Potassium feldspar	Quartz	Plagioclase	Calcite
Locality 2: SE1/4SW1/4 sec. 17, T. 41 N., R. 43 E.												
11	Tuff, light-gray	--	--	8	--	--	2	--	--	--	--	--
Locality 3: SE1/4SW1/4 sec. 3, T. 41 N., R. 43 E.												
15A	Tuff, yellowish-gray	8	Tr.	2	--	--	--	--	--	--	Tr.	--
15B	Tuff, white	9	--	--	--	--	--	--	--	--	1	--
15CA	Tuff, gray	3	--	6	--	--	--	--	--	--	1	--
15CB	Tuff, light-brown	1	--	8	--	--	--	--	--	--	1	--
Locality 4: SW1/4NW1/4 sec. 2, T. 41 N., R. 44 E.												
16C	Tuff, yellowish-gray	--	--	1	--	4	5	--	--	--	--	--
16B	Tuff, yellowish-gray	--	--	--	1	4	5	--	--	--	--	--
16A	Tuff, yellowish-gray	--	Tr.	1	--	4	4	1	--	--	--	--
Locality 5: NW1/4NE1/4 sec. 1, T. 41 N., R. 44 E. (unsurveyed)												
17F	Tuff, yellowish-gray, 16.65 m above base	--	1	1	--	--	5	--	--	--	--	3
17E	Tuff, yellowish-gray, 13.75 m above base	--	--	Tr.	--	3	5	--	--	--	2	--
17D	Tuff, yellow, 9.80 m above base	--	--	1	--	3	4	--	--	--	2	--
17C	Tuff, yellow, 5.65 m above base	--	--	--	--	2	Tr.	--	--	8	--	--
17B	Tuff, yellow, 3.50 m above base	--	--	--	--	3	4	--	--	--	3	--
17A	Tuff, yellow, base	--	--	--	--	5	3	--	--	--	2	--
Locality 6: SW1/4NE1/4 sec. 21, T. 41 N., R. 41 E.												
14C	Tuff, light-gray, convoluted bedding, upper part	--	--	Tr.	--	10	--	--	--	--	--	--
14B	Tuff, light-gray, convoluted bedding, lower part	--	--	Tr.	--	9	--	1	--	--	--	--
14A	Tuff, yellow, thin bed	--	--	Tr.	Tr.	1	--	9	--	--	--	--
Locality 7: NW1/4NE1/4 sec. 21, T. 41 N., R. 41 E.												
13G	Tuff, white, 9.35 m above base	--	Tr.	Tr.	--	10	--	--	--	--	--	--
13F	Tuff, white, 7.60 m above base	--	Tr.	Tr.	--	8	--	--	2	--	--	--
13E	Tuff, yellow, vuggy, 5.85 m above base	--	--	--	--	9	--	Tr.	1	--	--	--
130	Tuff, white, 4.25 m above base	--	--	Tr.	--	7	1	--	--	2	--	--
13C	Tuff, orange, 2.45 m above base	--	--	3	--	5	Tr.	--	--	--	2	--
13B	Tuff, yellow, 1.30 m above base	--	1	1	--	7	1	--	--	--	--	--
13A	Tuff, yellow, base	--	--	1	--	9	Tr.	--	--	--	--	Tr.

Table 3--Chemical analyses of tuffs, Little Humboldt River, Nevada

[X-ray spectrographic analyses in weight percent by J. Baker, A. Bartel, J. Taggart, and J. S. Wahlberg. LOI (loss on ignition) was determined at 900°C]

Sample No. Locality No.	Unaltered tuff	Clinoptilolite- rich tuff			Erionite- rich tuff	Potassium feldspar- rich tuff
	10-1 1	14C 6	13A 7	13G 7	10-10 1	10-5 1
SiO ₂	69.4	63.3	63.6	62.7	57.8	60.6
Al ₂ O ₃	11.7	13.0	11.2	12.2	13.5	14.8
Fe ₂ O ₃	2.04	0.31	1.34	1.22	3.45	2.92
MgO	0.26	0.84	1.02	0.42	2.63	1.31
CaO	0.97	1.18	1.98	1.68	2.76	0.98
Na ₂ O	2.22	3.08	2.93	3.52	1.62	0.73
K ₂ O	5.80	3.18	2.12	2.19	2.94	12.5
TiO ₂	0.33	0.46	0.15	0.12	0.47	0.39
P ₂ O ₅	<0.05	<0.05	<0.05	<0.05	0.06	0.11
MnO	0.02	0.04	<0.02	<0.02	0.03	<0.02
LOI	6.09	13.2	14.7	14.7	13.9	4.26
Total	98.83	98.59	99.04	98.75	99.16	98.60

The mineralogy of the tuffs and associated rocks in the thick stratigraphic section at locality 1 indicates a wide range in the chemistry of the original lake water during the depositional interval represented by the sampled sediments. The unaltered (but hydrated) vitric tuffs in the lower part of the exposed section were probably deposited in fresh water having a near-neutral pH. At the other extreme, the beds and nodules of Magadi-type chert and the authigenic potassium feldspar in the tuffs suggest a highly saline and highly alkaline (pH=9.5-10.5) depositional environment (Surdam and others, 1972; Surdam and Sheppard, 1978). The tuffs that are now rich in zeolites were probably deposited in water characterized by moderate salinity and a pH of about 7 to 9.5.

ECONOMIC POTENTIAL

Zeolitic tuffs at three localities along the Little Humboldt River may have economic potential for a variety of industrial or agricultural uses because of their purity of a single zeolite phase, extent, thickness, and thin overburden. Although many of the tuffs at locality 1 consist of two or three zeolites along with other impurities, a continuous interval of about 4 meters in the upper part of the section consists of nearly monomineralic erionite. Nearly monomineralic clinoptilolite tuffs, at least 2 m thick, crop out at locality 6. Clinoptilolite-rich tuffs, 3 to 4 m thick, also occur in the upper part of the section exposed at locality 7.

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