

# **SEDIMENTARY ZEOLITE DEPOSITS OF THE UPPER MATANUSKA VALLEY, ALASKA**

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## **SPECIAL REPORT 6**

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# SEDIMENTARY ZEOLITE DEPOSITS OF THE UPPER MATANUSKA VALLEY, ALASKA

by D. B. HAWKINS

## ABSTRACT

Mordenite, heulandite, and laumontite deposits of possible economic significance exist in the vicinity of Horn Mountain and Sheep Mountain in the upper Matanuska Valley. The mordenite deposit in particular bears further study.

Zeolitization in the area is the result of burial diagenesis and low-grade regional metamorphism. At the time of zeolite formation, temperatures and salinities were lower in the Horn Mountain area, where deposits of mordenite and heulandite were formed, than for the laumontite deposits of Sheep Mountain.

A chemical field test for the presence of zeolites was not effective in distinguishing zeolitized from un-zeolitized rocks in the area.

## INTRODUCTION

### PURPOSE

The purpose of this study was to investigate the type and extent of zeolitization in the rocks of the Talkeetna and Matanuska formations of the upper Matanuska Valley, and to determine if zeolite deposits of possible economic significance were present. See Plate 1, for the location of the area studied.

## ACKNOWLEDGEMENT

In this work, I am particularly indebted to Arthur M. Grantz of the U. S. Geological Survey who freely shared his special knowledge of the zeolite occurrence in the upper Matanuska Valley with me, and in particular for bringing to my attention the tuffs of the Horn Mountain area (see Plate 1). I also wish to thank Professor Leonard Sand of Worcester Polytechnic Institute, who, as a professional courtesy, evaluated several of the zeolite samples for me. I also wish to thank my colleague, Dr. Donald Grybeck for his helpful criticism of this report. Finally, I wish to thank Mr. William Fackler, Dr. Thomas E. Smith, Dr. Thomas Mowatt and Namok Veach of the Alaska State Division of Geological and Geophysical Surveys for the funding and analytical support of this work.

## BACKGROUND

Zeolites are hydrous aluminosilicate minerals structurally related to the feldspars and containing alkali or alkaline-earth ions. The zeolites are unique in that the aluminosilicate framework is so constructed that large channelways and cavities are present within the structure. The alkali and alkaline-earth cations and water molecules which occupy structural positions within these channels and cavities are readily replaceable by other ions or molecules. Because the channels have unique aperture dimensions, only ions and molecules of the appropriate size can enter the structure. Because of these properties, zeolites serve as ion exchangers, gas sorbents, and molecular sieves to name a few applications. The references at the end of this report and especially those listed in Appendix 1 indicate the uses to which zeolites are put.

In the United States, most of the uses are filled by synthetic zeolites. The natural zeolites are extensively used in other countries; in Japan for example, the exploitation of natural zeolites is a multi-million dollar industry.

Zeolites formerly were thought to be rather rare minerals occurring as vug fillings in volcanic rocks. It was not until the mid 1950's to early 1960's that zeolites were shown to be very common sedimentary minerals often formed as the result of the alteration of vitric tuffs in saline-lake environments. The numerous large deposits of sedimentary zeolites in the conterminous United States were formed in this manner (Shepard, 1971; Papke, 1972). The zeolite deposits of Japan however, formed as a result of the interaction of marine waters on volcanic materials (Utada, 1971). The zeolites respond quite readily to changes in temperature and pressure as a result of burial. These changes produce characteristic suites of zeolites and other minerals which have come to be recognized as the zeolite facies of metamorphism (Coombs, 1970). Because the zeolites are relatively unstable, over a sufficiently long period of time, they may alter to more stable minerals such as the

feldspars. Zeolite deposits are thus confined to relatively young rocks. The conditions for the formation and preservation of the sedimentary zeolites are:

1. Reactive parent material, e.g., vitric tuffs;
2. Fluids of the appropriate chemical composition, e.g., saline-lake water;
3. Time sufficient for the formation of zeolites but not so long that the zeolites formed have been transformed to more stable minerals, e.g., Mesozoic to present.

These conditions are shown schematically in Venn diagram form in Figure 1.

## THIS STUDY

### SEARCH STRATEGY

In searching for zeolite deposits of potential economic importance in Alaska, the zeolite deposits of Japan, formed by alteration of volcanic rocks in a marine environment, serve as an excellent guide. The model offered by the zeolite deposits of the conterminous United States is not applicable to Alaska because unlike the western United States, Alaska did not have extensive Tertiary lake basins in which volcanic detritus was deposited. Using the conditions of Figure 1 as a guide, attention was directed to the Talkeetna formation in the upper Matanuska Valley. A literature search pertaining to the area revealed that zeolites had long been known to be present in this area (Capps, 1927; Grantz, 1965). Parenthetically, using the same model Madonna (1973) has discovered two previously unreported zeolite deposits in Alaska, one of which is of potential economic significance.

### GEOLOGY OF THE UPPER MATANUSKA VALLEY

The geology of the area studied has been described by Capps (1927) and more recently by Grantz (1965). The geology of the gypsum deposits on Sheep Mountain has been described by Eckhart (1951).

The present study was limited to investigating zeolitization in the lower Jurassic Talkeetna formation and lower units of the upper Cretaceous Matanuska formation. In the area studied, the Talkeetna formation consists of primary and

reworked volcanic ejecta and lavas of andesitic and basaltic composition; mostly marine, partly non-marine. The formation consists of thick units of marine pyroclastic sandstone, siltstone and claystone (coarse and fine-grained, water-laid tuffs). The rocks of the Talkeetna formation are commonly somewhat altered to chlorite, clay minerals, zeolites and albite. At Sheep Mountain and vicinity strong hydrothermal activity has produced greenstone.

The Matanuska formation consists of claystones, siltstones, shales and sandstones with limestone concretions and lentils. Prismatic shells of the pelecypod *Inoceramus* are present in some units. Basal units consist of pebbly epiclastic volcanic sandstone with marine fossils, limestone concretions and wood fragments (Grantz, 1965).

### SAMPLING

Samples of fist-sized dimensions were collected mainly from numerous outcrops of the Talkeetna formation at three areas in the upper Matanuska Valley. To a lesser extent outcrops of volcanic sandstones of the Matanuska formation were sampled as well. (See Plate 1 for the location of the sample areas). Plate 1 shows the localities from which samples were collected. In sampling these areas particular attention was paid to sample vesicular volcanics, vein material and tuffs, as these materials are likely to contain zeolites.

As can be seen in Plate 1, the Sheep Mountain area was most extensively sampled, primarily because of the accessibility of the area and because no information was available a priori to suggest that zeolitization in the Horn Mountain and Goober Lake areas was any different from that expected at Sheep Mountain.

## LABORATORY STUDIES

### X-RAY DIFFRACTION

Portions of the samples collected were ground in an agate mortar, mixed with distilled water to form a slurry and spread on a glass microscope slide. X-ray diffraction patterns of these slides were obtained using Ni filtered Cu K $\alpha$  radiation at a scan speed of two degrees two-theta per minute. Diffraction peaks over the angular range between four degrees to forty degrees two-theta were recorded. The x-ray diffraction patterns of the samples were compared with x-ray diffraction

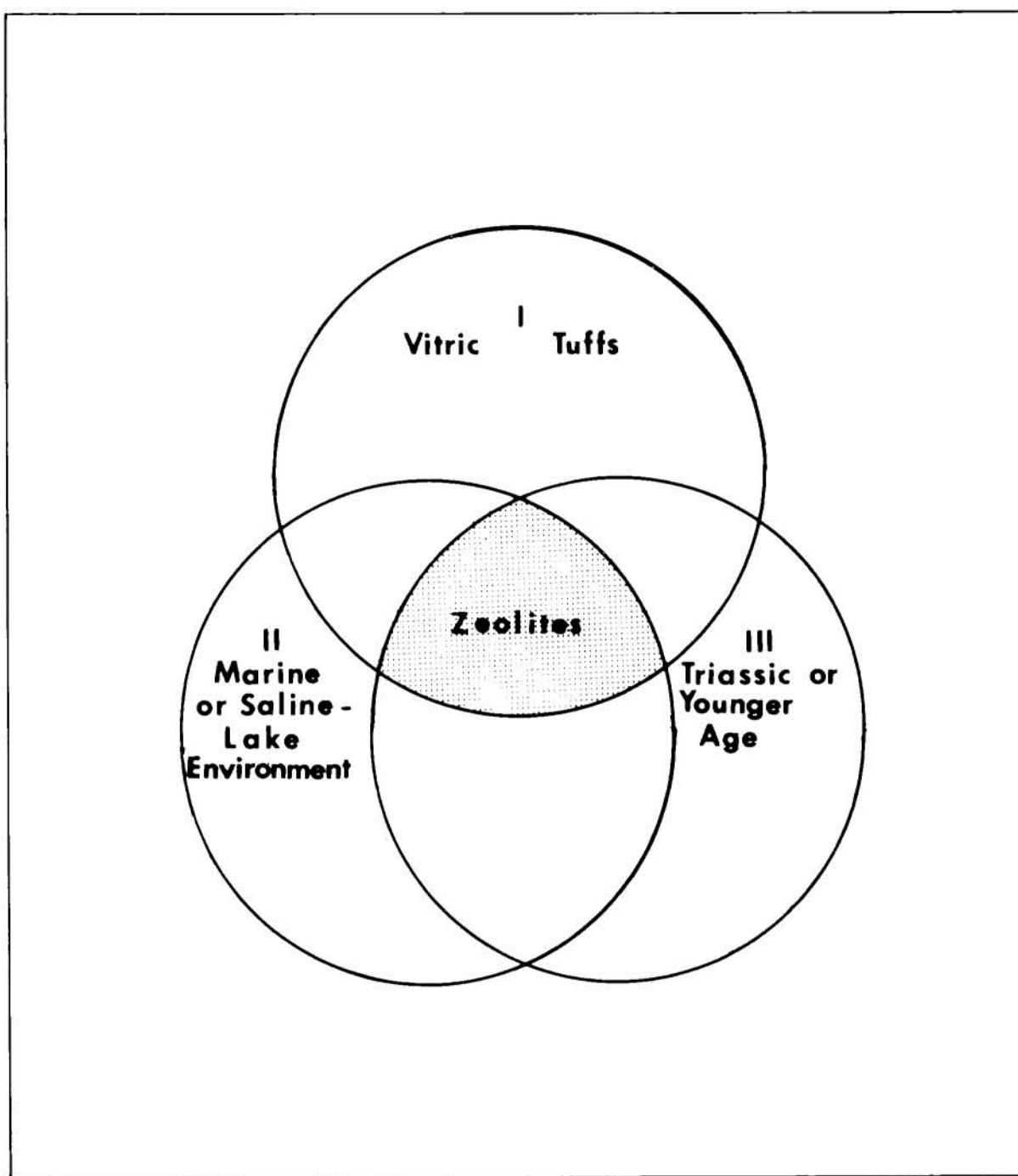


FIGURE 1. Venn diagram showing general conditions necessary for sedimentary zeolite formation and preservation.

TABLE 1. Sample number, hand-specimen description and mineralogy of samples as determined by X-ray diffraction. See Figures 3, 4, and 5 for the localities from which these samples were taken.

Sample Number	Description	Mineralogy (zeolites are indicated in bold faced type)
1	Massive, volcanic	Quartz, feldspar, chlorite
2	Volcanic breccia	Quartz, <b>laumontite</b> , chlorite
3	Water-laid tuff	Quartz, <b>laumontite</b>
4	Altered volcanic breccia	Quartz, <b>laumontite</b> , feldspar
5	Fine-grained volcanic sandstone	Quartz, <b>laumontite</b> , chlorite
6	Massive volcanic	Quartz, chlorite, feldspar
7	Water-laid tuff(?)	Quartz, <b>laumontite</b> , chlorite, feldspar
8	Massive volcanic	Quartz, <b>laumontite</b> , chlorite, feldspar
9	Vein filling in massive volcanic	Calcite, <b>laumontite</b> , chlorite
10	Fractured, vein bearing volcanic	Calcite, chlorite, feldspar
11	Fractured, vein bearing volcanic	Quartz, <b>laumontite</b> , feldspar
12	Massive volcanic	Quartz, chlorite, feldspar
13	Dense, volcano-clastic	Quartz, <b>laumontite</b> , feldspar
14	Claystone	Quartz, chlorite, feldspar
15	Vein bearing, fractured volcanic	Quartz, <b>laumontite</b> , calcite, chlorite, feldspar
16	Vein filling from fractured volcanic	Quartz, <b>laumontite</b> , feldspar
17	Water-laid tuff	Quartz, chlorite, epidote(?)
18	Vein bearing fractured volcanic	Quartz, <b>laumontite</b> , chlorite, calcite, feldspar
19	Massive volcanic	Chlorite, feldspar
20	Vein-bearing tuff	Quartz, <b>laumontite</b> , chlorite, calcite
21	Vein-bearing, fractured tuff	<b>Laumontite</b> , chlorite, feldspar
22	Fracture, vein-bearing siltstone	Quartz, <b>laumontite</b> , chlorite, datolite
23	Altered claystone	Quartz, kaolinite, calcite
24a	Vein filling	Quartz, calcite
24b	Altered pebbly breccia	Quartz, kaolinite, calcite, feldspar
24c	Vein-bearing, massive volcanic	Calcite, unidentified major phase
25	Vein-bearing, massive volcanic	Quartz, <b>laumontite</b> , calcite, feldspar



Table 1. - *Continued*

Sample Number	Description	Mineralogy (zeolites are indicated in bold faced type)
26	Siltstone	Quartz, calcite, kaolinite
27	Tuff	Quartz, <b>laumontite</b> , chlorite
28	Tuff	Quartz, <b>laumontite</b> , feldspar
29	Tuff	Quartz, <b>laumontite</b> , feldspar
30	Tuff	Quartz, <b>laumontite</b> , feldspar
31	Claystone	Quartz, <b>laumontite</b> , kaolin(?), calcite, feldspar
32	Pumice and tuff	Quartz, <b>laumontite</b> , chlorite
33	Massive volcanic	Quartz, chlorite, feldspar, calcite
34	Massive volcanic	Quartz, kaolinite, feldspar
35	Fractured, massive volcanic	Quartz, <b>laumontite</b> , chlorite, feldspar
36	Massive volcanic	Quartz, chlorite, feldspar
37	Siltstone	Quartz, calcite, chlorite, feldspar
38	Gypsum	Gypsum
39	Gypsum	Gypsum
40	Fractured, vein-bearing volcanic	Quartz, <b>laumontite</b> , chlorite, gypsum
41a	Vein filling, altered volcanic	Gypsum, <b>laumontite</b> , chlorite
41b	Vein filling, altered volcanic	Gypsum, chlorite
42	Greenstone	Epidote, calcite
43	Conglomerate	Quartz, <b>laumontite</b>
44	Greenstone	Quartz, chlorite, epidote
45	Conglomerate	Quartz, feldspar
46a	Vein-bearing fractured volcanic	<b>Laumontite</b> , chlorite, feldspar
46b	Hydrothermally altered fractured volcanic	Quartz, <b>laumontite</b> , feldspar, kaolinite
47	Vein-bearing fractured volcanic	Quartz, <b>laumontite</b> , feldspar
48	Volcanic sandstone	Quartz, <b>laumontite</b> , feldspar
49	Coarse volcanic sandstone	Quartz, <b>laumontite</b> , chlorite, feldspar
50	Vein-bearing fractured volcanic	Quartz, <b>laumontite</b> , chlorite, feldspar
51	Tuff	Quartz, <b>laumontite</b> , feldspar, chlorite
52	Greenstone	Prehnite
53	Volcanic sandstone	Quartz, <b>laumontite</b> , chlorite, feldspar
54a	Volcanic sandstone	Quartz, chlorite
54b	Hydrothermally altered massive volcanic	Quartz, chlorite

Table 1. - *Continued*

Sample Number	Description	Mineralogy (zeolites are indicated in bold faced type)
54c	Red-brown soil, from massive volcanic	Quartz, chlorite, calcite
55	Conglomeratic greenstone	Quartz, <b>laumontite</b> , feldspar, kaolinite
56	Vein-bearing fractured volcanic	Quartz, <b>laumontite</b>
57	Claystone	Sericite
58	Vesicular volcanic	Quartz, <b>laumontite</b>
59	Tuffaceous sandstone	Quartz, <b>laumontite</b>
60	Volcanic gouge with zeolite(?) porphyroblasts	Quartz, <b>laumontite</b> , feldspar
61	Coarse volcanic sandstone	<b>Laumontite</b> , chlorite, feldspar
62	Clayey gouge	Quartz, <b>laumontite</b> , chlorite
63	Vesicular volcanic with zeolite(?) vug fillings	Quartz, <b>laumontite</b> , feldspar
64	Tuff and pumice	Quartz, <b>laumontite</b> , chlorite, feldspar
65	Massive volcanic	Quartz, <b>laumontite</b> , chlorite
66	Massive volcanic	Quartz, <b>laumontite</b> , chlorite, feldspar
67	Tuff	Prehnite
68a	Vesicular volcanic	Chlorite, epidote
68b	Vesicular volcanic	Quartz, chlorite, epidote
69a	Massive volcanic	Quartz, chlorite
69b	Vesicular volcanic with zeolite(?) vug fillings	<b>Wairakite</b> (?), chlorite
69c	Quartz sericite rock	Quartz, sericite, chlorite, feldspar
70a	Massive andesite(?)	Chlorite, feldspar
70b	Hydrothermally altered andesite(?) with marcasite blebs	Quartz, chlorite, sericite
70c	Tuff, float	Quartz, epidote
70d	Vesicular, volcanic float, with quartz(?) vug fillings	Quartz, chlorite, feldspar
70e	Vein-bearing fractured volcanic	Quartz, <b>laumontite</b>
70f	Vesicular volcanic float, with zeolite(?) vug fillings	<b>Wairakite</b> (?), <b>laumontite</b>
71a	Massive andesite(?) float	Quartz, <b>laumontite</b> , chlorite, feldspar
71b	Tuff, float	Quartz, chlorite
72a	Volcanic conglomerate	Quartz, <b>laumontite</b> , feldspar

Table 1. - *Continued*

Sample Number	Description	Mineralogy (zeolites are indicated in bold faced type)
72b	Massive volcanic	Quartz, <b>laumontite</b> , feldspar
73	Vein-bearing tuff	Quartz, <b>laumontite</b> , chlorite, feldspar
74a	Massive volcanic	Quartz, <b>laumontite</b> , chlorite, feldspar
74b	Massive volcanic	Gypsum, chlorite
74c	Vein-bearing volcanic	Gypsum
75	Vein-bearing fractured volcanic	Quartz, <b>laumontite</b>
76	Massive volcanic	Quartz, chlorite, feldspar
77	Pumice	Kaolinite, <b>wairakite(?)</b> , <b>laumontite</b> , feldspar
78a	Gypsiferous rock and clay	Gypsum, quartz, feldspar
78b	Pumice	Gypsum, epidote
79	Vesicular basalt, with zeolite vug fillings	<b>Laumontite</b> , chlorite, epidote
80	Vein quartz with malachite and chalcopryrite	Quartz, chalcopryrite
81a	Vesicular volcanic with zeolite vug fillings	<b>Laumontite</b>
81b	Vein and fug filling from massive volcanic	<b>Laumontite</b>
81c	Vein and vug filling from massive volcanic	<b>Laumontite</b>
82	Vesicular volcanic with zeolite vug fillings	<b>Laumontite</b>
83	Tuff	Quartz
84	Tuff	Quartz, <b>laumontite</b> , chlorite
85	Massive volcanic, float	Quartz, <b>laumontite</b> , chlorite, feldspar
86	Vesicular volcanic	Quartz, prehnite
87	Vein filling from massive volcanic	Quartz, <b>laumontite</b> , chlorite, feldspar, calcite
88a	Massive volcanic	<b>Laumontite</b> , chlorite, feldspar
88b	Greenstone	Chlorite, epidote, feldspar
89	Massive volcanic	Quartz, <b>laumontite</b> , chlorite
90	Massive volcanic	<b>Wairakite(?)</b> , sericite, kaolinite, quartz
91	Volcanic sandstone, float	Quartz, prehnite, chlorite
92	Tuff	Quartz, <b>laumontite</b> , chlorite
93	Tuff, float	Quartz, <b>laumontite</b> , chlorite

Table 1. - *Continued*

Sample Number	Description	Mineralogy (zeolites are indicated in bold faced type)
94	Precipitate on stream cobble	Amorphous to x-rays
95	Vesicular volcanic	Quartz, <b>laumontite</b> , chlorite, feldspar
96	Massive volcanic	<b>Laumontite</b> , <b>wairakite</b> (?), chlorite, feldspar
97	Massive volcanic	Quartz, <b>laumontite</b>
98	Tuff	Quartz, <b>wairakite</b> (?), chlorite, feldspar
99	Tuff	Quartz, <b>laumontite</b> , chlorite
100	Tuff	Quartz, <b>laumontite</b> , chlorite, feldspar
101	Tuff	Quartz, <b>laumontite</b> , chlorite, feldspar
102	Tuff	Quartz, <b>laumontite</b> , chlorite, feldspar
103	Pumice tuff	Quartz, <b>laumontite</b> , chlorite, feldspar
104	Massive volcanic	Quartz, <b>laumontite</b> , chlorite, feldspar
105	Tuff	Quartz, <b>laumontite</b>
106	Tuff	Quartz, <b>laumontite</b> , chlorite, feldspar
107	Vein-bearing fractured volcanic	Quartz, <b>laumontite</b> , chlorite, feldspar
108	Vesicular volcanic	Feldspar, chlorite
109	Tuff	Quartz, <b>laumontite</b> , chlorite, feldspar
110	Massive volcanic	Quartz, <b>laumontite</b>
111	Pebbly volcanic sandstone	<b>Mordenite</b>
112a	Volcanic sandstone	<b>Mordenite</b>
112b	Volcanic sandstone	<b>Mordenite</b>
113	Tuff, float	<b>Mordenite</b>
114	Tuff	<b>Laumontite</b>
115	Tuff with zeolite veinlets	<b>Heulandite</b>
116	Tuff	<b>Mordenite</b>
117	Vug filling, vesicular andesite(?)	<b>Heulandite</b>
118	Tuff	<b>Heulandite</b>
119	Tuff	<b>Mordenite</b>
120	Tuff, float	Quartz, <b>laumontite</b> , chlorite, feldspar
121	Tuff, float	Quartz, <b>laumontite</b> , feldspar
122	Volcanic sandstone	Quartz, chlorite, feldspar
123	Volcanic sandstone	Quartz, feldspar
124	Vein-bearing volcanic sandstone	Quartz, calcite, possible <b>wairakite</b> (?)
125	Pebbly volcanic sandstone	Quartz, chlorite

patterns of a number of zeolites and common rock forming minerals to determine the gross mineralogy of the samples.

Those samples which contained zeolites of the heulandite-clinoptilolite group were heated following the method given in Alietti (1972) to distinguish between heulandite and clinoptilolite. The results of the x-ray diffraction and heat-treatment studies are given in Table 1.

#### FIELD TEST FOR ZEOLITES

Helfferich (1964) suggested a simple chemical test for the presence of zeolites. This test depends upon the ion-exclusion properties of zeolites and a hydrolysis reaction which is ultimately manifested as a pronounced increase in pH of the test solution. According to Helfferich, pH values of 9 to 11 are indicative of the presence of zeolites.

As recommended by Helfferich, tetra butyl ammonium bromide solutions were used to lessen interference with the test by the layer silicates. Measurements of pH were carried out using a combination microelectrode and a Beckman Model N pH Meter. The results of this test are shown in Table 2.

#### ION-EXCHANGE AND GAS-SORPTION MEASUREMENTS

Following the x-ray diffraction analysis, four zeolite-bearing samples were sent to Prof. Leonard Sand of Worcester Polytechnic Institute (W.P.I.) for evaluation of their ion-exchange and gas sorptive properties. The results of these analyses are shown in Table 3, along with those for a synthetic sodium mordenite for comparison. Also shown in Table 3 are the results of a heat-of-wetting test which serves as the basis for a proposed new field test for zeolites (Culfaz, Keisling and Sand, 1973).

#### PETROGRAPHIC STUDY

Thin sections were prepared of the samples sent to W.P.I. to determine the mode of occurrence of the zeolites in these samples. Time did not permit a more extensive petrographic study. The results of this study are presented and discussed in the following section on the mode of occurrence of zeolites.

## DISCUSSION

#### DISTRIBUTION AND GENESIS OF ZEOLITES

From Table 1, it is evident that many of the samples collected are zeolite bearing. Most of the samples collected from the Sheep Mountain area contained laumontite or its dehydration product, leonhardite. Laumontite (leonhardite) occurs in vugs and veins in fractured massive volcanics and as an alteration product of vitric tuffs.

A few samples from the Sheep Mountain area contained an analcime-group mineral tentatively identified as wairakite(?). It was not possible to distinguish between the sodium zeolite analcime and its calcium analog wairakite by means of x-ray diffraction. A thin section of this material (sample #98) revealed a mass of weakly birefringent fine grained zeolite as an alteration product of the felsic ground mass of an andesite(?). The birefringence of this material, plus the calcium rich nature of this rock and the zeolites and other minerals in the area suggests that wairakite rather than analcime is present. A much more detailed study involving mineral separation, chemical analysis and detailed petrographic and x-ray diffraction studies is needed before this zeolite can be identified unequivocally.

The layer silicate prehnite, a common associate of calcic zeolites, was detected in several samples from Sheep Mountain. No pumpellyite was observed. Chlorite was a nearly ubiquitous mineral in the samples from Sheep Mountain.

In contrast to the zeolite assemblage at Sheep Mountain, the samples from the Horn Mountain area (see figure 4) bore the zeolites mordenite and heulandite. Laumontite was present in one sample of tuff from Albert Creek. Neither prehnite nor wairakite were observed in these samples.

In the Horn Mountain area, mordenite occurs as an alteration product of the volcanic sandstones of the Matanuska formation (samples 111, 112a and 112b) and replacing glassy shards in the fine-grained vitric tuffs at the head of Albert Creek (samples 113, 116 and 119).

Heulandite is present as thin, tabular crystals in veins in an altered siliceous volcanic in Albert Creek (sample 115) and as large (1-2 cm) foliate aggregates in vug fillings of the massive volcanics of Horn Mountain (sample 117). Heulandite also occurs in an altered tuff, where it appears to have formed at the expense of the glass (sample 118).

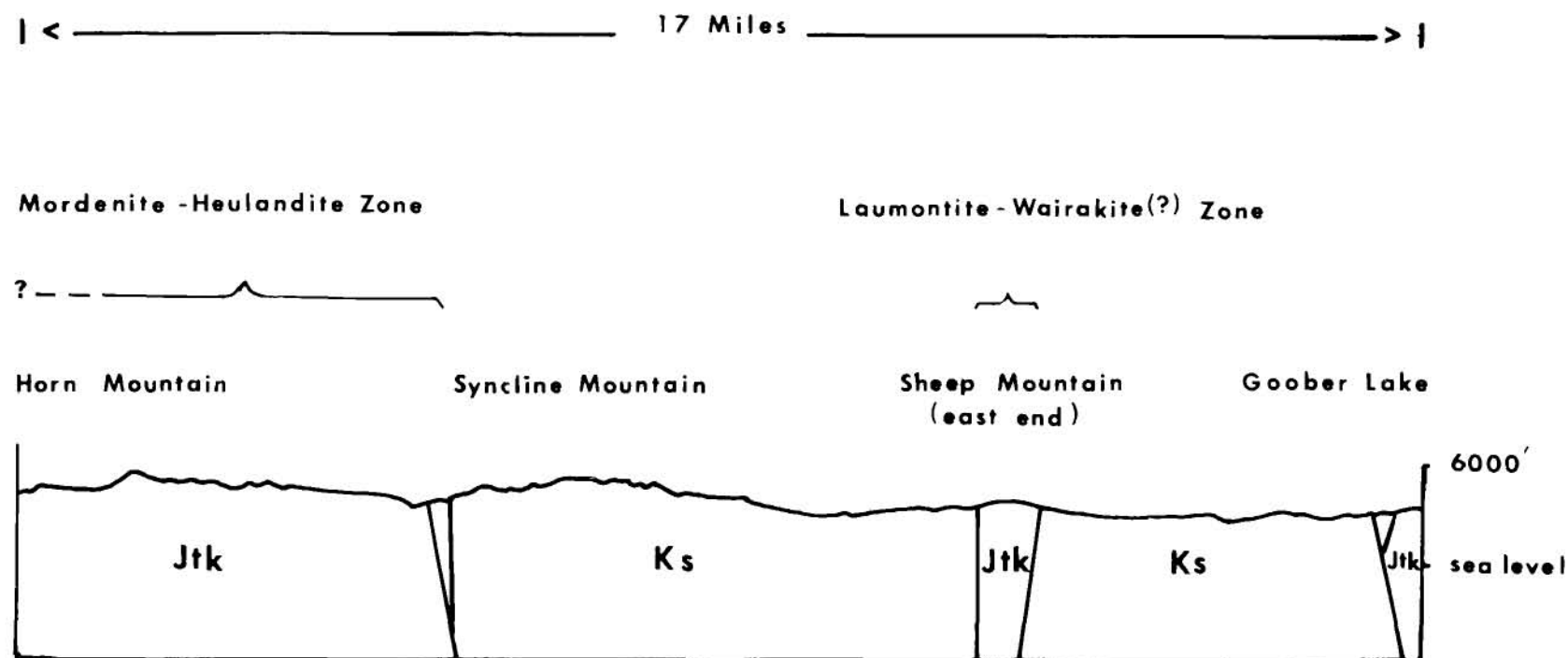


FIGURE 2. Cross section from near Goober Lake north to Horn Mountain showing probable zeolite zonation. See Plate 1 for areal relations and lithology. Cross section greatly simplified from section C-C' of Grantz (1965).

Laumontite occurs in an altered tuff (sample 114) on Albert Creek. This laumontized tuff appears similar to those of the Sheep Mountain area.

The samples from the Goober Lake area (See Plate 1) are for the most part unzeolitized. One sample (124) may contain an analcime-like zeolite, however.

The zeolite distribution of the areas sampled is shown schematically in cross section in Figure 2.

The different zeolite assemblages at Horn Mountain and Sheep Mountain are indicative of different conditions that prevailed at the time of zeolite formation. As shown in Figure 3, the mordenite-heulandite assemblage is typical of low temperatures and low partial-pressures of water ( $P_{H_2O}$ ). Laumontite and laumontite-prehnite are characteristic of higher pressure-temperature conditions. The important variable in these zeolite stability relations is the chemical potential of water as Zen (1960) has shown. The more hydrous heulandite ( $CaAl_2Si_7O_{18} \cdot 6H_2O$ ) and mordenite ( $CaAl_2Si_{10}O_{24} \cdot 7H_2O$ ) assemblage is stable under a higher chemical potential of water than are the less hydrous zeolites laumontite ( $CaAl_2Si_4O_{12} \cdot 4H_2O$ ) and wairakite ( $CaAl_2Si_4O_{12} \cdot 2H_2O$ ). The chemical potential of water may be varied (A) by altering the partial pressure of water on the system; or (B) by varying the salinity of the aqueous fluid. Increasing salinity of intra stratal waters at depth has the same effect as increasing temperature in promoting a zonation from more hydrous to less hydrous phases.

From the discussion above, the zeolites of the Horn Mountain area formed under lower temperature or salinity conditions than did those of the Sheep Mountain area. Sea-water reactions contemporaneous with the cooling of the submarine volcanics of the Talkeetna formation could have contributed to the zeolitization of these rocks. However, because the zeolitization extends to the basal volcanic sands of the Matanuska formation, it is more likely that reactions involving burial diagenesis and regional metamorphism are the cause of zeolitization. The zonation discussed above suggests that the volcanics and volcanic sands at Horn Mountain and vicinity were not as deeply buried as were the volcanics at Sheep Mountain.

Zeolitization of the Sheep Mountain area does not appear to be related to the intrusive that has so obviously hydrothermally altered the area (see greenstone area, Plate 1). Neither the laumontite nor prehnite, nor wairakite(?) distributions bear any obvious relation to the intrusive.

#### ECONOMIC POTENTIAL OF ZEOLITE DEPOSITS

The mordenite-bearing tuffs in the vicinity of Horn Mountain may be of economic importance (Plate 1). Although the tuff from which the mordenite bearing samples was obtained appears to form an extensive series of outcrops along the low ridge to the north of Albert Creek, it is emphasized that neither the extent nor grade of these tuffs is known at present.

As shown in Table 3, the mordenite-bearing tuff sample has a sulfur dioxide sorptive capacity approaching that of the synthetic mordenite. It also exhibits a reasonably high cation exchange capacity, and the highest surface area of the samples submitted although much less than that of the synthetic mordenite. These properties and the location of this deposit near the coal fields of the upper Matanuska Valley, the agricultural lands of the lower Matanuska Valley, the oil fields of the Cook Inlet area, and the population center of Anchorage suggest several potential uses: (A) sulfur dioxide sorbent in coal-fired power plants; (B) sorbent for the storage of natural gas from Cook Inlet (Munson and Clifton, 1971); (C) catalysts or catalytic carriers for the hydrocracking of petroleum; (D) conditioner for agricultural soils (Alaska State Division Geol. and Geophys. Surveys, 1973); (E) ion exchange medium for various waste disposal operations including the treatment of municipal sewage and the decontamination of radioactive wastes from future nuclear power plants. **It is stressed that these applications are highly speculative and depend upon determining the extent and grade of the mordenite deposits, determining the usefulness of the tuff for different applications and then establishing a market for this material for particular applications.**

The laumontite tuffs of Sheep Mountain, while extensive, are probably not as economically important as the mordenite tuff. Laumontite does not have the chemical stability of mordenite, nor does it have the catalytic properties of the higher silica zeolite. However, the laumontized tuff may have important agricultural uses and should not be ignored.

The heulandite bearing tuff at the head of Albert Creek should be investigated further. Heulandite, and particularly the higher silica variety clinoptilolite, have important industrial applicability (Sheppard, 1971b). The occurrence of heulandite as vug fillings is not economically important.

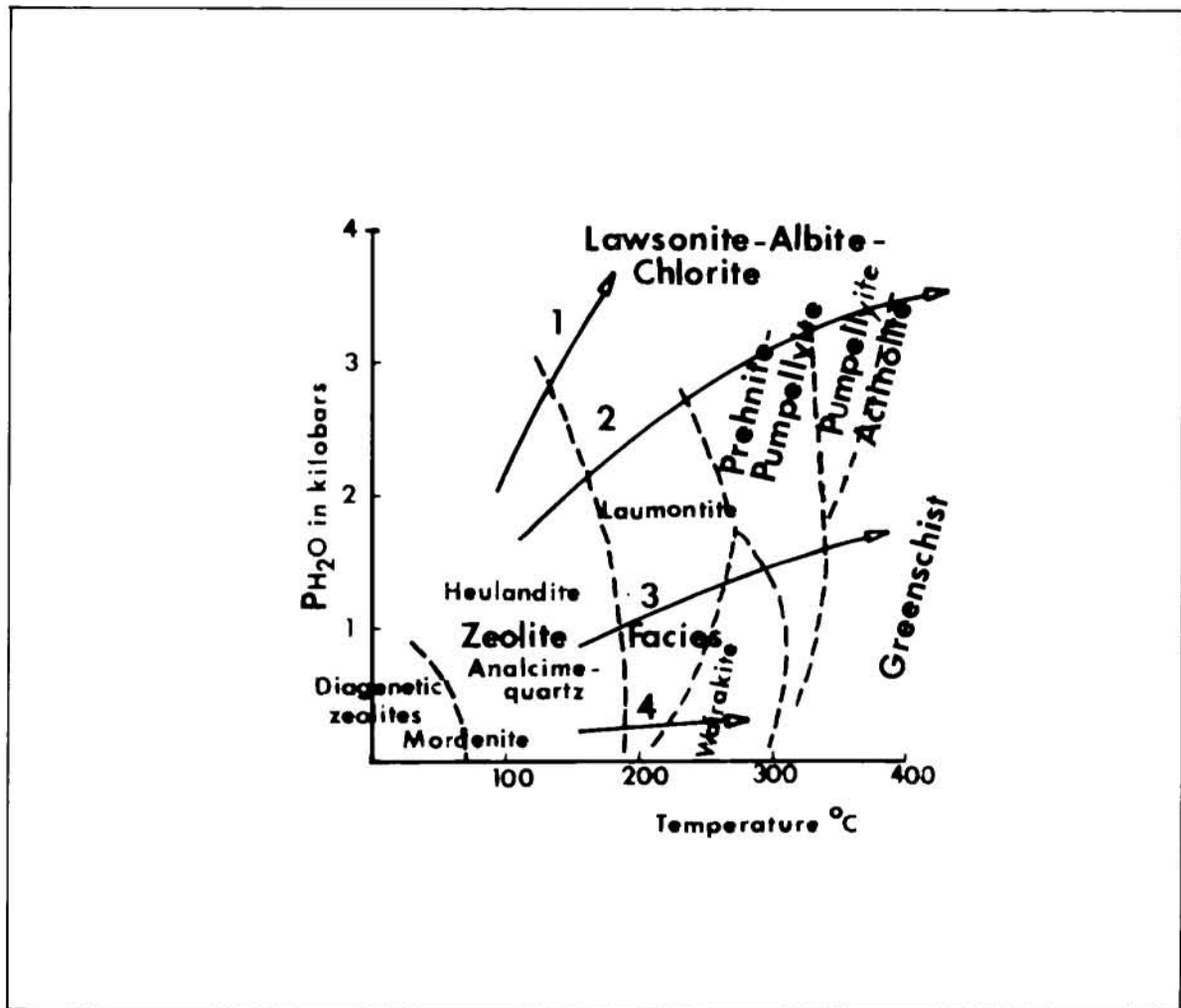


FIGURE 3. Possible P-T fields for low-grade mineral facies. Arrows represent facies series as follows: (1) High pressure, low temperature; (2) Intermediate; (3) Low pressure intermediate; (4) Lowest pressure. Diagram from Coombs (1970).



TABLE 2. *Results of chemical field test (Helfferich, 1964) for the presence of zeolites.*

Sample Number	Dominant Mineralogy (zeolites are indicated in bold faced type)	Final pH
1	Quartz, feldspar, chlorite	10.4
6	Quartz, feldspar, chlorite	10.2
10	Chlorite, calcite, feldspar	10.8
12	Quartz, chlorite, feldspar	10.4
19	Chlorite, feldspar	10.3
59	Quartz, <b>laumontite</b>	10.5
81a	<b>Laumontite</b>	10.3
81c	<b>Laumontite</b>	9.9
86	Prehnite	10.8
90	<b>Wairakite</b> (?)	10.2
91	Prehnite	10.0
96	<b>Laumontite</b>	10.8
97	<b>Laumontite</b>	9.2
98	<b>Wairakite</b> (?)	10.4
99	<b>Laumontite</b>	10.1
110	<b>Laumontite</b>	10.5
111	<b>Mordenite</b>	11.0
112a	<b>Mordenite</b>	10.0
112b	<b>Mordenite</b>	10.9
113	<b>Mordenite</b>	11.3
114	<b>Laumontite</b>	10.9
115	<b>Heulandite</b>	11.2
116	<b>Mordenite</b>	11.2
118	<b>Heulandite</b>	10.5
123	Quartz, feldspar	9.4
124	Calcite, quartz, feldspar, <b>wairakite</b> (?)	11.0
125	Chlorite, quartz, feldspar	9.0

TABLE 3. *Results of zeolite evaluation, Worcester Polytechnic Institute.*

Sample Number	Zeolite	SO <sub>2</sub> Capacity g/100 g dry Sample	Ag+ Exchange Capacity Mole Equiv. /100 g Sample	N <sub>2</sub> BET Surface Area m <sup>2</sup> /g	$\Delta T$ °C
59	Laumontite	0.458	0.1581	10.64	4.37
98	Wairakite(?)	0.252	0.1670	21.4	4.13
116	Mordenite	13.08	0.1104	33.2	13.03
118	Heulandite	1.937	0.1326	16.32	6.93
Synthetic Na-Mordenite		18.0	0.232	432.0	16.3

The wairakite(?) occurrence on Sheep Mountain is probably not economic, because of the properties of this zeolite and the sporadic distribution.

The method of establishing mining rights for zeolites on Federal lands has recently been established. The Bureau of Land Management indicates that zeolite deposits are subject to the sodium-potassium leasing law (Papke, 1972).

#### FIELD TEST FOR ZEOLITES

The results of the field test evaluation shown in Table 2 indicate that this test is inappropriate for the zeolite samples studied here. The failure of this test to distinguish zeolitized from unzeolitized samples, as shown by the broad range of pH values, is apparently due to the interference of layer silicates on this test.

A new field test for zeolites has just been proposed by Culfaz, Keisling and Sand (1973). This test was performed on the four samples submitted to W.P.I. for evaluation, the results of which are shown in column 4 of Table 3. According to the authors, values of  $\Delta T$  in the range 8 to 20°C are indicative of an intermediate to high-grade zeolite deposit depending upon the zeolite variety present. Values of  $\Delta T$  greater than 20°C are indicative of a high grade chabazite deposit. Note that the mordenite tuff had a  $\Delta T$  value of 13.03°C closely approaching that of the synthetic mordenite and suggestive of a high-grade deposit. No other

evaluation of this test was made in the present study. It is suggested that this method be investigated further.

#### CONCLUSIONS

Zeolite deposits of possible economic significance exist in the upper Matanuska Valley. The mordenite-bearing tuffs at the head of Albert Creek at the east end of Horn Mountain probably have the greatest economic potential. The heulandite-bearing tuffs in this same area and the laumontized tuffs at Sheep Mountain may also be valuable for certain applications. The extent, grade and market value of these deposits must be determined.

Zeolitization of the Sheep Mountain-Horn Mountain area is the result of burial diagenesis and regional metamorphism. The zeolites of the Horn Mountain area formed under conditions of lower temperature and salinity than did those of the Sheep Mountain area. The volcanics of the Sheep Mountain area may have experienced a greater depth-of-burial than did the sediments and volcanics of the Horn Mountain area. Zeolitization of the Sheep Mountain area does not appear to be related to the Sheep Mountain intrusive.

A published field test for zeolites is subject to interference from layer silicates and is inapplicable to the zeolitized rocks of the area studied. A proposed new field test may be applicable and should be investigated.

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