OREGON GEOLOGY

published by the

Oregon Department of Geology and Mineral Industries

VOLUME 49, NUMBER 1 JANUARY 1987

OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES

50th ANNIVERSARY

1937-1987

50 YEARS OF SERVICE

THIS MONTH:
SE Oregon field trip guide:
Sheaville and Rome zeolite deposits

OREGON GEOLOGY
(ISSN 0164-3304)
VOLUME 49, NUMBER 1 JANUARY 1987

Published monthly by the Oregon Department of Geology and Mineral Industries (Volumes 1 through 40 were entitled *The Ore Bin*).

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Oregon Geology is designed to reach a wide spectrum of readers interested in the geology and mineral industry of Oregon. Manuscript contributions are invited on both technical and general-interest subjects relating to Oregon geology. Two copies of the manuscript should be submitted, typed double-spaced throughout (including references) and on one side of the paper only. Graphic illustrations should be camera-ready; photographs should be black-and-white glossies. All figures should be clearly marked, and all figure captions should be typed together on a separate sheet of paper.

The style to be followed is generally that of U.S. Geological Survey publications (see the USGS manual *Suggestions to Authors*, 6th ed., 1978). The bibliography should be limited to "References Cited." Authors are responsible for the accuracy of the bibligraphic references. Names of reviewers should be included in the "Acknowledgments."

Authors will receive 20 complimentary copies of the issue containing their contribution. Manuscripts, news, notices, and meeting announcements should be sent to Beverly F. Vogt, Publications Manager, at the Portland office of DOGAMI.

COVER ILLUSTRATION

The Oregon Department of Geology and Mineral Industries is celebrating 1987 as the fiftieth year since its inception. In commemoration of the event, Department cartographer Mark Neuhaus designed and created this special department seal.

OIL AND GAS NEWS

MIST GAS FIELD

Tenneco Oil Company has plugged and abandoned Columbia County 24-28, located in sec. 28, T. 6 N., R. 5 W. Total depth was 1,928 ft.

Oregon Natural Gas Development (ONGD) has commenced drilling at the natural gas storage project at Mist. Located in sec. 10, T. 6 N., R. 5 W., OM 12d-10 was drilled as an observation well to a total depth of 2,805 ft. Two additional observation monitor wells are currently being simultaneously drilled. These are OM 43c-3, located in sec. 3, T. 6 N., R. 5 W., and OM 41a-10, located in sec. 10, T. 6 N., R. 5 W. These wells are permitted to total depths of 3,000 and 3,100 ft, respectively. ONGD will use the depleted Flora and Bruer Pools for gas storage.

DRILLING CONTINUES AT WILLAMETTE VALLEY WILDCAT

Operations continue at Damon Petroleum Corporation's Stauffer Farms 35-1, located in sec. 35, T. 4 S., R. 1 W., Marion County. Because of mechanical difficulties, the operator decided to plug and abandon the 335-ft casing string, skid the rig approximately 30 ft to the north, and commence a new well, where drilling is presently underway.

EPA PREPARES REPORT ON OILFIELD WASTE

The Resource Conservation and Recovery Act requires the Environmental Protection Agency (EPA) to study wastes from oil, gas, and geothermal operations. The final report by EPA is to be finished by August 31, 1987, to be followed by new regulations. An interim Technical Report has been prepared for public review.

The report outlines drilling techniques and describes EPA's proposed method for collecting and analyzing data to address aspects of drilling waste disposal. The public comment period has ended, but questions and perhaps late comments can be registered with Bob Hall of the EPA, phone (202) 475-7415. □

Stinchfield elected DOGAMI Governing Board Chair

At its November 24, 1986, meeting in Portland, the Governing Board of the Oregon Department of Geology and Mineral Industries (DOGAMI) elected Allen P. Stinchfield of North Bend to serve as new Chair of the Board. Stinchfield, who has served on the Governing Board since July 1, 1980, replaces previous Chair Donald A. Haagensen of Portland. □

DOGAMI to celebrate fiftieth birthday

On March 1, 1937, legislation creating the Oregon Department of Geology and Mineral Industries (DOGAMI) was passed. During the fifty years between 1937 and 1987, the State of Oregon has changed, as has the science of geology. We of DOGAMI are grateful to the citizens of Oregon for having allowed us to be a part of both processes.

During this, our fiftieth anniversary year, we will share with you some brief remembrances of the busy and exciting years of the past. But more importantly, we will continue to give you new information about Oregon's geology and related topics. Within its beauty and vastness, Oregon still has many relatively unexplored areas—places where the geology is still not known or understood. We thank you for your interest and support down through the years, and we urge you to join with us in the excitement of learning more about the geology of our wonderful state in the years to come. □

Field trip guide to the Sheaville and Rome zeolite deposits, southeastern Oregon

by R.A. Sheppard, U.S. Geological Survey, Denver Federal Center, and A.J. Gude, 3rd, U.S. Geological Survey, retired, Lakewood, Colorado

Part A of this article is a slightly modified version of "Field Trip Stop 3, Sheaville Zeolite Deposit, Sheaville, Oregon," and Part B is a version of "Field Trip Stops 4 and 5, Rome Zeolite Deposit, Rome, Oregon," both of which originally appeared in *Zeo-Trip '83*, a publication of the International Committee on Natural Zeolites that was used as a guide for the organization's field trip held from July 7 to 10, 1983. The 72-page book, which was edited by F.A. Mumpton, State University College, Brockport, New York, and prepared by R.A. Sheppard, A.J. Gude, 3rd, and F.A. Mumpton, also contains trip logs to the Durkee zeolite deposit (reprinted in the November 1986 issue of *Oregon Geology*); the Castle Creek zeolite deposit in Oreana, Idaho; the Lovelock zeolite deposit in Lovelock, Nevada; and the Tahoe-Truckee water reclamation plant in Truckee, California. In addition, there is a section on the discovery and commercial uses of the zeolite deposits described in the book. Copies of *Zeo-Trip '83* may be purchased prepaid for $12 from the International Committee on Natural Zeolites, c/o Department of Earth Sciences, SUNY, College at Brockport, Brockport, New York 14420. Permission to reprint the Oregon trip stops in *Oregon Geology* is gratefully acknowledged,

—Editor

PART A. SHEAVILLE ZEOLITE DEPOSIT, SHEAVILLE, OREGON (FIELD TRIP STOP 3 IN *ZEO-TRIP '83*)

INTRODUCTION

The Sheaville deposit is located near Sheaville, Malheur County, Oregon, about 72 km southwest of Boise, Idaho. The Sheaville field trip stop (shown as field trip Stop 3 on Figure 1) is to several small prospect pits, about 300 meters (m) east of U.S. Highway 95 and about 4 kilometers (km) north of Sheaville in the N½NE¼ sec. 1, T. 28 S., R. 46 E. (Figures 1 and 2). This southeastern part of Oregon is in the Owyhee Upland physiographic province, a moderately dissected surface about 600-1,800 m above sea level. Upper Cenozoic volcanic and sedimentary rocks underlie most of the region.

Clinoptilolite and associated authigenic minerals at the Sheaville stop occur in a Miocene sequence of fluviatile and lacustrine rocks known as the Sucker Creek Formation of Kittleman and others (1965). Kittleman and others (1967) reported that the Sucker Creek Formation in the Sheaville area unconformably overlies rhyolitic, latitic, and basaltic volcanic rocks of Miocene age and is unconformably overlain by Miocene and Pliocene rhyolitic and basaltic rocks.

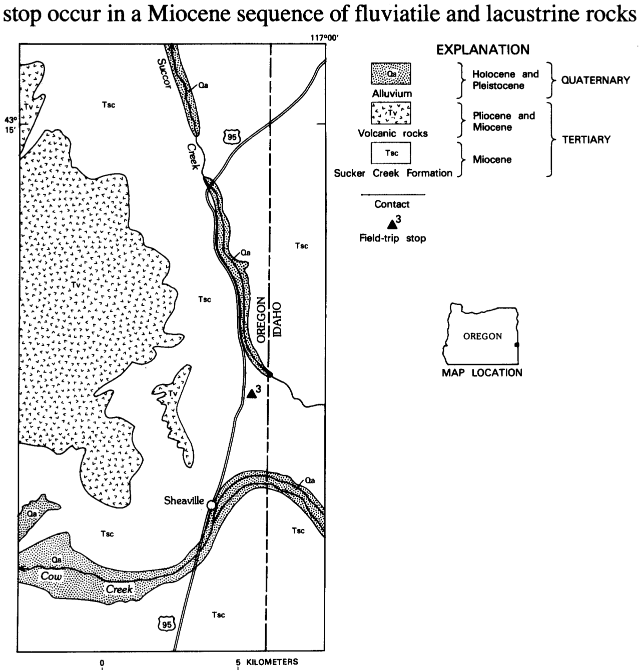

Figure 1. Generalized geologic map showing the field trip stop (Stop 3 in Zeo-Trip '83*) at the Sheaville, Oregon, zeolite deposit discussed in Part A of this paper. Map is modified from Kittleman and others (1967).*

Clinoptilolite in silicic tuffs of the Sheaville area was first recognized by R.H. Olson and F.A. Mumpton in 1958 during an exploration program for zeolites by Union Carbide Corporation. The Norton Company has actively prospected and drilled the zeolite deposits at the field trip stop since the early 1960's, but the company has produced only a small tonnage of zeolitic tuff. Since the late 1970's, clinoptilolite-rich tuff has, however, been mined from the Sucker Creek Formation at other nearby localities. Several thousand tons of clinoptilolite-rich tuff has been mined by Occidental Minerals Corporation about 1 km east of this stop and by Teague Mineral Products about 13 km north of this stop. The materials from both localities have reportedly been used chiefly in agricultural applications. In spite of the commerical interest in the clinoptilolite at the Sheaville deposit, published information on the mineralogy, chemistry, and physical properties of the zeolitic tuff is meager. Kittleman and others (1965) described clinoptilolite and associated authigenic silicate minerals in altered tuffaceous rocks as part of a regional study of the Sucker Creek Formation. More recently, Shedd and others (1982) published a scanning electron micrograph (SEM) of clinoptilolite-rich tuff from the Sheaville deposit.

LITHOLOGY AND DEPOSITIONAL ENVIRONMENTS OF THE SUCKER CREEK FORMATION

The Sucker Creek Formation is about 500 m thick and consists mainly of tuff, volcanic sandstone, arkosic sandstone, conglomerate, and carbonaceous volcanic shale. The formation is extensively exposed in the northeastern part of Malheur County, Oregon (Kittleman and others, 1967) and in the northwestern part of Owyhee County, Idaho (Ekren and others, 1981). In Malheur County, the formation also locally includes flows of basalt and a rhyolitic ash-flow tuff. Much of the vitric material in the sedimentary rocks of the formation is altered to smectite, clinoptilolite, and opal C-T, but fresh glass is preserved locally. Those parts of the formation that are zeolitic or silicified are commonly ledge formers, whereas those parts that are rich in clay minerals or relatively fresh glass are slope formers. In addition to vitric material or altered vitric material, the volcaniclastic rocks commonly contain trace to minor

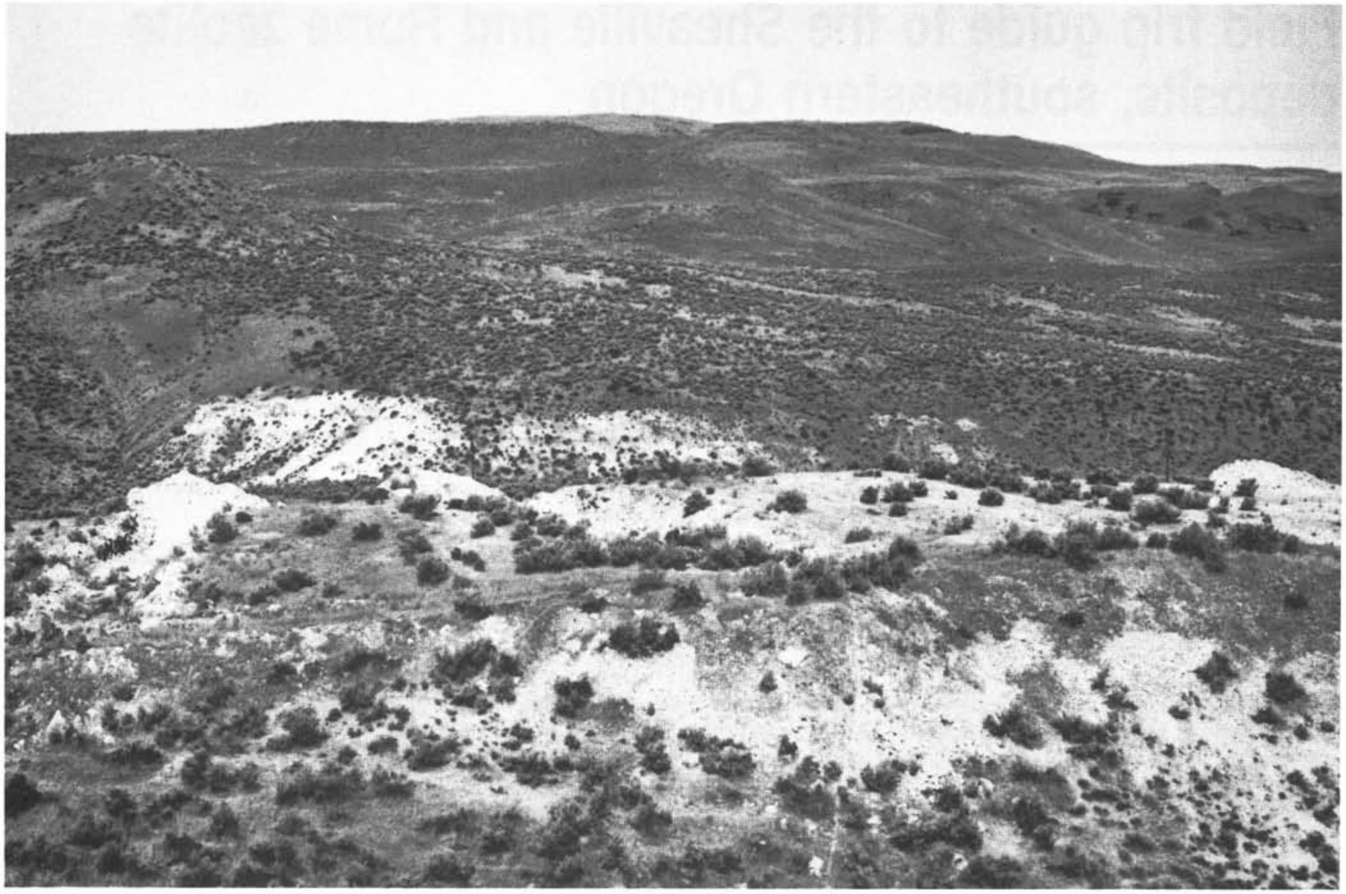

Figure 2. View west to the Sheaville, Oregon, zeolite deposit described in this paper. Bulldozer cuts in the foreground are in light-yellow, clinoptilolite-rich tuff of the Sucker Creek Formation. Hills in the background are underlain by upper Tertiary volcanic rocks that are younger than the Sucker Creek Formation.

amounts of pyrogenic quartz, sodic plagioclase, and biotite. Much of the volcaniclastic material in the formation was probably reworked from ash-fall deposits. Although detailed stratigraphic and sedimentologic studies of the Sucker Creek Formation have not been conducted, Kittleman and others (1965) suggested that the formation is chiefly the result of fluviatile deposition and only subordinate lacustrine deposition.

LITHOLOGY AND MINERALOGY OF THE SHEAVILLE ZEOLITE DEPOSIT AT THIS STOP

Clinoptilolite at the Sheaville zeolite deposit occurs in a thick tuff in the upper part of the Sucker Creek Formation. This locality is on the western limb of a northward-trending anticline, and the tuff dips about 15° northwestward. The tuff is cut by numerous faults of slight displacement. Brown, siliceous, carbonaceous shale underlies the zeolitic tuff and contains abundant well-preserved plant fossils.

The zeolitic tuff is yellowish gray to light gray, thin to thick bedded, moderately resistant, and about 18 m thick (Figure 3). It breaks with a hackly or subconchoidal fracture, and brown iron oxides coat the joint surfaces. Some beds show contorted laminations, and others, more rarely, show ripple marks. Thin lenses of carbonized plant debris are locally common. Although unaltered glass was not recognized in the zeolitic tuff at this locality, the original vitroclastic texture is well preserved. Irregular, green or dark-gray zones in the tuff are hard and siliceous.

X-ray diffraction (XRD) patterns of bulk samples of the tuff at this stop indicate that clinoptilolite generally makes up 70 percent or more of the tuff. The other authigenic constituents are opal C-T and smectite. A chemical analysis of the clinoptilolite-rich tuff is given in Table 1 and indicates that the clinoptilolite is a potassic variety. SEM's of the clinoptilolite-rich tuff (Figure 4) show the excellent preservation of the morphology of the original glass shards by the finely crystalline clinoptilolite. Figure 5 shows that the clinoptilolite occurs as plates and blades, commonly 2-10 micrometers (μm) long. This SEM is not representative of the entire sample, however, because most fields of view show the clinoptilolite as an aggregate of anhedral particles.

Figure 3. Clinoptilolite-rich tuff exposed in a bulldozer cut at the Sheaville, Oregon, zeolite deposit at the stop described in Part A of this paper. Bedding dips northwestward (to the left). The moderately resistant tuff breaks with a hackly to subconchoidal fracture.

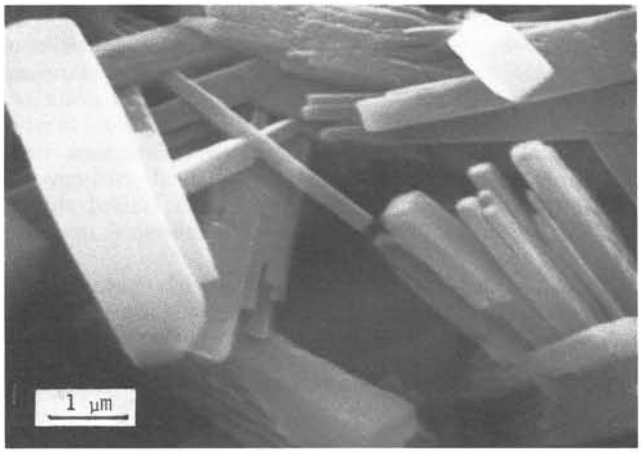

Figure 4. Scanning electron micrograph (SEM) showing the vitroclastic texture in clinoptilolite-rich tuff from the Sheaville, Oregon, zeolite deposit.

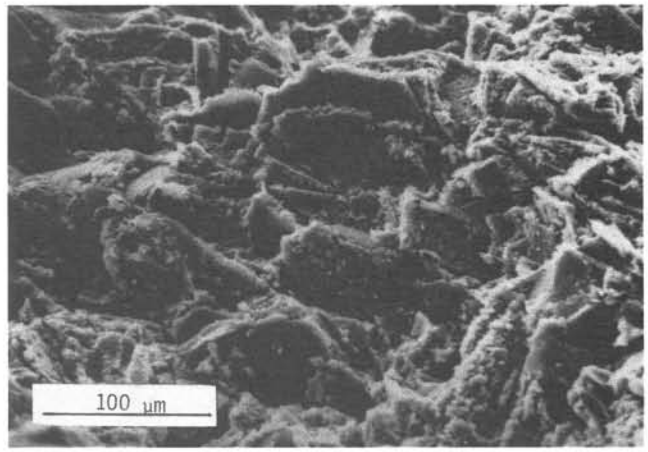

Figure 5. SEM showing plates and finely crystalline clinoptilolite from the Sheaville, Oregon, zeolite deposit.

ZEOLITE GENESIS

No published studies exist concerning the genesis of clinoptilolite and associated authigenic silicate minerals in the tuffs at the Sheaville zeolite deposit or anywhere in the Sucker Creek Formation. The zeolitic tuff originally consisted of silicic volcanic glass (Table 1) that was deposited in a fresh-water environment. Clinoptilolite, smectite, and opal C-T undoubtedly formed during diagenesis by reaction of the silicic glass with interstitial water. The apparent fresh-water depositional environment would probably not have provided connate interstitial water having characteristics favorable for alteration of the glass. Thus, the interstitial water necessary for the diagenetic alteration probably was flowing or percolating ground water that originated as meteoric water. In such open hydrologic systems, the ground water becomes chemically modified by hydrolysis and solution of the vitric material, and zeolitization can then proceed (Hay and Sheppard, 1977).

Additional data are needed with regard to the alteration pattern in the Sucker Creek Formation. Directly at this stop, the vitric material of the tuff seems completely altered. About 1 km north of the stop in the highway cuts and topographically lower than the stop, the same tuff is chiefly unaltered, gray glass. Also, about 1 km east of the stop and at about the same elevation, a tuff stratigraphically lower than that at this stop is completely altered to clinoptilolite, smectite, and opal C-T. At the type section for the Sucker Creek Formation, which is about 32 km north of this stop, Kittleman and others (1965) described both fresh and altered parts of the formation. A regional investigation, including subsurface information, is necessary before the zeolitization of tuffaceous rocks in the Sucker Creek Formation is understood.

Table 1. *Chemical analyses of vitric tuff and clinoptilolite-rich tuff from the Sucker Creek Formation, near Sheaville, Oregon.*[1]

Vitric tuff[2]				Clinoptilolite-rich tuff[3]			
SiO_2	69.1	K_2O	4.76	SiO_2	65.1	K_2O	4.76
Al_2O_3	11.7	TiO_2	0.31	Al_2O_3	11.4	TiO_2	0.34
Fe_2O_3	2.32	P_2O_5	<0.05	Fe_2O_3	2.64	P_2O_5	<0.05
MgO	0.27	MnO	0.04	MgO	0.28	MnO	<0.02
CaO	1.00	H_2O[4]	8.60	CaO	1.01	H_2O[4]	11.70
Na_2O	1.30	Total	99.40	Na_2O	1.71	Total	98.94

[1]X-ray spectrographic analyses on untreated samples by J. S. Wahlberg, Bartel, J. Baker, K. Stewart, and J. Taggert.
[2]Vitric tuff collected in roadcut of U.S. Highway 95, about 0.8 km north of field trip Stop 3. Sample consists of about 80% vitric material and 20% clinoptilolite, opal C-T and smectite.
[3]Clinoptilolite-rich tuff collected at field trip Stop 3. Except for a trace of smectite, the sample consists of clinoptilolite.
[4]H_2O determined by loss on ignition at 900°C.

PART B. ROME ZEOLITE DEPOSIT, ROME, OREGON (FIELD TRIP STOPS 4 AND 5 IN *ZEO-TRIP '83*)

INTRODUCTION

The Rome zeolite deposit is located near Rome, Malheur County, Oregon, about 140 km southwest of Boise, Idaho. This southeastern part of Oregon is also in the Owyhee Upland physiographic province. Neogene and Quaternary volcanic and sedimentary rocks are the principal rocks that crop out in the province. The zeolites and associated authigenic minerals occur in a Miocene sequence of alluvial and lacustrine volcaniclastic rocks known informally as the Rome beds (Figure 6). Walker and Repenning (1966) mapped the Rome beds during their geologic reconnaissance of the Jordan Valley quadrangle. The nearly flat-lying Rome beds unconformably overlie other Miocene sedimentary and volcanic rocks and are locally uncomformably overlain by basalt and sedimentary rocks of Pliocene and Quaternary age.

Although the Rome beds were briefly described by I.C. Russell as early as 1903, zeolites were not recognized until the late 1950's. During this period and in the 1960's, several companies, including Kennedy Minerals Company (Eberly, 1964), Norton Company (Regis and Sand, 1966; Sand and Regis, 1967), Shell Development Company (Studer, 1967), and Union Carbide Corporation, conducted exploration programs for zeolites in the Rome beds. Both Anaconda Minerals Company (Santini and LeBaron, 1982) and Occidental Minerals Company actively prospected and drilled the Rome deposit in the late 1970's, and at least two other companies prospected the zeolitic beds for fluorite in the 1970's. In spite of all the interest and activity concerning the Rome zeolite deposit since the 1950's, only a minor tonnage of zeolite, chiefly mordenite-rich ore, has been produced. A considerable amount of low-grade, erionite-rich tuff containing substantial unaltered ash was quarried from the area for dimension stone prior to 1960.

Published studies on the distribution and genesis of zeolites and associated authigenic minerals in the volcaniclastic rocks of the Rome beds include those of Sheppard and Gude (1969, 1974), Wolf and Ellison (1971), Campion (1979), and Santini and LeBaron (1982). These studies concentrated mainly on that part of the Rome beds between the Owyhee River and Crooked Creek and chiefly north of U.S. Highway 95 (Figure 6). Both field trip stops at the Rome zeolite deposit are in the same general area and are shown as field trip stops 4 and 5 in Figure 6.

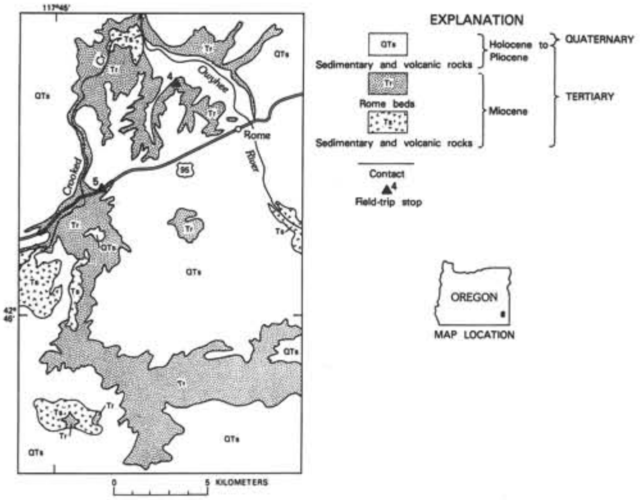

Figure 6. Generalized geologic map of the Rome, Oregon, area, modified from the reconnaissance map of Walker and Repenning (1966), showing the field trip stops (Stops 4 and 5 in Zeo-Trip '83) *at the Rome zeolite deposit discussed in Part B of this paper.*

STRATIGRAPHY AND DEPOSITIONAL ENVIRONMENTS IN THE ROME BEDS

Details of the stratigraphy and depositional environments of the Miocene Rome beds have been reported by Wolf and Ellison (1971) and by Campion (1979), so only a summary will be given here. The Rome beds are at least 100 m thick and consist of an alluvial and lacustrine sequence of chiefly conglomerate, sandstone, mudstone, tuff, and minor limestone and chert. The rocks of the Rome beds are volcaniclastic except for minor chert, limestone, and, possibly, mudstone. Campion (1979) divided the Rome beds into two informal units: (1) a lower, coarse-grained unit that consists of interbedded conglomerate, sandstone, siltstone, and minor mudstone and tuff, and (2) an upper, fine-grained unit that consists chiefly of mudstone, tuff, and minor sandstone and chert. The lower part of the fine-grained unit intertongues with the upper part of the coarse-grained unit. The lower, coarse-grained unit makes up about two-thirds of the thickness of the Rome beds and can be traced over an area, elongated north-south, of about 550 km². The upper, fine-grained unit, however, is traceable over an area of only about 20 km² and is restricted to a narrow north-south band in the west-central part of the basin. The upper, fine-grained unit may originally have had a greater extent, but the marginal parts of the unit were eroded prior to the deposition of the Pliocene and younger rocks overlying it.

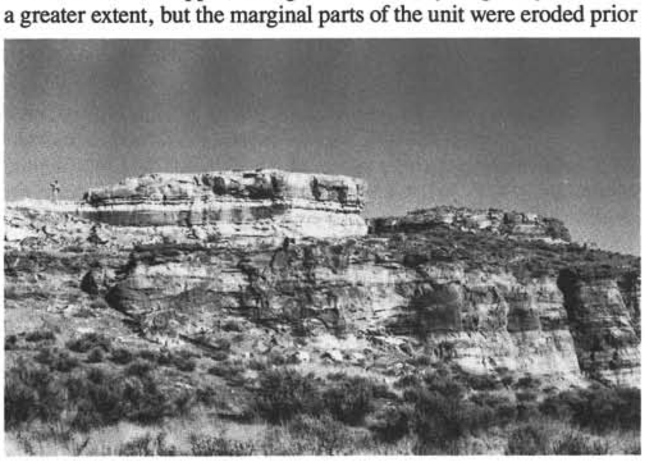

Figure 7. Erionite-rich lower marker tuff (right of 1.8-m-tall standing person) and underlying rocks of lower, coarse-grained member of the Rome beds, at the first trip stop described in Part B, which discusses the deposits at Rome, Oregon.

The lower, coarse-grained unit of the Rome beds consists of channel-form, tabular and sheetlike deposits of pebble conglomerate, coarse-grained sandstone, sandy mudstone, and minor mudstone. According to Campion (1979), these rocks were deposited in proximal braided stream and alluvial fan environments. Basinward, coeval deposits of the lower, coarse-grained unit are chiefly sandstone and mudstone that represent deposition in distal braided stream, floodplain, mudflat, beach, and offshore ephemeral lacustrine environments.

The upper, fine-grained unit of the Rome beds represents a late phase of deposition in the basin. It consists chiefly of mudstone and tuff but includes minor sandstone, chert, and limestone that are laterally extensive, unlike the rocks of the underlying coarse-grained unit. The upper, fine-grained unit of the Rome beds was probably deposited in a perennial lake.

LITHOLOGY AND MINERALOGY OF THE LOWER AND UPPER MARKER TUFFS AND ASSOCIATED ROCKS IN THE ROME BEDS

The two field trip stops at the Rome deposit (shown as stops 4 and 5 in Figure 6) are at thick, conspicuous zeolitic tuffs that herein are termed the lower marker tuff and the upper marker tuff. The lower marker tuff is in the upper part of the lower, coarse-grained unit of the Rome beds and is well exposed in the Rome Cliffs southwest of the Owyhee River, about 5 km northwest of the hamlet of Rome. The upper marker tuff is in the upper part of the upper, fine-grained member of the Rome beds and crops out along Crooked Creek and several tributaries that join Crooked Creek from the east (see Figure 6). The upper marker tuff is in the same unit as the marker tuff of Sheppard and Gude (1969), the upper marker tuff of Campion (1979), and the zeolitic tuff of Santini and LeBaron (1982).

FIRST STOP AT THE ROME BEDS (STOP 4 IN *ZEO-TRIP '83*): LOWER MARKER TUFF

The lower marker tuff and underlying rocks are easily examined at this stop (Stop 4), which is located on the west side of a small gulch in the NW¼ NW¼ sec 22, T. 31 S., R. 41 E. About 40 m of the lower, coarse-grained member of the Rome beds is well exposed at this locality (Figure 7). The lower marker tuff caps small knobs on the ridge west of the gulch, and the underlying grayish-green to grayish-brown sequence consists mainly of sandstone and conglomerate, with minor mudstone, siltstone, and tuff. The conglomerate is lenticular and consists chiefly of pebbles and cobbles of dark-colored chert and volcanic rocks. Pebbles of zeolitic tuff are also locally present in the conglomerate. The mineralogy of the lower marker tuff and underlying rocks is given in Table 2. In addition to detrital constituents, the volcaniclastic sandstone contains authigenic clay minerals, clinoptilolite, and most commonly, erionite.

At this locality, the lower marker tuff is about 6 m thick, but elsewhere it is only about 3 m thick. The lower marker tuff is light yellowish green but weathers brown to orange. The tuff is chiefly massive but is locally platy in the upper part (Figure 8). The base of the tuff is uneven, and cross-bedded tuffaceous sandstone or conglomerate locally occupies the basal part of the tuff. Saline-mineral molds occur locally in the upper part of the tuff. Although unaltered glass shards have not been recognized in this particular tuff unit at this locality, the relict vitroclastic texture is obvious. On the hilltop about 0.4 km east of this locality, the lower marker tuff has been quarried for local building stone and contains some unaltered glass.

The mineralogy of bulk samples of the lower marker tuff collected at this site is given in Table 2. Erionite is the principal authigenic constituent, but minor (10-20 percent) clay minerals, phillipsite, and chabazite occur locally with the erionite. SEM's of the lower marker tuff show that the erionite occurs as needles, rods, and clusters of acicular crystals that are generally 5-20 μm in length

Figure 8. Erionite-rich lower marker tuff at the first field trip stop (Stop 4 in Figure 6) at Rome, Oregon, showing the upper platy part of the unit.

(Figures 9 and 10). The erionite rods commonly display a hexagonal cross-section. Chabazite occurs as rhombohedra, generally 3-10 μm in size. Thin fibers or needles of erionite have commonly grown on the surfaces of the chabazite (Figure 11), attesting to the younger age of the erionite. The paragenetic relationships as determined by scanning electron microscopy are, from early to late, smectite,

Table 2. *Mineralogical composition of the lower marker tuff and associated rocks at the first stop (Stop 4 in* Zeo-Trip '83*) at the Rome, Oregon, zeolite deposit.*

Lithology	Position[2] (m)	X-ray diffraction analysis[1] (in parts of ten) Ch	Cp	Er	Ph	K-spar	Pl	Qtz	Mica	Sm
Tuff	+6.05	1	–	3	1	–	2	3	tr	tr
Tuff	+4.57	–	–	10	–	–	–	–	–	–
Tuff	+3.50	2	–	6	–	–	1	1	–	–
Tuff	+0.97	–	–	10	tr	–	–	–	–	–
Sandstone, tuffaceous	+0.45	–	–	2	–	–	3	4	–	1
Tuff, gray	–0.10	–	tr	–	–	6	–	1	1	2
Sandstone	–2.74	–	tr	1	–	–	1	5	2	1
Tuff pebble	–18.60	–	–	10	–	–	–	–	–	tr
Sandstone, tuffaceous	–20.34	–	–	2	–	–	1	3	2	2
Siltstone, tuffaceous	–23.85	–	–	2	–	–	1	2	3	2

[1]Ch = chabazite; Cp = clinoptilolite; Er = erionite; Ph = phillipsite; K-spar = potassium feldspar; Qtz = quartz; Mica = illite, muscovite, biotite; Sm = 14-Å clay mineral; tr = trace; – = looked for but not detected.
[2]Stratigraphic position of sample above (+) or below (–) base of lower marker tuff.

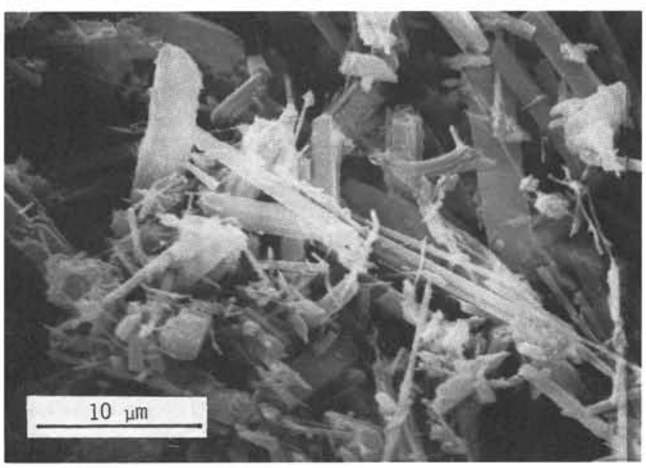

Figure 9. SEM of the lower marker tuff, Rome, Oregon, showing acicular erionite of various sizes.

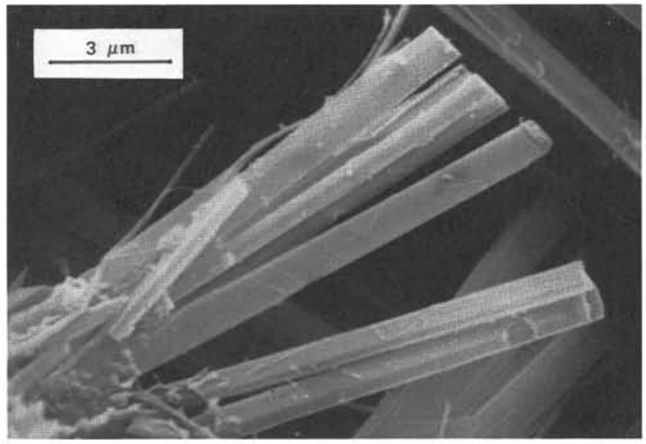

Figure 10. SEM of the lower marker tuff, Rome, Oregon, showing hexagonal rods of erionite.

chabazite, and then erionite. Neither the morphology nor the paragenetic relationship of the associated phillipsite was determined in the lower marker tuff.

A thin (0-20 centimeter [cm]) gray tuff is locally present beneath the lower marker tuff at this stop. This gray tuff consists mainly of authigenic potassium feldspar with minor to trace amounts of authigenic clay minerals and clinoptilolite. The presence and, especially, the abundance of authigenic potassium feldspar are unusual for volcaniclastic rocks of the lower, coarse-grained member of the Rome beds.

SECOND STOP AT THE ROME BEDS (STOP 5 IN *ZEO-TRIP '83*): UPPER MARKER TUFF

The upper marker tuff and underlying rocks of the upper, fine-grained member of the Rome beds crop out just north of U.S. Highway 95, about 0.9 km east of Crooked Creek in the SW¼NW¼ sec. 5, T. 32 S., R. 41 E. About 20 m of the upper, fine-grained member, including the upper marker tuff, is exposed at this stop (Figure 12). The upper marker tuff represents the top of the Rome beds at this locality, but drilling farther north of the highway by Anaconda Minerals Company (Santini and LeBaron, 1982) indicated that as much as 18 m of mudstone locally overlie the upper marker tuff. Grayish-brown mudstone and siltstone of Pliocene age unconformably overlie the upper marker bed at this stop, and basalt unconformably overlies the brown sediments. West of Crooked Creek,

Figure 11. SEM of the lower marker tuff, Rome, Oregon, showing thin needles or fibers of erionite (E) *that grew on rhombohedral chabazite* (Ch).

Figure 12. Upper marker tuff at the second field trip stop (Stop 5 in Figure 6) at the Rome, Oregon, deposit on the north side of U.S. Highway 95, about 0.9 km east of Crooked Creek. The upper marker tuff consists of ledge-forming lower gray (L) *and middle orange* (O) *subunits and a less resistant upper gray* (U) *subunit. A greenish-gray, vuggy bed occurs in the upper third of the lower gray subunit. The upper marker tuff grades into the underlying tuffaceous mudstone.*

the basalt rests on a part of the Rome beds that is stratigraphically lower than the upper marker tuff. The mudstone beneath the upper marker tuff is gray to grayish green and is commonly concealed by a punky "popcorn" coating formed by weathering of expandable clay minerals in the mudstone. Thin beds of tuff, chert, and ostracodal limestone occur in the lower part of the upper, fine-grained member of the Rome beds. A distinctive chert, known as Magadi-type chert (Sheppard and Gude, 1974), crops out 7-8 m beneath the upper marker bed at this stop. Nodules of this chert that show characteristic surface reticulation (Figure 13) are appropriately called snakeskin agates by rockhounds and lapidaries.

The zeolitic upper marker bed forms a conspicuous ledge and is probably the most distinctive unit in the Rome beds. This marker tuff consists of three subunits that total 6-7 m in thickness. At this locality, the upper part of the tuff was eroded prior to deposition of the overlying Pliocene sediments. From drilling north of the highway, Santini and LeBaron (1982) suggested that the original thickness of the upper marker tuff was as much as 13 m. A resistant orange subunit near the middle of the marker tuff separates the

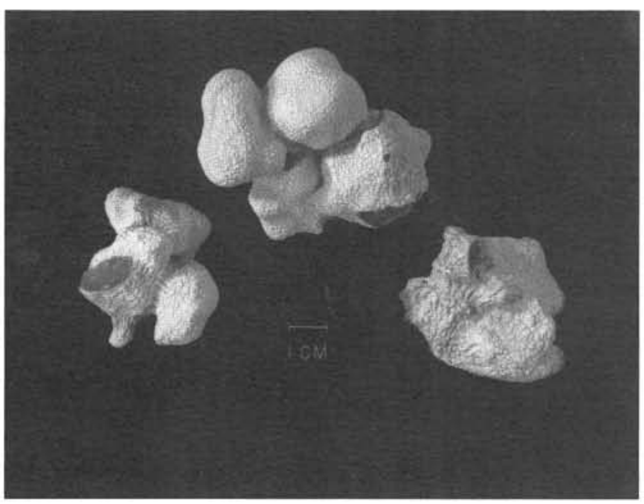

Figure 13. Small lobate nodules of Magadi-type chert (snakeskin agate) from Rome, Oregon, showing charateristic surface reticulation and thin white coating.

predominantly light-gray tuff into lower and upper subunits (Figure 12). Both gray subunits break with a blocky to conchoidal fracture and contain abundant crystal molds of gaylussite(?). A thin bed of greenish-gray, vuggy tuff occurs locally in the upper third of the lower gray subunit. The orange subunit is about 1 m thick and consists of a thin lower bed and a thicker upper bed (Figure 14). Both beds break with a hackly or irregular fracture and have contorted laminations in their basal parts.

The mineralogy (Table 3) of the upper marker tuff and underlying rocks of the upper, fine-grained member of the Rome beds at this stop was determined by study of XRD patterns of bulk samples. The mudstone consists mainly of authigenic constituents that formed from an originally high content of vitric material. Potassium feldspar and clay minerals predominate, but quartz, clinoptilolite, and erionite are locally obvious. Even the fluorite and some, at least, of the calcite in the mudstone are authigenic.

The upper marker tuff consists chiefly of authigenic zeolites, clay minerals, quartz, potassium feldspar, and locally minor fluorite, calcite, and opal C-T. The tuff originally consisted mainly of silicic glass shards and minor crystal fragments. Relict vitroclastic texture is well preserved in some parts of the tuff but is vague or absent in other parts. Unaltered glass was not recognized at this particular locality, but abundant unaltered glass occurs in parts of the upper marker tuff about 2.2 km south of this stop.

The zeolite mineralogy of the upper marker tuff (Table 3), though variable, shows a certain consistency with the subunits described above. Mordenite is the principal zeolite in the lower and upper gray subunits and is locally associated with minor clinop-

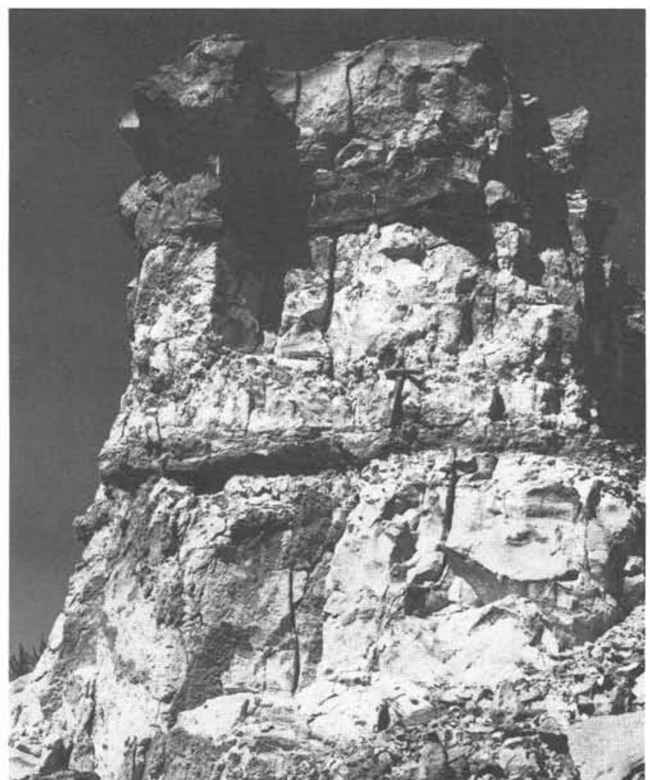

Figure 14. Upper marker tuff at the Rome, Oregon, zeolite deposit showing the lower gray subunit capped by the middle orange subunit. A distinctive greenish-gray vuggy bed occurs in the lower gray subunit beneath the hammer handle. The orange subunit splits into two beds. Mordenite is the principal zeolite in the lower gray subunit, but clinoptilolite, erionite, and phillipsite make up the orange subunit.

Table 3. *Mineralogical composition of the upper marker tuff and associated rocks at the second stop (Stop 5 in* Zeo-Trip '83) *at the Rome, Oregon, zeolite deposit.*

Lithology	Position [1] (m)	X-ray diffraction analysis[2] (in parts of ten)										
		Cp	Er	Mo	Ph	K-spar	Qtz	C-T	Mica	Sm	Cc	Fl
Tuff, upper gray	+6.25	–	–	4	–	–	1	–	1	1	3	tr
Tuff, upper gray	+5.64	tr	–	9	–	–	–	–	1	tr	–	tr
Tuff, upper gray	+4.57	1	–	7	–	–	2	–	–	–	–	tr
Tuff, orange	+4.27	8	1	–	–	–	–	–	1	tr	–	–
Tuff, orange	+3.84	2	8	–	–	–	–	–	–	–	–	–
Tuff, orange	+3.57	10	–	–	tr	tr	–	–	–	–	–	–
Tuff, orange	+3.55	7	–	–	1	–	–	–	1	1	–	–
Tuff, orange	+3.51	10	–	–	tr	–	–	–	–	tr	–	–
Tuff, orange	+3.38	9	–	–	1	–	–	–	–	tr	–	–
Tuff, orange	+3.23	5	–	–	5	–	–	–	–	–	–	–
Tuff, lower gray	+3.20	–	–	5	–	–	1	tr	1	2	1	–
Tuff, lower gray	+2.80	–	–	7	–	–	1	–	–	–	2	tr
Tuff, lower gray	+2.29	8	–	–	–	1	–	–	1	tr	–	tr
Tuff, lower gray, vuggy	+2.22	10	–	–	–	tr	–	–	–	–	–	tr
Tuff, lower gray, vuggy	+2.13	tr	–	–	4	2	–	–	1	3	–	tr
Tuff, lower gray	+2.04	tr	–	4	–	2	–	–	1	1	–	2
Tuff, lower gray	+1.07	–	–	4	–	–	3	–	–	1	2	tr
Tuff, lower gray	+0.52	–	–	3	–	–	3	tr	–	1	3	–
Tuff, lower gray	+0.02	tr	–	2	–	2	1	tr	2	2	–	1
Mudstone	–0.06	–	–	–	–	3	2	–	4	1	–	tr
Mudstone	–0.30	–	–	–	–	5	–	–	4	1	–	tr
Mudstone	–0.76	–	–	–	–	5	–	–	4	1	–	tr
Mudstone	–1.52	–	–	–	–	4	tr	–	3	3	tr	tr
Mudstone	–5.00	–	tr	–	–	4	tr	–	4	2	tr	tr
Mudstone	–6.83	–	1	–	–	3	tr	–	2	2	2	tr
Chert	–7.16	–	–	–	–	–	10	–	–	tr	–	–
Mudstone	–7.38	–	–	–	–	1	2	–	1	4	2	tr
Chert	–7.53	tr	–	–	–	–	10	–	tr	–	–	tr
Mudstone	–7.77	tr	–	–	–	tr	7	–	2	1	tr	tr

[1]Stratigraphic position of sample above (+) or below (–) base of lower marker tuff.
[2]Cp = clinoptilolite; Er = erionite; Mo = mordenite; Ph = phillipsite; K-spar = potassium feldspar; Qtz = quartz; C-T = opal C-T; Mica = illite, muscovite, biotite; Sm = 14-Å clay mineral; Cc = calcite; Fl = fluorite; tr = trace; – = looked for but not found.

tilolite. At this locality, the mordenite content varies from 20 to 90 percent and averages about 50 percent. The thin, greenish-gray, vuggy tuff in the lower gray subunit consists mainly of clinoptilolite and phillipsite. The lower part of the orange subunit consists of clinoptilolite and phillipsite, but the upper part of this subunit consists of clinoptilolite and erionite. The basal 1-3 cm of the orange subunit is especially rich in phillipsite.

SEM's of the upper marker tuff show that the abundant mordenite occurs as a mass of intergrown, curved, threadlike fibers that are only several tenths of a micrometer in diameter (Figure 15). Erionite commonly occurs as needles or clusters of acicular crystals that are 5-30 μm long. Clinoptilolite occurs as plates and tablets that are commonly 10-60 μm long (Figure 16). The phillipsite occurs as aggregates of elongated, prismatic crystals, as rosettes of prismatic crystals (Figure 17), or as spherulites. Most of the prismatic phillipsite is 5-10 μm long. Spherulitic phillipsite is particularly common at the base of the orange subunit. The paragenetic sequences

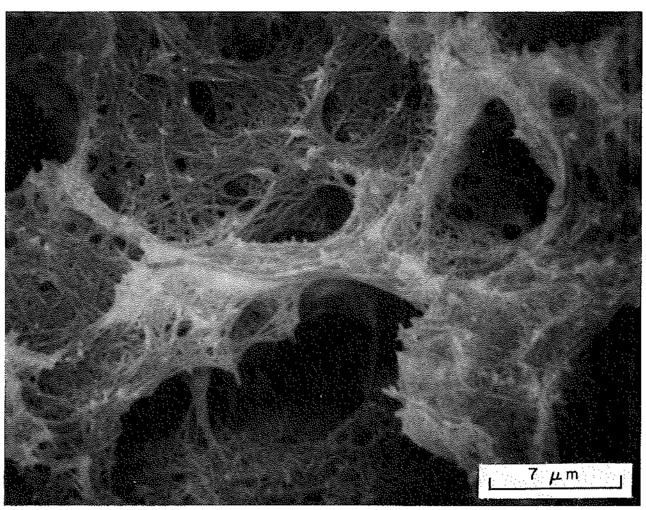

Figure 15. SEM of the upper gray subunit of the upper marker tuff at the Rome, Oregon, zeolite deposit, showing a mass of intergrown, threadlike fibers of mordenite.

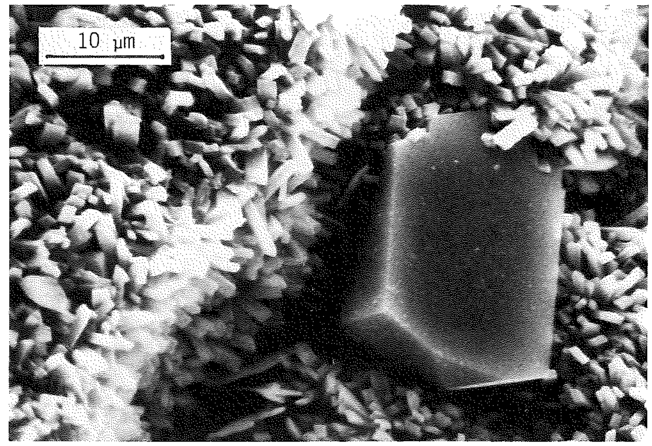

Figure 16. SEM of the basal part of the orange subunit of the upper marker tuff at the Rome, Oregon, zeolite deposit, showing a large clinoptilolite crystal resting on prismatic phillipsite.

as determined by scanning electron microscopy are, from early to late, smectite, erionite, and then clinoptilolite, and smectite, phillipsite, and then clinoptilolite. The paragenetic relationship between mordenite and clinoptilolite was not observed in the upper marker tuff.

Fluorite seems to be restricted to the upper, fine-grained member of the Rome beds (Table 3) and is especially abundant in parts of the upper marker tuff (Sheppard and Gude, 1969). The fluorite occurs as submicrometer-size, nearly spherical grains of diagenetic origin. The mordenitic, lower gray subunit of the upper marker tuff commonly has the highest fluorite content, and as much as 16 percent fluorite has been determined. The orange subunit consistently contains little or no fluorite. Similar fluorite has recently been reported from alkaline, saline-lake deposits elsewhere in the western United States (Sheppard and Gude, 1980) and in eastern Africa (Surdam and Eugster, 1976).

GENESIS OF THE ZEOLITES

The zeolites and associated silicate minerals in tuffs and other volcaniclastic sediments of the Rome beds formed during diagenesis by reaction of silicic glass with pore waters of various compositions. Campion (1979) showed that three diagenetic facies or zones can be delineated from the margin to the central part of the basin in which the Rome beds were deposited. A marginal, fresh-glass facies grades basinward to a zeolitic facies and then to a potassium feldspar facies in the central part of the basin. Campion's stratigraphic and sedimentological studies suggest that the basin center during the deposition of the upper, fine-grained member of the Rome beds was located about midway between the second stop at the Rome beds and the Owyhee River to the north (Figure 6). This general distribution of diagenetic facies is similar to the distribution of depositional facies from the marginal, alluvial environments to a basinward, lacustrine environment. The paragenesis of authigenic silicate minerals of glass $\rightarrow$ smectite $\rightarrow$ zeolite $\rightarrow$ potassium feldspar and the distribution of diagenetic facies in the Rome beds are similar to that recognized in tuffs of Pleistocene Lake Tecopa, near Shoshone, California (Sheppard and Gude, 1968).

If the original composition of all of the volcanic glass in the Rome beds was close to that shown in Table 4, the formation of zeolites and associated minerals was controlled mainly by the composition of the pore water. The pore water trapped with the rhyolitic volcanic glass during sedimentation probably varied from dilute and nearly neutral pH in alluvial environments to saline, alkaline brine having a pH of 9 or greater in the central lacustrine environment. Hydration and solution of the vitric material during diagenesis would have caused even further chemical modifications of the pore water.

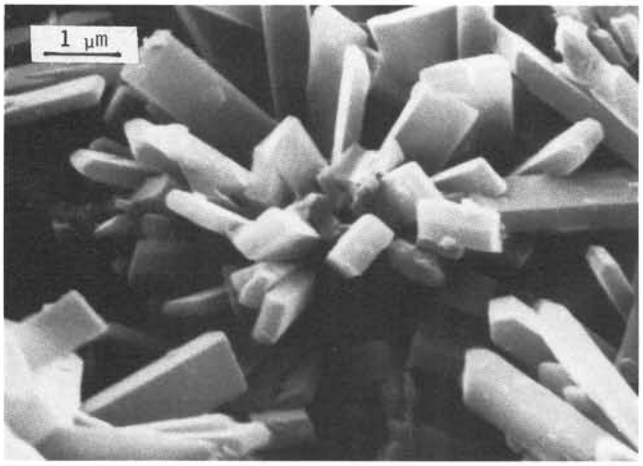

Figure 17. SEM of the basal part of the orange subunit of the upper marker tuff at the Rome, Oregon, zeolite deposit, showing a rosette of prismatic phillipsite.

Both high pH and high salinity of the pore water favor rapid solution of silicic vitric material (Surdam and Sheppard, 1978). Surdam and Sheppard (1978) indicated that the important chemical properties of the pore water during the reaction of glass to zeolites are as follows: cation ratios, Si:Al ratio, and the activity of H_2O. These properties are, of course, affected by changes in the salinity and/or alkalinity. The pH, in particular, influences the Si:Al ratio of the pore water and, thus, the Si:Al ratio of the zeolite that crystallizes from the pore water.

Campion (1979) showed that the authigenic potassium feldspar in the Rome beds formed from precursor zeolites as well as from clay minerals and detrital plagioclase. Although kinetic factors may be important for the zeolite to potassium feldspar reaction, high pH and high salinity of the pore water certainly favor the reaction.

Table 4. *Chemical composition of rhyolitic glass from the Rome beds.*[1]

SiO_2	72.44	MgO	0.10	CaO	0.46
Al_2O_3	11.26	K_2O	5.08	H_2O[2]	6.67
Fe_2O_3	1.14	Na_2O	2.85	Total	100.00

[1]Electron microprobe analysis from Campion (1979). Shards were separated from a tuff located in the SW1/4, SE1/4, Sec. 8, T32S, R41E (about 2.2 km south of Stop 5).
[2]Water calculated by difference.

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Released 12-30-86: *Geologic map of the northwest quarter of the Cave Junction quadrangle, Josephine County,* Geological Map Series GMS-38. □

Correction

In the October 1986 article on the Turner-Albright massive sulfide deposit (*Oregon Geology,* v. 48, no. 10, p. 117), the cobalt values in paragraph 2, line 17, should have read 0.05 percent cobalt.

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