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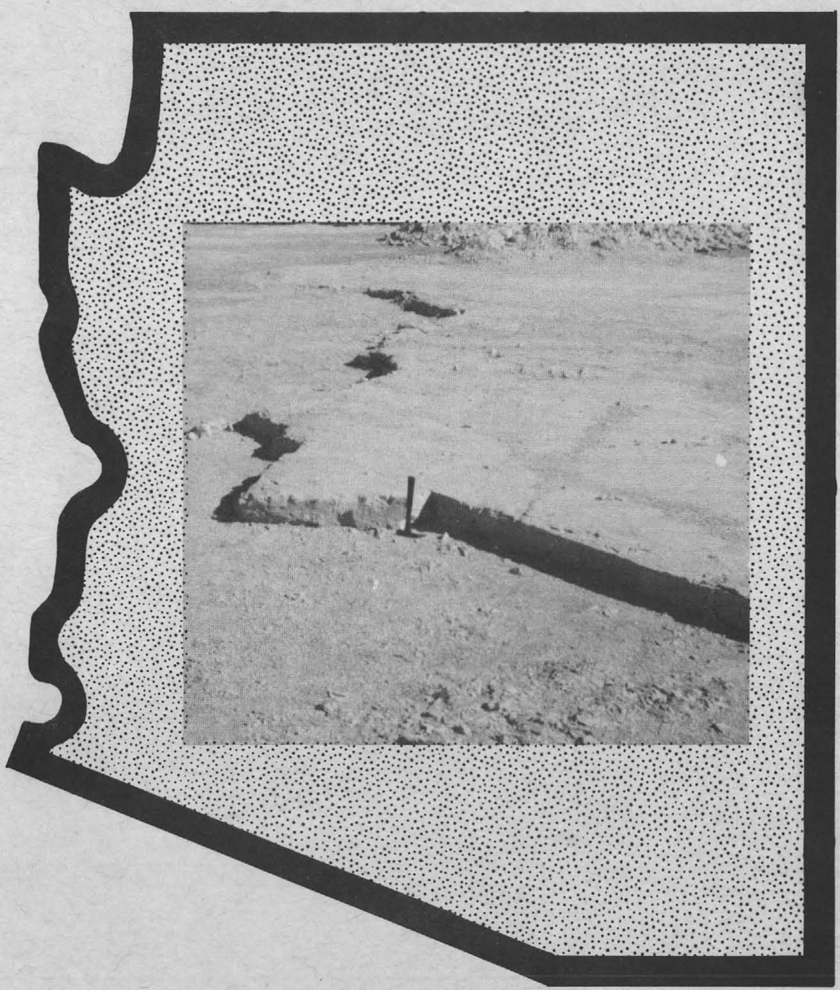
ARIZONA ZEOLITES

MINERAL REPORT NO. -1

By TED H. EYDE



STATE OF ARIZONA

DEPARTMENT OF MINERAL RESOURCES

MR - 1

A R I Z O N A   Z E O L I T E S

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STATE OF ARIZONA

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ZEOLITES IN ARIZONA

This Arizona Department of Mineral Resources publication describes Zeolite deposits in Arizona.

This report is made possible through the cooperative efforts of Mr. Ted H. Eyde, consulting geologist and G.W. Irvin, mining engineer for the Department of Mineral Resources. The wording, geology, interpretation and photographs are theirs.

Described herein are zeolite occurences including properties with production records. Between 1957 and 1978, Mr. Eyde visited and examined several hundred zeolite deposits in the Western United States and Mexico.

This report is intended as an informative release to be a useful aid to those seeking to find and produce Zeolite Minerals.

The Department appreciates Mr. Eyde's cooperation in the publication of this paper as a contribution to the mineral field and possible stimulant to zeolite exploration, development and research.

ARIZONA DEPARTMENT OF MINERAL RESOURCES

John H. Jett, Director

There are many restrictive environmental and health laws, rules, and regulations that may impede the prospecting for, and the eventual mining and processing of minerals. These laws, rules, and regulations can be either Federal, State, County, or Local, legislated or promulgated and enforced.

Potential problems include disruption of aquifiers, maintenance of air quality, disruption of existing land surface, vegetation and soils, possible conflict of user interest, maintaining workers' health and safety, controlling radiation and modification of socioeconomic patterns (including additional roads, population increase, powerlines, traffic, public services required, etc.)

These possible restrictions should not deter the prospector from actively seeking a mineral deposit or developing an ore body. The highly restrictive rules and regulation problems can be solved. If the potential problems are acknowledged, then solutions engineered into the proposed operation, compliance is possible and feasible. The Department engineers are available to discuss these problems and possible solutions with the prospector or operator.

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ZEOLITE MINERALS IN ARIZONA, OCCURRENCES AND USES

Introduction

Arizona is the nation's largest producer of zeolite minerals principally chabazite and mordenite, for industrial applications. The purpose of this publication is to acquaint the prospector with zeolite minerals, typical occurrences, analytical methods, industrial uses, and potential consumers. It also contains a comprehensive bibliography intended for the prospector who is interested in learning more about this unique group of minerals.

Zeolite Minerals

Since their discovery by the Swedish mineralogist Baron Cronstedt in 1756 over 30 naturally occurring zeolite minerals have been identified. The name Zeolite, which literally means boiling stones, is derived from the Greek "Zeo", meaning to boil, and "Lithos" meaning stone which referred to the conspicuous loss of water when zeolite minerals are heated. Three zeolite minerals chabazite, clinoptilolite, and mordenite are being used in industrial applications. Three other zeolite minerals erionite, phillipsite, and ferrierite may have potential industrial applications. With the exception of ferrierite all of these minerals are known to occur in Arizona principally as the alteration products of vitric tuffs. These so called "sedimentary zeolites" or "zeolitic tuffs" occur in extensive high purity deposits. A sample of zeolitic tuff from the Bowie deposit which contains over 90% chabazite does not appear to resemble the beautifully crystallized specimens of the same mineral exhibited in the mineral collections at the Department of Mineral Resources or at the University of Arizona. However, a scanning electron micrograph of the chabazite from Bowie bears a remarkable resemblance to the museum specimens. The only difference is the size of the crystals. The extremely small size of the crystals of zeolite minerals makes identification by visual examination whether by the unaided eye, hand lens, or microscope virtually impossible. X-ray diffraction analyses is usually the only reliable technique that can be used to positively identify the minerals in zeolitic tuffs. Unfortunately, no analytical laboratories in Arizona can run routine X-ray diffractograms. The names and addresses of laboratories equipped to run X-ray diffractograms are listed in this publication under Analytical Laboratories.

Uses

The first natural zeolite mineral marketed in the United States was chabazite from the Bowie, Arizona deposit. In 1963 the Linde Division of Union Carbide Corporation added the natural chabazite from Bowie, designated as AW 500, to their molecular sieve product line. AW 500 sold for $1.14 to $1.69 per lb. depending on the quantity purchased. This is comparable to the prices charged for synthetic zeolites. Linde AW 500 is used for acid gas drying, reformer hydrogen drying, chlorinated and fluorinated hydrocarbon purification, and hydrogen chloride removal from by-product hydrogen streams.

Reserve Synthetic Fuels Incorporated uses chabazite from the Bowie deposit in its proprietary NuFuel Process which removes water, carbon dioxide, hydrogen sulfide, and other contaminents from methane. Over 1,000,000 cubic feet per day of pipeline quality methane are produced from 2,000,000 cubic feet of contaminated gas in purification plant at the Los Angeles Sanitation District Palos Verdes land fill near Los Angeles, California. This plant will eventually produce 6,000,000 cubic feet of methane a day which is sufficient to supply the requirements of a city the size of Reno, Nevada. A pilot plant using the same process is being used to treat contaminated natural gas produced by Seaboard Oil and Gas Company at the Farmer's Market field in Los Angeles.

Chabazite from Bowie can also be used to remove carbon dioxide and hydrogen sulfide from methane gas produced during the digestion of sludge at municipal sewage treatment plants and of animal wastes from feedlots. The Bowie chabazite could also be used for the recovery and storage of radioactive cesium. Once trapped in the chabazite, the cesium can be stored for ease of shipment or disposal.

Several advanced water treatment plants utilizing clinoptilolite are in various phazes of operation, construction, and design planning. The ion exchange properties of clinoptilolite are highly selective in extracting ammonia from sewage in the presence of abundant calcium and magnesium. The Rosemount, Minnesota plant which has a 600,000 gpd (gallons per day) design capacity went on stream in late 1975. The plant now operating at 300,000 gpd utilizes three ion exchange columns, each containing 7.5 tons of clinoptilolite which reduces the ammonia nitrogen content of the effluent from 45 ppm to 1 ppm. When operating at design capacity, which will not be reached for several years, the plant will utilize a full charge of 45 tons of clinoptilolite. The plant has not been in operation long enough to determine the attrition rate, however, preliminary data indicate an attrition rate of about 50 lbs. per column daily. This indicates the plant will ultimately consume about 55 tons of clinoptilolite annually.

Another advanced water treatment plant under construction at Manassas, Fairfax County, Virginia for the upper Occoquan Sewage Authority will use a process developed by CH2/M Hill. The plant, which has a design capacity of 22,500,000 gpd, will treat an initial flow of 10,900,000 gpd when the plant becomes operational in 1978. The eight treatment tanks containing alternating layers of clinoptilolite and gravel will require an initial charge of 430 tons of clinoptilolite.

Construction started on the 6,000,000 gpd North Lake Tahoe, California plant in March of 1976. A 54,000,000 gpd expansion of the Alexandria, Virginia plant using clinoptilolite is in the design stage. The Fairfax County and North Lake Tahoe plants are in localities designated by the EPA as areas of critical environmental concern. Sewage effluent in such areas requires nearly complete ammonia nitrogen removal. If these plants operate successfully, the EPA may ultimately require that the effluent discharge from all sewage treatment plants contain no more than 1 ppm ammonia nitrogen.

In so called advanced waste water treatment plants the clinoptilolite attrition rate is influenced by many factors including the design of the ion exchange vessels, the composition and ammonia content of the waste water, and the composition of the regeneration solutions, So far, no accurate estimate can be made of the clinoptilolite consumption of these plants. It appears that a 10,000,000 gpd day plant, depending on the process used will require an initial charge of 450 to 750 tons of clinoptilolite plus 400 to 1000 tons per year to replace attrition losses. When fully operational in the mid 1930's, the Rosemount, Fairfax County, North Lake Tahoe, and Alexandria plants could consume between 2000 and 3000 tons of clinoptilolite a year.

Natural mordenite is used in a PSA (pressure swing absorption) process to produce oxygen for an iron foundry at Toyohashi, Japan. This unit operates at ambient temperature and is reported to operate at a cost which compares favorably with fractional air distillation plants.

Union Carbide Corporation has trial marketed molecular sieves produced from natural mordenite. Union Carbide also uses the PSA process utilizing synthetic zeolites to produce oxygen for its UNOX waste water treatment system. It is possible that Union Carbide could use mordenite in its PSA oxygen producing facilities at waste water treatment plants if the cost advantage of the natural mordenite offsets its lower adsorptive capacity.

Experiments are continuing in the United States and other countries to utilize the ion exchange capabilities of natural zeolites in removing heavy metal ions from low level waste streams produced by mining and milling operations. The Anaconda Company is doing research to determine whether natural zeolites may also be used to remove sulfur dioxide from smelter stack gases. The Linde Division of Union Carbide Corporation recently introduced three processes for controlling emissions based on absorption by a molecular sieve which may actually be a natural zeolite. The processes are the PuraSiv S (SO_2 removal), PuraSiv N (NO_x removal), and PuraSiv Hg (mercury removal).

Waste water treatment processes seem to be the most promising use for natural zeolites. It also appears that the production of natural zeolites in the United States will experience a modest, but continuing growth through the next decade as other uses currently being researched and tested are put into use. More widespread applications, nevertheless, will still depend on a reliable supply of a consistent quality available at a reasonable price in the range of $50-$100 per ton for the sized product F.O.B. the plant site.

General Geology

Zeolite minerals occur as:

1. Amygdules of zeolite minerals in basalt.

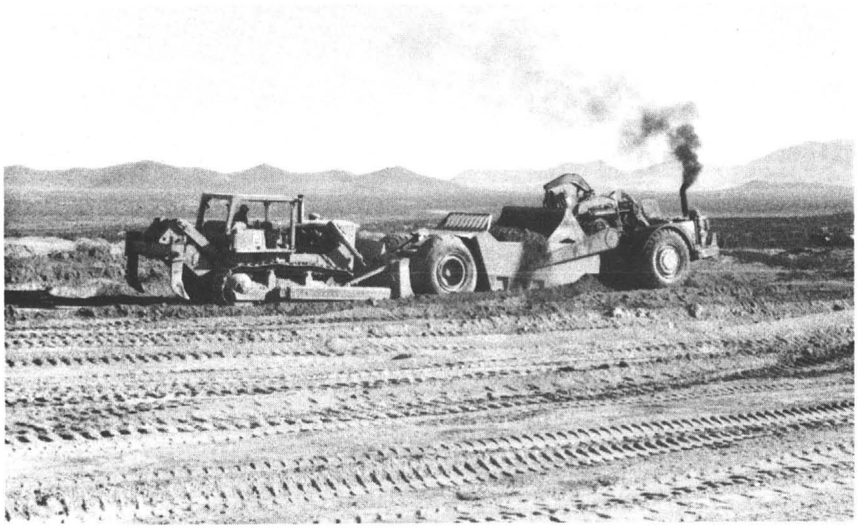
2. Water-laid deposits of vitric tuff that have been altered to zeolite minerals. These beds are intercalated in sections of basin fill and lacustrine beds. (Bowie and Horseshoe Dam)

3. Clastic tuffs, agglomerates, welded tuffs and vitrophyres that are altered to zeolite minerals. The zeolitic tuffs are interbedded in thick sections of volcanics. (Union Pass and Ajo Mountains.

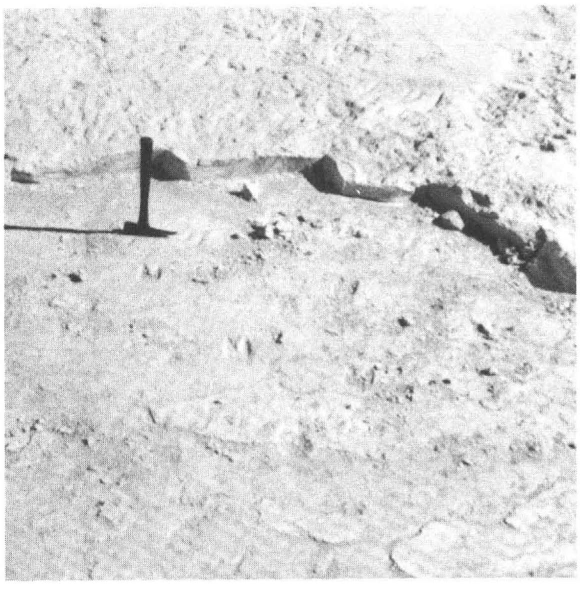
The occurrence of amygdules of zeolite minerals in basalt are economically unimportant. The amygdules are usually composed of successive growths of several different zeolite minerals usually accompanied by crystals of quartz, calcite and other hydrous minerals. It is rare when the zeolite fraction exceeds 5 to 10% of the basalt by volume. The best example of this type is the occurrence at the Bay of Fundy in Nova Scotia, Canada.

Deposits of water-laid vitric tuff that are altered to zeolite minerals comprise, economically, the most important type of zeolite deposit. Usually the

Pit 220 - Note Dip of Chabazite Beds



Removing Overburden



EZ 216 Pit - Note Llama Tracks
in Underlying Clay Beds

zeolite bed is interbedded in a section composed of unaltered vitric tuff, green and brown mudstone, conglomerates, sandstone and limestone beds. Most of the zeolite beds are in sections of Plio - Pleistocene age beds that deposited in basins which have about the same boundaries as the present basin. Usually the zeolite beds show definite sedimentary features such as ripple marks, mud cracks, and bedding.

Airborne volcanic ash deposited in lakes in the western part of the United States during Plio - Pleistocene time forming deposits of water-laid tuff. The volcanic ash which consisted primarily of glass shards was probably altered by the action of alkaline lake waters, ground water, or possibly a combination of both, into zeolite minerals.

The zeolite beds are usually yellowish-white, banded, "punky" (wood-like), light weight, altered vitric tuff that may still contain shards of unaltered vitric ash. Some of the beds are white to greenish-white in color whereas others are almost brown. The beds range from high purity altered vitric tuffs to sandy and clastic tuffs that contain a high percentage of lithic material (rock) and a low percentage of vitric ash. In general the zeolite beds composed principally of clinoptilolite are harder and more brittle than those composed of chabazite or erionite.

Often the zeolite beds have a wide lateral extent in comparison to their thickness. The lower massive tuff bed (also known as the zeolitic marker tuff) at the Bowie chabazite deposit though only a half foot thick crops out for six miles along San Simon Wash. The zeolite bed may change laterally or stratigraphically from one zeolite mineral to another, or it may be more uniform mineralogically such as at the Bowie deposit.

Following deposition and zeolitic alteration some of the zeolite deposits were extensively eroded and channeled. At the Bowie deposit the later channeling and erosion removed much of the zeolite bed. Though most occurrences of this type of zeolite deposit are undeformed,some of the beds are tilted and faulted, however, nowhere is the deformation severe.

The zeolite minerals that occur in this type of deposit are chabazite, erionite, clinoptilolite, phillipsite, and analcite. Some typical examples of this type of deposit are: the Bowie chabazite deposit, the Bear Springs chabazite deposit, and the Horseshoe Dam clinoptilolite deposit.

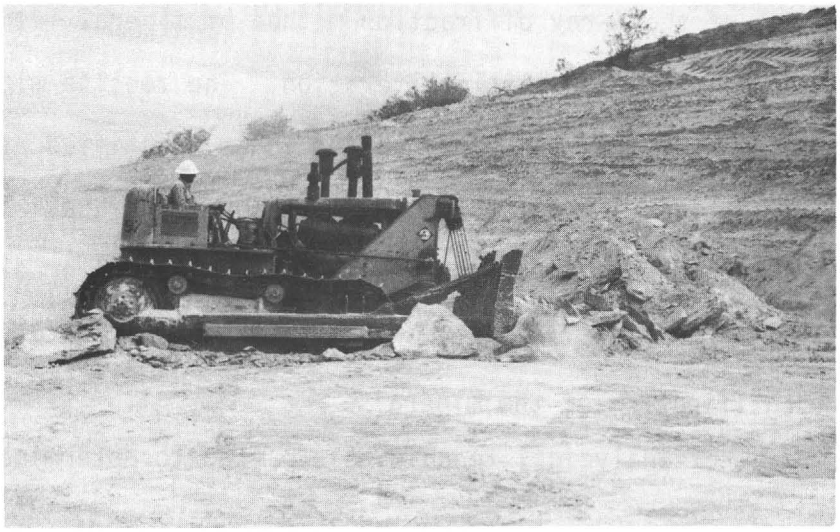
The occurrences of zeolite minerals in clastic tuffs, agglomerates, welded tuffs, and vitrophyres,with the possible exception of the Union Pass mordenite deposit,are less important economically than the deposits of water-laid zeolitic tuff beds. Clinoptilolite and mordenite usually occur in this type of deposit. The deposits are usually thick and extensive beds of zeolitically altered clastic tuffs, agglomerate, vitrophyre, which is probably a welded tuff, are interbedded within thick sections of volcanic rocks. Only the deposits of mordenite in altered vitrophyre are usually not contaminated by large amounts of unaltered lithic material and are sufficiently high grade to be of possible economic importance.

These deposits are generally older than the deposits of water-laid tuff in the valleys. It appears that deposition occurred in basins that did not conform to the present basins. Most occurrences are in mountain ranges composed of early Tertiary or Cretaceous age volcanics. Most of the deposits were involved in the tectonic activity accompanying the mountain building and as a consequence are often deformed and faulted.

The tuffs and agglomerates are frequently clastic, often coarsely so, pumiceous, and may be either water-laid or terrestrial. Seemingly, the matrix of vitric ash or pumice alters to clinoptilolite and less commonly to mordenite. Because of the large quantity of unaltered clastic (lithic) material in the zeolitic tuff it is sporadically altered and is ordinarily low grade. It is difficult to determine whether this type of deposit was altered to zeolite minerals in a lake, or by re-action with ground water or hydrothermal solutions. An excellent example of this type is the Whitlock Mountains clinoptilolite deposit.

EZ 185 Pit - Mining Chabazite

EZ 185 Pit - Mining Chabazite



EZ 185 - Cleaning Sandstone Overlying the Chabazite Bed

The vitrophyres or welded tuffs alter to a greenish to yellowish or pinkish-white conchoidally fracturing rock having an unusual wax-like luster. Often the altered vitrophyre grades laterally or stratigraphically into altered calstic tuff. Alteration of the vitrophyre is complete at some deposits whereas it is incomplete at others. Often the alteration extends only a few inches outward from cracks and fissures into the vitrophyre.

The vitrophyre alters to mordenite and less commonly to clinoptilolite though both minerals are present in many of the deposits. Field evidence at most of the deposits seems to indicate that either hydrothermal solutions or ground water altered the vitrophyre to zeolite minerals. Mordenite and clinoptilolite seem to occur as alteration minerals in the halo that surrounds the Oatman gold - silver deposit, suggesting that zeolitic alteration can be produced by hydrothermal solutions. Typical examples of this type deposit are the Union Pass mordenite deposit and the Coffee Pot Mountain mordenite - clinoptilolite deposit.

Chabazite and erionite do not usually occur associated with clinoptilolite and mordenite in the clastic tuffs and vitrophyres in the older volcanics. Conversely mordenite does not occur in deposits of water-laid vitric tuffs that contain chabazite and erionite.

Analytical Techniques

The development of the X-ray diffraction method of mineral identification resulted in the recognition of zeolitic alteration. The zeolite minerals in zeolitically altered tuffs are usually too fine-grained to be identified by the more conventional chemical or petrographic mineral identification techniques. Wet chemical analysis of the zeolite minerals determine only their chemical or elemental composition and yield no information on their crystal or atomic structure which is the key to the identification of the minerals.

Though two types of analytical techniques are used to determine the content of zeolite minerals in a sample, first, the sample must be analyzed qualitatively by X-ray diffraction to determine if zeolite minerals are present. The two types of analyses are X-ray and adsorption. The adsorption technique can use water, nitrogen, carbon dioxide, or ammonia nitrogen. Only the oxygen adsorption method will be described in detail.

In the X-ray method, the trace of the unknown sample is obtained at standard X-ray spectrometer settings. A standard 100% sample of the same zeolite is also obtained at the same settings, on the same day to avoid day to day spectrometer fluctuations. The summation of peak height intensities of a selected number of X-ray diffraction reflections of the unknown are divided by the same summation for the 100% standard. Differences in particale properties, size and shape, and methods of grinding samples can lead to variations in the peak height intensities. In particular, a very small crystallite size can lead to marked broadening of the X-ray reflections and a decrease in peak height intensities. This requires the more tedious method of reading and summing the integral intensities of the unknown reflections and comparing them with the summation of the integral intensities of the standard.

The X-ray method has been successfully applied to erionite and chabazite containing sediments. For most well-crystallized erionites and chabazites, the accuracy of the method is $\pm$ 15% of the amount present. However, in a few cases, much less reliable than the adsorption method.

In the adsorption method, the adsorption capacity of a zeolite containing sample is determined under standard conditions of adsorbate, pressure and temperature, and divided by the capacity of a 100% standard of the same zeolite under the same adsorption conditions. The capacity of the 100% zeolite standard, in practice, is the highest capacity observed for any sample natural or synthetic of a specific zeolite mineral.

The oxygen capacity at - 183 C and 100 mm. of Hg pressure has been adopted as the standard adsorbate conditions for determining chabazite, erionite, and mordenite content. The capacity is determined on a gravimetric adsorption balance. The low partial pressure and nature of the adsorbate were chosen to minimize adsorption by nonzeolite components.

In the case of phillipsite, the adsorption pore size is such that oxygen is not adsorbed at an appreciable rate at this temperature and pressure. With clinoptilolite which has a similar small pore size, the oxygen adsorbing properties seem to vary with locality. For these two zeolites, a CO_2 capacity at 250 mm Hg pressure and room temperature can be used.

Occurrences

Zeolite minerals probably occur in all of the 14 counties in Arizona. Zeolitic tuffs have been quarried for building stone near Kirkland where several buildings are constructed of tuff that is zeolitically altered to clinoptilolite. At least four separate deposits in Arizona have produced zeolite minerals used in industrial applications. The largest operation is about 13 miles north of Bowie, Arizona in the San Simon Valley. A combined tonnage of about 1,500 tons of chabazite are produced annually by:

Union Carbide Corporation

The Norton Company

W.R. Grace Company

NRG - Reserve Synthetic Fuels Venture

Filtrol Corporation

Letcher and Associates

The chabazite is shipped both by rail and truck to out of state processing plants where it is ground, pelletized and activated. The finished product is marketed along with the companies synthetic zeolite product lines. The companies marketing both synthetic and natural zeolites refer to the natural and synthetic zeolite products as molecular sieves. Reserves at the Bowie deposit are estimated at several million of high grade chabazite.

The Union Pass Mordenite deposit is about 20 miles west of Kingman, Arizona on the north side of State Route 68 west of the summit of Union Pass. Union Carbide has mined several carloads of high purity mordenite which was shipped out of state by rail for processing.

The Yuma Zeolite deposit, operated by Harrison Western Corporation, is on the east side of U.S. Highway 95 about 50 miles north of Yuma, Arizona. Clinoptilolite was produced from a thick pumiceous tuff bed. About 400 tons of clinoptilolite crushed and screened to -20+50 mesh was shipped to the Upper Occoquan Sewage Authority Advanced Waste Water Treatment Plant at Manassas, Virginia for use in ammonia nitrogen removal. Apparently, the clinoptilolite did not meet specifications and all operations at the property were suspended.

Gulf American Mining Enterprises, Inc., is on Constellation Road about five miles east of Wickenburg. A rhyolitic tuff bed is being mined, crushed and screened, and bagged. The product is marketed for cat litter under the trade name Cat's Pause. Samples from similar tuff beds in the same general area contained substantial amounts of clinoptilolite. This zeolite mineral adsorbs ammonia nitrogen which forms as a decomposition product of urine. X-ray analyses of the tuff indicates it is composed of clinoptilolite and montmorillonite (a clay mineral).

<u>Analytical Services</u>

Minerals Research
Box 591
Clarkson, New York 14430

X-ray diffraction analyses, ammoninum ion-exchange analyses, adsorption analyses for carbon dioxide, sulfur dioxide, and oxygen.

J.L. Post
Department of Civil Engineering
California State University, Sacramento
6000 J. Street
Sacramento, California 95819

X-ray diffraction analyses, scanning electron microscope.

Potential Buyers of Natural Zeolite Minerals and Properties

Akzo Chemic BV
Ketjen Catalysts
Amersfoort, Holland
Stationsstraat 48
P.O. Box 247

The Anaconda Company
Industrial Minerals Marketing Department
660 Bannock Street
Denver, Colorado 80204

CH2/M Hill
Box 2088
1525 Court Street
Redding, California 96001

Double Eagle Petroleum and Mining Company
Box 766
Casper, Wyoming 82601

Englehard Minerals and Chemical Corporation
Menlo Park
Edison, New Jersey 08817

Filtrol Corporation
3250 East Washington Boulevard
Los Angeles, California 90023

FMC Corporation
Box 8
Princeton, New Jersey 08540

FOSECO MINSEP, INC.
Minerals Division
20200 Sheldon Road
Cleveland, Ohio 44142

Harrison Western Corporation
1208 Quail Street
Denver, Colorado 80215

Letcher and Associates
Box 107
Lancaster, California 93534

Mobil Research and Development Corporation
Billingsport Road
Paulsboro, New Jersey 08066

Occidental Minerals Corporation
Irongate Building 4
777 South Wadsworth Boulevard
Lakewood, Colorado 80226

N.L. Industries
Baroid Division
2404 Southwest Freeway
Houston, Texas 77006

The Norton Company
Box 350
Akron, Ohio 44309

PQ International Incorporated
Valley Forge Executive Mall
Box 840
Valley Forge, Pennsylvania 19482

Reserve Synthetic Fuels, Inc.
1602 Monrovia Street
Newport Beach, California 92663

Union Carbide Corporation
Linde Division
Molecular Sieve Department
Old Saw Mill Road, Route 100C
Tarrytown, New York 10591

W.R. Grace
Davison Chemical Division
Washington Research Center
Clarksville, Maryland 21029

DESCRIPTIONS OF INDIVIDUAL ZEOLITE OCCURRENCES

Alpine - Nutriosa Area Clinoptilolite - Analcite Occurrences

Clinoptilolite and analcite occur in Tertiary age sandstones which crop out along Stone Creek in Section 2, T.6N., R.30E. The occurrence is about 3.5 miles northeast of Alpine. Other occurrences of clinoptilolite and analcite are reported in Sections 15 and 16, T.6N., R.30E., and Section 11, T.%N., R.30E.

The Ash Creek - Rattlesnake Basin Clinoptilolite Occurrence

A rhyolite tuff partially altered to clinoptilolite crops out in Sections 20 and 29, T.5S., R.17E., nine miles east of Winkleman, Arizona. The geologic map of Pinal County indicates that the occurrence is in Tertiary age andesites. The altered tuff is a pinkish-white color and is composed principally of pumice fragments. The large basin-like area is underlain by the tuff which has weathered to an unusual erosion remnants consisting of irregular forms and shapes, one of which is a prominent landmark known as Eskiminzin Fort Rock.

The Bear Springs Chabazite Deposits

Three zeolite beds crop out on the east side of the Gila River Valley. Two of the occurrences are near Bear Springs in Section 1, T.7S., R.23E., seven miles southwest of Pima, Arizona, and one is in Section 27, T.6S., R.24E., three miles southwest of Pima. The 1:250,000 Silver City quadrangle and the 1:62,500 Thatcher quadrangle provide topographic coverage of the occurrences.

The zeolite beds occur in the Solomonsville beds of Plio-Pleistocene age. In the vicinity of Bear Springs the Solomonsville section is composed of brown mudstone, limestone, sandstone and conglomerate beds. Many of the mudstone beds contain a high percentage of vitric ash. The Solomonsville beds dip slightly toward the center of the Gila River Valley.

The zeolite beds were vitric tuffs that altered to chabazite and erionite. Because of the microcrystallinity of the zeolite minerals it is not possible to determine the exact percentage of each mineral occurring in the beds. In addition to chabazite and erionite, the zeolite beds also contain traces of quartz, feldspar, mica and phillipsite.

The lower bed at Bear Springs is a yellowish-white, massive, punky, altered vitric tuff containing chabazite. Locally the bed has two lithologies; an upper massive bed a foot thick and a lower bed half a foot thick. The flat-lying lower bed crops out for nearly a mile along strike. The chabazite bed is exposed for almost 100 feet along the bottom of a drainage ditch at Bear Springs.

The upper zeolite bed is about 30 feet vertically above the lower bed. The interval between the two beds consists of mudstone and a few intercalated sandstone and ashy tuff beds. The zeolite bed is a yellowish to grayish-white massive, altered, vitric tuff containing chabazite. The outcrops exposed along the road to Bear Springs consists of two massive beds each half a foot thick separated by a thin clay parting. The upper bed is high grade chabazite and the lower a somewhat lower grade chabazite. It is possible to trace the flat-lying upper bed continuously for about half a mile.

The zeolite bed that crops out about four miles northeast of Bear Springs appears to be about 100 feet lower (down section) in the Solomonsville beds than the Bear Springs zeolite beds. This bed is composed of about a foot of grayish-white altered vitric tuff which contains chabazite. The flat-lying bed crops out continuously for about 500 feet.

<u>The Black Mountains Mordenite and Clinoptilolite Deposits</u>

Mordenite and clinoptilolite occur at several localities in the Black Mountains in western Mohave County, Arizona. The major mordenite deposits are the Union Pass, the Union Pass south, and the Black Mountains mordenite occurrence.

Minor deposits include the Union Pass west and the Topock clinoptilolite occurrence. These occurrences consist of zeolitized vitrophyre and clastic tuff beds in what is mapped as Tertiary age rhyolite, which also includes some interbedded tuffs and agglomerates. The McHeffy Butte, McHeffy Butte south mordenite occurrences and the Oatman, Cottonwood road and Mohave Ranchos clinoptilolite occurrences are in the Cretaceous age Gold Road volcanics.

The Black Mountain Mordenite Deposit

A zeolitized tuff bed crops out on the east side of the Black Mountains in the SW 1/4, Section 31, T.21N., R.19W., about 22 miles west of Kingman, Arizona. The zeolite bed is an altered vitrophyre overlain by a clastic vitric tuff which altered to mordenite and clinoptilolite. The lower part of the bed seems to be an altered vitrophyre; it is a yellowish to greenish-white and pink mottled color and breaks with a conspicuous conchoidal fracture. Overlying it is a clastic tuff containing unaltered rock fragments in a matrix of yellowish-white altered vitric ash and pumice. The contact between the two lithologies seems to be gradational. The base of the bed is concealed by recent alluvium and talus. Basalt and andesite flows overlie the tuff bed.

The Cottonwood Road Clinoptilolite Occurrence

Clinoptilolite occurs in an altered rhyolite tuff or flow in the Black Mountains in T.25N., R.21W., about 26.5 miles northwest of Kingman, Arizona. The occurrence is along the Cottonwood road, 14.5 miles west of U.S. Highway 93.

The McHeffy Butte and McHeffy Butte South Mordenite Occurrences

Mordenite occurs in a brownish-yellow altered clastic tuff near McHeffy Butte in the Black Mountains in T.18N., R.20W. The occurrence is 1.1 mile west of old U.S. Highway 66 at a point 10 miles south of Oatman, Arizona.

Mordenite also occurs in a gritty to pebbly, bedded, light yellowish-white tuff bed that dips 20 S. The bed is about 50 feet thick and can be traced eastward for about 300 feet.

The Mohave Ranchos Clinoptilolite Occurrence

A thin-bedded light gray to light brown altered clastic tuff about 100 feet thick that contains clinoptilolite crops out in the Mohave Ranchos area near the 1/4 corner between Sections 29 and 30, T.26N., R.19W. Though not in the Black Mountains, this occurrence is in the Gold Road volcanics as are several of the mordenite-clinoptilolite occurrences in the Black Mountains.

The Oatman Clinoptilolite Occurrence

A pale greenish-white altered tuff bed 20 feet thick containing clinoptilolite is exposed in a road cut on the south side of old U.S. Highway 66 about 3.5 miles northeast of Oatman, Arizona.

The Topock Clinoptilolite Occurrence

Clinoptilolite occurs in a white tuff 15.4 miles north of Topock along Oatman road, which is old U.S. Highway 66.

The Union Pass Mordenite Deposit

The Union Pass mordenite deposit is in the Black Mountains in the E½SW¼SW¼NW¼ and the W½SE¼SW¼NW¼ of Section 11, T.21N., R.20W., on the north side of Arizona Route 68, just west of Union Pass. The deposit is 20 miles by paved road west of Kingman, Arizona, which is on the main line of the Santa Fe Railroad and on State and Federal highways. Topographic coverage of the deposit is provided by the Union Pass 7½-minute quadrangle.

The Black Mountains are a block-faulted range that forms the west side of the Sacramento Valley. The range is composed of Precambrian granite and gneiss that are overlain by Cretaceous age Gold Road Volcanics. During the Laramide Orogeny (early Tertiary?), the older rocks were intruded by granitic rocks. A rhyolite, probably an extrusive phase of the granitic intrusives, was extruded during middle (?) Tertiary, accompanied by considerable pyroclastic activity. The volcanism resulted in the formation of a thick and extensive pyroclastic deposit, called the Golden Road Volcanics. The Union Pass mordenite deposit is in a tuff that was deposited at this time. During late Tertiary or early Quarternary, basalt extruded and capped the erosion surface that had formed on the older rocks. Uplift and faulting were probably continuous during Tertiary and Quarternary.

The mordenite deposit is a distinct zone of yellowish to greenish-white and pink, conchoidally fracturing, altered vitrophyre within a thick, crudely bedded, medium to coarse grained, "trashy" pinkish-white clastic tuff. The enclosing tuff is altered to oxygen-adsorbing clinoptilolite and mordenite. On the west side of the pass, the enclosing tuff dips about 20° east; whereas, on the east side, the tuff dips about 10° to 20° west. Several faults transect both the mordenite zone and the enclosing tuff. Some of the fault zones are weakly mineralized with manganese oxides. The displacement along the faults seems to be a few tens of feet.

It is uncertain whether the mordenite zone is a pipe-shaped or a lenticular zone of altered vitrophyre within the clastic tuff. The second explanation, however, seems to be more in accord with the field relationships seen both here and at other mordenite deposits. Following deposition of the tuff, ground water or hydrothermal solutions altered the glass fragments of the tuff and vitrophyre to zeolites, cristobalite, and montmorillonite. Because the vitrophyre was mostly glass and contained almost no lithic matter, it altered chiefly to mordenite. Though the vitric fragments in the clastic tuff probably altered completely to zeolite minerals, the high percentage of lithic materials lowered the grade. Vitrophyres seem to alter to mordenite, whereas clastic or pumiceous tuffs altered to clinoptilolite.

To the west, the mordenite zone is in contact with a brown, hard, unaltered, aphanitic flow (?) or welded tuff. It is difficult to determine whether the flow underlies or is in fault contact with the mordenite zone.

The mordenite zone is nearly circular, having a diameter of about 300 feet (90 m). Its outline is determined by assay rather than lithology, and the limits of the zone are 60 percent mordenite. Actually, the limits of the altered vitrophure conform very closely to the assay limits. The zone averages about 65 percent mordenite by X-ray powder diffraction. The mordenite zone seems to plunge northeast under the overlying bed of trashy tuff.

The Union Pass South Mordenite Deposit

A zeolitized tuff bed crops out on the west side of the Black Mountains in Section 25, T.21N., R.20W., about 25 miles west of Kingman, Arizona. The zeolite bed is a yellowish-white, hard, vitrophyre that is now composed principally of mordenite and small amounts of clinoptilolite. It is over 100 feet thick on the south side of the arroyo and crops out continuously for about 1000 feet along both sides of the arroyo. Erosion has removed all of the overlying beds.

The Union Pass West Mordenite Occurrence

Mordenite occurs in an altered brownish-white pumiceous tuff exposed in a road cut on the old highway right of way on the north side of Arizona 68 about two miles west of Union Pass.

The Bloody Basin Clinoptilolite Occurrence

A clinoptilolite bed crops out in T.9N., R.5E., two miles southeast of the Dugar Ranch on the southwest side of Tangle Creek. The main road from Arizona 69 to Sheep Bride passes within 1000 feet of the deposit at a point six miles east of its junction with the Cave Creek road. The 1:125,000 Turrent Creek quadrangle and the

1:250,000 Holbrook quadrangle furnish topographic coverage of the deposit.

The clinoptilolite bed is intercalated in a section of green, violet, and brown mudstone and analcime beds which have no formational name. The bed is composed of two lithologies: a lower massive altered white tuff a foot thick containing clinoptilolite and an upper altered white tuff bed a foot thick also containing clinoptilolite. The clinoptilolite beds are exposed for about 100 feet along the strike.

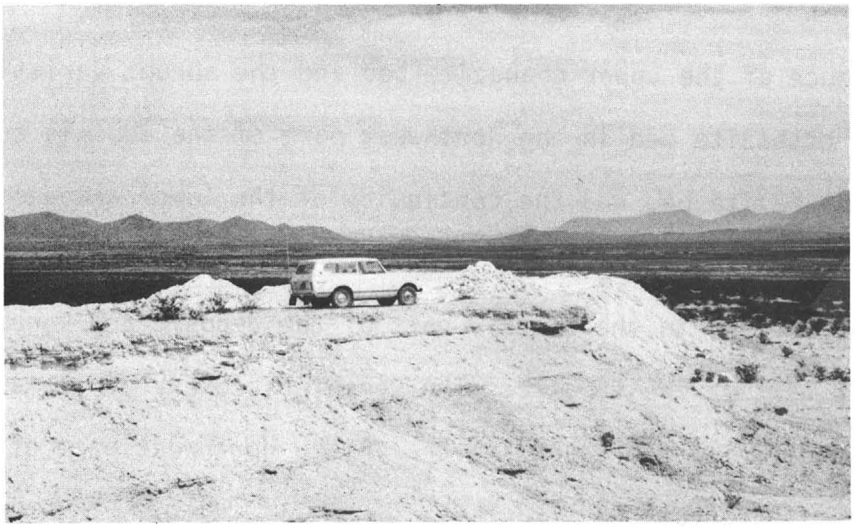
<u>The Bowie, Chabazite Deposit</u>

The Bowie deposit is in the San Simon Valley underlying parts of several sections in T.11 and 12S., R.29 and 30E., in Graham and Cochise Counties, Arizona, 12 miles north of Bowie. Topographic coverage is provided by the 1:62,500 Bowie quadrangles and the entire deposit by the 1:250,000 Silver City quadrangle.

The zeolite bed is in an unnamed section of Plio-Pleistocene lake beds composed of brown and green clays, sandstone, and conglomerate beds. The section may correlative with the Solomonsville beds which crop out in the Safford area about 25 miles north of the deposit.

The chabazite deposit consists of a marker tuff bed which is a brownish to yellowish-white color. Occasionally, the chabazite bed contains visible unaltered glass shards. The lower tuff bed is from 0.10 to 0.50 feet thick and contains from 60 to 85 percent chabazite. Overlying the lower bed is a section of thin-bedded grayish-white tuff that contains 30 to 50 percent chabazite and ranges from under a foot to over five feet thick.

The lower chabazite bed is remarkably regular, both in thickness and grade, throughout the deposit. It is thickest in the central part of the deposit and thins toward the northwest part of the deposit. The upper beds also follow the same pattern, being thickest in the central part of the deposit and nearly absent in the northwest part of the deposit.



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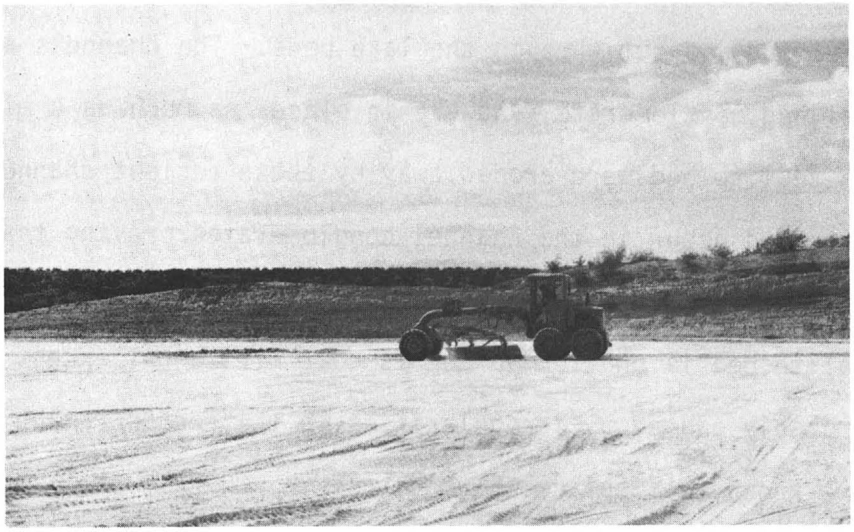


EZ 228 Pit - Cleaning Top of Beds

EZ 228 Pit - Sweeping Top of Beds

The absence of the upper chabazite bed and the abrupt variations in the thickness of the lower chabazite bed in the northwest part of the deposit contrasts with the thick upper chabazite bed and the continuity of the lower chabazite bed in the central part of the deposit. This seems to suggest that the lake in which the airborne ash deposited was deepest in the central part of the deposit and became shallower toward the northwest part of the deposit. The recent discovery of llama and camel tracks in the clay underlying the chabazite bed in the northwest part of the deposit tends to confirm this observation.

Some time after the vitric tuff altered to zeolite minerals, the lake, in which the ash fell, dried up and the lake beds were subjected to erosion. Large stream channels developed and cut through the lake beds. The channels are now filled with coarse gravel and conglomerate, and are in places as much as a mile wide. Large areas of the zeolite bed were eroded away by these ancient channels. Large fragments of the zeolite bed occur in the channel conglomerates proving that the channels formed after the vitric ash altered to zeolite minerals.

The zeolite bed is undeformed and is near horizontal except for undulations that were probably caused by irregularities in the configuration of the lake bottom. No faults are known to displace the bed.

Both the upper and lower beds are composed of a mixture of erionite and chabazite. Toward the central part of the deposit the chabazite becomes more sodic. It is difficult to determine the exact percentage of each mineral present in the bed because of their microcrystallinity. Clinoptilolite, analcime, and traces of gmelinite have also reported in samples from the deposit. Small amounts of quartz, montmorillonite, and gypsum also occur in the zeolite beds. The Bowie deposit is the largest known high grade deposit of chabazite in the United States. Reserves are conservatively estimated at several million tons of high grade chabazite.

The Castle Dome Plain (Yuma Zeolite Company) Clinoptilolite Occurrence

Clinoptilolite occurs in a yellowish-white altered clastic tuff and an altered vitrophyre. Quarternary rhyolite flows, agglomerates and tuffs. The occurrence is a quarter of a mile east of U.S. Highway 95 about 50 miles north of Yuma, Arizona. A small tonnage of clinoptilolite was mined from the deposit by Harrison Western Corporation.

The Cerro Colorado Clinoptilolite Occurrence

A bed of tuff breccia and agglomerate over 100 feet thick that is partially altered to clinoptilolite crops out on the south side of Cerro Colorado in Section 1, T.20S., R.10E., northeast of Arivaca, Arizona. The tuff bed is enclosed by volcanics that are mapped as Cretaceous andesites on the geologic map of Pima and Santa Cruz Counties.

The Coffee Pot Mountain - Organ Pipe Cactus National Monument Clinoptilolite - Mordenite Occurrences

Several clinoptilolite and mordenite occurrences are described collectively because of their similar mode of occurrence. All of the occurrences are within a radius of 30 miles of Ajo, Arizona. Though the distance between some of the deposits is as great as 50 miles, all of them appear to occur in a similar volcanic section. Topographic map coverage of all the area is furnished by the 1:250,000 Ajo and Sonoyta quadrangles.

Because of the geologic similarities of the occurrences, only the Ajo Mountains, and Coffee Pot Mountains occurrences are described. The Ajo Mountains occurrence is in the Cretaceous age Sauceda volcanics which are composed of rhyolite, latite, andesite, and locally uitrophyre (volcanic glass). The Ajo Mountains and the other deposits occur in similar volcanic sections; even though the volcanics are mapped as Tertiary age latites and andesites on the Pima County geologic map and Cretaceous age Sauceda volcanics on the Maricopa County geologic map. The geologic mapping in this area is of the reconnaissance type in which only gross lithologies and structures are mapped. It seems possible that all of the zeolite deposits occur in volcanics of the same age.

The area is typical of the basin and range province. All of the zeolite occurrences are in volcanics that have been elevated to their present position by block faulting along the valley margins. The valleys are filled with Tertiary sediments.

The Ajo Mountains Clinoptilolite Occurrence

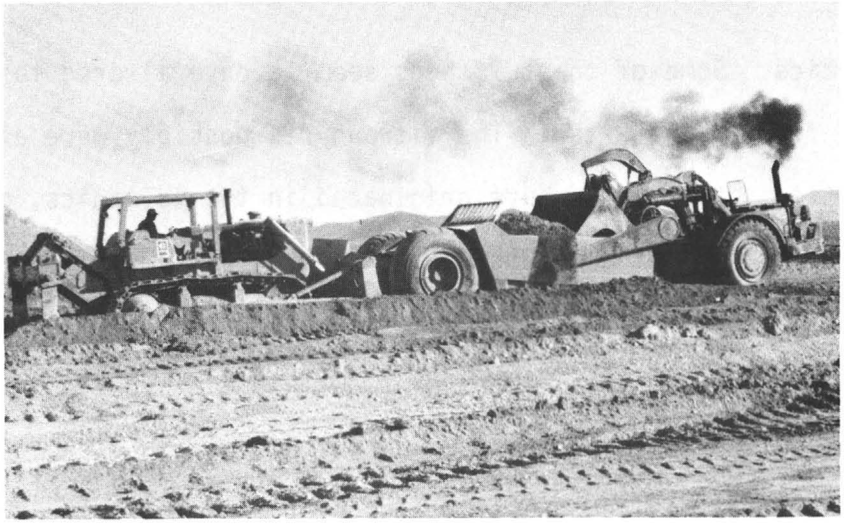
This occurrence is in Organ Pipe Cactus National Monument on the west side of the Ajo Mountains. It is accessible from the Monument headquarters over the 21 mile loop road. The best exposure of the tuff bed is directly above stop nine of the loop road.

Flows enclose the zeolitized tuff bed that crops out in the Ajo Mountains. The tuff bed consists of four distinct gross lithologies that are 50 to 100 feet thick depending upon where the tuff bed is measured: a lower tuff-agglomerate bed composed of large angular vitrophyre (volcanic glass) and pumice fragments in a yellowish-white matrix of altered ash which contains a trace of chabazite; an agglomerate bed composed of abundant coarse unaltered pyroclastics and pumice fragments in a yellowish-white altered ash matrix which contains clinoptilolite; a bed of similar lithology that contains a smaller amount of unaltered pyroclastics which contains clinoptilolite; a partially devitrified gray vitrophyre altered in part to a hard yellowish-white rock with a conchoidal fracture that contains clinoptilolite. The alteration of the gray vitrophyre seems to extend outward from cracks and joints.

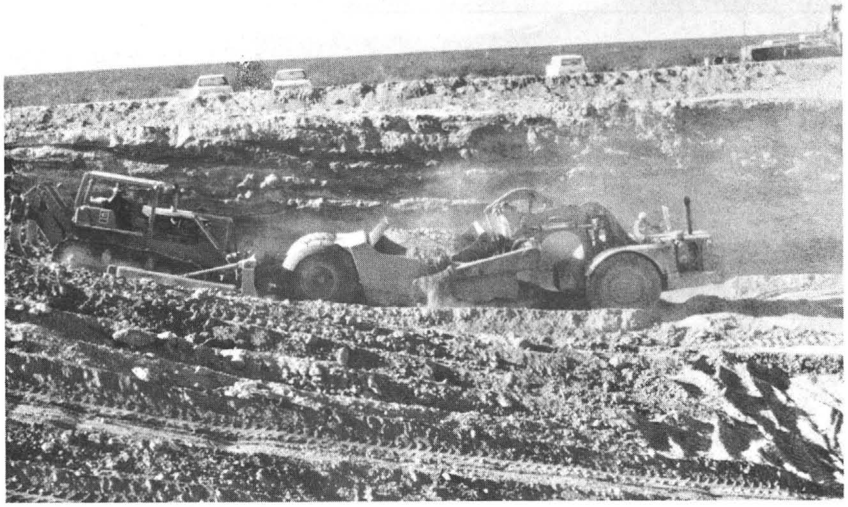
The Coffee Pot Mountain Mordenite - Clinoptilolite Occurrences

The principal occurrence is in the Sikort Chuapa Mountains half a mile south of the El Paso Gas Company pipeline about 15 miles northeast of Ajo, Arizona, and about three miles southwest of the prominent landmark known as Coffee Pot Mountain. Clinoptilolite occurs at several other localities in the vicinity of Coffee Pot Mountain.

Mordenite and clinoptilolite occur in a tuff bed 50 to 60 feet thick that is composed of a heterogeneous mixture of altered and unaltered vitrophyre fragments



EZ 185 Pit



Pit No. 160

Pit No. 160

and pyroclastics. Some of the tuff beds seem to have altered to zeolite minerals in a lake or from ground water. The vitrophyres possibly were altered by hydrothermal solutions, that could have originated in the volcanics, or by ground or surface water following the joints in the vitrophyre.

The zeolitized tuff beds which are from less than a foot to over 100 feet thick are usually intercalated in sections of flows and tuffs. Zeolitized tuffs crop out from the Sauceda Mountains south of Gila Bend to Ajo and along both sides of the Valley of the Ajo to Mexico, a distance of over 70 miles. The tuff beds contain hundreds of millions of tons of low grade clinoptilolite and mordenite.

The Cottonwood Basin Phillipsite Occurrence

Phillipsite occurs in Cottonwood Basin which is on the 1:250,000 Holbrook quadrangle. From Camp Verde, Arizona, the occurrence can be reached by following the Payson road to the Clear Creek bridge; the road to the basin turns south from the main road at a point four miles beyond and southeast of the bridge. The phillipsite beds crop out near the top of the high bluffs on the north side of the road about two miles west of the highway turnoff.

Two altered vitric tuff beds crop out in a section of mudstone in the Verde formation. The lower bed consists of 1.2 feet of non-calcareous vitric tuff that is altered to phillipsite, and a smaller amount of mordenite. About 20 feet of brown mudstone separate the upper bed from the lower bed. The upper bed consists of two feet of vitric tuff that is altered to phillipsite.

The Dripping Springs Valley Chabazite Deposit

A zeolite bed is exposed in a road cut on the east side of Arizona 77 about 23 miles south of Globe, Arizona, in Section 27, T.3S., R.15E. The 1:250,000 Mesa quadrangle provides the topographic coverage of the deposit and adjacent area.

The zeolite bed occurs in a section of basin fill composed of brown mudstone that contains a few conglomerate, sandstone, and fresh water limestone beds. In the absence of any local formational name for this section it would be placed in the Gila Conglomerate, a "lump" formational name that includes most of the valley fill pres med to be of Tertiary and Quaternary age in southern Arizona.

The zeolite bed is a vitric tuff that is partially altered to chabazite. It is a grayish-white color, contains a few scattered biotite crystals, and though soft is "punky", that is tough and difficult to break. Three well defined lithologies, compose the bed: a lower thin-bedded to platy bed, a middle massive bed, and an upper thin-bedded to platy bed. The zeolite bed ranges from 0.90 to 1.80 foot thick.

Along the east side of the road cut, the tuff bed is exposed continuously for 300 feet. It is cut off near both ends of the cut by deposits of younger gravels. Recent washes have dissected the gravels and the older basin fill at both ends of the cut and the zeolite bed cannot be traced across either wash. The flat-lying zeolite bed is covered by about 40 feet of weakly indurated mudstone and sandstone capped by coarse gravel.

The Horseshoe Dam Clinoptilolite Deposit

Several zeolite beds crop out on both sides of the Verde River about a mile downstream from Horseshoe Dam. The deposit is accessible from Cave Creek, Arizona, over 26 miles of county road.

The zeolite beds crop out in an unnamed Tertiary age section of weakly indurated gray to white tuff and green and brown mudstones. Unlike most of the other bedded zeolite deposits in Arizona, such as Bowee and Bear Springs, which are flat-lying, the Horseshoe Dam clinoptilolite beds are faulted and tilted about 45 to 55^{o}. The vitric tuff beds seem to have been altered to clinoptilolite before being tilted to their present attitude.

On the west side of the river the mudstone-tuff section strikes about N50^{o}W and dips about 50^{o}SW. The strike and dip of the individual beds may deviate somewhat from the average, but these differences are presumably due to minor faulting, folding, and slumping of the individual zeolite beds.

The section crops out on the east side of the river along the projected strike, suggesting that the section is not displaced by a fault in the vicinity of the river. To the east the beds gradually change strike to about east, whereas the dip remains a constant $50^{O}S$. Further to the east the beds disappear beneath more recent flat-lying basin fill.

Six clinoptilolite beds crop out on the west side and on the east side of the Verde River though it is possible that some of the beds may be repeated by faulting. Whereas some of the beds are uniform, having the same lithology from the bottom to the top, others are composed of several lithologies. Individual beds are from 1 1/2 to 18 feet thick and strike N40 to $60^{O}W$, dip 45 to $55^{O}W$. The main clinoptilolite bed crops out continuously for about 5000 feet. It is from 8.5 to 17.5 feet thick and consists of one to six beds of differing lithologies.

The physical properties and mineralogy of the zeolite beds are similar so that a description of the main zeolite bed should suffice for the entire deposit. The zeolite bed is a vitric tuff that is altered to clinoptilolite. It is a yellowish to brownish-white color and in some areas has a speckled appearance caused by numerous brown spots that are possibley grains of iron oxides that result from the alteration of ferromagnesian minerals. Though relatively soft, the clinoptilolite is tough and difficult to break. Letcher and Associates shipped a small amount of clinoptilolite from this deposit to test its ammonia nitrogen adsorption properties.

The Horseshoe Dam Phillipsite Occurrence

Two altered vitric tuff beds which contain phillipsite are exposed in a road cut 2 1/4 miles south of Horseshoe Dam on the west side of the Verde River. The beds are intercalated in a section of mudstone capped by a basalt flow. Presumably this section is of Quaternary or Tertiary age.

The Kirkland Phillipsite Occurrence

Phillipsite occurs in a one to two foot thick bed of soft, punky tuff on the

James Stewart Company lithium claims nine miles west of Kirkland, Arizona.

The Kirkland Junction Clinoptilolite - Erionite Occurrence

A four to six foot thick section of vitric tuff beds that are partially altered to clinoptilolite and erionite crop out on the west side of U.S. Highway 89 about 4.2 miles south of Kirkland Junction, Arizona. The tuff section is capped by a basalt believed to be of Tertiary-Quaternary age.

The Klondyke Clinoptilolite - Mordenite Occurrences

Along the Klondyke-Pima road on the west side of the divide between Underwood Canyon and Crazy Horse Wash in Section 28, T.7S., R.21E., a road cut exposes an altered rhyolite dike. X-ray analysis of the dike rock shows it contains clinoptilolite.

In Section 32, T.7S., R.21E., where the base of the Gila Conglomerate appears to be unconformably overlying Precambrian granitic rock, are several altered tuffaceous beds. These beds are from 1 to 1 1/2 feet thick and overlain by a great thickness of conglomerate. The tuffaceous beds contained clinoptilolite and mordenite.

The Maggie Canyon Analcime Occurrence

Analcime is reported to occur in a Pliocene age sandstone in Maggie Canyon. The occurrence is in Sections 30 and 31, T.12N., R.13W.

The Mineral Wash Clinoptilolite Occurrence

Clinoptilolite occurs in an altered yellowish-orange colored tuff enclosed by a reddish-violet agglomerate that crops out in Mineral Wash 24.5 miles east of Parker, Arizona. The locality is about two miles west of the Planet Ranch.

The Morenci Mordenite Occurrence

Mordenite and clinoptilolite occur in a tuff and lapilli tuff in an unnamed Tertiary formation near Morenci. The occurrence is in Section 16, T.3S., R.9E.

The Mormon Flat Lake - Salt River Clinoptilolite Occurrences

Clinoptilolite occurs in Tertiary volcanics exposed in a road cut on Arizona Route 88, 12 miles northeast of Apache Junction, Arizona. The occurrences are along the south side of Mormon Flat Lake at the lookout point and in a road cut three miles northeast of the lookout point. The tuff beds were probably ignimbrites, in which ground water or hydrothermal solutions altered the glassy matrix to clinoptilolite.

The Muggins Mountains Clinoptilolite Occurrences

The clinoptilolite-bearing tuffs crop out in the foothills of the Muggins Mountains on the north side of the Gila River in the N. 1/2, Section 23, T.8S., R119W., and a quarter of a mile west in the NW 1/4, Section 23, T.8S., R.19., northwest of Wellton, Arizona. Topographic coverage of the area is provided by the 1:62,500 Wellton quadrangle.

Clinoptilolite occurs both in a hard, white, altered vitric tuff bed a foot thick, and also in the overlying three foot thick bed of grayish-white altered ashy tuff. A quarter of a mile west in the NW 1/4 of Section 23, clinoptilolite occurs in a 15 foot thick bed composed of a lower bed five feet thick of altered white rhyolite tuff or flow, a four foot thick bed of altered thin-bedded white tuff, and a six foot thick bed of altered grayish-white sandy tuff. About 150 feet west of this locality a bed of white ashy altered tuff crops out near the bottom on an arroyo. This bed is principally high purity clinoptilolite.

The Picacho Reservoir Analcime Occurrence

Analcime occurs in a Tertiary age siltstone in the vicinity of Picacho Reservoir. The occurrence is in Section 25, T.7S., R.8E.

The Proto Canyon - Nogales Clinoptilolite Occurrence

Clinoptilolite occurs in Tertiary age sediments in road cuts along Arizona

Route 82 northeast of Nogales. At Proto Canyon, 2 1/2 miles from Nogales, in Section 35, T.23S., R.14E., a 10 foot thick rhyolite tuff bed contains clinoptilolite. At the Nogales city limits in Section 9, T.24S., a 0.50 foot thick white clay bed contains clinoptilolite.

The Roosevelt Lake - Tonto Creek Chabazite Deposits

Five known zeolite deposits crop out in the Salt River-Tonto Creek drainage area above Roosevelt Dam. The valleys are filled by sediments deposited during late Tertiary and Quaternary time. Though the sediments have no formational names, they would, presumably, be lumped into the Gila Conglomerate.

The section consists of a typical (lake bed) sequence of weakly indurated mudstones interbedded with sandstone, conglomerate, and less commonly limestone and gypsum beds. Throughout the basin the mudstone facies interfinger with and grade laterally into sandstone and conglomerate facies. Generally the lake beds dip gently toward the center of the valley. Overlying the nearly flat-lying lake beds are alluvial fans and coarse, unsorted conglomerate beds that dip more steeply toward the center of the valley than the lacustrine beds.

The zeolite deposits, with the possible exception of the Tonto Basin and the Tonto Basin East, do not seem to be the same tuff bed. Only one zeolite bed crops out at each locality, each seemingly, at a different stratigraphic horizon. The thickness, color, and grade of the zeolite bed appears different at each locality. Each zeolite bed appears to represent a separate ash fall.

The Horrel Ranch Chabazite Deposit

The chabazite bed crops out for about 50 feet along the west bank of Spring Creek, a quarter of a mile downstream from the Horrel Ranch. It is reached from Globe, Arizona, by driving 25 miles northwest on Arizona 88 to the Horrel Ranch road turnoff. This dirt road turns off the south side of Arizona 88 about one mile west of the Pinto Creek bridge. The road is followed 1 1/4 miles to a point about a quarter of a mile north of the Horrel Ranch. From here an old grave may be seen just west of the road. By walking from the grave westward to Spring Creek and ten up the wash, through a fence that crosses the wash, the zeolite bed can be seen cropping out along the west side of the wash.

The zeolite bed is a vitric tuff bed that is partially altered to chabazite. It is a dull grayish-white color, is about a foot thick, and crops out for a distance of 50 feet. The bed is conformable with the enclosing brown mudstone section.

The Roosevelt Lake Chabazite Deposit

The chabazite beds are exposed in a road cut on the north side of the road which follows the north shore of Roosevelt Lake in Section 4, T.4N., R.13E., 15 miles northwest of the Salt River bridge on Arizona 288.

Two chabazite beds, which crop out 500 feet apart, amy be the same bed. Both chabazite beds are conformable to the enclosing mudstone. The easterly outcrop is composed of half a foot of vitric tuff that is altered to chabazite. It is exposed for a short distance on each side of the sample site.

The westerly outcrop is composed of three lithologies: the lower is a foot of white, altered vitric tuff, the middle is 0.30 foot of grayish to whitish-brown altered ashy mudstone, and the upper is 0.80 foot of pinkish to brownish-white altered ashy tuff. All of the lithologies contain chabazite. The chabazite bed has total thickness of about two feet.

The Dager Ranch Chabazite Deposit

A chabazite bed crops out a mile southwest of Dager Ranch in Section 31, T.5N., R.13E. This is about a mile north of the road that follows the north shore of Roosevelt Lake at a point about nine miles west of its junction with Arizona 288. The outcrop is composed of brownish-white altered vitric tuff that contains chabazite.

The Tonto Basin Chabazite Deposit

The largest chabazite deposit in the Roosevelt Lake-Tonto Creek area crops out on the east side of the Tonto Creek Valley a quarter of a mile south of the Greenback Valley road at a point 2 1/2 miles east of Tonto Basin, Arizona, in Section 12, T.6N., R.10E. The deposit has been quarried for building stone.

From three to as many as six distinct lithologies can be recognized in the outcrop. A typical section consists of a lower altered mottled pink and white altered vitric tuff 0.75 feet thick, an altered massive pinkish-white ashy tuff a foot thick, an altered massive pinkish-white ashy tuff 1.3 foot thick, an altered pinkish-white vesicular ashy tuff 0.40 foot thick, and an overlying slightly altered pinkish-white ashy tuff bed two feet thick. All of the lithologic units contain chabazite and traces of clinoptilolite.

The zeolite bed ranges from 4 to 7.6 feet thick. It is conformable to the enclosing flat-lying mudstone beds, crops out continuously for 250 feet along the northeast side, and 80 feet along the southwest side of a dry wash before disappearing beneath the overlying alluvium.

The Tonto Basin East Chabazite Deposit

The chabazite bed crops out in T.6N., R.11E., half a mile northwest of the Tonto Basin-Greenback Valley road at a point four miles northeast of Tonto Basin near the top of a terrace. A flat-lying, conspicuous pink vitric tuff bed in places about 20 feet thick caps the terrace.

The outcrop is a pinkish-white, massive, altered vitric tuff bed about two feet thick that contains chabazite. It isthe thickest of several thick; discontinuous chabazite beds that occur scattered throughout the ashy tuff bed. The enclosing thick massive ashy tuff bed may correlate with the chabazite bed at the Tonto Basin deposit. The zeolite bed can be traced for about 50 feet along the strike.

The Roosevelt Lake Phillipsite Occurrence

A thin bed of vitric ash that has altered to phillipsite crops out near the top of a high bluff on the north side of Roosevelt Lake, enclosed by a mudstone section. The occurrence is in Section 34, T.5N., R.12E., half a mile north of the Bacon Ranch. It can be reached by walking half a mile south of the road along the north shore of Roosevelt Lake at apoint 13 miles west of its junction with Arizona Route 288.

The Trigo Mountains Clinoptilolite Occurrence

Clinoptilolite occurs in a massive yellowish-white altered clastic tuff interbedded with Cretaceous age andesites that include flows, dikes, plugs, tuffs, and agglomerates. The occurrences are in Section 29, T.1S., R.21W., and in the NW 1/4, Section 28, T.1N., R.21W.

The Verde Valley Phillipsite Occurrence

Phillipsite occurs in an altered vitric or ashy tuff bed 0.5 foot thick about 7.5 miles southeast of Cottonwood, Arizona, in T.15N., R.3E. The bed crops out in the location pit of the Clay claim near the top of the Verde formation.

A tuff bed altered in part to phillipsite crops out in Section 1, T.14N., R.4E., near Middle Verde, Arizona. The phillipsite bed is intercalated in a section of dolomites in the Verde formation.

The Whitlock Mountains Clinoptilolite Occurrence

A thick clinoptilolite bed crops out about half way up the Whitlock Mountains in T.9S., R.29E., 22 miles southeast of Safford, Arizona. The Whitlock Mountains, which form the east side of the San Simon Valley, are composed of Tertiary flows and tuffs.

The outcrop is composed of 20 to over 80 feet of yellowish-white tuff that is altered to clinoptilolite. In addition to the clinoptilolite the bed contains 10 to 50 percent unaltered fragments of volcanics. Though most of these fragments are small, a centimeter or less in diameter, some of them are boulders over a foot in diameter.

The clinoptilolite bed strikes about east and dips gently northward. It can be traced for about three miles along the west slope of the Whitlock Mountains until it disappears beneath the valley fill. Another thinner clinoptilolite bed crops out about 200 feet above the main bed. On U.S. Highway 70, 19 miles east of Safford, in T.8S., R.29E., another clinoptilolite bed is exposed in a road cut.

The Wickenburg Clinoptilolite Occurrence

A rhyolitic tuff partially altered to clinoptilolite is exposed in a road cut on U.S. 60 and 89, about five miles east of Wickenburg, Arizona, in Section 28, T.7N., R.4W. These volcanics are mapped as being Cretaceous in age. Two samples of a clastic tuff with a yellowish to greenish-white altered matrix contained clinoptilolite.

The Wickieup Phillipsite, Erionite, and Analcite Occurrence

Vitric tuff beds that are altered to analcite, phillipsite, erionite, and at one locality, clinoptilolite, crop out in Tertiary-Quaternary age basin fill that is composed of sandstone, conglomerate, and green and brown mudstone. The outcrops are on the east side of the Big Sandy River Valley southeast of Wickieup, Arizona, in Section 1, T.15N., R.13W., and in Section 20, T.15N., R.12W.

The Willcox Playa Analcime Occurrence

Analcime is reported interbedded with the mudstones in Willcox Playa. The occurrence is in Section 12, T.15S., R.24E.

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ARIZONA DEPARTMENT OF MINERAL RESOURCES

The Department was created to aid in the promotion, development, and conservation of the Mineral Resources of the State. Particular emphasis is placed on providing prospectors and small miners with semi-technical assistance and economic information.

The general goal of the Department is developed by working with the following objectives:

- Provide technical assistance to prospectors and operators of small mines.
- Disseminate comprehensive mining and mineral information to the citizens and government officials of Arizona counties.
- Study conditions regarding small mine activity and seek solutions of problems.
- Serve as the State's public bureau of mining and mineral information.
- Maintain and expand the Department's mine file library.
- Provide educational services in the field of Mineral Resources and mining.
- Analyse proposed Federal and State administrative actions.
- Develop interagency cooperation between the Department and other local State and Federal offices.
- Gather all information available on mineral occurrences, prospects, partially developed properties and known mines in the State in order to promote further exploration.
- Provide publications in the form of mineral reports, annual directories, technical reports, annual mineral industry surveys, information circulars, and media articles.