STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES

PUMICE, PUMICITE, AND VOLCANIC CINDERS IN CALIFORNIA

BULLETIN 174
1956

DIVISION OF MINES
FERRY BUILDING, SAN FRANCISCO

CALIFORNIA. DEPT. OF NAT. RES.
DIV. OF MINES.
Pumice, pumicite, and volcanic
cinders in California.

STATE OF CALIFORNIA
GOODWIN J. KNIGHT, Governor
DEPARTMENT OF NATURAL RESOURCES
DeWITT NELSON, Director

DIVISION OF MINES
FERRY BUILDING, SAN FRANCISCO 11
OLAF P. JENKINS, Chief

SAN FRANCISCO — BULLETIN 174 — DECEMBER 1956

PUMICE, PUMICITE, AND VOLCANIC CINDERS IN CALIFORNIA

By CHARLES W. CHESTERMAN

and

TECHNOLOGY OF PUMICE, PUMICITE, AND VOLCANIC CINDERS

By F. SOMMER SCHMIDT

Price $2.50

LETTER OF TRANSMITTAL

To The Honorable Goodwin J. Knight
Governor of the State of California

Dear Sir: I have the honor to transmit herewith Bulletin 174, *Pumice, Pumicite, and Volcanic Cinders in California*, prepared under the direction of Olaf P. Jenkins. Pumice, pumicite, and volcanic cinders represent important natural volcanic lightweight aggregate materials in California. These materials are used widely by the construction and agricultural industries. The bulletin contains two parts: Part I, prepared by Charles W. Chesterman, a member of the staff, deals with the history of the industry, the geological occurrence and origin of the deposits, and descriptions of the many deposits of pumice, pumicite, and volcanic cinders in California. Part II, prepared by F. Sommer Schmidt, consulting mining engineer, deals with the technology of pumice, pumicite, and volcanic cinders, and especially with the pumice concretes. Bulletin 174 contains numerous geological maps and photographs of the important producing districts, and charts and graphs illustrating graphically the relationships between pumice concrete and ordinary sand-gravel concrete.

This bulletin is of interest not only to those utilizing pumice, pumicite, and volcanic cinders, but also to those who are in search of a source of supply of these materials and basic information concerning them.

Respectfully submitted,

DeWitt Nelson, Director
Department of Natural Resources

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By Charles W. Chesterman *

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* Mining geologist, California State Division of Mines.

ABSTRACT

Pumice, pumicite, and volcanic cinders are products of explosive volcanic activity. They are mined from volcanic and pyroclastic rocks that range in age from early Tertiary to Recent and are widely distributed throughout California. Magmas of acidic to intermediate (rhyolite to andesite) composition give rise to pumice and pumicite. Most volcanic cinders are basic (basaltic) in composition, although a few are dacitic. On the basis of mode of deposition, size distribution of the particle or fragment, and origin of the material, deposits of pumic and pumicite are grouped into five separate types: (1) subaerial deposits, (2) subaqueous deposits, (3) vesiculated surfaces of obsidian domes or flows, (4) Nuee Ardente deposits, and (5) reworked deposits. Volcanic cinder deposits are subaerial in character and are commonly cones built up around a central vent. The major proportion of pumice output in California is and has been from subaerial and subaqueous deposits. Most of the pumicite output in California has been from subaqueous deposits.

Alteration of the pumice and pumicite ranges from almost none to an extensive development of montmorillonite, especially in older pumicite deposits of subaqueous deposition and certain early Tertiary pumice deposits.

Deposits of pumice and pumicite range in size from a few thousand tons to hundreds of thousands of tons. They contain layers of pumice tuff that range from a few feet to well over 100 feet in thickness. Overburden commonly is a thin covering of loosely consolidated pumiceous soil. At a few deposits the overburden is a well-consolidated tuff that ranges from a few feet to several tens of feet in thickness.

Some pumice and pumicite deposits were mined by underground mining methods. Present production, however, is from quarries where the material is mined by open pit methods. The loosely consolidated tuffs commonly require only a bulldozer or dragline to mine the pumice or pumicite, whereas blasting is required to break down the pumice in well-consolidated tuffs.

Very little pumice, pumicite, or volcanic cinders is used directly as mined from the quarry. Some crushing and screening are necessary to produce materials and aggregate for specific uses, which include concrete aggregate, insulating plaster, interior and exterior stucco, abrasive, cleansing and scouring compounds, fillers in rubber and paints, cement additive, insecticide carrier, and soil conditioner. The principal market for volcanic cinders has been as aggregate in concrete.

First recorded production of pumice in California was about 60 tons in 1883. From 1909 to the late 1930's most of the pumice and pumicite output in California was used for abrasive purposes. From the latter part of the 1930's to date more of the pumice output has gone into construction where it was used as aggregate in concrete either for precast blocks or slabs, or for monolithic structures. The total combined output of pumice and pumicite in California from 1909 to 1953 was 1,801,564 short tons valued at $9,059,030. Production statistics for volcanic cinders are incomplete, but for the period from 1916 to 1953 the output for California was about 4,617,000 short tons valued at about $3,996,000.

INTRODUCTION

Acknowledgments

It is a pleasure to acknowledge the cooperation of the many property owners and operators, especially R. N. Fouch, Jr., Joseph Smith, and Sheldon P. Fay. Also, especial thanks are due Drs. Olaf P. Jenkins, Chief of the Division of Mines and L. A. Wright, Senior Mining Geologist, both of whom took particular interest in the investigation and offered many valuable suggestions.

Scope of the Industry

Probably the earliest recorded production of pumice or pumicite in California was obtained in 1883 when a small volume of pumice-stone (pumicite) was mined from deposits at Lake Merced, formerly known as Lake Honda, in San Francisco (U. S. Mineral Resources, 1883, p. 480). The 60 or 70 tons of pumicite that was produced from this source was used as an abrasive on the Pacific Coast.

An even earlier use for pumice (rhyolite tuff) in California was in the construction of many types of buildings along the Mother Lode (Heizer and Fenenga, 1948, p. 93). As early as 1851 rhyolite tuff was a popular building material, and has withstood the test of time. It is soft enough to be easily cut and dressed into building blocks of many shapes, and it is readily available. The Col. Agoston Haraszthy champagne cellar, which was built in 1857 near Sonoma, Sonoma County, was constructed of rhyolite tuff blocks cut from an extensive tuff bed that underlies much of the area near the cellar.

As early as 1888 a rhyolite tuff was used as a building material at Owensville and Bishop in Inyo County. It was obtained from a formation now known as the Bishop tuff, although not actually a pumice or pumicite, is tuffaceous, easily worked, and serviceable as a building stone. Goodyear in his account of field investigations in Inyo County briefly mentions the use of the Bishop tuff. ". . . I visited the southeast corner of the volcanic tableland and took some specimens of its material, which seems to be a mass of somewhat consolidated volcanic ash. It is a soft rock, can be easily cut and dressed with edge tools, and was used for many of the houses of Owensville" (Goodyear, 1888, p. 286).

During the construction of the Los Angeles aqueduct from 1908 to 1918, considerable quantities of ground pumice were mixed with portland cement and used as a lining for the aqueduct (Lippincott, 1913).

Despite their early use as building stone and aggregate material, most of the pumice and pumicite mined up to the early part of 1930 was used for abrasive purposes. Only a minor proportion of the total output was employed for other purposes such as aggregate and chicken litter.

During World War I the use of pumice as lightweight aggregate was investigated, but the actual production of pumice for aggregate purposes did not commence until the mid-1930's. At that time much of the pumice production in California was used in the production of roofing and acoustical granules for soundproof plaster. However, with the outbreak of hostilities in Europe in 1939, and the final culmination of World War II, the demand for lightweight aggregate materials for both military and domestic consumption increased markedly.

Pumice properties throughout California and other western states were developed and numerous public buildings as well as domestic dwellings were constructed of pumice concrete. This widespread use of pumice as aggregate has extended into the post-war period and probably will continue to overshadow its use as an abrasive.

The status of pumicite also has changed, but not as much as that of pumice. Although pumicite is being extensively used as an abrasive, it is also being applied widely in other fields where fillers are needed, particularly as a diluent in paints and rubber goods, as an insecticide carrier, and as an additive in the manufacture of cement.

The volcanic cinder industry which, in California, is comparatively recent compared to the pumice industry, probably began about 1916 when substantial amounts of it were used as railroad ballast. Within the past ten years more and more volcanic cinders have been used as aggregate in concrete blocks, as stucco, and as ballast and backwinding in railroad construction.

The total production of pumice and pumicite in California from 1905 to 1953 was 1,801,564 short tons valued at $9,059,030. Production figures for volcanic cinders are incomplete, but between 1916 and 1953 approximately 4,617,000 short tons were mined and valued at about $3,996,000.

Pumice for aggregate purposes from deposits in Mono, Inyo, Kern, Imperial, and eastern Siskiyou counties has been shipped to markets in Arizona, Oregon and Nevada. The actual volume of pumice exported is substantial, and probably exceeds many times the volume imported into California.

The volume of pumicite sent to out-of-state markets from deposits in California is considerable and probably amounts to the consumption of this material in the state. Prior to the use of pumicite as an insecticide carrier, and during that period where a bulk of the pumicite was used in the manufacture of cleansing compounds and soaps, much of the pumicite was shipped to eastern markets. Substantial amounts of pumicite for insecticide carrier are being shipped to out-of-state markets although the agricultural industry in California is the principal consumer of this material.

There probably has been very little or no shipment of volcanic cinders into or out of California.

Most of the deposits of pumice, pumicite, and volcanic cinders in California are readily accessible to consuming markets by rail or highway transportation.

These volcanic materials—pumice, pumicite, and volcanic cinders—are abundant in California and the reserves are large enough to support the vigorous, expanding building industry.

Although there are numerous deposits of pumice, pumicite, and volcanic cinders in California, very little data are available on (1) size and geological setting of most of the deposits, and (2) the physical characteristics of the materials they contain. Several large deposits have been studied in detail by Federal or State agencies, or by private industry. However, very little is known about the smaller deposits and even many of the large productive deposits have been examined only superficially.

Deposits of volcanic cinders characteristically lie on the surface of the ground where they are easily mined by surface methods. A number of pumice and pumicite deposits in California can be mined easily, but in many of them an overburden handicaps mining. Deposits with excessively thick overburdens cannot be mined economically even though they are nearer markets than other deposits with little or no overburden. Then too, underground mining methods are more expensive than open cut methods, and since pumice, pumicite, and volcanic cinders are industrial nonmetallic raw materials which compete with sand and gravel that are mined by the cheapest possible methods for markets, it is therefore almost necessary to employ cheap methods in the mining of pumice, pumicite, and volcanic cinders.

The mining of pumice and pumicite, like the mining of many other nonmetallic mineral commodities, should include a well-integrated program of exploration, development, production, and marketing. Careful control must be exercised in the mining of pumice and continued sampling and testing of the product is necessary. Uniformity of the marketed product must be assured to obtain and hold many large contracts. To assure customers of adequate, uniform supplies, pumice producers commonly stockpile the mined material well in advance of the time it is to be used.

The trends in the change in the uses of pumice and pumicite are well-illustrated in figure 15 which shows the rapid decrease in the consumption of California pumice and pumicite as abrasives as compared to that used in all types of aggregate. Figure 15 does not indicate that the overall consumption of abrasive pumice and pumicite in California has decreased. There are just as many industries in California that use abrasive pumice as there were 20 years ago—perhaps more—but the production of abrasive pumice in California has virtually stopped and pumice for this purpose is being imported into the United States and California from sources in Italy.

The decrease in the production of aggregate pumice can be attributed almost wholly to an increase in the demand for expanded and sintered shale aggregate. In 1950 there were only three plants in California producing light-weight aggregate from expanded and sintered shale; in 1955 there were four plants operating around the clock trying to meet the demand of the building and construction industry in California.

The value of California concrete aggregate pumice at the mine has ranged from $3.00 to $8.00 per ton and the average for the period from 1935 to date is about $5.00 per ton. Pumice speciality products, including acoustical granules and filler material, demand a higher price ranging from $15 to $30 per ton at the plant.

The United States domestic price for ground, coarse to fine pumice ranges from 3 cents to 5 cents per pound in ton lots.

The pumicite used as an insecticide carrier sells for from $15 to $20 per ton in carload lots at the plant. Some grades of pumicite are marketed as speciality products. They require special handling and packaging, and thus demand a price far in excess of that paid for the bulk of the pumicite which is used as an insecticide carrier.

Volcanic cinders used as aggregate in concrete building blocks sell for $3.00 to $5.00 per ton at the mine. Volcanic cinders used in roofing, stucco, and in agriculture command a higher price.

Summary of Geologic Occurrence, Mode of Formation and Distribution of Deposits

Most pumice, pumicite, and volcanic cinders are of pyroclastic origin but some are cellular lavas. The term "pumice" should be restricted to rocks that are the light-colored ejecta from acidic and intermediate magmas and consist of pumiceous glasses that are markedly cellular, light enough to float on water and are larger than 4 mm. In California, however, the term pumice has been employed very loosely and includes a wide variety of cellular glassy rocks of volcanic origin such as volcanic scoria and pumicite (volcanic ash) as well as actual pumice and cellular and amygdaloidal lavas of low apparent bulk density.

"Pumicite" and volcanic ash are one and the same, and are terms that should be applied to uncemented and loosely cemented glassy pyroclastic debris consisting of fragments less than 4 mm in diameter. Pumicite has also been known as "volcanic dust," "geyserite," "diamond grit," and even "silica." With regard to use of the term volcanic ash it is well to point out that it is not a product of combustion like ash but finely comminuted natural pumice atomized by volcanic explosions. "Volcanic cinders" (scoria) is a term applied to a clinker-like scoriaceous form of basic lava.

As pumice, pumicite, and volcanic cinders have generally similar origins, they are distinguished mainly by their physical and chemical properties.

Basic magmas, which yield volcanic cinders, behave quite differently from acid and intermediate magmas which produce pumice and pumicite. Basic magmas soften at rather low heat because of their low silica and high lime and magnesia contents. Moreover, the low viscosity and large gas content of basic magmas do not lead to explosive activity but to rapid boiling, a phenomenon characteristic of various lava lakes in active volcanos of the Hawaiian Islands. Basaltic pumices, however, do occur and are probably much more abundant than was once realized. Pumiceous basalts and ashes are common on the Hawaiian Islands and Vesuvius, and at numerous other localities (Sonder, 1937, p. 499) throughout the world.

Acidic magmas are more viscous than basic magmas. Largely, because of their relative high silica content, they melt at relatively high temperatures and solidify at temperatures at which basic magmas remain quite fluid. Therefore, during periods of quietness in the volcano, acidic magma commonly ceases to flow, and forms a plug of solid rock below which enormous pressures are built up. Eventually these pressures cause the forcible discharge of the solid material into the air.

Average chemical analyses of acidic, intermediate, and basic igneous rocks.

	Acidic (1)	Intermediate (2)	Basic (3)
SiO_2	72.08	54.5	48.4
Al_2O_3	13.86	17.2	15.5
Fe_2O_3	0.86	3.2	2.8
TiO_2	0.37	1.4	1.8
FeO	1.67	4.6	8.1
MgO	0.52	3.2	8.6
CaO	1.33	5.8	10.7
Na_2O	3.08	5.1	2.3
K_2O	5.46	3.6	0.7
H_2O+	0.53	0.8	0.7
P_2O_5	0.18	0.39	0.27
MnO	0.06	0.16	0.17

(1) Average of 22 analyses of granite (calc-alkali granite). (Nockholds, 1954, p. 1012).
(2) Average of 635 analyses of intermediate igneous rocks. (Nepheline not included) (Nockholds, 1954, p. 1032).
(3) Average of 637 analyses of basic igneous rocks. (Nepheline not included) (Nockholds, 1954, p. 1032).

If the dissolved gases in the viscous magma are able to produce a froth of fine particles, or a large quantity of bubbles in a short time, the formation of pumicite (volcanic ash) is likely (Verhoogen, 1951, p. 738). However, if relatively few bubbles develop and the glass comprising the bubbles is allowed to harden rapidly enough to prevent collapse, pumice will form.

The development of an abundance of crystals increases the viscosity of the magma and hence favors ash formation. Crystalline constituents are not common in all of the pumice deposits in California, but in a few of the deposits they constitute a nuisance. These constituents occur as phenocrysts in the pumice, and as loose crystals scattered among the pumice fragments in tuffs. Quartz and feldspar are most common; biotite and hornblende are less abundant. Crystalline constituents are particularly abundant in the subaqueous deposits in the southern Coso Range of Inyo County and in the deposits along the east and west sides of Hamil Valley between Laws and Benton Station, Inyo and Mono counties.

The formation of volcanic cinders from basic magmas is similar to the formation of pumice from acidic magmas. Many scoriaceous and clinkery types of basaltic lavas yield a relatively lightweight material resembling volcanic cinders. However, some of the so-called volcanic cinders in California appear to be formed through the agglutination of basaltic ash or small clinkerlike fragments into strong cellular masses that range in diameter from an inch to a foot or more. Such fragments are typical of several deposits in Inyo, Lake, and Modoc counties.

Pumice, pumicite, and volcanic cinders are mined from various kinds of pyroclastic rocks, including breccia, lapilli tuff, tuff breccia, and volcanic conglomerate. The classification of pumice, pumicite, and volcanic cinder deposits therefor envolves a classification of pyroclastic rocks, and such classifications were made as early as 1886.

Of the many classifications of pyroclastic rocks, perhaps the earliest was proposed in 1886 by Johnston-Lavis and based upon their mode of origin. In the same year, Walther and Schirlitz grouped them according to mode of deposition and recognized four types, (1) produced by eruptions on land and deposited subaerially (Trockentuffe), (2) those resulting from eruptions under water (Wassertuffe), (3) material deposited in water from subaerial eruptions and there admixed with sediment (Sedimenttuffe), and (4) deposits laid down on land but later removed by running water (Transporttuffe).

In 1932, the most comprehensive of several later classifications was proposed by Wentworth and Williams and was based upon the shape, size, and surface features of the fragments, their internal texture, physical composition (whether glassy or crystalline), and mode of origin.

For a working classification of pumice, pumicite, and volcanic cinder deposits, the writer proposes one based upon (1) mode of deposition, (2) size distribution of particles and fragments, and (3) origin of the material being projected from the volcano. With the exception of a few occurrences of pumice, pumicite, and volcanic cinders nearly all deposits of these materials are products of explosive volcanic activity, probably from central openings or vents rather than from fissure openings. This is especially true for cinder (scoria) deposits which actually are volcanic cones built up around central vents. When the lava was discharged from the vent into the air it came to rest on dry land, in streams of running water, or bodies of standing water. On the basis of these distinct modes of accumulation, most deposits of pumice and pumicite can be grouped into (1) subaerial—those deposited on dry land and (2) subaqueous—those deposited in standing or running water. In addition to these two types of deposits of explosive origin, a third type was formed on the upper surfaces of obsidian flows and domes. This type ordinarily consists of pumice rather than pumicite or volcanic cinders, and it formed by quiet vesiculation of viscous, glassy lava as it rose to the surface. A fourth type of deposit is the nuee ardente, which is also of explosive origin, but contains pumice fragments of many different sizes enclosed in a pumicite-like matrix. Reworked deposits constitute the fifth type which represents material of any other type of deposit that has been subjected to the reworking action of running water.

Subaerial Deposits. The subaerial deposits of pumice and pumicite, though not as extensive as the subaqueous types in California, cover small and large areas in Inyo, Imperial, Modoc, Mono, and Siskiyou counties. Nearly all volcanic cinder (scoria) deposits are subaerial in origin. Subaerial pumice deposits are characterized by a lack of well-defined bedding and sorting, and a general lack of the finer fraction or pumicite. The pumice fragments are angular, range in size from dustlike particles less than 1/16 of an inch in diameter to lumps as much as 8 to 10 inches across. They range in color from light to dark gray, shades of buff and pink, and white. Scattered throughout subaerial pumice deposits are several different types of nonpumiceous materials, such as obsidian, rhyolite, andesite, and basalt. Some of these stony materials probably originated in the magma that yielded the pumice; others probably were torn from the vent during explosions. In addition, there are noticeable quantities of quartz, feldspars, biotite, hornblende, and hypersthene, all of which had crystallized in the vesiculating magma prior to extrusion.

The pumice in subaerial deposits ranges from rhyolite to andesitic in composition. The composition of any one deposit is usually fairly constant.

Some of the subaerial pumice deposits in California cover several square miles and range in thickness from a thin veneer several inches thick to massive tuff layers as much as 60 feet thick. A few of the subaerial deposits contain layers of pumice separated by lava flows or dirty pumiceous soil zones.

The subaerial deposits of pumice that contain relatively large proportions of pumicite ordinarily are more compacted than those that consist essentially of pumice fragments more than ⅛ of an inch in diameter. The degree of composition varies from one deposit to another and also within single deposits.

Subaqueous Deposits. Subaqueous deposits are widely scattered throughout California and cover extensive areas in Contra Costa, Fresno, Imperial, Inyo, Kern, Mono, San Luis Obispo, and San Bernardino counties.

One of the most distinctive characteristics of subaqueous pumice deposits is an inverted graded bedding in which there is an increase in size of pumice particle from the bottom to the top of an individual bed (fig. 16). Perhaps the main reason for inverted bedding in pumice deposits is due to the differences in bulk densities of the various grain sizes. The bulk density of pumicite, crystal fragments, and lithic fragments is greater than that of the pumice fragments. The pumice fragments commonly float on water and will sink at a slow rate following settling-out of the pumicite, rock, and crystal fragments. Laboratory experiments have demonstrated that pumice fragments up to several inches in diameter will remain afloat in water for several days to a week and then will sink only as they become thoroughly waterlogged (Bateman, 1953, p. 1499).

Layers of pumice ten feet thick commonly show a dozen or more inverted beds as well as an overall increase in grain size from the bottom to the top. Moreover, much of the nonpumiceous material, such as mineral fragments and various rock types discharged with the pumice, will be concentrated in the lower, finer-grained layers.

Another feature that characterizes subaqueous deposits of pumice and pumicite is the presence of layers of sand, clay, silt, or gravel that alternate with layers of pumiceous material (fig. 82). This feature is most conspicuous in deposits that formed near shore lines of former lakes where pumice that fell into the water became interbedded with near shore and beach sediments, or sediments brought in by streams. Bedding is more pronounced in pumicite deposits than it is in deposits of pumice. Because of their finer particle size, the individual beds in deposits of pumicite commonly are only a millimeter or less in thickness. Thin bedding is well displayed in pumicite near Friant, Madera County (fig. 21), where extensive deposits have been mined for many years.

Vesiculated Surfaces of Obsidian Flows and Domes. Pumice deposits that exist as vesiculated surfaces of obsidian flows and domes have been observed in California only at Glass Mountain in eastern Siskiyou County and at Mono Craters in Mono County. At both of these places the pumice occurs only at the upper surfaces of these extrusive bodies and grades downward into obsidian. The pumice occurs in blocks that range in size from a few inches to 5 feet or more in diameter. The blocks are not systematically arranged, although they form domical piles on domes and elongate ridges on flows (fig. 20).

The pumice contains cavities that range in size from 1/32 of an inch to 6 inches in maximum diameter, and range in shape from lenticular to nearly rounded. Rock fragments and crystals of quartz, feldspars, and ferromagnesian minerals are present but rare. The actual thickness of the pumiceous crust is not known, but an average estimate of 10 feet would be conservative.

Nuee Ardente Pumice Deposits. Pumice and pumicite deposits that owe their origin to nuee ardentes probably are much more extensive in California than any of the other types noted above. The nuee ardente or "glowing cloud" has been described and defined by Perret (1935, p. 84) as follows: "A highly heated mass of gas-charged lava is ejected from a vent or pocket, more or less in a certain azimuth, onto an outer slope where it continues its course as an avalanche, following swiftly, however slightly the incline, by virtue of its extreme mobility. The mobility is due to an immediate subdivision of the lava into discrete particles and the development of the particles in a highly compressed gaseous atmosphere, due largely to continuous vapor emission by the particles themselves. There is thus developed during the descent of the avalanche a violently expanding cloud of gas and ash . . . Thus we reach the conclusion that the more or less forcible expulsion of lava from its pocket or dome is brought about by increase of temperature, but favored by rise of the material to a zone of lessened pressure."

One of the most characteristic features of the nuee ardente deposits is the complete lack of sorting (fig. 18). The material in this type of deposit commonly ranges

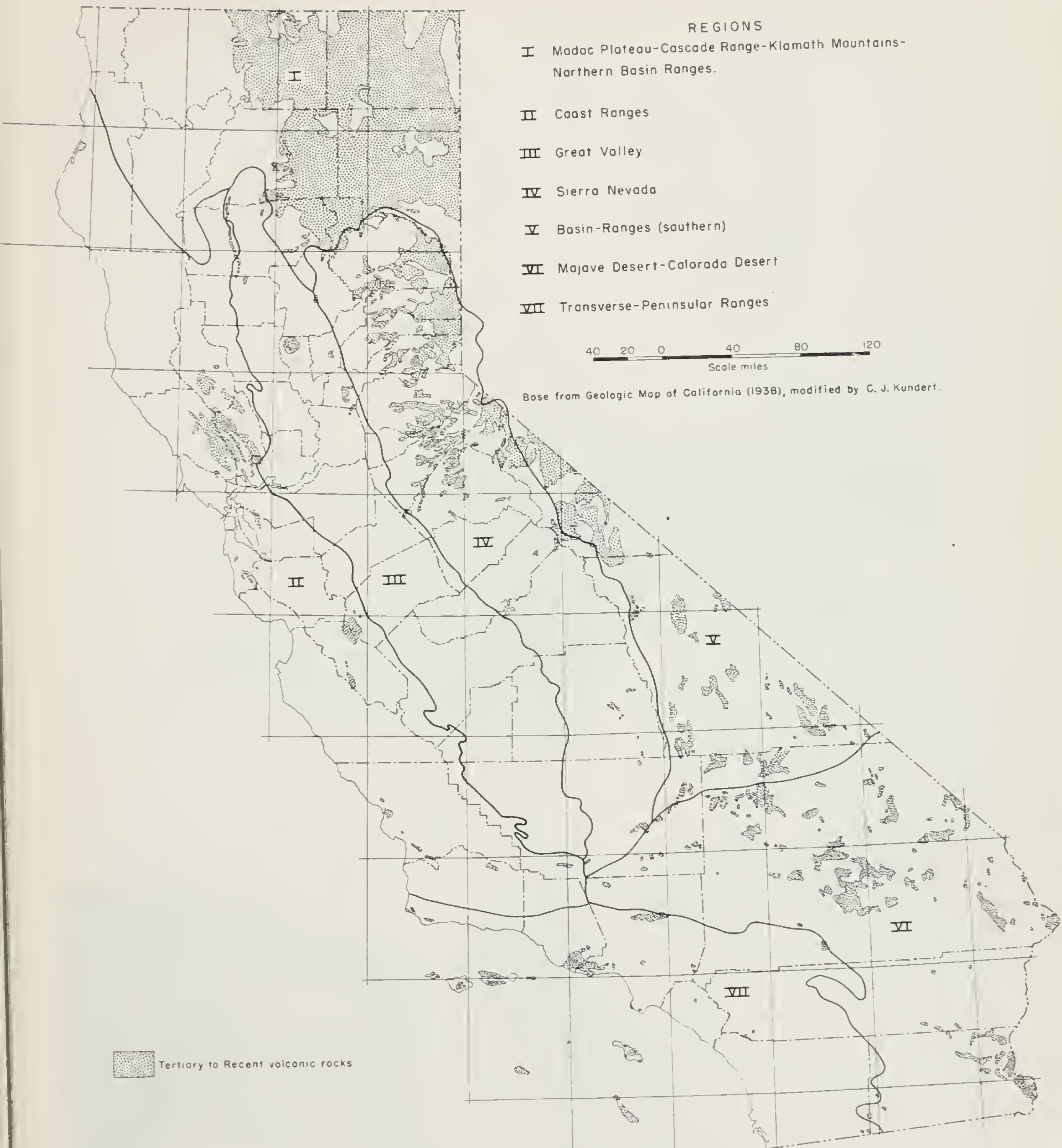

Figure 1. Map of California showing areas underlain by Tertiary to Recent volcanic rocks, and major regions under which the deposits of pumice, pumicite, and volcanic cinders are discussed.

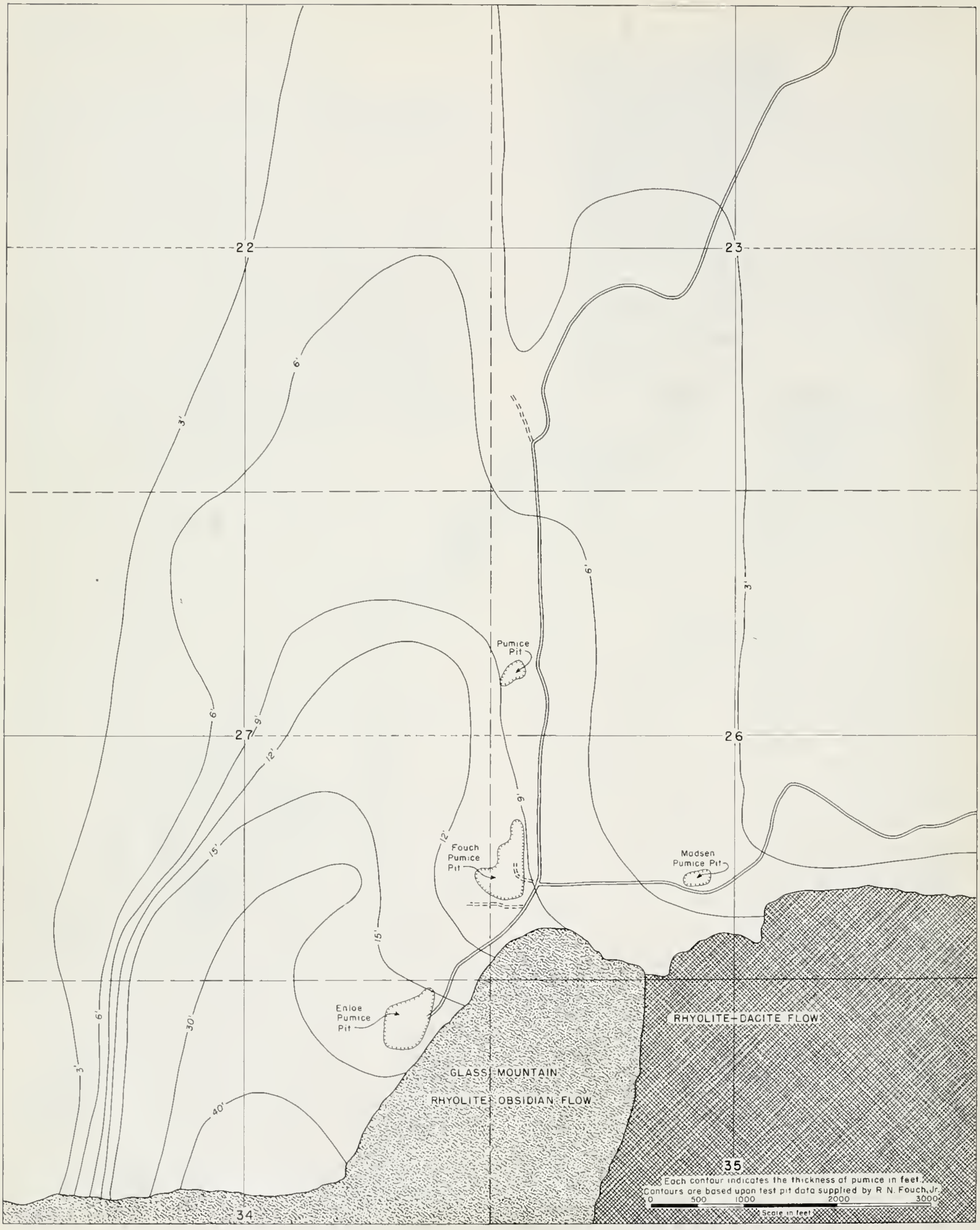

FIGURE 2. Isopach map of the Glass Mountain pumice area, Siskiyou County.

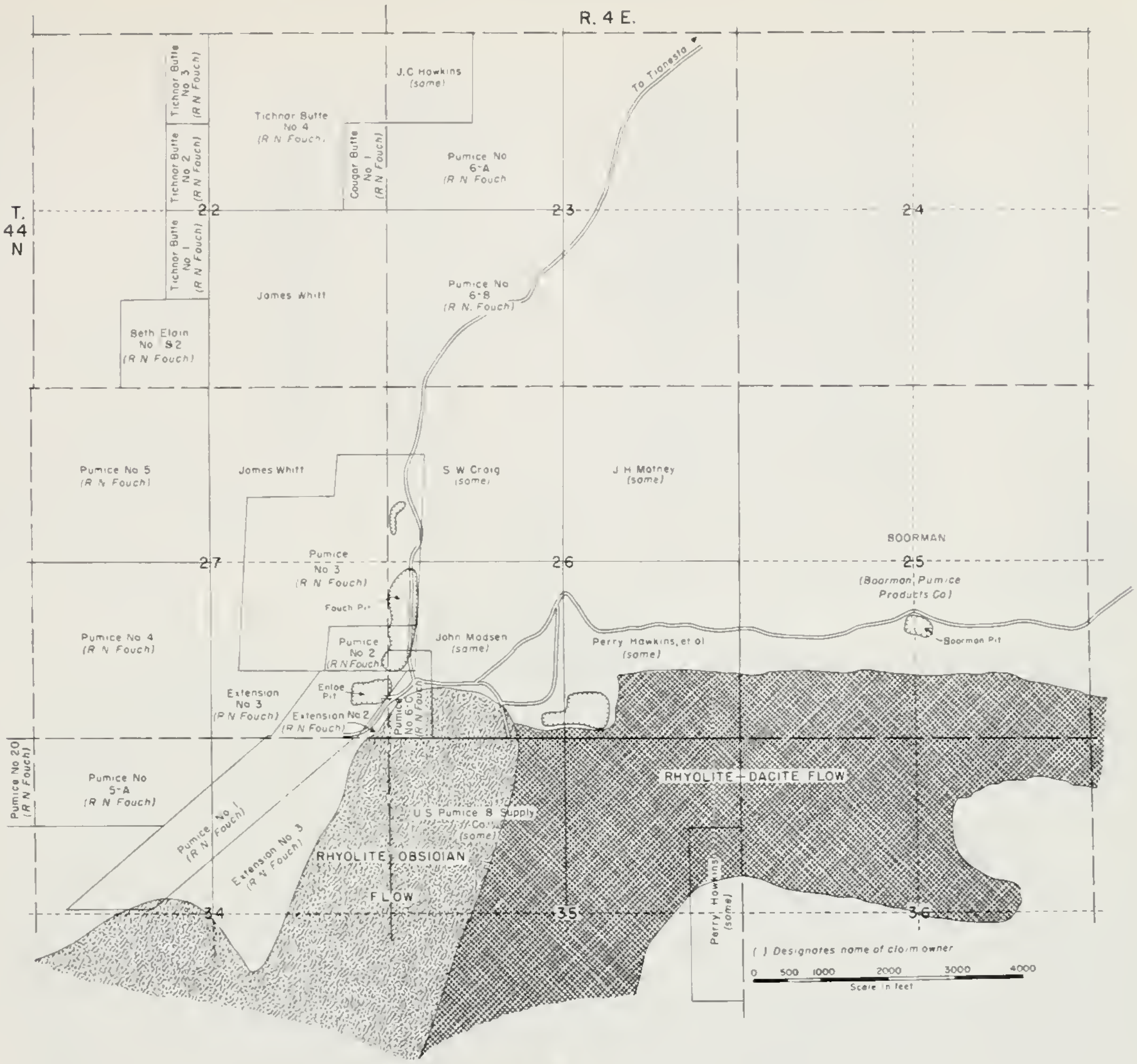

FIGURE 3. Claim map of the Glass Mountain pumice area, Siskiyou County.

Claim name	Ownership	Location	Size
Tichnor Butte No. 1	R. N. Fouch	E½NE¼SW¼ sec. 22, T. 44 N., R. 4 E.	20 acres
Tichnor Butte No. 2	R. N. Fouch	E½SE¼NW¼ sec. 22, T. 44 N., R. 4 E.	20 "
Tichnor Butte No. 3	R. N. Fouch	E½NE¼NW¼ sec. 22, T. 44 N., R. 4 E.	20 "
Tichnor Butte No. 4	R. N. Fouch	NE¼ sec. 22, T. 44 N., R. 4 E.	140 "
Cougar Butte No. 1	R. N. Fouch	E½SE¼NE¼ sec. 22, T. 44 N., R. 4 E.	20 "
Beth Elain Nos. 1 & 2	R. N. Fouch	SE¼SW¼ sec. 22, T. 44 N., R. 4. E.	40 "
Pumice No. 1	R. N. Fouch	Parts of secs. 26, 27, 34, T. 44 N., R. 4 E.	160 "
Pumice No. 2	R. N. Fouch	Parts of secs. 26, 27, T. 44 N., R. 4 E.	20 "
Pumice No. 3	R. N. Fouch	Parts of secs. 26, 27, T. 44 N., R. 4 E.	160 "
Pumice No. 4	R. N. Fouch	SW¼ sec. 27, T. 44 N., R. 4 E.	160 "
Pumice No. 5	R. N. Fouch	NW¼ sec. 27, T. 44 N., R. 4 E.	160 "
Pumice No. 5A	R. N. Fouch	N½NW¼ sec. 34, T. 44 N., R. 4 E.	88 "
Pumice No. 6A	R. N. Fouch	NW¼ sec. 23, T. 44 N., R. 4 E.	120 "
Pumice No. 6B	R. N. Fouch	SW¼ sec. 23, T. 44 N., R. 4 E.	160 "
Pumice No. 6C	R. N. Fouch	W½SW¼SW¼ sec. 26, T. 44 N., R. 4 E.	20 "
Extension No. 2	R. N. Fouch	SE cor. sec. 27, T. 44 N., R. 4 E.	8 "
Extension No. 3	R. N. Fouch	N½ sec. 34, T. 44 N., R. 4 E.	40 "
Pumice No. 20	R. N. Fouch	N½NW¼ sec. 34, T. 44 N., R. 4 E.	20 "
J. C. Hawkins	J. C. Hawkins	NW¼NW¼ sec. 23, T. 44 N., R. 4 E.	40 "
S. W. Craig	S. W. Craig	NW¼ sec. 26, T. 44 N., R. 4 E.	120 "
John Madsen	John Madsen	Part of E 2/3 SW¼ sec. 26, T. 44 N., R. 4 E.	110 "
U. S. Pumice and Supply Company	same	NW¼ sec. 35, T. 44 N., R. 4 E.	160 "
J. H. Matney	same	NE¼ sec. 26, T. 44 N., R. 4 E.	160 "
Perry Hawkins	same	E½SE¼NE¼ sec. 35, T. 44 N., R. 4 E.	40 "
Perry Hawkins et al.	same	SE¼ sec. 26, T. 44 N., R. 4 E.	160 "
Boorman	Boorman Pumice Products Co.	Sec. 25, T. 44 N., R. 4 E.	640 "

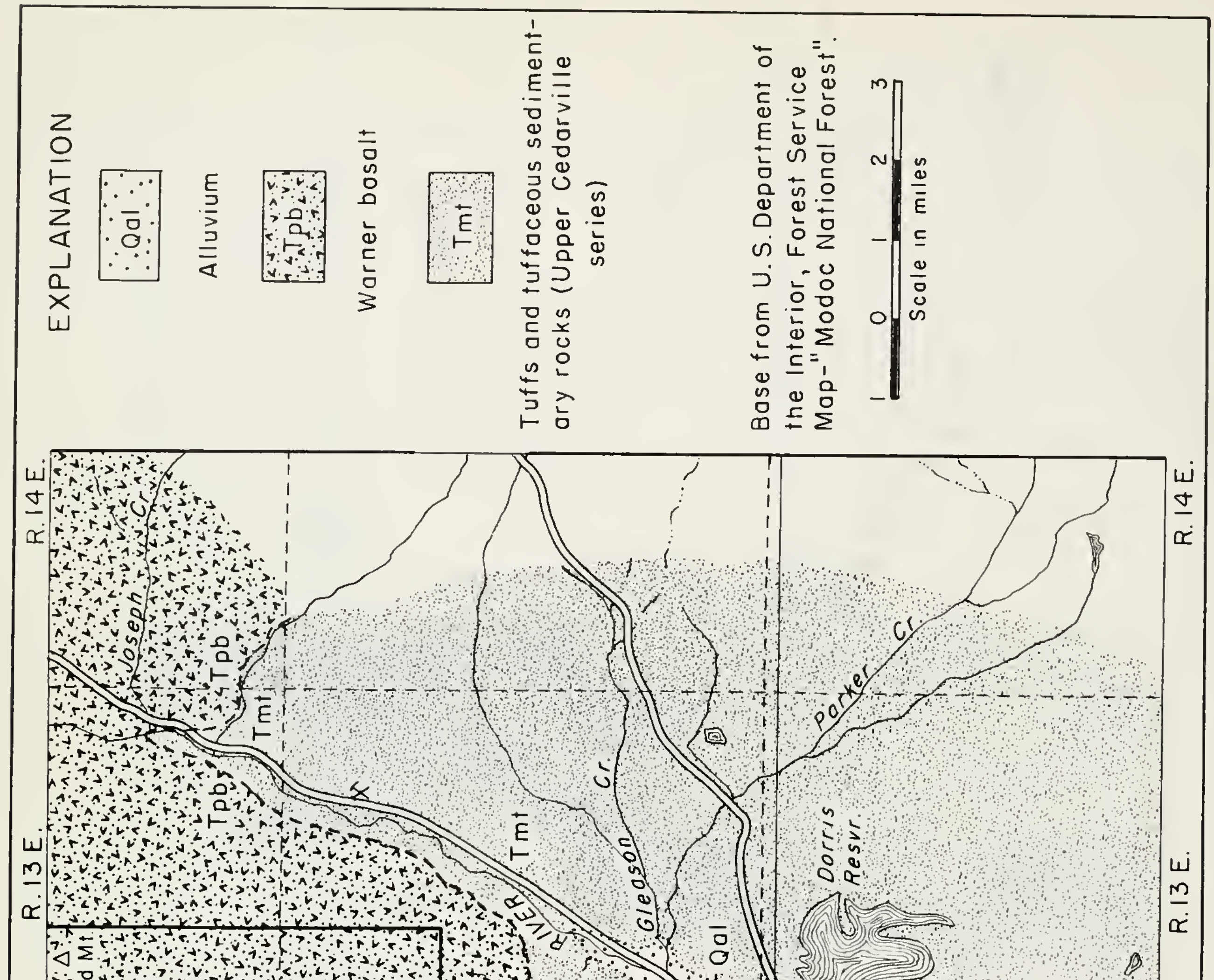

FIGURE 4. Geologic map of the Alturas pumice area, Modoc County.

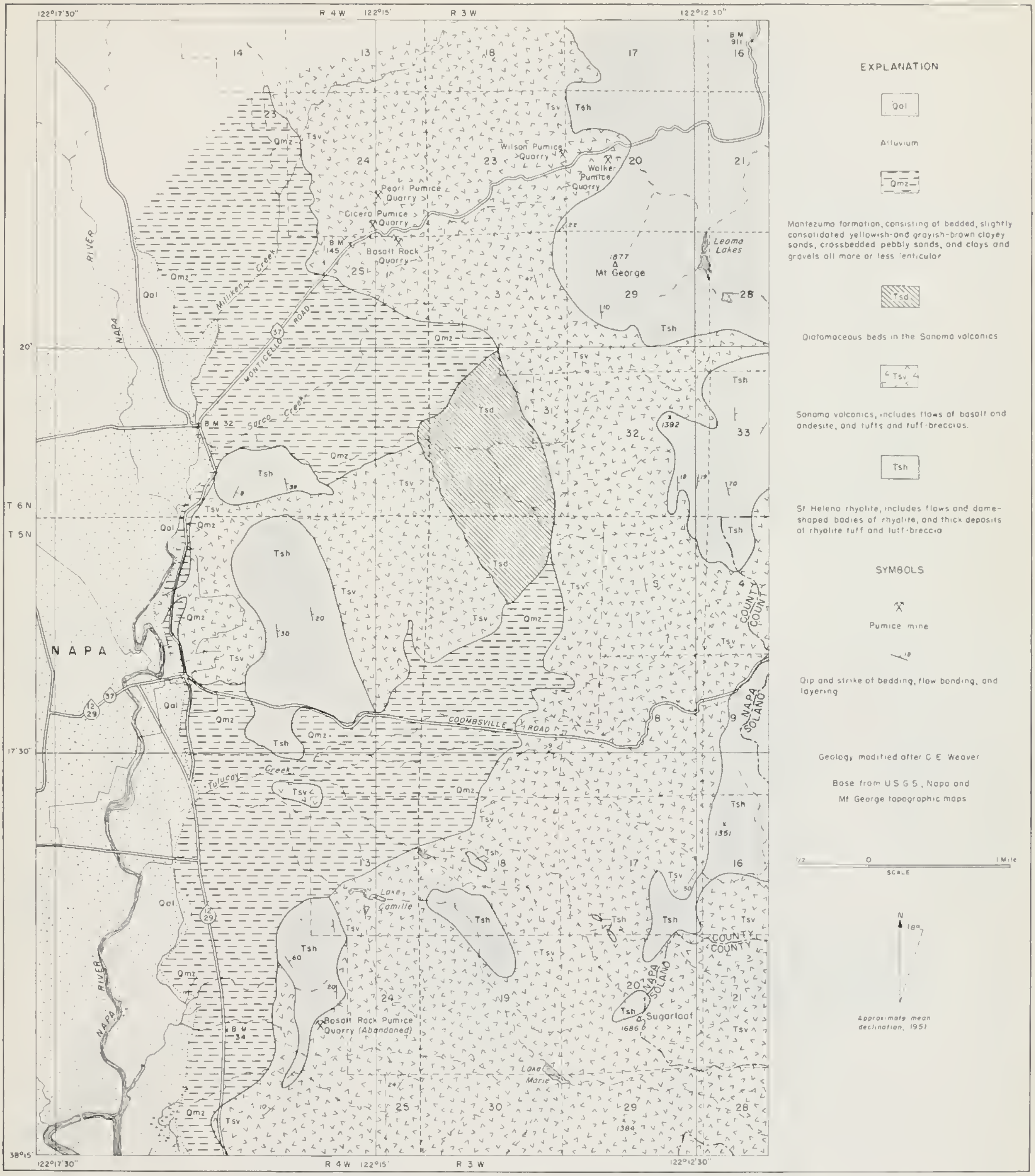

FIGURE 5. Geologic map of the Napa pumice area, Napa and Solano Counties.

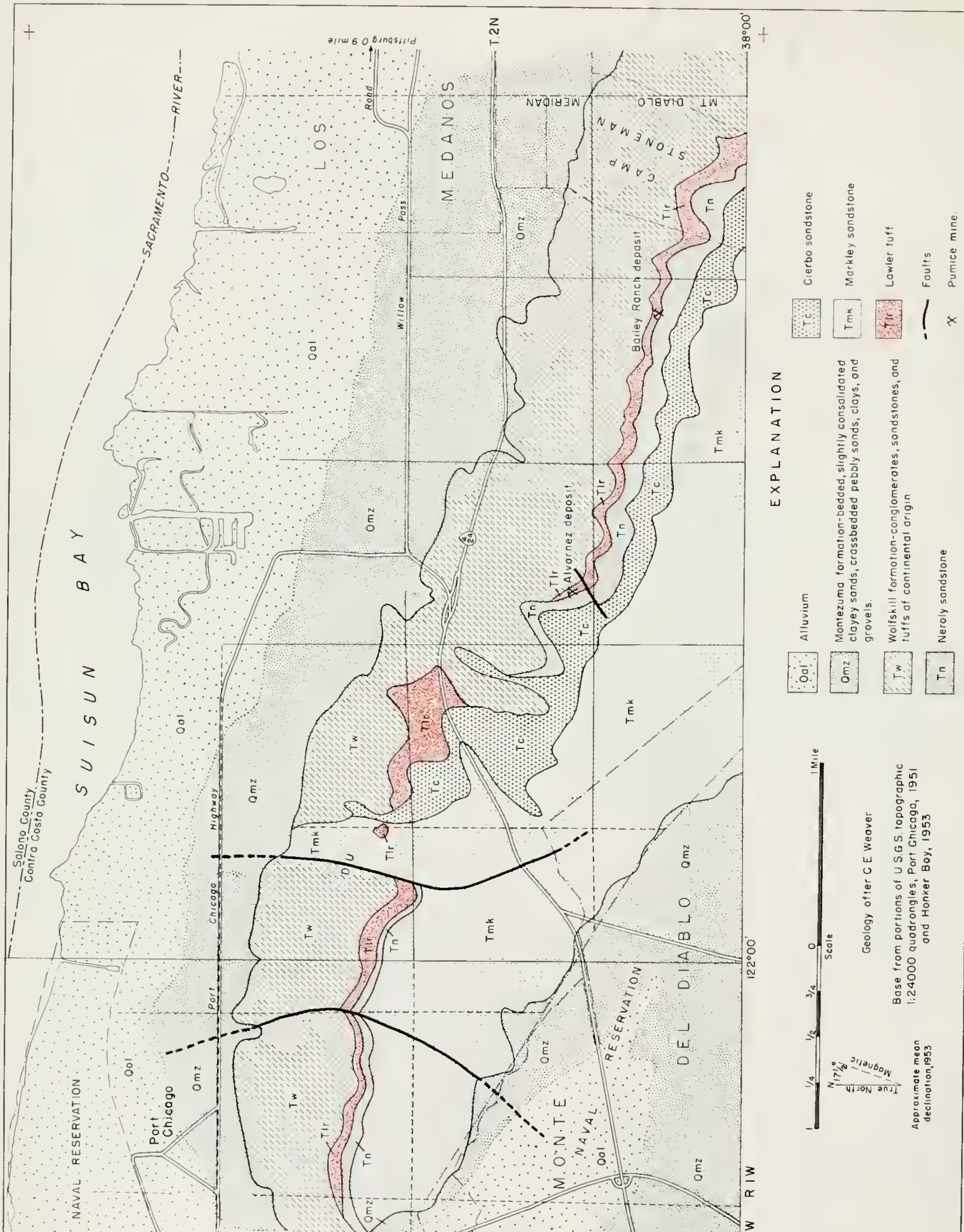

FIGURE 6. Geologic map of the Pittsburg pumice area, Contra Costa County.

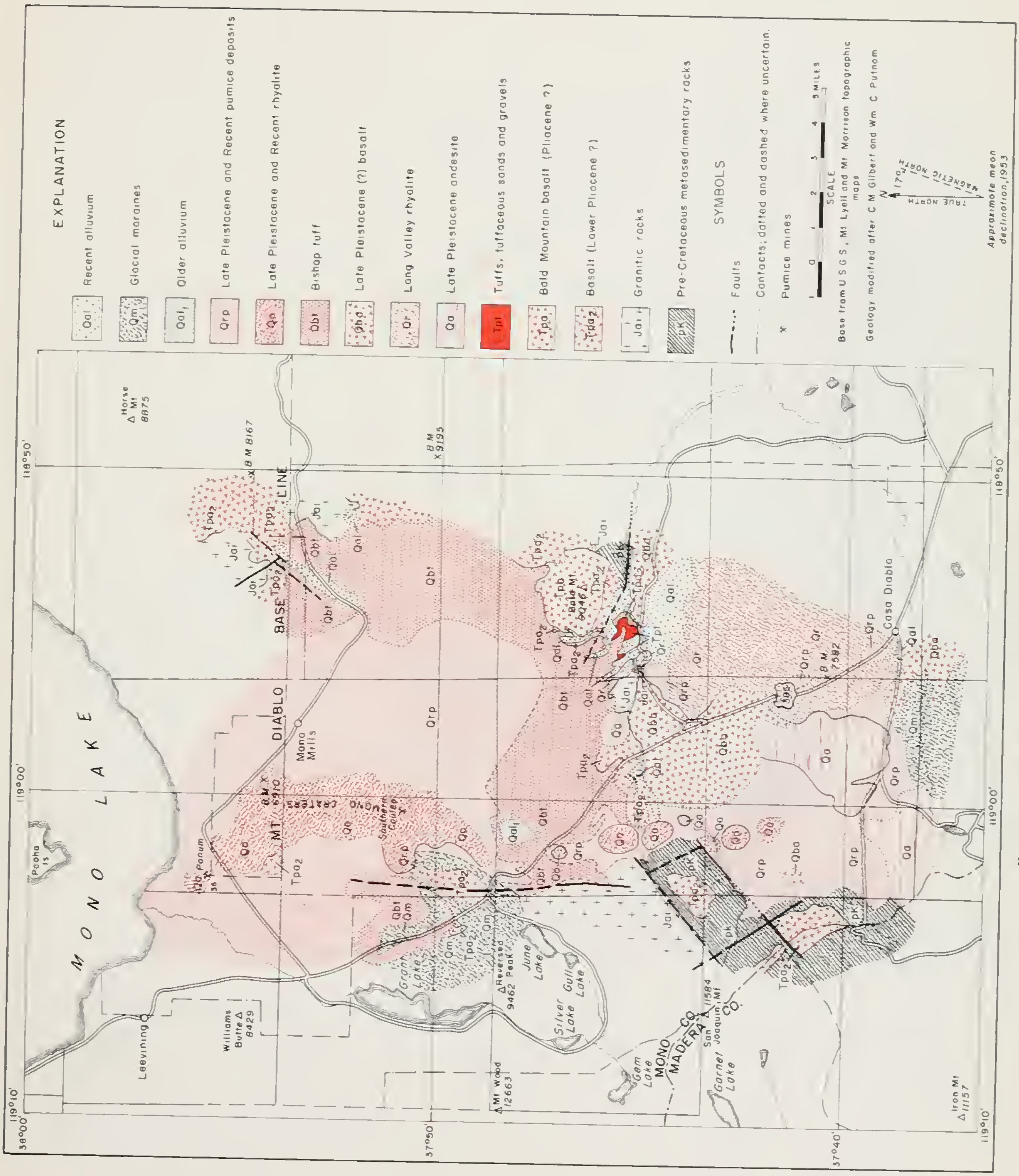

FIGURE 7. Geologic map of the Mono Craters pumice area, Mono County.

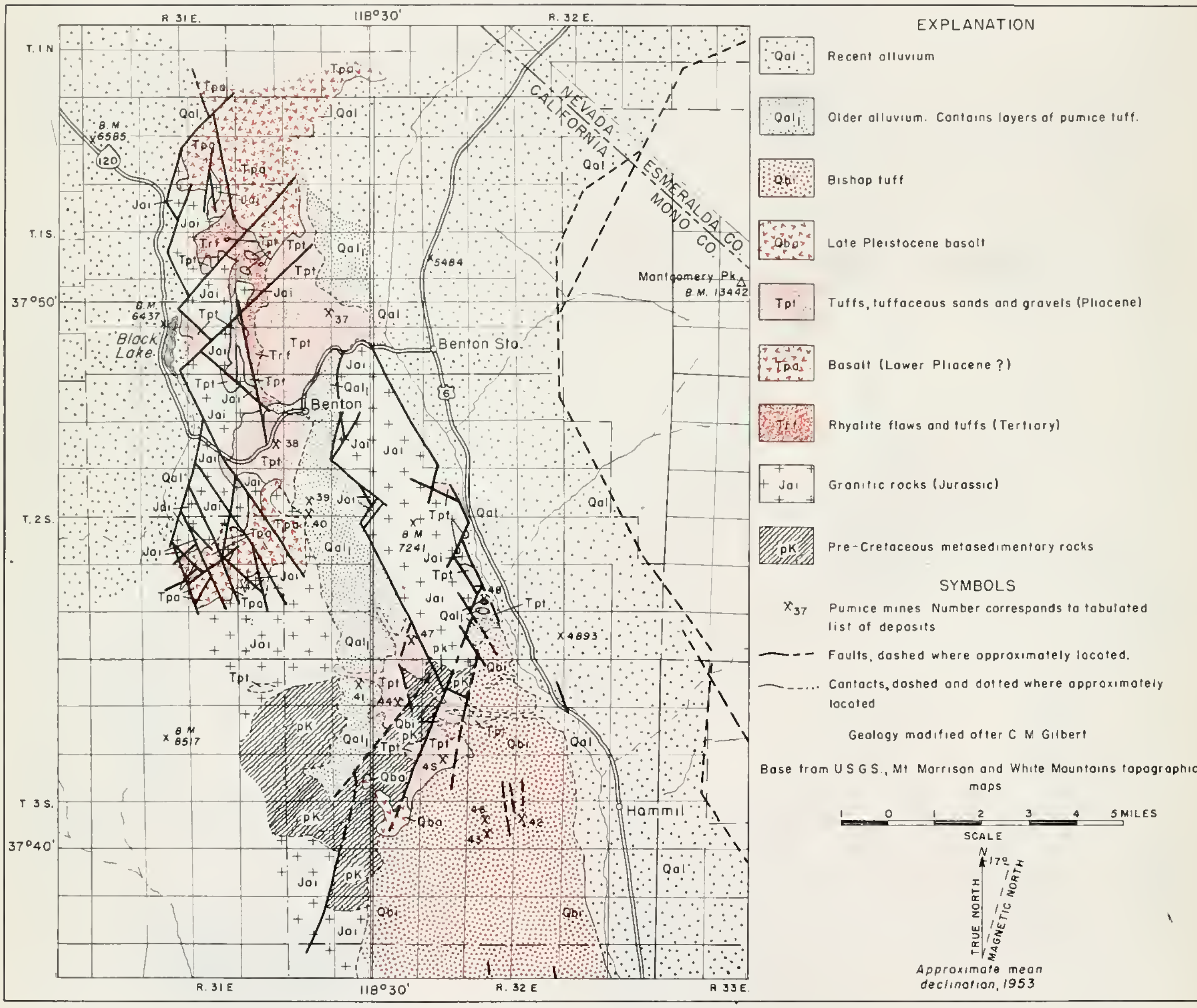

FIGURE 8. Geologic map of the Blind Spring Valley—Yellowjacket Spring pumice area, Mono County.

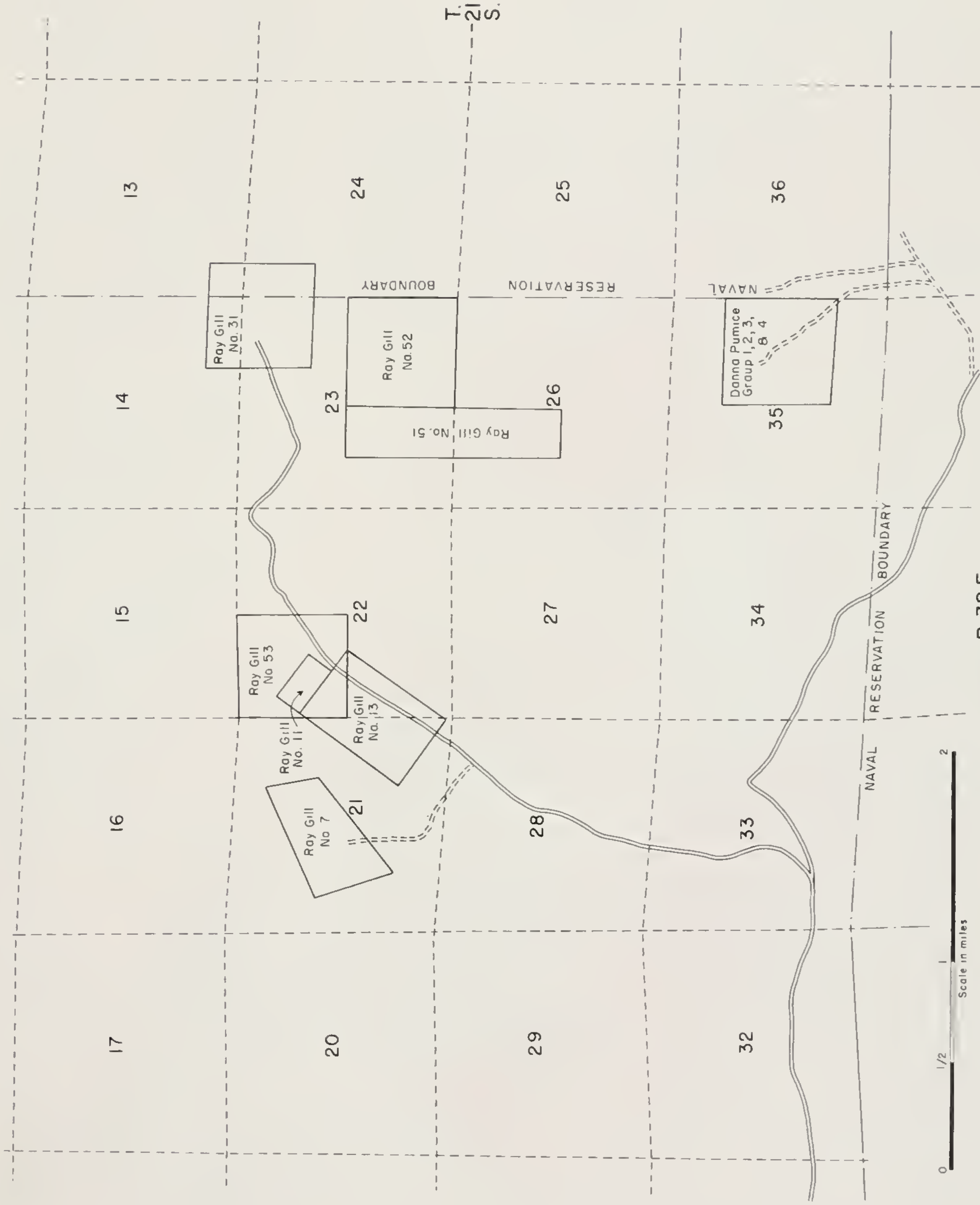

Figure 9. Claim map of Crownite Corporation's pumice deposits, southern Coso Range, Inyo County.

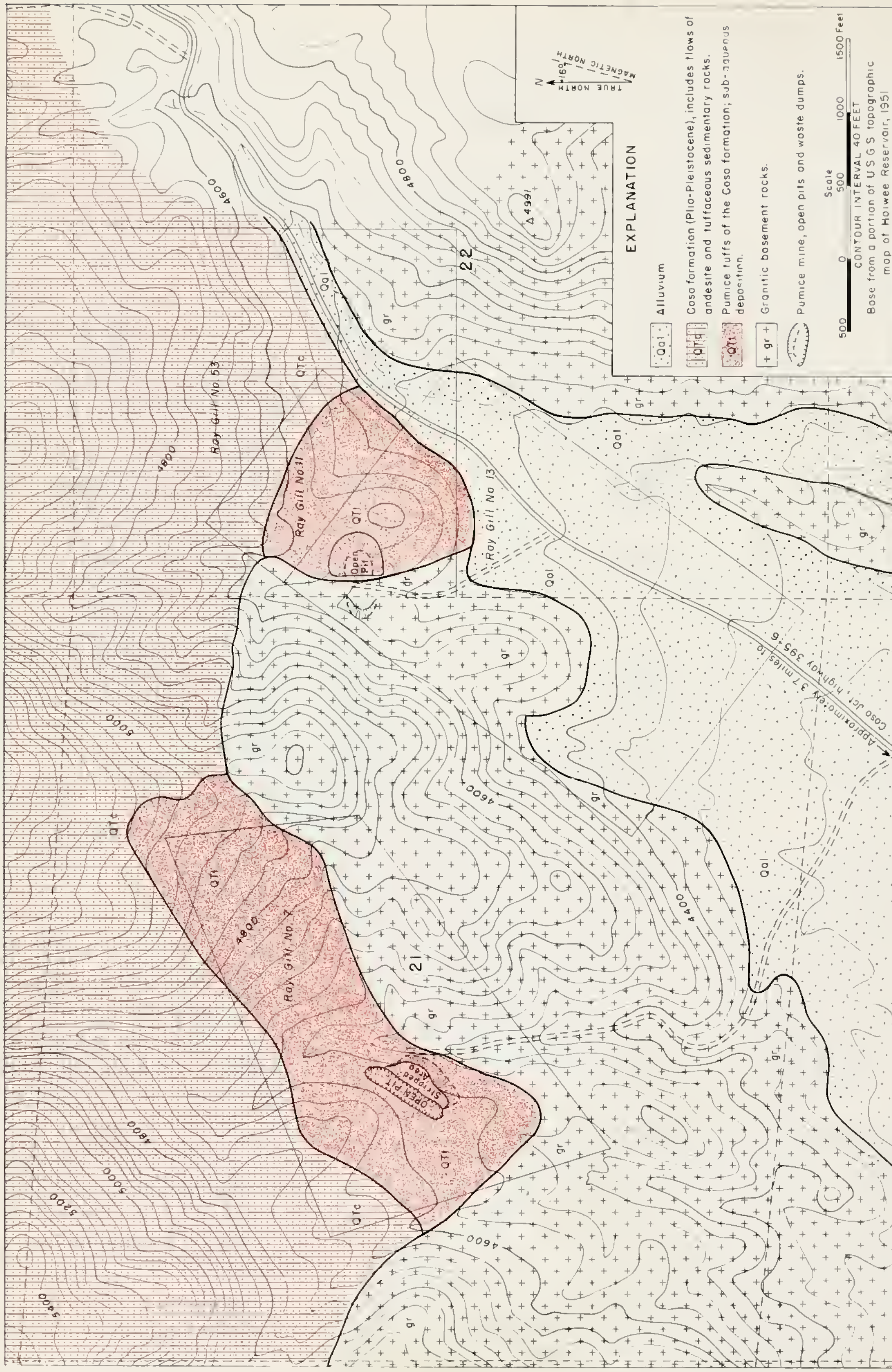

FIGURE 10. Geologic map of the Ray Gill Nos. 7, 11, 13, and 53 pumice deposits, southern Coso Range, Inyo County.

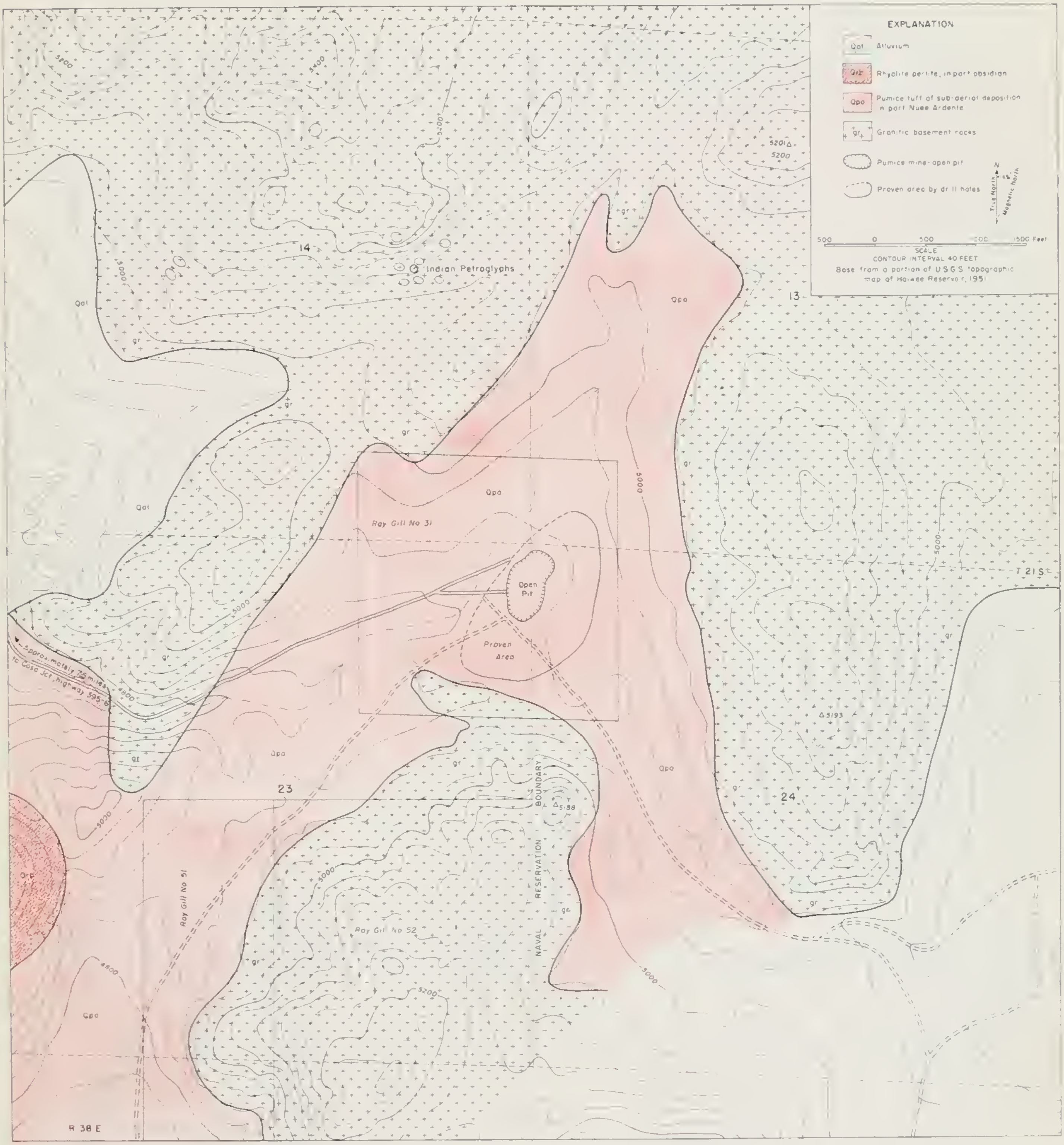

FIGURE 11. Geologic map of the Ray Gill Nos. 31, 51, and 52 pumice deposits, southern Coso Range, Inyo County.

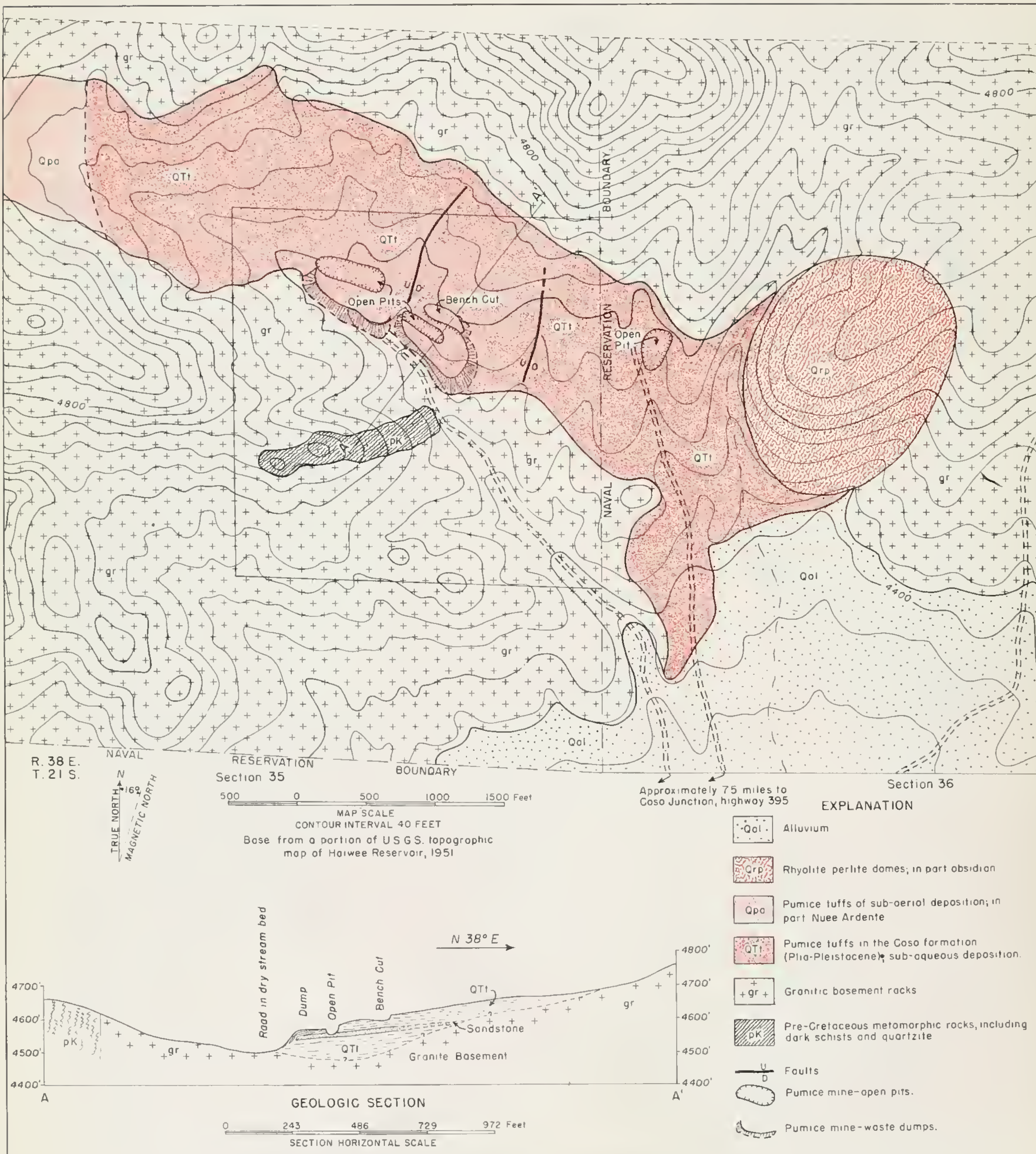

FIGURE 12. Geologic map of the Donna group of pumice deposits, southern Coso Range, Inyo County.

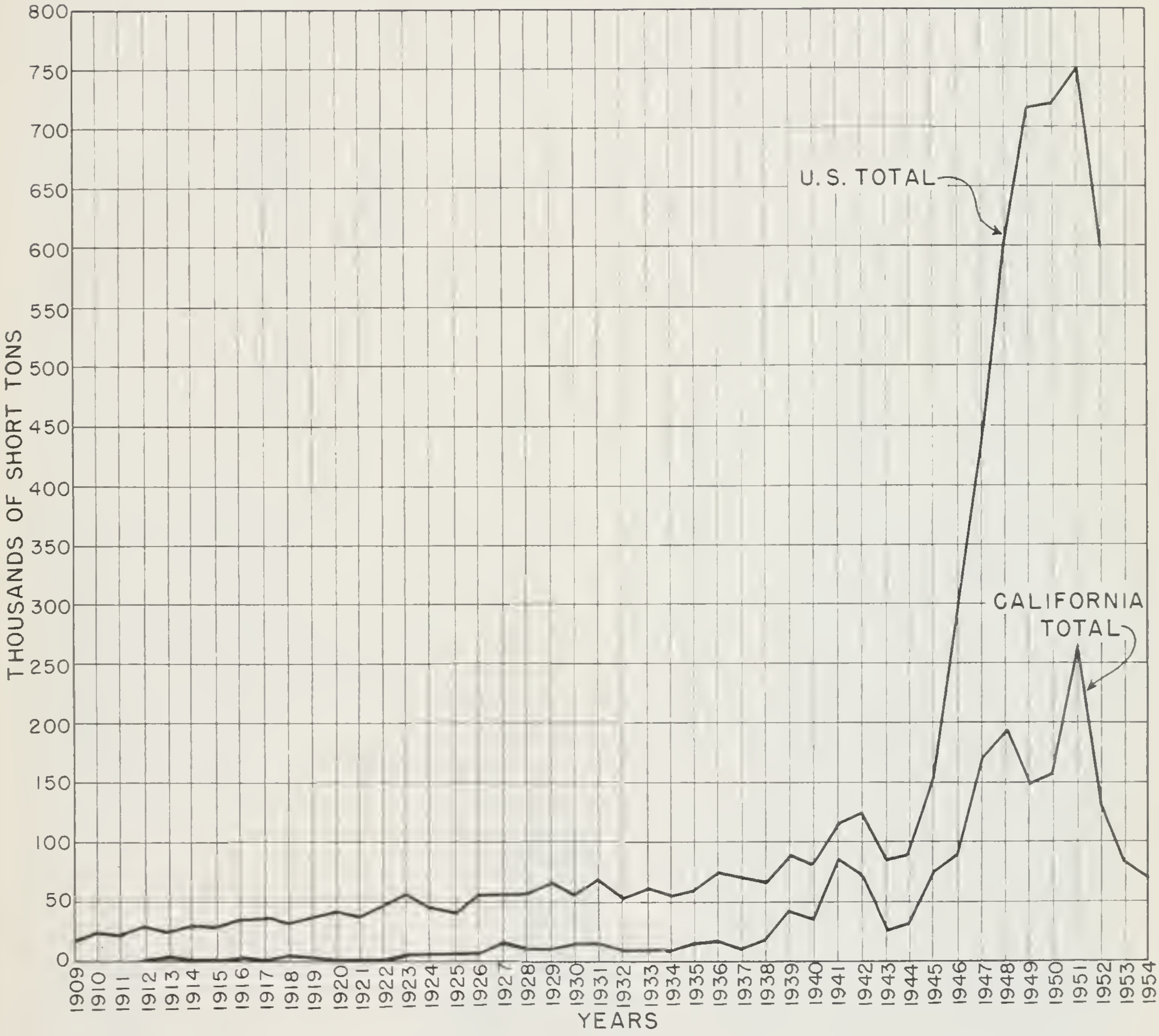

FIGURE 13. Chart showing production of pumice and pumicite in California and the United States, 1909-53.

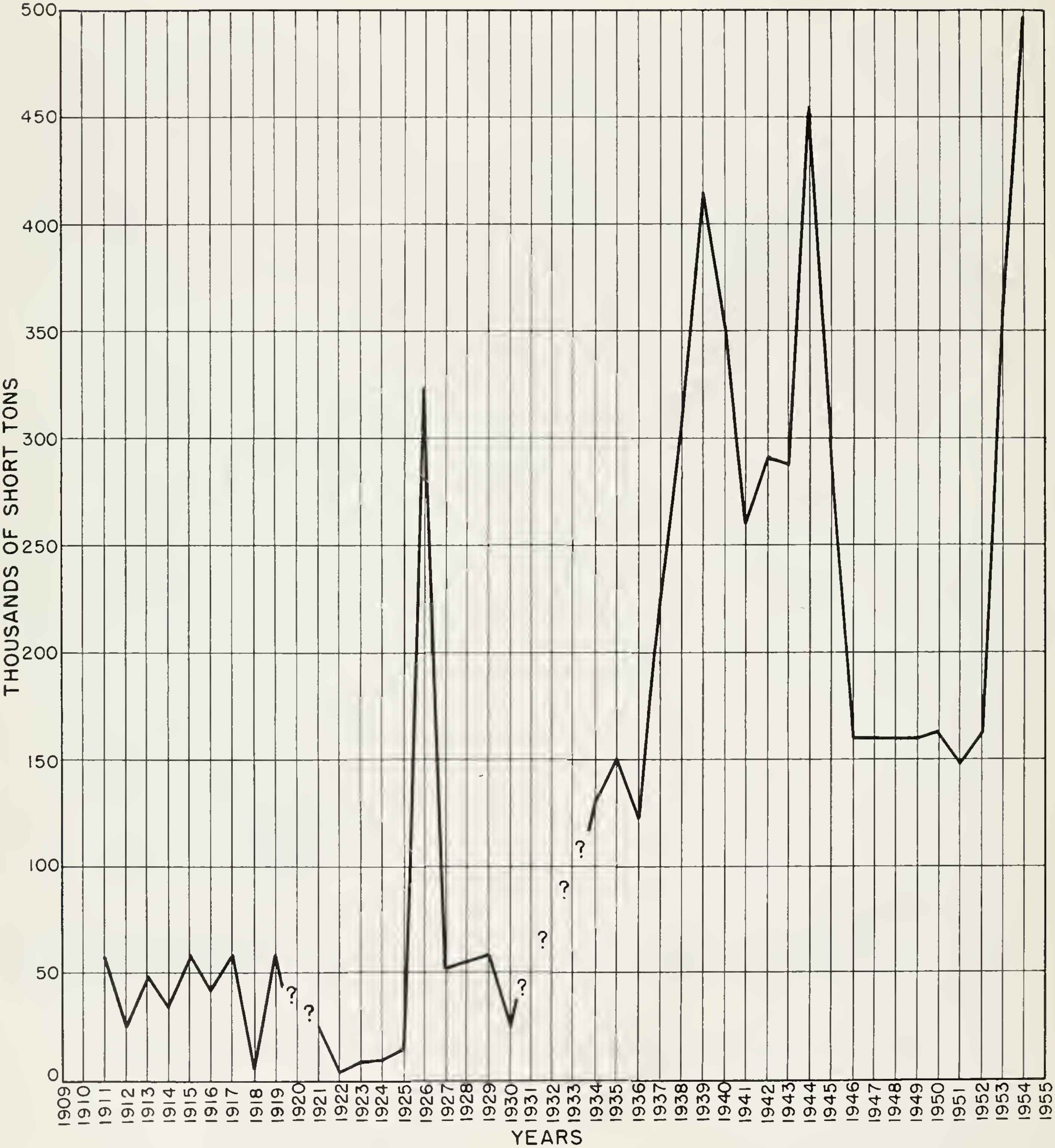

FIGURE 14. Chart showing production of volcanic cinders (scoria) in California, 1909-53.

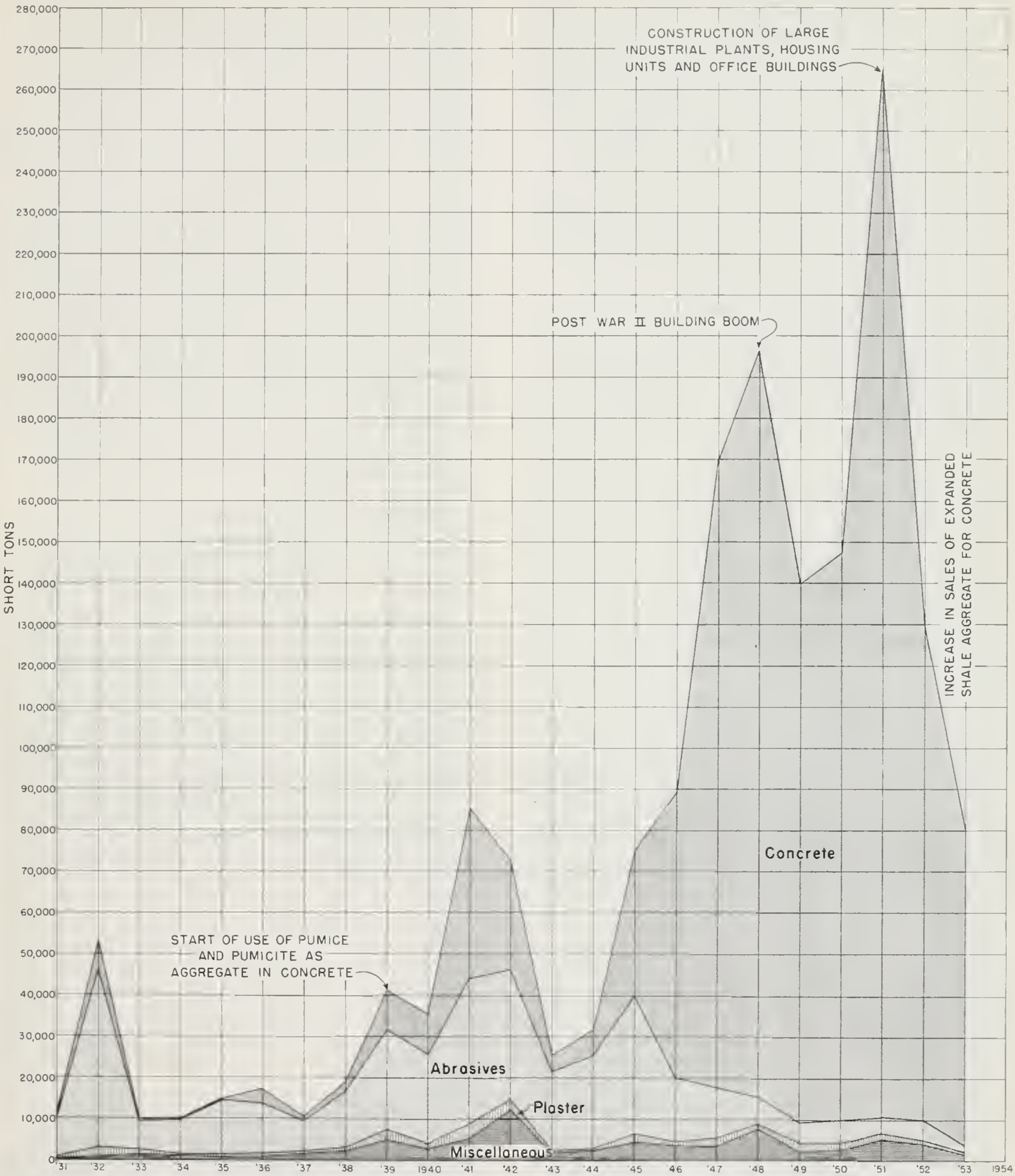

FIGURE 15. Chart showing amount (in short tons) and major use of pumice and pumicite produced in California, 1931-53.

in size from impalpable powder to blocks as much as 4 feet across. The larger blocks commonly are not pumice, but boulders and blocks of andesite, rhyolite, or even granitic rock that were caught up by the onrush of moving pumice fragments and dust. In a few deposits these blocks are completely rimmed by a zone of chalky-white pumicite that ranges in thickness from a few inches to a foot, and usually much thicker on large blocks than it is on the smaller boulders and blocks.

Most of the pumice deposits of the nuee ardente type are more compacted than the other types. This compaction combined with a partial fusion produced by the high temperatures commonly has produced a dense rock that resembles rhyolite and is called "welded tuff." An excellent example of this is the Bishop tuff in northern Inyo County (Gilbert, 1938, p. 1833).

Pumice fragments in the nuee ardente deposits range from angular to rounded, and the degree of rounding depends largely on the distance that the material travelled from its source. Almost none of the rounding appears to be due to attrition, but probably is caused by a spalling-off and breaking up of the larger pumice blocks as they continue to emit gas (Perret, 1935, p. 90).

Reworked Pumice Deposits. Any of the types of pumice and pumicite deposits that have been noted above are subject to erosion by running water. Material that is thus eroded and redeposited has many features in common with other types of sedimentary rocks. Cross-bedding, interbedding with nonpyroclastic material, and rounding of fragments characterize the reworked deposits (fig. 19).

Reworked deposits occur along the west side of Hamil Valley between Laws and Benton Station and in the area north of Bishop, in Mono and Inyo counties.

GEOLOGY OF THE DEPOSITS

The deposits of pumice, pumicite, and volcanic cinders in California are found in many of its 58 counties but more abundantly in those counties underlain in part by Tertiary to Recent volcanic rocks (fig. 1). Although very little may be known regarding some of these deposits, many of them, especially those in Inyo, Kern, Napa, Mono, Modoc, Siskiyou, and San Bernardino counties have been investigated in detail. The deposits in these counties also have yielded most of the output of pumice, pumicite, and volcanic cinders in California.

In California nearly all of the deposits of these materials occur in rocks that lie within the age range of late Tertiary to Recent. Since most glassy and partly glassy rocks are not as chemically and physically stable as sandstone or granite, they become devitrified, lithified, and metamorphosed with age. Volcanic activity was widespread throughout the whole of the Tertiary period in California. Thin beds of pumicite and pumiceous diatomite occur interbedded with Eocene sedimentary rocks. Extensive beds of pumice and pumicite can be found interbedded with both Miocene and Pliocene sedimentary rocks. Although considerable pumice and pumicite have been produced from tuffs of upper Pliocene age, a bulk of California's output of these materials has come from tuffs said to be Quaternary and Recent in age. Probably the youngest pumice deposits in California occur in the vicinity of Glass Mountain, eastern Siskiyou County, where radiocarbon method of dating wood found buried in the pumice indicates a probable age of the pumice at about 1100 years (Chesterman, 1953, p. 1501).

All of the cinder deposits that have been worked in California are Quaternary in age.

Volcanic cinder cones at Kegg in Siskiyou County and near Tionesta, Modoc County, are probably Quaternary in age. The same age may be assigned to the cinder cone near Little Lake, Inyo County, where a bulk of the present-day cinders are mined, and to Mount Pisgah and the Amboy Crater on the Mojave Desert.

In the following discussion of deposits of pumice, pumicite, and volcanic cinders in California, they have been grouped on the basis of the natural geomorphic provinces of the State (fig. 1). Some of the deposits are grouped into single provinces; other groupings embrace two or more adjoining provinces.

A cross indexed listing of all properties by counties may be found accompanying the tabulated list which is arranged according to regions. On this basis, the following areal headings will be employed:

I. Modoc Plateau—Cascade Range—Klamath Mountains—Northern Basin Ranges Region
II. Coast Ranges
III. Great Valley
IV. Sierra Nevada
V. Basin-Ranges (southern)
VI. Mojave Desert-Colorado Desert
VII. Transverse-Peninsular Ranges

Modoc Plateau—Cascade Range—Klamath Mountains—Northern Basin Ranges

The vast region that includes the parts of the Modoc Plateau, Cascade Range and Klamath Mountains that lie within California, as well as part of the Basin Range province, embraces most of California north of 40 degrees of latitude. The most characteristic land forms are towering volcanic peaks and plateaus of lava flows bedecked with many small volcanic cones. This region contains a wide variety of rock types, but the volcanic rocks of the late Tertiary and Quaternary ages are by far the most extensively exposed. These cover nearly all of Modoc County and large areas in Siskiyou, Lassen, and Shasta counties. In the western part of this region older rocks of a wide variety of types and ages are exposed in steep, rugged mountains. Cinder cones from which aggregate cinders may be mined are common in the region. Pumice and pumicite deposits are not common and are localized in those areas where acidic volcanic rocks are exposed. The bulk of the pumice used for concrete aggregate has come from deposits in the Glass Mountain area of eastern Siskiyou County, though a small amount has come from deposits near Alturas, Modoc County. In addition, pumice scouring blocks have been produced from a pumiceous obsidian crust on top of Glass Mountain.

Glass Mountain Area

The Glass Mountain area (plate 2) is in eastern Siskiyou County and western Modoc County, and comprises an area of about 10 square miles centered about Glass Mountain. This area is accessible by well-graded dirt roads from Tionesta, a station on the Great Northern Railroad, or from the Lava Beds National Monument, which lies only a few miles north of Glass Mountain.

Aggregate Pumice Deposits

The pumice in the Glass Mountain area is obtained from a loosely consolidated pumice tuff-breccia mantle that rests upon older lavas of the Modoc basalt (Anderson, 1941, p. 367). The mantle of pumice tuff-breccia ranges in thickness from 1 foot to 60 feet and contains at least two distinct layers separated by a third soil layer that represents a period of quietness between the volcanic outbursts. The soil layer ranges from a few inches to several feet in thickness and has not prevented mining the lower bed.

All of the mining has been done in the upper bed. Bedding is prominent in the upper layer. Individual beds range from a few inches to a foot or more in thickness, and are poorly sorted. Each bed contains the coarsest fragments at the bottom and the finest at the top. This bedding was probably an effect of a volcanian type of eruption which is characterized by repeated explosions and violent outbursts. The upper layer ranges in thickness from one foot to 20 feet. The pumice fragments are subangular to rounded in shape and range from dust particles less than $\frac{1}{16}$ inch to bombs 6 inches in diameter.

Screen analysis of pumice obtained from the Fouch pit in section 27, T. 44 N., R. 4 E., M. D. M., Siskiyou County

Size of screen	Percent retained	Accumulative percent retained
1 inch	7.52	7.52
$\frac{3}{4}$ inch	12.80	20.32
$\frac{1}{2}$ inch	26.80	47.12
$\frac{1}{4}$ inch	39.01	85.13
10 mesh	12.97	98.10
100 mesh	0.35	98.45
150 mesh	0.55	100.00

The pumice in the pumice tuff-breccia in the Glass Mountain area is light grayish-white. Angular fragments of black obsidian, brown basalt, and light gray rhyolite are present in the pumice tuff-breccia in amounts too small to affect the utilization of the pumice for aggregate.

The tuff-breccia consists essentially of pumice that is rhyolitic in composition.

Chemical analysis of the pumice from the Glass Mountain area, eastern Siskiyou County, California. Analysis reported in Anderson, 1941, p. 397

Oxide	Percent
SiO_2	72.75
Al_2O_3	13.83
Fe_2O_3	0.78
TiO_2	0.25
FeO	1.61
MgO	0.62
CaO	1.80
Na_2O	3.80
K_2O	4.00
H_2O+	0.30
H_2O-	0.20
MnO	nil
P_2O_5	tr.
S	tr.

The tuff-breccia was derived from a series of vents along a northwest-trending fissure that passed through the high point on Glass Mountain. Steep sided cones formed at these vents and are composed of fragments and blocks of pumice that range in diameter from 1 inch to as much as 2 feet. Bombs with the characteristic glassy or breadcrust surface are scattered between them. Most of the coarser pumiceous ejecta fell near the vents, whereas successively finer-grained material was deposited at successively greater distances from the vents. The prevailing wind direction at the time of the eruption was probably toward the northeast as indicated by the greater abundance of pumice on the north and northeast sides of Glass Mountain.

On the Thompson Pumice Company's property, located at the north toe of Glass Mountain, test pits on or near the pumice cones have indicated a depth of tuff-breccia as much as 60 feet. As one proceeds in a northeasterly direction from Glass Mountain, the mantle of tuff-breccia thins and at Craig Cove, 8 miles to the northeast, it is only 1 foot thick.

Following the laying-down of the pumice tuff-breccia, Glass Mountain was formed by outpourings of two separate flows of glassy volcanic rocks. The bottom and most extensive is a composite flow of glassy rhyolite and dacite. The second or top flow is rhyolite obsidian. These two flows lie discontinuously upon the mantle of pumice tuff-breccia, and the whole sequence of glassy rock above described is no more than 1100 years old (Chesterman, 1953, p. 1501).

Thompson Pumice Company Deposit. Location: secs. 26 and 27, T. 44 N., R. 4 E., M. D. M. Ownership: R. N. Fouch, Tionesta, California; leased to Rodney Gordenker, R. F. D. 12A, Glen Ellen, California.

At the property of the Thompson Pumice Company, mining operations have been carried on extensively in a layer of pumice tuff-breccia which averages about 12 feet in thickness and which continuously underlies all of the property. The pumice fragments are light gray in color, sub-angular to rounded in shape, and range in size from dust particles less than $\frac{1}{16}$ inch to bombs 6 inches. Mining has been done in two quarries. The northern, or Fouch quarry, is about 600 feet long and 300 feet wide. The southern, or Enloe quarry, is about 300 feet long and 150 feet wide. Pumice has been mined to a depth of about 12 feet in both quarries. Mining is by open pit methods. A bulldozer is used to clear the surface of the ground of forest litter and shrubs and to remove a veneer of dirty pumiceous soil which ordinarily is a foot or less in thickness. The pumice tuff-breccia is loosely consolidated and the pumice is loaded directly by a tractor loader into trucks. The pumice is hauled over well-graded roads about 11 miles to Tionesta, a small settlement on the Great Northern Railroad, where it is loaded directly into gondola cars for shipment, or crushed and screened for shipment (fig. 29). Small amounts of pumice are hauled by truck to processing plants at Klamath Falls, Oregon, but much of it is shipped to block plants in the San Francisco Bay area. Some of the pumice is used locally in block plants at Tionesta and Perez.

Mount Hoffman Pumice Claims. Location: secs. 28 and 29, T. 44 N., R. 4 E., M. D. M. Ownership: F. L. Jameson, J. O. Miller, and Dan Williams. Mr. Williams lives at Salinas, California. The Mount Hoffman pumice claims cover 960 acres which embrace a large part of a pumice-covered ridge that extends in a northwesterly direction from Glass Mountain. The pumice on this property is similar in many respects to that at the

Thompson Pumice Company's property. The Mount Hoffman pumice, however, is in larger and more angular blocks. These are as much as 5 inches in diameter. A small pit about 30 feet long and 15 feet wide was opened on the west side of the ridge and a small amount of pumice was mined and shipped to a processing plant at Salinas, California. As late as 1935 (Averill, 1935, p. 335) some pumice was shipped from block pumice deposits in section 33, T. 44 N., R. 4 E., for sawing into scouring blocks and crushing to small sizes for use in acoustic plaster. This operation was closed down in 1947 when the writer first visited the area.

Boorman Pumice Products Deposit. Location: sec. 25, T. 44 N., R. 4 E., and sec. 19, T. 44 N., R. 5 E., M. D. M. The pumice is quarried from pits in the northeast ¼ sec. 25, T. 44 N. R. 4 E., and on a well-graded dirt road that leads to Tionesta about 9 miles east. Ownership: Clarence, Carl, Leonard, and Irvine Boorman, P. O. Box 624, Klamath Falls, Oregon.

Large tonnages of pumice have been mined from the property of the Boorman Pumice Products Company and shipped to block plants in Klamath Falls, Oregon. and in the San Francisco Bay area. The pumice in this deposit closely resembles that at Thompson Pumice Company's pits, but the deposit itself is only about 4 feet thick. At the main Boorman pit which measured in 1953 about 100 feet by 100 feet, the pumice is scraped by a bulldozer into a bin which loads directly into trucks which haul the pumice to a plant at Tionesta. At the plant the pumice is screened and loaded into gondola cars for shipment to block makers.

Volcanic Products Corporation Deposit. Location: T. 44 N., R. 4 E., M. D. M. Ownership: Volcanic Products Corporation; Paul Dalton, Manager, Williams Building, Klamath Falls, Oregon; leases many unpatented mining claims including 3,411 acres near Glass Mountain from the Christie Estate and other claims from Roy N. Fouch, Tionesta, California.

Pumice for aggregate purposes was mined by a small Byers gasoline shovel and hauled by truck to a crushing and screening plant at Leaf, a siding on the Southern Pacific Railroad. The plant included a set of rolls and vibrating screen operated by a gasoline engine (O'Brien, 1947, p. 458).

Block Pumice Deposits

Pumice suitable for the manufacture of scouring blocks has been produced from two places in the Glass Mountain area; from pumiceous obsidian blocks obtained from the surface of Glass Mountain and from pumice blocks mined from pumice breccia which crops out near the base of a pumice cone on the northwest side of the Glass Mountain obsidian flow. Although this latter deposit produced some very fine scouring block pumice, the property is closed down and has not been operated for at least 7 years.

Pumice blocks are being produced in considerable quantities from Glass Mountain which has probably been the most important source of block pumice in this area.

The surface of Glass Mountain is exceedingly rough and contains numerous low, sharp ridges concave outward from the center of the mountain, and intervening trough-like depressions that lie in a transverse direction to the long direction of the flow (fig. 23). These ridges are referred to as pressure ridges, and were formed as the flow of thick, pasty obsidian moved sluggishly down the northeast slope of the mountain. Also, dotting the surface of Glass Mountain are fantastic spines, some of which extend as much as 10 feet above the surface of the flow. Nearly all of the spines show polished surfaces and striations which indicate that nearly solid obsidian was squeezed through restricted openings in the flow very much as icing is forced through ornately shaped openings by cake decorators. Although many of the spines have collapsed and formed mounds of angular blocks, many still retain almost their original shape.

Much of the surface of Glass Mountain is composed of rough, angular blocks of pumiceous obsidian (hereafter referred to as block pumice) mixed locally with correspondingly rough, angular blocks of dense black, black and gray, and greenish-gray rhyolite obsidian which shows all gradations into pumice. This jumbled mass of loose blocks rests upon the actual crust of the obsidian flow which grades downward from pumiceous obsidian at the top into dense, nonpumiceous obsidian beneath. The thickness of the pumiceous crust ranges from a few feet to several tens of feet. Not all of the pumiceous obsidian is suitable for scouring blocks, but only that portion which is free of hard obsidian ribs and which is uniformly cellular and comparatively light in weight (fig. 26).

The blocks of pumice range in size from a few inches to several feet in diameter. The openings are tubular, a shape that probably is an effect of flow movement in the glass as it was being vesiculated. The openings range in diameter from less than 1 millimeter to several centimeters, and range in length from several millimeters to as much as 10 centimeters (fig. 27).

In general the block pumice is somewhat friable and breaks into small, angular fragments (shards) with a marked abrasive quality. It is rhyolite in composition as indicated by the chemical analysis in the accompanying table.

Chemical analysis of pumiceous rhyolite obsidian from top of obsidian flow at north end of Glass Mountain, eastern Siskiyou County, California. Analysis cited in Shepherd, 1938, p. 327.

Oxide	Percent
SiO_2	73.38
Al_2O_3	13.69
Fe_2O_3	1.84
FeO	0.13
MgO	0.37
CaO	1.38
Na_2O	3.92
K_2O	4.22
H_2O+	0.34
H_2O-	0.05
TiO_2	0.12
ZrO_2	trace
P_2O_5	0.08
Cl	0.12
S	0.03
MnO	0.02

The pumice cone that has been mined is near the center of section 33, T. 44 N., R. 4 E., M. D. M., and is just one of several similar cones that formed along a northwest-trending fracture which also extended in a southeasterly direction through the high point on Glass Mountain. The pumice cone rises about 150 feet above its base and is about 700 feet in diameter at the base.

The pumice cone consists predominantly of pumice breccia with a sprinkling of bombs. The blocks in the pumice breccia are angular, white to gray in color, and range from a few inches to several feet in diameter. Near the base of the cone, especially along the southwest side, fumarolic action of hot escaping gases effected a slight alteration to the pumice and produced some clay, secondary opaline silica, and colored the pumice tan and brown. The summit of the cone is occupied by a mass of gray, vesiculated obsidian which locally is dense, black and devoid of any large vesicles. The obsidian was intruded into the vent of the pumice cone and rose as dome of viscous glass. The upper surface of this dome is characterized by polished and slickensided spines, many of which have disintegrated into heaps of angular blocks.

The development of the scouring block industry in the Glass Mountain area probably dates back to 1923 when claims for pumice and obsidian were staked on Glass Mountain. Very little block pumice was produced and nothing was done with the obsidian. In 1933 a rock sawing plant was set up near the north edge of Glass Mountain and an attempt was made to cut blocks of black and black- and gray-banded obsidian into bathroom tile. This operation was not successful, however, and was soon abandoned. In 1936 block pumice claims then called "scoria claims" were relocated on Glass Mountain and scouring blocks were successfully cut from block pumice. Many of the early blocks were cut with regular cross-cut saws similar to the saw commonly used in felling timber in the nearby forests.

Because of conflicting claims to various sections of Glass Mountain, several lawsuits evolved which were later settled in and out of the courts. From 1936 to 1948 there was a steady output of scouring blocks from properties on Glass Mountain. In 1948 the United States Pumice and Supply Company, Incorporated, purchased nearly all the claims in Glass Mountain and at the same time located new mining claims in order to provide themselves with a reserve of material for pumice blocks.

The history of scouring block operations at the deposit on the pumice cone is not known. It can be inferred, however, from mining operations and sawing-plant remnants that considerable numbers of scouring blocks were produced.

United States Pumice and Supply Company, Inc., Deposit. Location: secs. 33, 34, and 35, T. 44 N., R. 4 E., and secs. 3 and 4, T. 43 N., R. 4 E., M. D. M. Ownership: United States Pumice and Supply Company, Inc., Sheldon P. Fay, president, 6363 Wilshire Boulevard, Los Angeles, California, owns much of a property formerly held by John Madsen and Charles P. Van Doren of Klamath Falls, Oregon; H. W. Free of Tionesta, California; and the Christie Estate.

Access to the property is by way of a road built by Van Doren which has been extended to allow access to a wider area for mining the pumiceous obsidian.

Pumiceous obsidian suitable for making scouring blocks is intermixed with jumbled mass of angular blocks of block obsidian and coarsely dense, pumiceous obsidian which forms the crust of the Glass Mountain rhyolite obsidian flow. The depth to which this jumbled mass extends beneath the surface of the flow is not known. Mining operations are primarily concerned with locating areas on the surface of Glass Mountain where there are concentrations of usable blocks. In general these areas are in trough-like depressions between the pressure ridges where there are fewer collapsed obsidian spines and where the pumiceous obsidian crusts are the thickest. Therefore, all mining operations have been of a surface scalping type which does not include blasting, but bulldozing. Choice blocks ranging in size from 1 foot to 3 feet across are loaded into trucks by a tractor loader. Several small pits, each about 50 feet long, 25-30 feet wide, and from 6 to 8 feet deep were opened up in areas where there was a concentration of usable pumiceous obsidian blocks. Following mining, the blocks are hauled to the processing plant at Newell, California, where they are cut into "Grillmaster"-scouring blocks measuring 3 inches by 3 inches by 6 inches and 4 inches by 4 inches by 8 inches.

Skoria Star Brick Company. Location: sec. 26, T. 44 N., R. 4 E., M. D. M. Ownership: A small portion of section 26, one claim of 20 acres, is owned by John Madsen, P. O. Box 711, Klamath Falls, Oregon.

Mr. Madsen, as late as 1954, produced a small amount of scouring blocks from the pumiceous obsidian which he mines from the north part of Glass Mountain. The scouring blocks were cut at a small plant which is located on the property. The cutting is done with gasoline engine-powered circular saws. Blocks of several sizes are made and shipped to Klamath Falls, Oregon, for further distribution (fig. 28).

Little Glass Mountain Area

The little Glass Mountain area lies to the west of Medicine Lake and takes its name from Little Glass Mountain (plate 2), a prominent mass of rhyolite-obsidian that comprises most of secs. 13 and 24, T. 43 N., R. 2 E., and Secs. 18 and 19, T. 43 N., R. 3 E., M. D. M., about 4 miles west of Medicine Lake.

Although a mantle of pumice tuff-breccia covers a very extensive area around Little Glass Mountain, the mineable pumice is generally restricted to an area of about 16 square miles.

The pumice in the Little Glass Mountain area occurs as a mantle of loosely consolidated pumice tuff-breccia which covers earlier flows of andesite and basalt and basaltic cinder cones of Plio-Pleistocene age. According to Anderson (1941, p. 376) the pumice eruptions were a prelude to explosive volcanic activity that culminated in the emplacement of obsidian flows at Little Glass Mountain. During the period of pumice eruptions, a pumice cone was built at the site of Little Glass Mountain, and it was destroyed when Little Glass Mountain was formed. The pumice eruption so completely covered the countryside that even today one has difficulty in finding exposures of older rocks on gentle slopes. Many believe that the source of the pumice was Pumice Stone Mountain and Paint Pot Crater, two prominent knobs which lie less than a mile west of Little Glass Mountain. Actually, both of these knobs are composed of basaltic rocks and have only a mantle of loose pumice ranging in thickness from a few inches to 10 feet. That Little Glass Mountain was the source of the pumice is strongly suggested by the general increase in size of pumice fragments toward the mountain. The pumice fragments at Paint Pot Crater (fig. 31) have an average diameter of 1 inch and form a loose mantle ranging from a few inches to 10 feet in thickness. On the east side of Little Mount Hoffman, which lies about 1 mile east of Little Glass Mountain, the average size of the pumice fragments is about $\frac{3}{4}$-inch, and the mantle is no more than a foot in thickness. At Grasshopper Flat, $3\frac{1}{2}$ miles south of Little Glass Mountain, the pumice fragments are much smaller and form only a mere sprinkling on the ground.

Most of the pumice at Little Glass Mountain is comparable to the pumice at Glass Mountain. It is light grayish-white in color, medium vesicular, and occurs in angular fragments that range in size from $\frac{1}{16}$-inch to 3 inches in diameter. Large fragments are rare, and the average particle size is approximately a quarter of an inch.

Perhaps the first pumice mined in this section of Siskiyou County was at an abandoned pit on the south side of Paint Pot Crater as early as 1905 (fig. 31). Considerable research was done on this pumice to determine its field of usefulness and it was found that the pumice was suitable for the manufacture of concrete blocks. Latest recorded production was in 1935 (Averill, 1935, p. 335) although there has been a small amount of pumice mined for test purposes since then.

Pumice Stone Mines. Location: secs. 13, 14, 23, 24, 26, and 27, T. 43 N., R. 2. E., M. D. M. Richmond P. Hobson & Associates, 6440 Madera Street, Long Beach 15, California, ownes 2,560 acres, including a bulk of Little Glass Mountain. There has been very little pumice mined from this property. The pumice reserves are large and the material is very easily mined.

Alturas Area

Extensive layers of fine-grained pumiceous lapilli-tuff are well exposed along the north fork of the Pit River northeast of Alturas, Modoc County, and in the low hills north and northwest of Alturas. At Surprise (fig. 4), a small station on the Southern Pacific Railroad about 7 miles northeast of Alturas, the tuff is exposed in roadcuts and cutbanks on both sides of the north fork of the Pit River. Near the highway are several cone-shaped structures (Chimney Rocks) (fig. 15) that were formed as a result of local cementing and veining of the tuff by secondary calcite deposited from short-lived springs. These conical structures stand about 20 feet high, and occur either singly or in clusters of two or more. The pumice lapilli-tuff is part of the Upper Cedarville series which, according to Russell (1928, p. 412), is upper or middle Miocene in age. The exact thickness of the tuff is not known. It appears to be generally flat-lying. A section exposed in the hills east of Surprise Station consists essentially of fine-grained pumiceous lapilli-tuff that is at least 75 feet thick. In sec. 36, T. 42 N., R. 15 E., M. D. M., the same bed of tuff is well exposed in a series of roadcuts of U. S. Highway 395. Here, the tuff is at least 20 feet thick.

The general character of the pumiceous lapilli-tuff bed differs somewhat from place to place. About $1\frac{1}{2}$ miles south of Surprise Station it is fairly well indurated. At Surprise Station the bed is loosely consolidated and only locally indurated. The material is mostly fine-grained. Although the writer has no accurate screen analysis of the tuff, probably at least 50 percent of the material will pass through a 20-mesh screen, and as much as 10 percent will pass through a 150-mesh screen. The largest fragments are pumice lapilli. They are angular, white, and moderately well vesiculated and range in diameter from $\frac{1}{8}$-inch to 1 inch. The fine-grained material or pumicite is also white and appears to consist almost wholly of angular glass shards and small pumice fragments. Small amounts of quartz, orthoclase, plagioclase, and biotite are present. Several small angular fragments of rhyolite were also found, but this material seems to be a rare constituent.

Volcanic Cinder Deposits

Volcanic cinders have been quarried from cinder cones at several places in the northern part of California. Volcanic cinder cones are common features in this part of California and form conspicuous landmarks. These cones range in size from low mounds to spectacular cones as much as 500 feet high. The cinders that comprise the cones ordinarily are red, brown, or black. They range in diameter from a fraction of an inch to several inches and are mostly angular. Associated with the cinders are various proportions of lapilli and bombs, some of which are as much as 3 feet in diameter.

The mining of volcanic cinders is a rather simple operation. Because they are surficial in occurrence, they are mined mostly by shoveling the loosely consolidated cinders into trucks. Because most of the cinders produced in this region of California have been used either for railroad ballast or highway construction, no elaborate screening machinery is needed to prepare the cinders for use. The bombs and large clusters of cinders are removed by a grizzly made of rails spaced several inches apart.

Southern Pacific Company Deposits. Location: Two cinder cones, one located at Kegg in sec. 5, T. 44 N., R. 1 W., and the other on the Soule Ranch in sec. 24, T. 44 N., R. 2 W., M. D. M. Also, from another cone in sec. 29, T. 48 N., R. 3 W., M. D. M., about a tenth of a mile west of Copco Dam. Ownership is unknown (Williams, 1949, p. 59).

The cinder cone at Kegg, which has been almost wholly removed by mining, was from 50 to 75 feet high and covered about 150 acres as inferred from the topographic map, the Macdoel quadrangle which was surveyed in 1933. This cone consists essentially of red and black basaltic cinders and minor amounts of lapilli and bombs, some of which are 4 feet in diameter. Several narrow irregular stringers of basalt cut the cinders (Williams, 1949, p. 42).

Quarrying operations have all but removed the cinder cones in sec. 24, T. 44 N., R. 2 W., near the Soule Ranch. The material making up this cone is composed essentially of red scoriaceous lumps that range in size from $\frac{1}{2}$-inch to a gourd. The cinders are well stratified and are covered locally by masses of cinders, which, when partly pasty, adhered together following flight.

There are three cinder cones near Copco Dam. Nearly all of the cinders produced came from the central or largest cone which is situated about 500 feet west of the dam. This cone, prior to almost complete removal by quarrying, was probably not over 75 feet high and covered not much more than 100 acres. The cinders are red, brown, and black and admixed with various proportions of lapilli, ash, and ropy and spindle-shaped bombs up to a foot or more across (Williams, 1949, p. 47).

Several hundred thousands of tons of volcanic cinders have been mined from these three cones and used as railroad ballast. Minor amounts have gone into highway construction. All mining is done by open pit methods and the cinders loaded directly into railroad cars designed primarily for discharging ballast materials.

Great Northern Railroad Deposit. Location: East Sand Butte in sec. 3, T. 44 N., R. 5 E., M. D. M., about 4 miles northwest of Tionesta. Ownership: U. S. Department of Agriculture, Forest Service, which sells the cinders to the Great Northern Railroad (fig. 22).

East Sand Butte is a volcanic cinder cone which projects about 300 feet above a comparatively level floor of basalt flows. The cone is accessible by dirt roads from Tionesta and a spur railroad track from Ainshea Butte. The spur connects with the main line of the Great Northern Railroad, which passes through Tionesta and Klamath Falls, Oregon.

The cinders range in color from black to red, are angular, and range in size from ¼-inch to 3 inches in diameter. They are mined from an open pit by a crawler shovel that loads the cinders directly into gondola or ballast cars. The cinders are used as ballast and bank-widening for the Great Northern line between Klamath Falls, Oregon, and Bieber, California.

McCloud River Railroad Deposit. Location: sec. 36, T. 41 N., R. 4 E., M. D. M., at Porcupine Port, Siskiyou County. Ownership: Undetermined. At the operation of the McCloud River Railroad red volcanic cinders are being mined with a bulldozer which pushed them onto a loading ramp and grizzly which feeds directly into gondola cars. The cinders are being used on the new line under construction between Lookout and Hambone by the McCloud River Railroad (Piratt, E. F., p. c., 1952).

Hotlum Cinder Deposit. Location: sec. 22, T. 42 N., R. 4 W., M. D. M., about 1 mile east of Hotlum, a station on the Southern Pacific Railroad. Ownership: Shastalite Brick Company, Yreka, California. Fred W. Burton, president, owns 12 claims formerly held by Clem and Nettie Baker of Yreka, California.

At the Hotlum deposit cinders are being quarried from the southwest side of a volcanic cinder cone which consists essentially of cinders, a few bombs, and several irregular stringers of basalt. The cinders are basaltic in composition and consist of scattered small crystals of olivine and colorless plagioclase enclosed in dull grayish-brown basic volcanic glass. The bombs are angular and range in size from $1/16$ of an inch to 4 inches. About 10 percent of the material is black basalt volcanic ash. The cinders are well stratified (fig. 34) and in the quarry they dip about 25 degrees in a northeasterly direction.

The quarry is on a slope about 100 feet above the floor of a steep-walled, northwest-trending canyon. The quarry in June 1955 measured about 250 feet long and had a face averaging about 20 feet high. The overburden is thin and consists of brown cindery soil about 12 inches thick.

A small tractor loader is used to mine and load the cinders which are trucked to Yreka and other nearby towns. The cinders weigh about 40 pounds per cubic foot and are being used as aggregate for making concrete building blocks.

Pumicite Deposits

Anderson Ranch Deposit. Location: sec. 24, T. 37 N., R. 9 E., M. D. M., about 15 miles southeast of Bieber, Lassen County. Ownership: H. P. Anderson, Bieber, California.

The Anderson Ranch deposit consists of a pumicite bed, at least 20 feet thick, that rests upon basaltic lavas. Because it is well consolidated, the bed forms prominent outcrops. It is composed mostly of angular rhyolitic glass shards of which 90.4 percent pass through the 100-mesh screen and 9.6 percent are retained on the 100-mesh screen. The deposit has not been worked, but it has been partly developed by means of several shallow pits and cuts (Laizure, 1920, p. 511).

Liberty Bell Deposit. Location: sec. 13, T. 34 N., R. 8 W., about 35 miles northwest of Redding, California. Ownership: Frank Sarcletti, Joe Merciari, Louis Sarcletti, and Joe Dallartorre, all of French Gulch, California, own five claims.

The pumicite at the Liberty Bell mine occurs in a bed that strikes east and dips gently toward the south. The bed is overlain by andesitic lavas and rests upon slate of the Bragdon (Mississippian?) formation. It is well exposed in a tunnel driven along the andesite-slate contact where it is 4 feet wide at the face. No pumicite has been produced from this property (Laizure, 1920, p. 544).

Weisman Pumicite Deposit. Location: secs. 11 and 14, T. 43 N., R. 13 E., M. D. M., about a quarter of a mile southeast of Surprise Station, a small station on the Southern Pacific Railroad. Ownership: John Weisman, Alturas, California. Formerly owned and operated by Leroy F. Foster.

Poorly consolidated pumice lapilli-tuff was mined for several years from a quarry about a quarter of a mile southeast of Surprise Station and used to sand cattle cars.

The bed of pumice lapilli-tuff is very extensive at this property. It appears to be flat-lying and its actual thickness is not known although it is well exposed throughout nearby hills which rise at least 50 feet above the floor of the quarry. The quarry itself is about 200 feet long and 100 feet wide. The tuff has been quarried to a depth of about 10 feet. For this purpose the mining operation was quite simple and consisted essentially of scraping the tuff onto a truck loading ramp by means of a horse-drawn Fresno scraper. The material was trucked to the siding at Surprise Station where the floors of cattle cars were covered to a depth of several inches. The pumiceous material in the tuff appears to have been well suited for this purpose because of its absorbing properties. Small amounts of this tuff were used locally as plaster aggregate.

Coast Ranges

The Coast Ranges region consists essentially of the California Coast Ranges and extends from Trinidad Head in Humboldt County to the Transverse Ranges in Santa Barbara County (plate 1). It is bounded on the west by the Pacific Ocean and on the east by the Great Valley of California. This region contains several types of igneous, sedimentary, and metamorphic rocks that range in age from pre-Franciscan (pre-Upper Jurassic) to Quaternary and have been folded and faulted to produce a system of longitudinal ranges that trends from N. 30° W. to N. 40° W.

Pumice and Pumicite Deposits

The deposits of pumice and pumicite in the Coast Ranges range in age from Miocene to Pleistocene. During Miocene time, in particular, volcanism was widespread. Explosive eruptions were responsible for the formation of rhyolite tuffs, flows of andesite and basalt, thick sills of analcite diabase, and plugs of andesite and rhyolite porphyries (Taliaferro, 1941, pp. 147-150). The tuffs were deposited in basins, and in the San Luis Obispo-Huasna basin they are several thousand feet thick.

In the vicinity of San Francisco Bay, however, much of the volcanism took place during the Pliocene. Flows, tuffs, and agglomerates of andesites, basalts, and rhyolites were deposited. In places these were pierced by rhyolite breccia necks and plugs.

Volcanism during the Quaternary epoch was not as extensive as volcanism during the Miocene and Pliocene in the California Coast Ranges. Flows, breccias, and tuffs of basalt were deposited in basins.

Following the deposition of the volcanic and associated sedimentary rocks in the Coast Ranges, deformation took place. The rocks were folded, faulted and, finally, eroded. Rhyolite tuffs that once occupied wide areas in the many basins now remain as isolated patches in which they are interbedded with other sedimentary rocks. Some of the deposits of tuff are large; others are small. Many of the deposits, however, are overlain by thick sections of sedimentary rock and because of this, they are not available to inexpensive mining operations. Other deposits, because of the physical nature of the tuff and the high proportion of lithic material in it, are equally unsuited to any of the present-day usages for pumice or pumicite.

In spite of the rather wide distribution of rhyolite tuffs in the California Coast Ranges, the pumice and pumicite produced has come mostly from deposits north of San Francisco Bay.

Pumice has been mined from certain lapilli-tuff layers in the Sonoma volcanics (Pliocene) in the vicinity of Napa, in Napa County (plate 1 and fig. 5). The most important pumice-producing area is just a few miles northeast of Napa along Sarca Creek and on the north flank of Mount George. Production began in 1932 on a small scale and has increased to an annual output in 1952 of over 75,000 tons.

Some pumice has been produced from the Lawler tuff (Pliocene) near Pittsburg, Contra Costa County. Production in this area began during World War II and came to a standstill in 1953.

Pumice has been produced from tuffs in the Monterey formation (Miocene), a few miles southeast of Creston, San Luis Obispo County. Production of pumicite in this area commenced on a small scale in 1923 and continued at this rate for only a few years.

Napa Area

Basalt Rock Company Pumice Deposit. Location: sec. 24, T. 5 N., R. 4 W., M. D. M., about 3½ miles southeast of Napa, California. Ownership: Basalt Rock Company, Inc., Napa, California; A. G. Streblow, president.

At this deposit (abandoned) of the Basalt Rock Company, pumice was mined from a massive lapilli-tuff layer interbedded with other tuffaceous and volcanic rocks of the Sonoma volcanic (Pliocene). The exact thickness of the lapilli-tuff layer is not known, although core drilling indicated it to be more than 100 feet. The lapilli-tuff and associated volcanic rocks were folded and the Basalt Company's pumice deposit is on the west limb of a north-trending syncline. The lapilli-tuff consists essentially of small fragments of pumice imbedded in a fine-grained volcanic tuff. Fragments of rhyolite, black obsidian, and basalt bombs are also present. The pumice fragments are angular, light grayish-white in color, and range in size from dustlike particles to blocks several inches in diameter. The average is about half an inch. The lapilli-tuff layer is discontinuously overlain by rhyolite which, prior to removal by erosion, covered most of the tuff.

Mining was done in a semi-circular quarry whose face was 600 feet long and 75 feet high at the center (Davis, 1948, p. 173). This quarry was in operation from 1934 to 1946. In 1946, however, the Basalt Rock Company abandoned the quarry and opened a new one in a more favorable deposit on Mount George, a few miles northeast of Napa.

Basalt Rock Company Mount George (King) Pumice Deposit. Location: SE ¼ sec. 24 and NE¼ sec. 25, T. 6 N., R. 4 W., M. D. M., on Highway 37, about 4½ miles northeast of Napa, California. Ownership: Basalt Rock Company, Inc., A. G. Streblow, president, Napa, California.

The Basalt Company in 1939 acquired a new pumice deposit of about 43 acres as a reserve measure to supply pumice to their block plant at Napa. The deposit occupies a small hill which rises about 150 feet above the highway entrance to the quarry.

The pumice is mined from a massive pumice tuff-breccia that is about 150 feet thick. The bed of pumice tuff-breccia dips gently southwestward and consists essentially of angular pumice fragments although some lapilli of black obsidian, basalt bombs up to 3 feet across, and angular fragments of red scoria 1 to 2 inches in diameter are present also.

Tan-colored clay material surrounds the rock fragments in the pumice tuff-breccia. This clay was formed through alteration of fine-grained pumice and pumicite contained in the tuff-breccia.

There is no overburden other than soil at Mount George deposit. Nearby, however, the pumice tuff-breccia is overlain by a dark andesitic lava.

The quarry was opened in 1947 and was closed early in 1953. During the 7 years of continuous operation the quarry had a total output of over 300,000 tons of pumice which was used primarily as an aggregate in building blocks.

The quarry in 1953 was about 450 feet wide, 500 feet long, and had exposed a face on the north side about 50 feet high. The pumice was mined by Caterpillar diesel D-8 scrapers that loosen the pumice and push it to a truck loading bin located at the west edge of the quarry (fig. 21). A "sheep-foot" roller was also used to break the oversize lumps. At the loading bin there was a grizzly of 3-inch pipes set at 9-inch openings. The oversize was broken by sledging and loaded into trucks which haul the pumice to a crude stockpile or washing south of Napa (Davis, 1948, p. 173).

Cicero Pumice Deposit. Location: SE ¼ sec. 24, T. 6 N., R. 4 W., M. D. M., on Highway 37, about 4½ miles northeast of Napa, California. Ownership: Frederica A. Pearl owns the property which is leased to C. Cicero, 849 South Jefferson Street, Napa, California.

The Cicero pumice deposit is on the southeastern slope of a southwest-trending ridge low in the foothills of the Howell Range. At the Cicero quarry, pumice is mined from the same layer of tuff-breccia that is exposed in the Basalt Rock Company's Mount George quarry nearby. The upper part of the tuff-breccia layer shows poorly defined bedding which dips about 20 degrees southwest. The pumice fragments are angular, pink to gray in color, and range in diameter from dust particles to several inches. Lapilli of obsidian and rhyolite, as well as an occasional bomb of black basalt are also present. A section measured near the center of the quarry gives the sequence shown in the accompanying table (Davis, 1948, p. 174).

Section of the lapilli-tuff breccia as exposed in the quarry of the Cicero pumice deposit, Napa area, Napa County.

Estimated thickness in feet	Description
1-2	Soil, chocolate-brown, mud, rock fragments.
1.5	Pumice, fragmental, pink with brown clay coating.
0.3	Pumice, fragmental, pink in gray pumicite matrix.
4.0	Pumice, gray with obsidian lapilli.
0.6	Pumice, fragmental, pink, brown clay coatings.
20.0	Pumice, massive, gray, some pumicite and obsidian lapilli.

The actual thickness of the lower gray pumice bed is not known although drilling in the floor of the quarry indicated massive gray pumice to a depth of 80 feet. Soil and a few scattered outcrops of light vesicular rhyolite lava constitutes the overburden. Crude pumice is trucked a short distance from the quarry to a plant where the pumice is dried in an inclined Madison No. 147 rotary drier. Following drying, the pumice is crushed and passed through a series of vibrating screens which produce three sizes of aggregate: plus 20- minus 14 mesh, plus 14- minus $\frac{3}{16}$ inch, plus $\frac{3}{16}$ inch -minus ⅜ inch. All plus ⅜ inch is returned for recrushing. The screened pumice is then conveyed to a block-making plant at the crushing plant and used in the manufacture of pumice concrete building blocks.

Pearl Pumice Deposit. Location: S ½ sec. 24, T. 6 N., R. 4 W., M. D. M., about 4½ miles northeast of Napa, California. Ownership: Frederica A. Pearl; operated by John Pearl.

The quarry of the Pearl pumice deposit is in the same pumice tuff-breccia bed that contains the Basalt Rock Company's Mount George and Cicero deposits and is located about 1,000 feet in a northerly direction from the Cicero quarry. The tuff-breccia is grayish-white in color and the section exposed in the Pearl quarry is similar to that in Cicero quarry. The overburden is mainly soil although small outcrops of light-colored vesicular rhyolite can be found capping the pumice tuff-breccia.

The quarry is on the north side of the same ridge that contains the Cicero quarry. It is about 200 feet long, 30 feet wide and has a face about 30 feet high. Blasting occasionally was required to break the tuff-breccia before its removal. The pumice was drawn from the quarry face to the grizzly with 12-inch openings by an anchor-type dragline scraper. The pumice that passes through the grizzly is crushed by a Bennett crusher and conveyed by bucket elevator to an inclined wire mesh trommel screen with ¼, ½ and ¾-inch openings. The oversize is returned for recrushing (Davis, 1948, p. 175).

Walker Pumice Deposit. Location: NW ¼ sec. 26, T. 6 N., R. 3 W., on Snow Flat along Highway 37, about 6 miles northeast of Napa, California. Ownership: D. C. Walker; formerly leased to Messrs. Rice, Bergum and Pankost, who gave up their lease in 1949. Property inactive in 1955, although Mr. Walker occasionally quarries some pumice to repair the road leading from the County Highway to his home.

The quarry, which is about 100 feet long, 75 to 80 feet wide, and from 10 feet deep is in a pumice lapilli-tuff bed which is similar to the bed exposed in the Basalt Rock Company's Mount George quarry. The bed dips about 10 degrees southwest. It consists of angular pumice fragments set in a pumicite matrix. The pumice fragments are light gray in color and range in size from $\frac{1}{16}$-inch to 2 inches, average about ⅜-inch. The pumicite matrix is also gray in color, altered in part to tan clay, and constitutes about 30 percent of the tuff. Actual thickness of the tuff was not measured, but it is at least 50 feet as indicated by hillside exposures.

Pittsburg Area

In Contra Costa County pumice was mined from the Lawler tuff (Pliocene) which is exposed in the Los Medanos Hills, about 5 miles west of Pittsburg (fig. 6). A thick section of tuffaceous rocks, referred to as the Pinole tuff (Pliocene) by Lawson (1914, p. 13), is exposed at Pinole, at Wilson Point on San Pablo Bay, at Rodeo, on Sobrante Ridge, at Walnut Creek, and on the north slope of Mount Diablo. The Lawler tuff and Pinole tuff are similar in lithology and may be equivalent in age.

The Pinole tuff is made up of a series of lapilli and vitric-crystal-lithic tuff layers, which occur near the base of the Orinda formation (lower Pliocene). The thickest occurrences of the Pinole tuff, and the one that contains the largest rock fragments, is exposed near Rodeo. The coarseness of these rock fragments of the tuff decrease to the east and southeast of Rodeo. The Pinole tuff consists essentially of broken fragments of pumice which range in size from small angular pea-size pieces to angular fragments 6 to 8 inches in diameter scattered throughout a matrix of yellowish to grayish pumicite (volcanic ash). It also contains minor proportions of orthoclase, oligoclase-andesine, augite, hypersthene, green and brown hornblende, and rarely zircon. The glass has an average index of refraction of 1.515. Glass with this index of refraction ordinarily is dacitic in composition (George, 1924, p. 365), but a lack of quartz and the presence of both augite and hypersthene suggests an andesitic composition.

In the Los Medanos Hills which lie to the southwest and west of Pittsburg the Lawler tuff (Pliocene) forms an outcrop about 300 feet wide that can be traced almost continuously along its strike in a northwesterly direction for about 8 miles. The tuff dips from 15 degrees to 30 degrees northeast, and ranges in thickness from 50 to 100 feet. The tuff rests conformably upon the Neroly sandstone (upper Miocene) and is overlapped by the Wolfskill (Pliocene) formation. In places the tuff disappears entirely (Weaver, 1949, p. 61).

The pyroclastic rock comprising the Lawler tuff is actually a lapilli tuff. It consists essentially of angular, broken fragments of white and grayish-white pumice which range in size ⅛ inch to 2 inches set in a matrix of white pumicite. Broken crystals of feldspar, hypersthene, and green and brown hornblende are present in small amounts. Locally the tuff is well compacted and forms prominent exposures.

Alvarnez Pumice Deposit. Location: sec. 15, T. 2 N., R. 1 W., M. D. M., about 4½ miles southwest of Pittsburg, California. Ownership: Mr. Alvarnez, Route 1, Box 589, Pittsburg, California; leased to Pittsburg Pumice Industries, Route 1, Box 21, Pittsburg, California (Davis, 1951, p. 578).

The Alvarnez quarry is on the steep slope of a short west trending ridge. It was opened up in 1946 and operated intermittently for the next few years. The quarry was not in operation in 1953 and had every indication of having been closed down for at least several years (fig. 40). The quarry is about 50 feet long, 30 feet wide, and has exposed a face in the tuff about 30 feet high. The Lawler tuff at the Alvarnez quarry is about 40 feet thick and is overlain by a 20-foot thick compacted sandstone layer of the Wolfskill formation.

Bailey Ranch Pumice Deposit. Location: sec. 23, T. 2 N., R. 1 W., M. D. M., about 4 miles southwest of Pittsburg, California. Ownership: A. S. Bailey, Route 1, Box 163, Pittsburg, California.

The quarry from which considerable pumice was mined is about 1500 feet east of the Bailey house, and is near a saddle in a low ridge that trends in northerly direction. The quarry is on a dip slope. The Lawler tuff is covered by several feet of sandy overburden which was stripped away by a bulldozer (Davis, 1951, p. 578). The Lawler tuff at the Bailey Ranch quarry is about 40 feet thick, strikes N. 75° W., and dips about 30° northward. The tuff contains interbeds of sandstone and sandy tuff, and at the bottom the tuff grades into sandstone. The pumice fragments are grayish-white in color, angular in shape, and range up to 1 inch in diameter. They are set in a matrix of pumicite which locally has been altered to tan clay. The quarry is about 100 feet long, 30 feet wide, and has a face about 30 feet high. Mining began on the property in 1946 and continued intermittently for the next few years. The quarry was inactive in May 1954, and showed indications of having been inactive for several years.

Clear Lake Area

Coleman Pumice and Volcanic Cinder Deposits. Location: secs. 16 and 17, T. 13 N., R. 7 W., M. D. M., about a quarter of a mile north of Clear Lake Park, Lake County. Ownership: V. V. Coleman, Lower Lake, California, owns several hundred acres of land which include the deposits of pumice and volcanic cinders.

Since the middle 1940's V. V. Coleman has obtained plaster sand and ornamental stone from extensive deposits of vesiculated obsidian and pyroxene dacite near Clear Lake Park, Lake County. The vesiculated obsidian and dacite form flat-lying flows (Anderson, 1936, p. 654). The obsidian rests upon the dacite and is said to be later than the dacite. The actual thickness of the vesiculated obsidian at the Coleman quarry is not known, but it must be at least 100 feet as indicated by the exposures. The vesiculated obsidian has an areal extent of about a square mile and has been opened up to mining at several widely spaced quarries of which the largest, the Coleman pit, measures about 500 feet by 500 feet and 10 to 30 feet deep (fig. 38).

The obsidian flows are more or less vesiculated throughout. The coarsely vesiculated areas are dark gray, whereas the finely vesiculated areas are light gray in color. In places the obsidian is stained brown by oxides of iron. Flow banding is a common feature of the vesiculated obsidian (fig. 39). Individual bands range from a fraction of an inch to several inches in width and often display wavy and distorted structures. The vesiculated obsidian is rhyolitic in composition and has a refractive index of 1.485 (Anderson, 1936, p. 655). Scattered throughout the vesiculated obsidian are rounded bouldery masses of black obsidian. In addition, one can find local areas of the vesiculated obsidian which contain perlite and partially perlitized obsidian.

The vesiculated obsidian is incoherent and easily mined by open pit methods. It is passed over a series of screens to produce sand for plaster and concrete aggregate and large fragments of coarsely vesiculated obsidian up to 3 inches across for ornamental stone.

The pyroxene dacite is in a flow of unknown thickness. The upper surface of the flow is vesiculated and scoriaceous. The non-vesiculated dacite is dark to light gray in color, whereas the scoriaceous dacite ranges from red and orange-red to purplish-black in color. Actual exposures of the dacite are poor, but in the Coleman cinder quarry the rock is well exposed and shows there a cindery appearance similar to that exhibited by cinder cones in eastern Siskiyou County. Apparently, the surface of the dacite flow is made up of loosely consolidated angular blocks of scoriaceous dacite.

The dacite is being mined by open pit methods from a quarry which in June 1955 measured about 80 feet long, 50 feet wide, and about 20 feet deep. The material is used almost exclusively as decorative stone in gardens. It is shipped by truck to markets in the San Francisco Bay area, and is extensively used by local builders.

Although no attempt has been made to crush and screen the scoriaceous dacite for aggregate, it is possible that the material would prove quite satisfactory for this purpose.

Pumicite Deposits

Deposits of pumicite are not common in the Coast Ranges of California. Some pumicite was obtained from a deposit in the Merced (Pliocene) formation at Lake Merced (formerly Lake Honda), San Francisco County. In 1923, however, operations at the Lake Merced deposit were abandoned when a golf course was constructed on the property containing the pumicite (Laizure, 1929, p. 244).

In 1880 small amounts of pumicite, once thought to be diatomite, were mined from a deposit in sec. 23, T. 26 S., R. 10 E., M. D. M., near Adelaida, San Luis Obispo County. The pumicite here is about 6 feet thick and nearly flat-lying. The pumicite was packaged for sale as "Magic Polish" (Franke, 1935, p. 461). Near the forks of Old Creek and the town of San Luis Obispo in San Luis Obispo County beds of pumice and pumicite occur above the Vaqueros (lower Miocene) sandstone. Pumice and pumicite also are associated with beds of diatomaceous earth in the Santa Margarita (upper Miocene) formation near Santa Margarita and Atascadero (Fairbanks, 1904, p. 4). Although much of the pumice and pumicite in this area have been altered and mineralized in part with pyrite and silica, there still remains a considerable amount of pumice and pumicite that have commercial possibilities should there arise a local demand for them.

Weatherby Ranch Pumicite Deposit. Location: 4 miles south of Elk River, Humboldt County; adjacent to the Weatherby Ranch. Ownership: Hanify Lumber Company, Eureka, California.

The Weatherby Ranch pumicite deposit consists of a bed that is about 2 feet thick and occurs in the Wildcat (Pliocene) group. It is overlain and underlain by shale and is nearly horizontal. The pumicite is white to creamy-white in color and consists mostly of glass shards that have a refractive index of 1.505. The chemical analysis and the refractive index indicate a rhyolitic composition for the pumicite.

Partial chemical analyses of Weatherby Ranch pumicite. W. H. Gallagher, Eureka, California, analyst.

SiO_2	70.0
Al_2O_3	18.5
Fe_2O_3	0.6
CaO	3.4
MgO	0.5
Na_2O	3.4
K_2O	2.4
Undetermined	1.2
	100.0

Both prospecting and mining were done through a short adit which is now closed (Laizure, 1925, p. 324). The property was inactive in 1925, and has had no production since that year.

Grey Eagle Mine and Black Eagle Pumicite Claims (Formerly Francis Cleanser Mine). Location: secs. 21 and 22, T. 28 S., R. 15 E., M. D. M., about 10 miles southeast of Creston, San Luis Obispo County. Ownership: M. L. Francis, R. D. Box 233, Paso Robles, California.

At the Grey Eagle mine and Black Eagle claims pumicite has been produced from an extensive layer of tuff which is interbedded with sandstone and siliceous shales of the Santa Margarita (upper Miocene) formation. The tuff is well consolidated, fine-grained, grayish-white in color, and is from 40 to 50 feet thick. The section containing the tuff strikes N. 60° W. and dips about 30 degrees toward the northeast.

The property was discovered in 1923 by the owner who produced a small amount of pumicite. It is now inactive and has not produced any pumicite since 1936.

All mining was done underground through several tunnels and dynamite was used to break the tuff in the mine. The crude tuff was ground in a small hammer mill, passed through a 40-mesh screen, and sacked for distribution by house-to-house canvassing (Franke, 1935, p. 461).

Volcanic Cinder Deposits

Wilson Cinder-Pumice Deposit. Location: W. ½ sec. 20, T. 6 N., R. 3 W., and E. ½ sec. 19, T. 6 N., R. 3 W., 700 feet north of Monticello road about 5½ miles northeast of Napa, California. Ownership: T. D. Wilson, 2751 Monticello Road, Napa, California.

The Wilson cinder-pumice property was opened up in 1946 and leased to the Lava-Lite Products Company, D. G. Saunder, manager, 815 Louisa Drive, Santa Rosa, California. The Lava-Lite Products Company operated the property from 1946 to 1948 and produced about 600 tons of cinders and pumice combined. In 1948 Lava-Lite Products Company's lease was terminated and the property has remained idle since then.

The material quarried on the Wilson property is known locally as "black pumice." Actually, both volcanic cinders and pumice were produced. The cinders are black, basaltic, and angular, ranging from ⅛ inch to 3 inches in diameter, and are embedded in a basaltic tuffaceous matrix. Angular fragments and large boulders of basalt as much as 2 feet across are scattered among the cinders. The cinders occur in a bed about 30 feet thick and rest upon a dark scoriaceous basalt. They are overlain by a pumice lapilli-tuff layer which at the quarry is about 40 feet thick. The pumice lapilli-tuff layer consists mostly of angular, dark gray pumice fragments that range in size from $\frac{1}{16}$ inch to 1 inch; average about ¼ inch. Several layers of pumicite as much as 6 inches thick are in the pumice lapilli-tuff. Locally, the lapilli-tuff is firmly consolidated, forming prominent exposures. The entire section dips gently toward the southwest.

The Wilson quarry is in the south side of a low ridge. The quarry is about 100 feet long and 90 feet wide. A thin soil overburden of several feet was scraped away by a bulldozer.

The cinders were mined with a bulldozer that scraped up the cinders and delivered them to a wooden hopper where the plus 9-inch size (loosely consolidated clusters of smaller cinders) were sledged by hand. A conveyor belt fed the cinders from the hopper to a portable one-piece screening plant driven by a Caterpillar 65 diesel engine. The cinders and pumice produced at the plant were used in the manufacture of building blocks (Davis, 1948, p. 176).

Great Valley

The Great Valley region extends in a southeasterly direction from Redding on the north to the mountains south of Bakersfield (plate 1). It is about 400 miles long, 50 miles wide, is bounded on the east by the rolling foothills of the Sierra Nevada, and on the west by the Coast Ranges. It is ordinarily divided into two parts, the northern or Sacramento Valley and the southern or San Joaquin Valley.

On the east side of the San Joaquin Valley in the vicinity of Friant are the famous pumicite deposits that have yielded pumicite for agricultural and industrial purposes since the early part of the 1900's. Pumice also has been obtained from this area and has been used successfully in the manufacture of lightweight building blocks.

The pumice and pumicite deposits near Friant, California, occur in the Friant (Pleistocene?) formation which crops out in the low foothills north and east of Friant. The Friant formation is flat-lying and consists mostly of lacustrine and fluviatile deposits of silt, sand, gravel, and thinly layered pumicite. Pumice occurs only locally as thin beds or admixed with sands overlying the pumicite. Although the maximum thickness of the Friant formation is not known, locally the pumicite is at least 150 feet thick.

The pumicite is in layers that range in thickness from a few hundredths of a millimeter to an inch (fig. 43). Individual layers of pumicite are uniform in thickness and can be traced for several tens of feet along their strike. The pumicite particles are flat and angular, ranging in size from 0.001 to 0.015 mm (Tranger, 1951, p. 1531). They consist mostly of clear glass that has an average refractive index of 1.5058, which is the index of a natural glass containing 70 percent silica, thus indicating a rhyolitic composition (George, 1924, p. 365). Minor amounts of quartz, feldspars, biotite, and diatoms are present. In color, the pumicite ranges from grayish-white through pink to brick red. The redness is caused by an iron oxide stain. Local alteration, especially in several layers near the base of the sequence has developed a pink colored clay. Fractures are filled locally by brown opaline silica.

Lying above the pumicite is a layer of pumiceous sandstone which contains, especially near its base, beds of pumice lapilli-tuff up to 5 feet in thickness. The pumice fragments in the tuff are sub-rounded to sub-angular in shape, white to pale pinkish-brown in color, and range in size from less than $\frac{1}{16}$-inch to 4 inches in diameter. In addition to the pumice, the tuff contains minor proportions of rhyolite in well-rounded fragments. The glass in the pumice has a refractive index that ranges from 1.496 to 1.502, indicating a silica content of about 74 percent and a rhyolitic composition.

The layer of pumiceous sandstone that contains the beds of pumice lapilli-tuff is about 30 feet thick. It is well exposed in the Erickson pumice pit and forms a discontinuous capping upon the pumicite. The pumiceous sandstone is pink to buff-colored, and consists of approximately equal proportions of pumice, pumicite and crystal fragments. The pumice fragments are sub-rounded, white to pinkish-brown in color, and rarely exceed $\frac{3}{4}$ inches in size. In addition to the pumice, there are well-rounded fragments of lapilli-tuff containing fragments of pumice. The presence of lapilli-tuff fragments in the pumiceous sandstone indicates that some of the pumiceous material was derived from beds of well-consolidated tuff by erosion. The pumice and lapilli-tuff fragments are enclosed in a matrix of sand and pumicite that is firmly cemented with clay and iron oxide. Since nearly all of the matrix material passed through the 20-mesh screen, microscopic examinations were made of all screen sizes below and including the 20-mesh screen. A bromoform separation yielded less than 1 percent of heavy minerals which include ilmenite, magnetite, epidote, zircon, green and brown hornblende, augite, hypersthene, sphene, biotite, muscovite, garnet, and rutile. This list of heavy minerals is comparable to one prepared by MacDonald (1941, p. 265) from the sand fraction obtained from sandy pumice gravels of the Friant formation at Lanes Bridge, about 7 miles southwest of Friant.

Screen analysis of pumiceous sandstone from the Erickson pumice quarry. Analysis made by the writer in the laboratory of the Division of Mines.

Screen size	Percent retained	Accumulative Percent retained
10-mesh	7.15	16.99
20-mesh	14.61	31.60
30-mesh	16.15	47.75
40-mesh	17.75	65.50
50-mesh	8.04	73.54
60-mesh	5.51	79.05
80-mesh	5.65	84.70
100-mesh	3.11	87.81
140-mesh	3.05	90.86
200-mesh	5.89	96.75
250-mesh	3.25	100.00

Mineralogical constitution of sand fraction of the pumiceous sandstone from the Erickson pumice quarry. Analysis made by writer in laboratory of the Division of Mines.

Size	Percent quartz and feldspar	Percent micas	Percent hornblende and augite	Percent volcanic glass
20-mesh	45-50	tr	tr	45-50
30-mesh	45-50	tr	tr	45-50
40-mesh	55-60	tr	tr	40-45
50-mesh	60-65	5	tr	30-35
60-mesh	60-65	5	tr	30-35
80-mesh	70-75	tr	tr	25-30
100-mesh	70-75	tr	tr	25-30
140-mesh	75-80	tr	tr	20-25
200-mesh	75-80	tr	tr	20-25
250-mesh	80-85	tr	tr	15-20

Pumice Deposits

During construction of the Friant Dam, it was found that the waters to be impounded behind the dam would cover a large deposit of pumice. Arrangements were made with the U. S. Bureau of Reclamation to remove the pumice and a total of 103,000 cubic yards were stockpiled on land above the high water mark (Logan, 1951, p. 527). The pumice is owned by the McKenzie estate and very little of it has been used since it was stockpiled.

Pumice and Pumicite Mining Company's Deposit. Location: sec. 1, T. 11 S., R. 20 E., M. D. M., about 2 miles north of Friant. Ownership: Mrs. Eva V. Erickson, Box 98, Friant, California.

Pumiceous sandstone is quarried from the Erickson pit by the Pumice and Pumicite Mining Company in the SW $\frac{1}{4}$ sec. 1, T. 11 S., R. 20 E., M. D. M., from a deposit that shows a maximum thickness of about 30 feet (fig. 41). The quarry when visited in fall of 1954 measured about 300 feet long, 150 feet wide, and 10 to 15 feet deep. The sandstone is well consolidated and is dug with a D-7 Caterpillar which further breaks the sandstone by running over it. The crude pumiceous sandstone is stockpiled under an open shed. From the shed the material is conveyed by belt to a vibrating screen with a $\frac{3}{8}$-inch opening. The oversize passes to a hammer mill for further crushing, and the minus $\frac{3}{8}$-inch material is lifted by bucket elevator to storage bins.

The property was opened up in the late 1920's, and has been in almost continuous operation since then.

The crushed and screened material is used as aggregate in making concrete building blocks (fig. 42).

Pumicite Deposits

California Industrial Minerals Company Deposit. Location: sec. 1, T. 11 S., R. 20 E., M. D. M., about 2 miles north of Friant, California. Ownership: Forrest S. Taylor and Louisa M. Taylor.

In the Taylor pit is a bed of pumicite about 20 feet thick overlain by a 20- to 25-foot-thick layer of buff-colored sandstone that contains several distinct 8-inch beds of grayish-brown clay (fig 43). The pumicite bed rests upon a layer of greenish sand. Exposed in the pit within the pumicite is a lenslike body of grayish-colored silty sand. This lens has an exposed length of 40 feet and may be as much as 10 feet thick. Similar lenses of silty sand have been encountered before in this pit and in drill holes.

The pumicite ranges in color from grayish-white to brick-red. The bottom foot of pumicite in the pit is very red, and when completely saturated with water, it tends to flow like soft putty.

Mining is done in a quarry which in 1954 measured about 100 feet long, 75 feet wide, and 30 feet deep.

In mining the pumicite the overburden is stripped back from the quarry face by a D-7 Caterpillar. The pumicite is blasted, then dug and loaded into trucks by a $\frac{1}{2}$-cubic yard shovel and hauled to the processing plant at Friant. At the plant the pumicite is dumped into a hopper from which it passes into a dryer. A furnace that burns crude oil heats air which is forced by a fan to a heater where the moisture is removed from the pumicite. The pumicite, which averages about 85 percent minus 325-mesh, is mostly removed by a Multicyclone dust collector. It is packaged in 101-pound paper bags and marketed under the trade name "Frianite AC3X." The material collected in the baghouse is nearly all minus 325-mesh and is packaged in paper bags and sold as Frianite B4X. (Logan, 1950, p. 463).

Ol' Rebel Minerals, Inc. (Formerly Pumice Industries). Location: sec. 6, T. 11 S., R. 20 E., M. D. M., about $1\frac{1}{2}$ miles north of Friant, California. Ownership: Edward A. Wagner, Friant, California; leased to Ol' Rebel Minerals, Inc., Carl H. B. Morrison, president, 140 Harbard Avenue, Fresno, California.

The pumicite on the Wagner Ranch occurs in several distinct beds which have been prospected by means of a series of drill holes, trenches, and partly caved tunnels (fig. 44). At the quarry, which is on the hillside about 200 feet west of Cottonwood Creek, pumicite has been well exposed by bench workings 600 feet long and 40 feet deep. In this quarry the pumicite occurs in distinct beds that differ in color, grain size, and thickness. In downward succession the section in the quarry shows about 2 feet of pumiceous soil, a dirty-gray layer of pumicite about 6 feet thick that probably derives its color from the overlying soil, a 15-foot layer of white pumicite that shows ripple marks and thin laminations, a thin layer of pinkish-gray clay that ranges in thickness from a fraction of an inch to several inches, and numerous beds of pink pumicite as much as 12 inches thick that alternate with thin layers of pinkish-brown clay. The lowest pumicite bed, which is about 8 inches thick and brick-red in color, rests upon a layer of greenish-gray sand. Scattered throughout the entire pumicite section are numerous fractures that are filled in part with brown silica.

The pumicite is dug with a bulldozer which is used to push the pumicite to a plant where it is dried, screened, and packaged for use.

Other Deposits. In the western part of Amador County, about 5 miles west of Ione, pumicite is being mined from a flat-lying bed, about 10 to 15 feet thick that occurs between sediments of the Mehrten (Mio-Pliocene?) and Ione (Eocene) formations. The pumicite is used in the chemical industry.

In addition to the occurrences of pumice and pumicite in Fresno, Amador, and Madera counties, the Nomlaki tuff (Pliocene) is prominently exposed for 40 miles along the west side of the Sacramento Valley from Gas Point on Cottonwood Creek to Rice Creek, about 4 miles southeast of Paskenta. It is also exposed in stream cuts along the east side of Sacramento Valley.

This tuff has been used as a horizon marker in geological investigations of the west side of the Sacramento Valley (Anderson, 1939, p. 243). It ranges in thickness from 15 feet at its most southerly exposure to 300 feet along Bear Creek near Inwood, Shasta County. The tuff shows marked variation in character. At its type locality, near the former headquarters of the Nomlaki Indian Reservation, about 6 miles northeast of Paskenta, the tuff is about 40 feet thick and consists of at least four distinct layers that have slightly different characteristics. In descending order these consist of 20 feet of pale brownish-yellow tuffaceous silt; a 10-foot layer of light gray tuff composed of pumice fragments, as much as half an inch in diameter, in a fine-grained matrix; a 2-foot layer of deep salmon-pink tuff composed of white pumice fragments 8 inches in maximum diameter; and a bottom layer, whose base is not exposed, composed of light, salmon-pink tuff with white pumice fragments as much as $1\frac{1}{4}$ inches in diameter (Anderson, 1939, p. 244).

Much of the Nomlaki tuff is poorly consolidated, but at a few localities it is massive, moderately indurated, and shows columnar jointing. The general character of the tuff, the presence of columnar jointing in thick sections, lack of sorting, and the widespread distribution of pumice fragments and glass-rich fragments indicate a nuee ardente origin for the Nomlaki tuff. The better consolidated occurrences of Nomlaki tuff are suitable for use as building stone. It was quarried for this purpose on South Cow Creek, 3 miles east of Millville, and at the headquarters of the old Nomlaki Indian Reservation in Tehama County.

Sierra Nevada

The Sierra Nevada, as considered here, includes the Sierra Nevada—a range nearly 400 miles long that extends from Lake Almanor in Plumas County southeast to Antelope Valley in southern Kern County and the Tehachapi Mountains west of Antelope Valley. In width, the Sierra Nevada region averages about 70 miles, being bounded on the west by the Great Valley, and on the east by the Owens and Indian Wells Valleys. Much of the Sierra Nevada consists of various types of Mesozoic granitic rocks and older metamorphic rocks. Extensive areas in the northern part contain middle and late Tertiary volcanic rocks.

Both pumice and pumicite have been mined from tuffs in the Sierra Nevada. Small amounts of aggregate pumice have come from extensive tuffs of late Tertiary age in Placer and Calaveras counties, and pumicite from a series of tuffaceous sediments of probable Miocene age in southeastern Lassen County.

The tuffs from which much of the pumice has been mined are moderately well consolidated. They are rhyolitic in composition and range in color from light gray to buff. The tuffs contain pumice fragments that range in size from impalpable dust to angular fragments as much as 1 inch or more in diameter.

The pumicite, on the other hand, occurs in well-bedded deposits of subaqueous origin that are loosely consolidated. The material is dull grayish-white and ranges in size from minus 325-mesh to 1 millimeter in diameter.

During the widespread volcanism of the late Tertiary, a thick blanket of rhyolite ash was deposited upon the uneven surface of a pre-Cretaceous tuff. The ash was largely removed as the streams reoccupied and incised their channels. Where the ash was removed, fragmental andesite erupted from vents in the Sierra Nevada took its place; in those patches where the tuff remained, the andesite capped it. Some of the andesite was later stripped away by erosion, but a large part of it still covers extensive areas (Lindgren, 1911, p. 25, and Curtis, 1954, p. 454).

Pumice Deposits

Peirano Quarry. Location: sec. 27, T. 3 N., R. 13 E., M. D. M., near Altaville. Ownership: John Lemue, Angels Camp, owns the property which is leased to Jupiter Lumber Company, Deb Bentley and Hugh Preston, owners, Hathaway Pines, California.

Rhyolite pumice is currently being quarried from a prominent tuff layer half a mile northeast of Altaville (fig. 47). Here, the tuff is about 130 feet thick. It caps a low hill and is underlain by green schist and late Tertiary gravels (Turner, 1894, p. 5). Only the top 20 feet of the tuff layer is quarried. This tuff is massive, hard, light grayish-white in color, and consists principally of small glass shards, some glassy quartz and feldspar, and dark-brown biotite. The crystalline constituents comprise less than 10 percent of the tuff. Lapilli of pumice are rare in the layer of tuff that has been quarried. However, in the tuff layer beneath the quarried tuff layer, lapilli of pumice are moderately common as are rounded lapilli of gray and pink colored rhyolite.

The tuff has no overburden and is quarried from the south side of the hill. The quarry in February 1955 measured about 40 feet long, 25 feet wide, and 15 feet deep. The tuff is firmly consolidated and breaks into angular blocks and fragments rather than into individual pumice fragments. It is blasted down, loaded into an ore car, pushed some 40 feet to the outer edge of the quarry, then dumped into a chute leading to a jaw crusher. From the crusher the broken rock is conveyed by a bucket elevator to a double-deck screen which produces two sizes of crushed tuff, minus $\frac{3}{4}$ plus $\frac{3}{8}$ inch and minus $\frac{3}{8}$ inch (fig. 33). These are stored in steel bins. The smaller size is used in the making of concrete blocks sold under the trade name "Tuftile"; the larger size is used as road metal, road gravel, decorative gravel, and terrazzo. The crushed tuff is trucked to Murphys, California, some 6 miles for further processing.

Irvine Quarry. Location: sec. 25, T. 5 N., R. 11 E., M. D. M., near Mokelumne Hill. Ownership: The New Materials and Metals Company, Robert Irvine, president and secretary-treasurer, Soledad, Monterey County, California.

The Irvine quarry is high on a steep mountain side in a layer of rhyolite tuff which rests upon quartz gravels and steeply tilted older metamorphic rocks. The tuff layer has a gentle southwesterly dip, and ranges in thickness from 20 to 60 feet. The tuff is fine-grained, firmly consolidated, and ranges in color from pinkish buff to light gray.

Three quarry openings have been made into the tuff layer. The largest opening is about 50 feet long, 20 feet wide, and has a face about 40 feet high. The smallest quarry opening is about 35 feet long, 10 feet wide, and has a face about 15 feet high.

The Irvine quarry has been worked intermittently for building and terrazzo. It was inactive in February 1955.

Sierra Placerite Corporation Quarry. Location: sec. 29, T. 10 N., R. 12 E., M. D. M. Ownership: W. B. Willson, Route 3, Box 252, Placerville, California.

The rhyolite tuff at the Placerite Products quarry which is near the base of a west-trending ridge rests upon quartz gravels and older metamorphic rocks, and ranges in thickness from a few feet to 150 feet. The tuff is fine-grained, firmly consolidated, and yellowish to buff in color. It is quarried from a quarry which in February 1955 measured about 150 feet long, 100 feet wide, and 10 to 15 feet deep.

Most of the tuff is sawed into flagstone and ashlar strips and fired to a temperature of 2000°F. During the course of firing, the tuff changes color from buff to deep red or brown. Some of the tuff is sawed into specialty products such as bookends and lamps, and some has been sold for use in terrazzo.

Warren Pumice Deposit. Location: sec. 12, T. 3 N., R. 9 E., M. D. M., about 5 miles southwest of Burson, Calaveras County. Ownership: H. D. Warren, Route 1, Box 295, Valley Springs, California.

The Warren pumice deposit is in low rolling hills which are capped by a layer of rhyolite tuff. The rhyolite tuff layer, which rests upon the Ione formation, forms very poor outcrops and is well exposed only in test pits and pumice quarries. The tuff layer has an exposed thickness of 20 feet and consists of alternating lenselike beds of pumice conglomerate and tuffaceous sandstone (figs. 45, 46). The lenses of pumice conglomerate range from a few inches to 3 feet in thickness, and from 1 foot to as much as 40 feet in length. The beds of tuffaceous sandstone have about the same range in thickness as the pumice conglomerate beds, but are as much as 100 feet in length. The tuffaceous sandstone is buff-colored, medium to fine-grained, and crossbedded. The pumice conglomerate is moderately consolidated and consists of angular and well rounded pumice pebbles set in a fine-grained matrix of pumicite. The rounded pumice pebbles are grayish-white and range from $\frac{1}{8}$

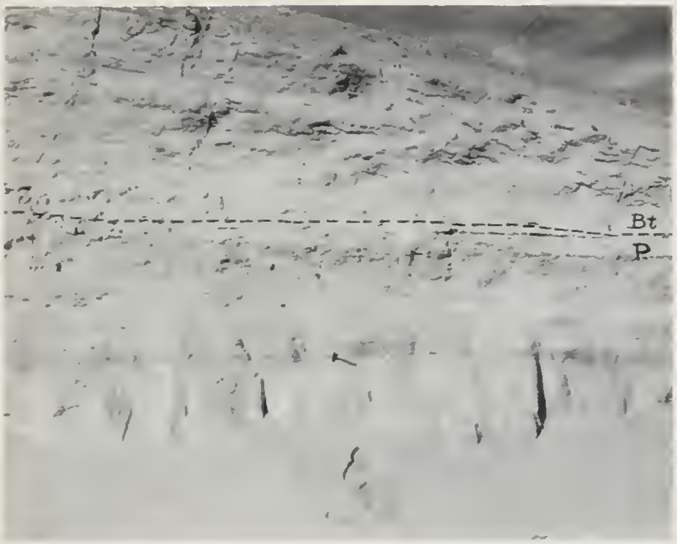

Figure 16. Pumice of subaqueous origin in quarry face at Insulating Aggregates, Incorporated pumice deposit, Mono County. The pumice layer (P) here is about 12 feet thick and is overlain by loosely consolidated Bishop tuff (Bt). Scale is indicated by pick handle which is 12 inches long. Observer faces west.

Figure 17. Pumice of sub-aerial origin, southern Coso Range, Inyo County. Dark layer separating successive pumice layers is soil. Lack of sorting and lack of well-defined bedding are noticeable in these pumice layers. Scale is indicated by pick handle which is 12 inches long.

Figure 18. Close-up of pumice of nuee ardente origin, Van Loon "Fines" pumice deposit, Yellowjacket Spring area, Mono County. The pumice fragments are angular, pale pinkish in color, and range in size from dust to chunks 5 inches across. Lack of sorting and bedding are easily seen in this photograph. The scale is indicated by the 6-inch rule.

Figure 19. Crossbedding in reworked pumice at the Snoeshoe pumice deposit, Yellowjacket Spring area, Mono County, where reworked pumice as well as pumice of subaqueous origin are exposed. Scale is indicated by 6-inch rule.

Figure 20. Quarry in block pumice, U. S. Pumice and Supply Company's pumice deposit on the eastern side of Southern Coulee, Mono Craters, Mono County. Blocks of pumice are blasted down, loaded into trucks, and hauled to the sawing plant at Lee Vining. Flow banding and jointing are plainly visible in the lower central part of the photograph. Scale is indicated by the figure on the floor of the quarry. Observer faces northwest.

FIGURE 21. Pumicite in the quarry of the California Industrial Minerals Company, near Friant, Madera County. The pumicite is well-bedded, and unconformably overlain by tuffaceous sandstone. The pumicite bed is flat-lying and here it is about 12 feet thick. Scale is indicated by the pick handle which is 12 inches long. Observer faces north.

FIGURE 22. Volcanic cinder quarry, Great Northern Railroad, southeast side of East Sand Butte, a late Quaternary cinder cone near Tionesta, Modoc County. Layering represents repeated volcanic outbursts. Solid blocks of rock on quarry floor and in quarry face represent fragments of volcanic bombs. The cinders from this cone are used for railroad construction. Observer faces north.

FIGURE 23. Aerial view of the northern part of Glass Mountain, eastern Siskiyou County showing location of the pumice operations: (1) Fouch Pit, (2) Enloe Pit, (3) Boorman Pit, (4) Madsen block pumice, and (5) U. S. Pumice and Supply Company's block pumice. Pumice for aggregate purposes is mined from loosely consolidated pumice tuff-breccia (TB) which lies upon earlier flows of basalt. Pumice for scouring blocks is obtained from the upper surface of the Glass Mountain rhyolite obsidian flow (RO) which rests upon the pumice tuff-breccia as well as an earlier composite flow of rhyolite-dacite (RD). Aerial photograph courtesy of the U. S. Department of Agriculture, Forest Service.

FIGURE 24. Fouch pumice pit, Glass Mountain area, eastern Siskiyou County. The pumice mined from this pit is obtained from a layer of loosely consolidated pumice tuff-breccia (P) about 12 feet thick. The northern tip of Glass Mountain obsidian flow (O) is in the background. The pumice mined from this pit is used as aggregate in building blocks. Pumice for scouring blocks is obtained from the pumiceous crust on top of the obsidian flow. Observer faces east.

FIGURE 25. Close-up of the pumice in the face of the Fouch pumice pit, Glass Mountain area, eastern Siskiyou County. The pumice fragments range in size from 1/16-inch to 3 inches, and are poorly sorted. Scale is indicated by knife which is 4 inches long.

FIGURE 26. Block of pumice, typical of the pumice mined on top of Glass Mountain, eastern Siskiyou County. Scale is indicated by knife which is 5 inches long.

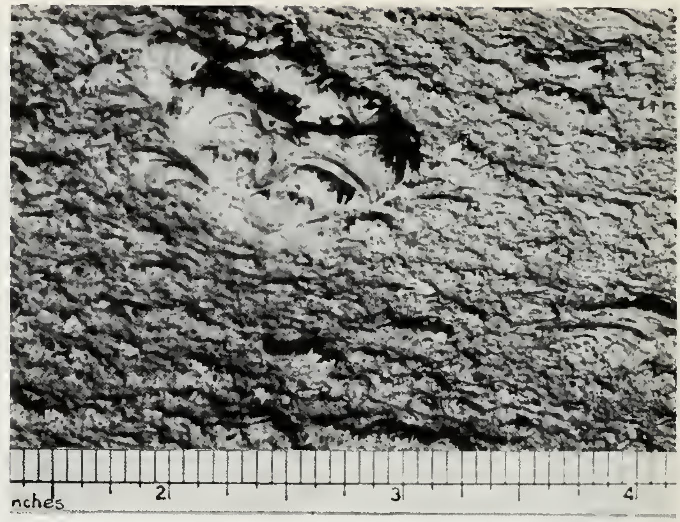

FIGURE 27. Pumice from the top of Glass Mountain, eastern Siskiyou County. Hand specimen showing size and shape of openings. Similar to the pumice that is being cut into blocks and sold as grill cleaners.

FIGURE 28. Portable rock saw which is used to cut lumps of pumice into scouring blocks. Stockpile of uncut blocks to the right of the saw is obtained from the top of Glass Mountain. The rough, craggy rock in the background is glassy rhyolite-dacite (RD), a composite flow which underlies the Glass Mountain obsidian flow (O). Light colored material between the saw and the flow of rhyolite-dacite is pumice which is being used as aggregate in concrete blocks. Observer faces south.

FIGURE 29. Pumice screening and crushing plant of the Thompson Pumice Company, Tionesta, western Modoc County. Pumice which is mined at the Fouch and Enloe pumice pits at Glass Mountain, about 11 miles west of Tionesta, is prepared here for shipment by rail or truck to markets in California. Observer faces north.

FIGURE 30. Chimney rocks, near Surprise siding, Modoc County. Chimney rocks are composed of compacted and cemented rhyolite lapilli tuff which has been eroded into their present form. The tuff at the Chimney rocks is of unknown thickness. It is well exposed on the west side of the north fork of the Pit River, in the background of the photograph, where it is overlain by a flow of the Warner basalt. Observer faces northwest.

FIGURE 31. Paint Pot Crater, a volcanic cinder cone covered by grayish-white pumice, near Little Glass Mountain, eastern Siskiyou County. Upright posts at base of the cone near center of photograph represent remains of early pumice mining operation in Siskiyou County. Observer faces northwest.

FIGURE 32. Pumice Stone Mountain, near Little Glass Mountain, eastern Siskiyou County. Pumice Stone Mountain is a volcanic cinder cone covered by a mantle of grayish-white pumice similar to the material that covers the ground in the foreground. Observer faces southwest.

FIGURE 33. Cinder quarry of the Shastalite Brick Company, near Hotlum, Siskiyou County. Cinders are mined from a volcanic cinder cone and are used as aggregate in the manufacture of concrete building blocks. Observer faces northeast.

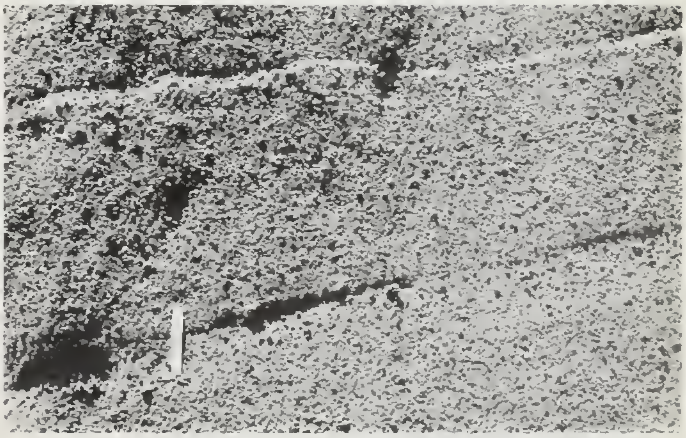

FIGURE 34. Close-up of the volcanic cinders in the Shastalite Brick Company's cinder quarry, near Hotlum, Siskiyou County. Scale is indicated by six-inch rule.

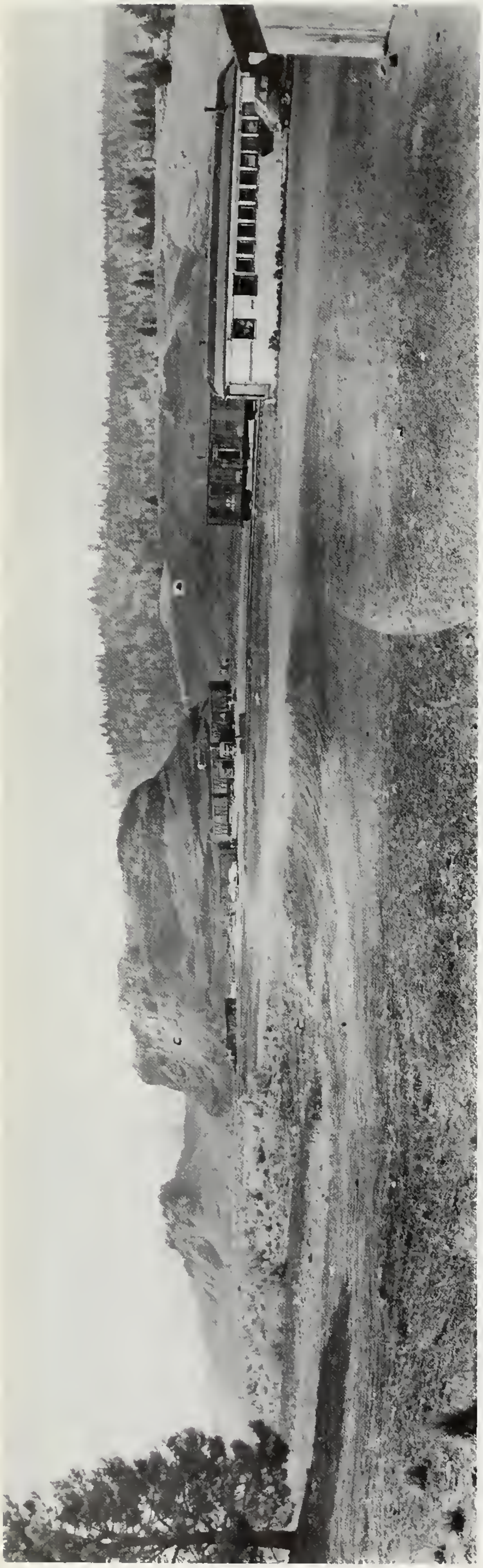

FIGURE 35. Panorama of the Southern Pacific volcanic cinder operation at the Kegg pit, north central part of Siskiyou County, California. The central core (C) of lava and a low partly encircling rim of volcanic cinders is all that remains of a former cinder cone which measured about 3000 feet across at the base and stood about 125 feet above a small alluviated valley. Observer faces in a northwesterly direction. Photograph courtesy of the Southern Pacific Company.

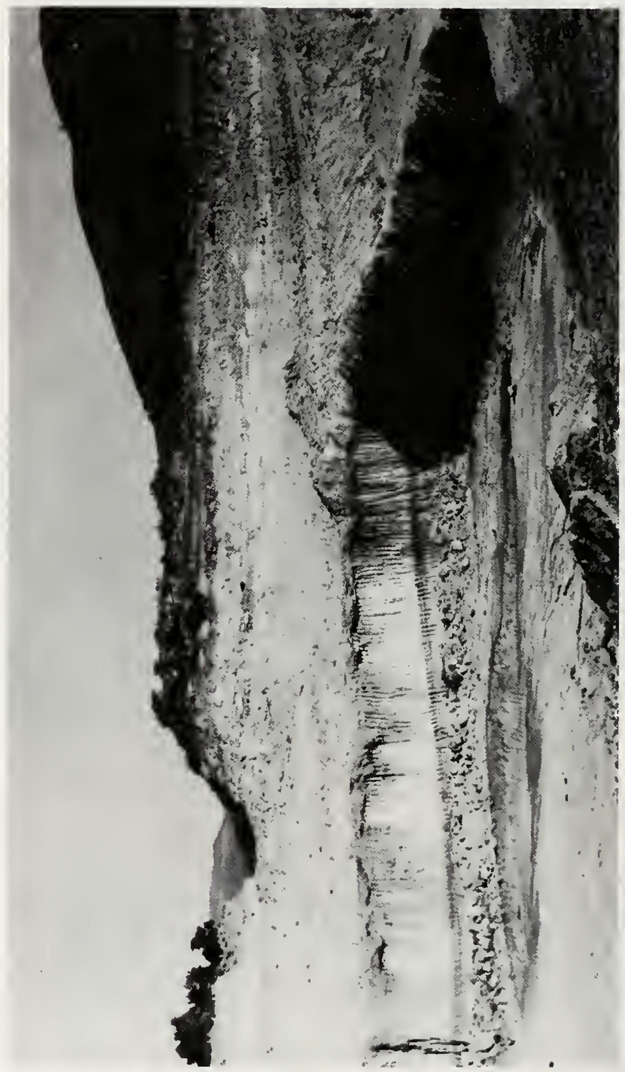

FIGURE 36. Pumice quarry of the Basalt Rock Company, Napa County. Pumice was mined here from a layer of massive pumice tuff-breccia about 150 feet thick and used as aggregate in the manufacture of concrete building blocks. Observer faces north.

Figure 37. Cicero pumice quarry, Napa County. Pumice layer of unknown thickness is mined by open pit methods and the pumice used as aggregate for concrete building blocks. Observer faces north.

Figure 38. Coleman quarry, near Clear Lake Park, Lake County. Rock in the quarry is a highly vesiculated rhyolite obsidian which is being mined and used as aggregate in concrete and plaster. The hills in the background consist of Franciscan greenstone. Observer faces northeast.

Figure 39. Highly vesiculated rhyolite obsidian as exposed in the face of the Coleman quarry, near Clear Lake Park, Lake County. Rock is strongly banded and individual bands are caused by differences in color and degree of vesiculation. Coarsely vesiculated glasses are usually darker than the minutely vesiculated glasses. The bands are essentially flow bands, and in this quarry they show unusually steep dips. Scale is indicated by pick handle which is 12 inches long.

Figure 40. Quarry, Alvarnez pumice deposit, Contra Costa County. Pumice for aggregate purposes was mined here from the Pliocene Lawler tuff. Observer faces northwest.

FIGURE 41. Quarry and screening plant of the Pumice and Pumicite Mining Company (Erickson's property), near Friant, Madera County. Aggregate for concrete building blocks is obtained from a layer of tuffaceous sandstone. The tuffaceous sandstone is dug with a rooter pulled by a Caterpillar tractor and pushed to the stockpile and thence to the screening plant and storage bins. Observer faces north.

FIGURE 42. Block plant and storage yard of the Pumice and Pumicite Mining Company, near Friant, Madera County. Several sizes and shapes of concrete blocks are made with the tuffaceous sandstone aggregate and portland cement. After the blocks are made, they are steam cured and then stacked outside in the drying yard. Observer faces north.

FIGURE 43. Close-up of the pumicite as exposed in the quarry of the California Industrial Minerals Company, near Friant, Madera County. Individual beds of pumicite range from a fraction of an inch to several inches in thickness. Here one can see the contact between the pumicite and a lense of greenish-gray sand. Such lenses of sand have been encountered in all pumicite operations in the Friant area. Scale is indicated by the pencil which is 5 inches long.

FIGURE 44. Tunnels and quarry face of the Ol' Rebel Minerals Incorporated pumicite deposit, near Friant, Madera County. Pumicite layer is about 15 feet thick, and is overlain by fine-grained tuffaceous sandstone. Observer faces northeast.

Figure 45. Warren pumice quarry, Calaveras County. Pumice for aggregate purposes is mined from layers of pumice tuff in the Miocene (?) Valley Springs formation. Observer faces northeast.

Figure 46. Well-rounded pumice fragments in reworked pumice at the Warren pumice deposit, Calaveras County. Scale is indicated by pick handle which is 12 inches long.

Figure 47. Peirano pumice quarry, near Altaville, Calaveras County. Massive, consolidated rhyolite tuff of the Miocene (?) Valley Springs formation is mined here and used as aggregate in concrete and terrazzo. Observer faces north.

Figure 48. Crushing and screening plant at the Peirano pumice deposit, near Altaville, Calaveras County. Observer faces northwest.

FIGURE 49. Pumicite (P) and tuffaceous sands (Ts) as exposed in a railroad cut at the Red Rock pumicite deposit in southeastern Lassen County. The pumicite is well-bedded, and is only partially exposed. It is overlain by fairly well-bedded tuffaceous sands and silts. Scale is indicated by the pick handle which is 12 inches long. Observer faces north.

FIGURE 50. Close-up of the pumicite (P) and overlying tuffaceous sands and silts (Ts) exposed near the entrance to a shallow shaft at the Red Rock pumicite deposit, southeastern Lassen County. The bedding dips to the northwest, away from the observer. Scale is indicated by the pick handle which is 12 inches long.

FIGURE 51. Panorama of the western side of Mono Craters, Mono County. (1) Panum Crater, (2) U. S. Pumice and Supply Company's mine, (3) Basalt Hill, (4) Northern Coulee, (5) Russell Peak, (6) Johnson Peak, (7) Southern Coulee, (8) Sierra Nevada, and (9) U. S. Highway 395.

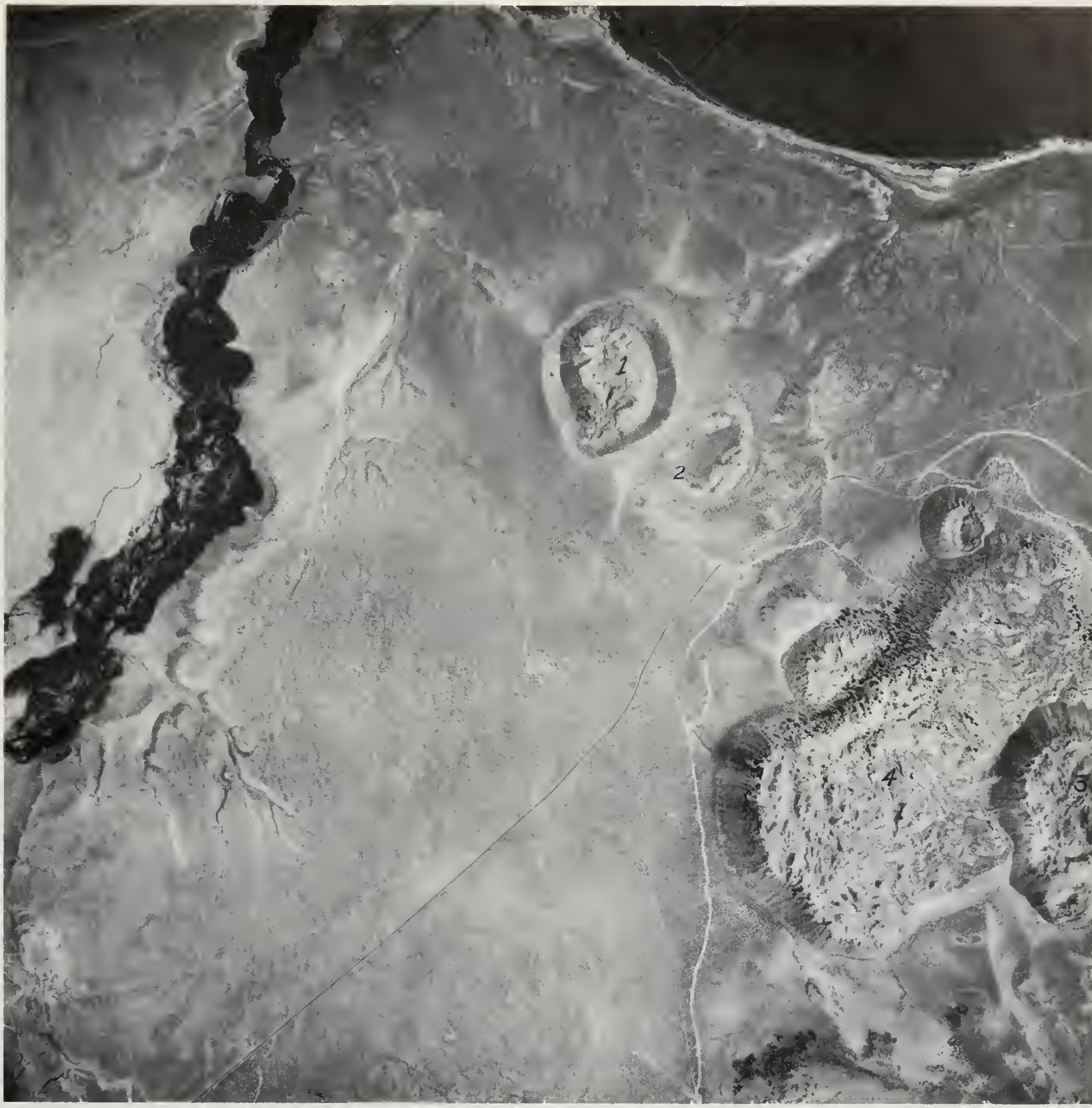

FIGURE 52. Aerial view of the northern part of the Mono Craters, Mono County, showing (1) Panum Crater, (2) U. S. Pumice and Supply Company's pumice mine, (3) Northern Coulee and (4) Northwest Coulee. Aerial photograph courtesy of the U. S. Department of Agriculture, Forest Service.

FIGURE 53. Quarry, U. S. Pumice and Supply Company, near Panum Crater, Mono County. Blocks of pumice to be cut into grill blocks are mined from the northwest part of a volcanic dome whose surface expression is indicated by a low lapilli rim and several spires of pumiceous obsidian. Blasting is required to break down the pumice from the quarry face. Observer faces east.

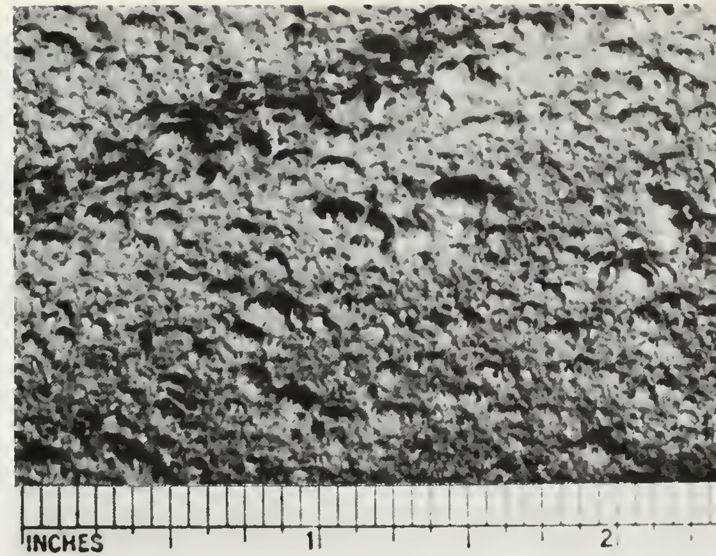

FIGURE 54. Pumice from the eastern side of Southern Coulee, Mono Craters, Mono County. Typical of the pumice that is mined in the Mono Craters area and cut into blocks and marketed as grill cleaners.

FIGURE 55. U. S. Pumice and Supply Company's plant at Lee Vining, Mono County, where blocks of pumice are trimmed and cut into blocks of several sizes to be used as scouring bricks and grill cleaners. Observer faces east.

FIGURE 56. Quarry and loading chute at the Sand Doon pumice deposit, Mono County. The pumice layer of unknown thickness dips gently toward the east. It is overlain by dirty gray pumiceous soil. Scale is indicated by the figure on the quarry floor. Observer faces northwest.

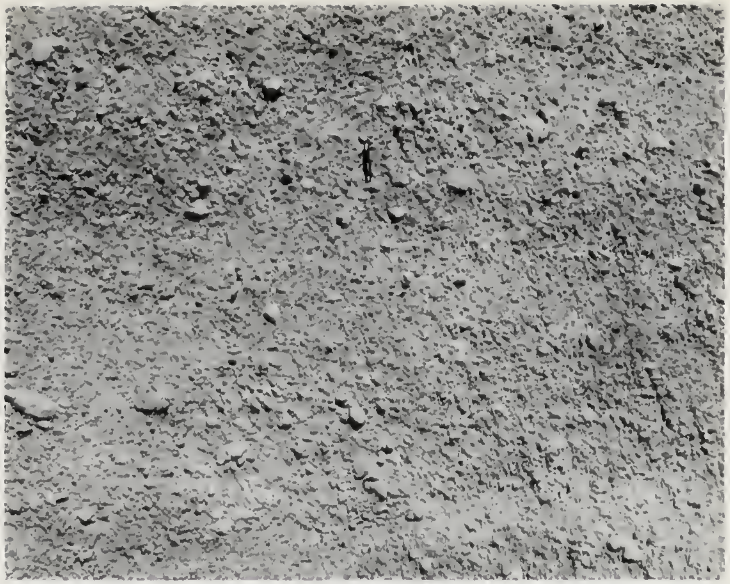

Figure 57. Close-up of the pumice in the face of the quarry at the Sand Doon pumice deposit, Mono County. The pumice fragments are angular, light gray in color, and range in size from 1/16-inch to 5 inches. Sorting is nearly absent and bedding is very poorly defined. Scale is indicated by knife which is 4 inches long.

Figure 58. Screening plant at the Buckley pumice deposit, near Benton, Mono County. Quarry is to the left of the photograph. Pumice from the quarry is pushed by bulldozer to a ramp (R) over a grizzly and passes by way of a bucket elevator to a series of screens to produce pumice for aggregate. Observer faces north.

Figure 59. Victory pumice deposit, Mono County. Here pumice for aggregate purposes is mined from a layer of pumice tuff of unknown thickness. A pumiceous soil overburden up to 4 feet thick is removed before the pumice is mined. Observer faces northeast. Scale is indicated by figure in the floor of the quarry.

Figure 60. Quarry, White Rock Placer pumice deposit, Mono County. The pumice here occurs in several relatively flat-lying layers overlain by dirty-gray pumiceous soil. Scale is indicated by the figure on the quarry floor. Observer faces northwest, toward the Benton Range.

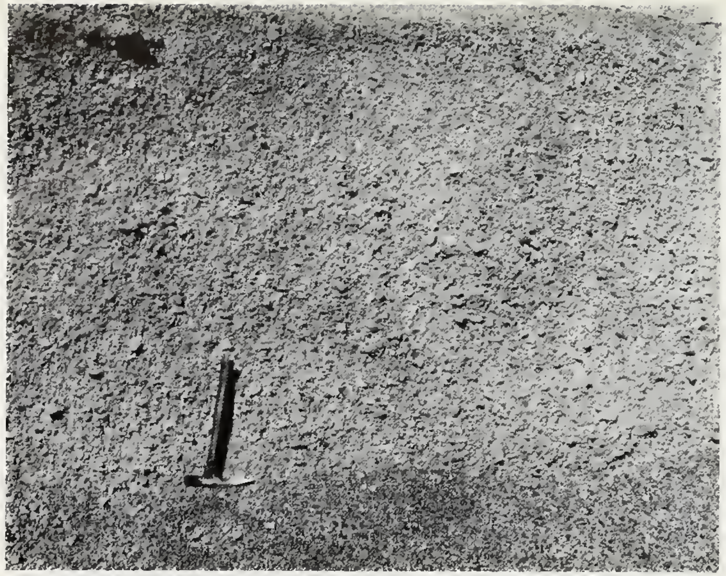

Figure 61. Close-up of the pumice as exposed in the quarry face at the White Rock Placer pumice deposit, Mono County. The pumice fragments are angular, grayish-white, poorly sorted, and range in diameter from 1/16-inch to 4 inches. Scale is indicated by pick handle which is 12 inches long.

Figure 62. Faulted pumice beds at the Van Loon "Fines" West pumice deposit, Mono County. Two pumice beds are separated by a dark layer of sandy pumiceous soil. The upper pumice bed, about 20 feet thick, is overlain by dirty-brown pumiceous soil overburden. Scale is indicated by the figure on the quarry floor. Observer faces northwest.

Figure 63. Pumice layer and tunnels at the Rae-Spencer pumice deposit, Mono County. Several long tunnels were driven into the pumice layer and the pumice was hauled to a nearby screening plant for processing into aggregate for markets in Southern California. Scale is indicated by the figure on the quarry floor. Observer faces southwest.

Figure 64. Bench cut in pumice at the Snoeshoe pumice deposit, Mono County. There are several pumice layers exposed in this quarry face and the aggregate thickness of the pumice is about 40 feet. Scale is indicated by the figure on the quarry floor. Observer faces northeast.

FIGURE 65. Quarry in the pumice at the Comstock pumice deposit, Mono County. The contact between the pumice and the overlying fanglomerate is well shown here. The pumice is well-bedded and is at least 18 feet thick. Scale is indicated by the figure on the quarry floor. Observer faces southeast.

FIGURE 66. Quarry in the pumice at the Comstock pumice deposit, Mono County. The darker fanglomerate unconformably overlies the pumice. Scale is indicated by the figure on the quarry floor. Observer faces northeast.

FIGURE 67. Quarry face at the Comstock pumice deposit, Mono County. The pumice is well-bedded and the contact between it and the overlying fanglomerate is unconformable although it does not appear to be so. Scale is indicated by the figure. Observer faces east.

FIGURE 68. Quarry and screening plant at the Van Loon "Fines" pumice deposit, near Bishop, Inyo County. The dark rock in the left-hand portion of the photograph is semi-consolidated Bishop tuff. In the distance are the White Mountains. The pumice (P) is scraped up with a bulldozer which pushes the pumice to a screen and loading ramp. Observer faces northeast.

FIGURE 69. Quarry, Insulating Aggregates, Inc., Mono County. The pumice (P) occurs in a layer which is overlain by loosely consolidated Bishop tuff (Bt). Observer faces west.

FIGURE 70. Crossbedded sand and gravel which underlie the pumice at the quarry of Insulating Aggregates, Inc. pumice deposit, Mono County. The gravels are overlain by a layer of pumice 2 feet thick which is separated from the main pumice layer by a thin bed of dirty-gray pumiceous sand. The crossbedded character of the lower sands and gravels indicates deltaic deposits. Scale is indicated by the pick handle which is 12 inches long. Observer faces west.

FIGURE 71. Processing plant, Insulating Aggregates, Inc., Mono County. At this plant quarry-run pumice is processed for use as aggregate in plaster and for other special uses. Observer faces northwest.

FIGURE 72. Quarry and screening plant at the Jamieson pumice deposit, Inyo County. The pumice layer (white) is overlain and underlain by dark fanglomerate. The pumice layer dips toward the west and was mined on a limited scale by open pit methods. Observer faces north.

inch to 8 inches in diameter. The angular pumice fragments are gray and range from ½ inch to 1 inch in diameter. Phenocrysts of black biotite and glassy quartz and sanidine are common in both pumices, and grains of these minerals constitute much of the sandy fraction of the tuffaceous sandstone.

The rounded pumice has undergone alteration and when it is saturated with water, it is easily broken and loses much of its crushing strength. Allen (1929, p. 412) discusses this alteration and suggests that the pumice has recrystallized and changed to montmorillonite. The gray, angular pumice, however, has not undergone alteration and remains as a strong material even when thoroughly saturated with water. Much of the pumice in Warren deposit is the rounded pumice.

Pumice has been mined from two separate quarries at the Warren pumice deposit (fig. 45). The first quarry was opened in 1942, a few hundred feet south of the Warren home. This quarry is shallow and in February 1955 measured roughly 85 feet square and 10 feet deep. The second quarry was started in the early 1950's, and in February 1955 measured about 175 feet long, 100 feet wide, and a maximum depth of 15 feet. In mining the pumice, the overburden, which consists largely of a few feet of pumiceous soil, is removed first and the pumice pushed to a loading ramp where it is screened as it is loaded into the truck. Only the minus ¾-inch material is used, the oversize is rejected.

Pumice mining at the Warren deposit has been intermittent since it was started in 1942, and has amounted to about 20 cubic yards per month.

Pumicite Deposits

Red Rock Pumicite Deposit. Location: sec. 2, T. 23 N., R. 17 E., and sec. 35, T. 24 N., R. 17 E., M. D. M., adjacent to the Western Pacific Railway, a few miles southwest of Red Rock, a small station in the southeastern part of Lassen County on the Western Pacific Railroad. Ownership: Property consists of 200 acres owned by the Galeppi family and leased to P. F. Frund, 1709 Bridgeway, Sausalito, California.

The Red Rock pumicite deposit is on the northwest side of Long Valley about three-quarters of a mile northwest of Long Valley Creek. The layers of pumicite are exposed along the southeastern slopes of low-rolling hills at the eastern base of the Sierra Nevada. The hills are for the most part eroded out of soft sedimentary rocks and rise from an elevation of 4,670 feet at the pumicite mine to 5,100 feet at the contact with basement granitic rocks about 1 mile farther northwest. The pumicite layers are a part of a section of sedimentary rocks that consists mostly of sandstone, siltstone, tuffaceous sandstone, and pumicite (fig. 49). The sedimentary rocks have been deformed and in the vicinity of the pumicite mine they dip 32° NW. and strike N. 35° E.

The pumicite layers are best exposed at the pumicite mine and in a railroad cut about 300 feet southwest of the mine. The basal pumicite layer exposed at the mine can be traced along its outcrop to the railroad cut where it forms the top pumicite layer in the exposed section. In general, the pumicite layers range in thickness from a few inches to 10 feet and have an aggregate thickness of at least 18 feet. The layers of pumicite are separated by thin beds of grayish-brown tuffaceous sandstone and siltstone that range in thickness from a fraction of an inch to a foot or more.

The following partial section was measured at the pumicite mine and railroad cut:

Partial section measured at Red Rock pumicite deposit and railroad cut.

Thickness in feet	Description
1–3	Soil, sandy and clayey. Sandstone, silty, fine-grained, tuffaceous in part, dirty gray in color; locally cross-bedded. This plus the soil constitutes the overburden, and ranges in thickness from a few feet to several hundred feet.
8–10	Pumicite, in part sandy and silty; made up of several layers of fine-grained, white pumicite separated by thin beds of cross-bedded, sandy pumicite. White pumicite layers range in thickness from 1 inch to 18 inches.
5	Pumicite, fairly coarse-grained, dirty gray in color; a few 1-inch beds of white pumicite.
½	Siltstone, tuffaceous, dirty gray.
1	Pumicite, very coarse-grained, white in color; in layers up to 3 inches in thickness.
5	Pumicite, well stratified in beds ranging from ½ inch to 3 inches; fine-grained, vertically jointed, grayish-white in color.
1	Sandstone, tuffaceous, dirty-gray in color.
3	Pumicite, fine-grained, grayish-white, vertically jointed, much limonite along joints; bottom not exposed.

The pumicite is fine-grained, light-gray in color, and compact. Much of the material is less than 200-mesh in size, and contains appreciable quantities of biotite, quartz, and feldspar.

The mining has been on a limited scale and the workings, which consist of a shallow incline shaft, are confined to the one layer that is 8 to 10 feet in thickness.

However, because the Red Rock pumicite deposit is near rail transportation, the additional cost of underground mining may not prevent its operation.

Basin-Ranges

The Basin-Ranges region is in the eastern part of California and consists of that part of the state that lies directly east of the Sierra Nevada scarp. It includes most of Inyo County and parts of Kern, Mono, and San Bernardino counties. Tertiary to Recent volcanic rocks are widely distributed throughout this section of California, and underlie extensive areas. They are especially abundant in Mono County.

Most of the pumice scouring bricks that have been produced in California have been obtained from the Mono Craters in Mono County, and a large proportion of the state's output of aggregate and abrasive pumice also has been mined from deposits in Inyo and Mono counties. Volcanic cinders for aggregate purposes are being produced from deposits in both Inyo and Mono counties.

The Basin-Ranges probably contain the greatest number of pumice, pumicite, and volcanic cinder deposits in California. These deposits occur in Tertiary to Recent volcanic rocks which cover extensive areas in the low mountains and the Volcanic Tableland that lie at the northern end of Owens Valley between the towering Sierra Nevada and the White Mountains, in the Coso Range at the southern end of Owens Valley, and in the El Paso Mountains of eastern Kern County.

In general, the deposits are grouped in geographic areas, and will be discussed in the following order: (1) Mono Craters, (2) Blind Spring Valley area, (3) Yellowjacket Spring area, (4) Bishop-Laws area, (5) Coso Range, and (6) El Paso Mountains.

Mono Craters Area

The Mono Craters area is in the west-central part of Mono County. The Mono Craters themselves are a group of conspicuous volcanic domes of late Pleistocene age and lie immediately south of Mono Lake. The Mono Craters consist mostly of obsidian and rise abruptly from a plain covered by a mantle of loose pumice ejecta. The domes were formed by the rise of viscous obsidian through narrow openings above the floors of shallow explosion pits. The sides of the domes are steep and their tops contain jumbled masses of collapsed spines, crags, and loosely piled blocks of brownish-gray pumice.

The pumice that covers the ground is in white, angular fragments that range from 1/16 of an inch to several inches in diameter. It is rhyolitic in composition and appears to consist almost wholly of glass. Crystals of quartz, feldspar, and dark-brown biotite are present in very minor proportions. The mantle of pumice ranges from a few feet to several tens of feet in thickness, and probably is thicker near the domes than in the outlying areas.

The tops of several domes are made up largely of loosely piled blocks of pumice (herein referred to as dome pumice which is used primarily for making scouring blocks). The dome pumice in the Mono Craters area is brownish-gray on weathered surfaces but light-gray on freshly broken surfaces. The rock is indistinctly streaked with light and dark-gray bands that range in width from a fraction of an inch to several inches. The bands apparently are an effect of flowage. Locally hard narrow ribs cut across the banding. These ribs are ordinarily less than 1 inch in width, are slightly darker in color than the other pumice, and appear to consist mostly of glass that is denser and less vesiculated than the enclosing rock. They are hard and wherever possible are avoided in mining operations.

The openings in the dome pumice are tubular and drawn out in the direction parallel to the flow banding. They have a wide range in size from 0.01 of an inch to 1 inch in diameter and from a sixteenth of an inch to 2 inches in length (fig. 54).

Quarrying operations for block pumice at the Mono Craters have exposed massive pumice beneath the loose pumice blocks on Southern Coulee and at Panum Crater. Near the southeastern part of Panum Crater, the northernmost and most perfect in the chain of volcanic domes at Mono Craters, massive pumice is exposed in a quarry (fig. 53) of a poorly exposed volcanic dome whose surface expression is more or less limited to several spires of massive dome pumice encircled by a low ridge of lapilli. Massive dome pumice is well exposed in the quarry to a depth of 40 feet, and drilling in the quarry passed through several hundred feet of massive pumice before encountering dense, vesiculated obsidian.

Minor amounts of volcanic cinders have been quarried from a cinder deposit at Black Point, on the north side of Mono Lake. The cinders are angular fragments of dark brownish-black olivine basalt that range from an eighth of an inch to one inch or more in diameter. The cinders form a cone that developed before the growth of the obsidian domes south of Mono Lake. Action of the waves in Mono Lake have all but destroyed the original cone and now one can recognize only the general form of the cone.

U. S. Pumice and Supply Company's Pumice Deposits. Location: secs. 18 and 19, T. 1 N., R. 27 E., and secs. 16 and 21, T. 1 S., R. 27 E., M. D. M., on the south side of Panum Crater, about 4½ miles southeast of Lee Vining, and on the Southern Coulee, about 10 miles southeast of Lee Vining, California. Ownership: The U. S. Pumice and Supply Company, Inc., 6331 Hollywood Boulevard, Los Angeles, California, Sheldon P. Fay, president, owns 12 claims in the vicinity of Panum Crater and 7 claims on the Southern Coulee. Six claims on Southern Coulee are leased from Frank Sam, Lee Vining, California.

The U. S. Pumice and Supply Company obtains pumice for making scouring blocks, which are used in restaurants and hotels for cleaning grills, from quarries at Panum Crater and Southern Coulee. The block-sawing plant is at Lee Vining. At the quarries only enough blasting is done to dislodge the large blocks of dome pumice and to break them into small blocks that can be loaded into trucks. Highgrade pumice blocks, ranging in size from 1 to 4 feet in diameter, are selected and hauled 8 miles to the block-sawing plant where they are stockpiled.

At the plant (fig. 55) the pumice blocks are first trimmed and then sawed into blocks by means of circular saws rimmed with carborundum. Late in 1953 blocks of two sizes were being prepared: 3 inches by 3 inches by 6 inches and 4 inches by 4 inches by 8 inches. In addition, several larger sizes of blocks with hollowed-out centers were being made for flower and plant pots. Saw cuttings and dust were being collected and sold as abrasive pumice. Reject and scrap pumice is stockpiled near the plant and a limited amount of this material is shipped to eastern cities where it is ground and marketed as an abrasive.

Only a small amount of aggregate pumice has been mined in the Mono Craters area.

Blind Spring Valley Area

The Blind Spring Valley pumice area is in eastern Mono County, and occupies much of Blind Spring Valley (plate 1, fig. 8). The area is about 6 miles long and 2 miles wide, and is bounded on the east by Blind Spring Hill, on the west by the Benton Range, on the south by the Yellowjacket Spring pumice area, and extends north of Benton for about 4 miles.

The pumice in the Blind Spring Valley area is of subaerial origin and occurs in discontinuous layers that lie near the surface of the ground. Natural exposures of the pumice are few and very poor. However, it is well exposed in a series of trenches, bulldozer cuts, and quarries. The pumice is overlain by a sandy pumiceous soil covering that ranges in thickness from a few inches to 6 feet. Between the soil overburden and the pumice there is a thin zone of white caliche not more than a few inches thick. In several places the pumice rests upon granite, but in most of the quarries and open cuts the pumice is underlain by coarse-grained, dirty-brown sandy soil.

The pumice layers range in thickness from a few feet to at least 20 feet. A bulldozer cut 2½ miles north of Benton shows one pumice layer which is at least 8 feet thick below which lie three thin pumice layers, each several feet thick, separated by buff, sandy pumiceous soil horizons about 1 foot thick each. The lowest pumice layer probably represents the earliest eruptions in the Benton area.

North of Benton the pumice layers strike N. 25-30° W. and dip 20° NE. About 2 miles south of Benton the pumice layer strikes N. 30-35° E. and dips from 7-15° SE. Bedding is poorly developed in the pumice and in several places it can not be detected.

The pumice fragments range in color from light-gray to white. The white pumice has larger cells, lower bulk density, and less crushing strength than the light-gray pumice. The fragments are angular and range from $\frac{1}{16}$ of an inch to 4 inches in diameter. The vesicles are both spherical and tubular. Phenocrysts of quartz, sanidine, and biotite are present but rare. Scattered throughout the pumice, and apparently more or less concentrated in the lower part of the beds are loose angular grains of quartz, feldspar, and biotite. This assemblage of crystalline materials locally referred to as silica sand by the pumice producers is being discarded because no present use has been determined for it.

Screen analysis of quarry-run pumice from the Sand Doon pumice pit, Mono County, California. Analysis by writer.

Screen size	Percent retained	Accumulative percent retained
⅜-inch	8.9	8.9
½-inch	8.7	17.6
¼-inch	19.8	37.4
10-mesh	20.8	58.2
20-mesh	23.4	81.6
30-mesh	8.8	90.4
40-mesh	4.2	94.6
50-mesh	1.9	96.5
60-mesh	0.8	97.3
80-mesh	0.6	97.9
100-mesh	0.3	98.2
120-mesh	0.2	98.4
140-mesh	0.3	98.7
200-mesh	1.2	99.9
240-mesh	0.1	100.0

All of the silica sand examined by the writer is very fine-grained and apparently would pass through a 10-mesh screen. The data in the accompanying table derived from petrographic examination of several screen sizes of the silica sand, show the amounts of crystalline constituents and pumice (volcanic glass) present.

Percentage of crystalline constituents and pumice in the silica sand

Screen size	Crystalline constituents percent	Pumice percent
−10, + 20	50-60	40-50
−20, + 30	80	20
−30, + 40	90	10
−40, + 60	95	5
−60, +100	95	5

The quartz in the silica sand is in clear, angular grains and in doubly terminated crystals.

The feldspar consists of angular grains of sanidine. The biotite is less abundant than the quartz and feldspar and occurs in flat, platy crystals.

Included in the pumice layers are angular and rounded fragments of rhyolite, and an occasional fragment of dark mica schist.

Sand Doon Pumice Deposit. Location: secs. 25 and 26, T. 1 S., R. 31 E., M. D. M., about 2½ miles northeast of Benton, California. Ownership: Guy S. Way, Benton, California, owns one claim.

The Sand Doon pumice deposit is in the low rolling hills along the east side of the Benton Range. The pumice occurs in several extensive flat-lying layers which do not crop out, but which are exposed in a series of bulldozer cuts and test pits. The exact thickness of the pumice is not known, but a thickness of at least 10 feet is exposed in one of the deep test pits (fig. 57). The pumice is overlain by a mantle of pumiceous soil which averages about 3 feet thick.

The pumice is in angular, white to light-gray fragments that range from dust-like particles to 4 inches in diameter. The average grain size is about ¼ of an inch. The white pumice contains larger cells than the gray pumice.

Silica sand is scattered through the pumice, but more abundant in the lower part of the bed. Also scattered throughout the pumice are angular fragments of granite, schist, and basalt. The silica sand and stone fragments constitute about 5 percent of the pumice layers.

Mining operations at the Sand Doon pumice deposit started late in the 1940's and continued intermittently for the next few years. The pumice was mined with a bulldozer which removed the loose pumiceous soil overburden before scraping the pumice into a bulkhead-like hopper for truck loading.

The pumice was used locally or trucked to Los Angeles where it was used in making concrete blocks.

Buckley Pumice Deposit. Location: secs. 10 and 11, T. 2 S., R. 31 E., about half a mile south of Benton. Ownership: Tom Buckley, Benton Station, California; leased to Clarence Comstock and Gordon Bacon, Benton, California.

The Buckley pumice deposit lies on the gently sloping, rolling foothills east of the Benton Range. The pumice layer is well exposed in an open pit which measures about 200 feet long, 100 feet wide, and 20 feet deep, and in several deep test pits scattered over the property. The pumice layer is lense-like, and ranges in thickness from one to 20 feet. It is overlain by loose pumiceous soil which ranges in thickness from 2 to 4 feet. Bedding is not well developed in the pumice, but wherever it was observed the strike is N. 15° W., and the dip between 5 and 10 degrees northeastward.

The pumice is white and occurs in angular fragments that range from dust-like particles to 3 inches in diameter. Silica sand is present and constitutes about 10 percent of the pumice layer.

The pumice was mined from an open pit by the use of a bulldozer which scraped the loose pumice to a bin at the nearby screening plant. From the storage bin the pumice was conveyed to the screening plant where it passed first over a ⅛-inch single-deck vibrating screen. The plus ⅛-inch pumice was crushed to minus ⅜-inch in a set of rolls and stored in bins. The minus ⅛-inch material from the vibrating screen consisted largely of silica sand and was discarded.

Pumice produced at the Buckley deposit was trucked to markets in Reno, Nevada, and Los Angeles, California where it was used for making lightweight building blocks.

Victory Pumice Claims. Location: South ½ sec. 14, T. 2 S., R. 31 E., M. D. M., on the west side of Blind Spring Valley, about 2 miles south of Benton. Ownership: Cowan & McGraw, 350 Clark Street, Bishop, California.

The Victory pumice deposit is situated low on the eastern slope of the Benton Range on the west edge of Blind Spring Valley. The surface of the ground is low and rolling and cut by a small number of shallow ravines. The pumice occurs in layers which do not crop out, but which are well exposed in bulldozer cuts, test pits, and extensive mining operations. From the distribution of the test pits, it is evident that much of the property is underlain by pumice. In general, the pumice layers strike N. 10-20° E., and dip from 5-7° SE. The pumice layers range in thickness from 5 to 20 feet, and are overlain by a loose pumiceous soil which ranges from 1 to 4 feet in thickness.

The pumice is white and is in angular fragments that range from dust-like particles to 3 inches in diameter. The cells in the pumice are round and evenly distributed throughout the pumice. Phenocrysts of glassy quartz and sanidine, as well as dark-brown biotite are rare. Silica sand is present and is most abundant in the lower portions of the layers. Small fragments of rhyolite, dark-gray andesite, and small rounded grains of black obsidian also are minor constituents.

Mining is by open pit methods. Pumice is scraped with a Caterpillar and pushed to a bin at the nearby plant. At the plant the pumice passes over a double-deck screen. The minus ⅛-inch material consists principally of silica sand and is discarded. The plus ⅛, minus ½ is stored in bins, and the plus ½-inch pumice is passed through a set of rolls adjusted to crush to minus ⅛-inch. The crushed pumice is returned to the screens by a bucket elevator and stored in bins.

The first pumice mined from the Victory pumice deposit came from an open pit which is located about half a mile north of the present operation. This mining was done during the middle 1940's, and continued intermittently until 1949 when the present pit was opened which in 1955 measured about 300 feet by 300 feet. The pumice is used as aggregate in lightweight building blocks, and the annual output from the deposits is well over 1500 tons.

Yellowjacket Spring Area

The Yellowjacket Spring is near the center of section 6, T. 3 S., R. 32 E., M. D. M., about 7 miles south of Benton Station. This area, which includes several extensive pumice deposits, is bounded on the north and northeast by Blind Spring Valley, on the west by the Benton Range, on the east by Chalfant Valley, and gradually merges to the south into the Volcanic Tableland.

While much of the pumice in the Yellowjacket Spring area is of subaqueous origin, several deposits show layers of reworked pumice and other deposits are thinly covered by nuee ardente pumice, especially the ones along the southern part of the area. Layers of pumice which have been exposed at several places by mining operations consist of loosely consolidated pumice fragments and consequently do not form prominent outcrops even in steep, narrow gullies or on steep, cliffy hillsides. Unlike the pumice mined in the Benton area, pumice produced in the Yellowjacket Spring area has not been obtained from a single layer but from several layers.

Probably the thickest sequence of pumice layers in this area is exposed in a surface operation located about 1000 feet south of Yellowjacket Spring. Here, one can see about 60 feet of pumice overlain by sandy, dirty-brown pumiceous soil and underlain by buff pumiceous sand. Individual layers of pumice range in thickness from 1 to 5 feet. They are commonly separated by thin beds of white pumicite and local discontinuous layers of sandy conglomerate. About 3½ miles southeast of Yellowjacket Spring, the layers of subaqueous pumice are overlain by a covering of pinkish-tan, fine-grained pumiceous tuff of nuee ardente origin. A similar sequence exists in a deposit of a few hundred yards northwest of the Mathieu ranch house 2½ miles northeast of Yellowjacket Spring. Here, the main pumice layer of subaqueous origin is about 18 feet thick and is overlain by a pinkish-tan tuff of nuee ardente origin. To the west and north of Yellowjacket Spring the pumice layers are of subaqueous origin and contain a few local areas of reworked pumice.

In general, the pumice layers in this area have nearly the same attitude. They strike northward and dip eastward at angles ranging from 5 to 20 degrees.

The pumice in the layers of subaqueous origin contains white and grayish-white, angular fragments that range in size from dustlike particles to particles 3 inches in diameter. The screen analysis shown below of the angular pumice from the Crawford Lease indicates that most of the pumice is retained on a 10-mesh screen. The average size is about ¼ inch.

Screen analysis of quarry-run pumice from the main pumice bed at the Crawford lease, Mono County. Analysis by writer.

Screen size	Percent retained	Accumulative percent retained
¾-inch	2.8	2.8
½-inch	8.0	10.8
¼-inch	28.8	39.6
10-mesh	39.2	79.8
20-mesh	11.6	91.4
30-mesh	1.7	93.1
40-mesh	1.1	94.2
50-mesh	1.1	95.3
60-mesh	0.8	96.1
80-mesh	1.0	97.1
120-mesh	0.6	97.7
140-mesh	0.4	98.1
200-mesh	0.6	98.7
240-mesh	1.3	100.0

Phenocrysts of quartz are rare. Silica sand is present and seems to be rather conspicuous throughout the layer. It commonly is concentrated in the lower beds, and consists of small, angular grains of quartz, sanidine, and biotite. An occasional rounded fragment of rhyolite, dark mica schist, or andesite may be found in the pumice.

Bedding in the Yellowjacket Spring area is well defined and individual beds range from a fraction of an inch to 20 feet in thickness. The layer near the Mathieu ranch is 18 feet thick; at the Brewster pit, about 3½ miles southeast of Yellowjacket Spring the layer is 20 feet thick; and at the Van Loon pit west of Yellowjacket Spring the layer is approximately 12 feet thick. Variations in thickness appear to be ascribable to (1) irregularities on the original surface upon which pumice was deposited and (2) the amount of post-pumice erosion. The thin beds are ordinarily much whiter than the thicker beds and contain an abundance of silica sand and scattered rounded pebbles of dark mica schist.

Within the thicker layers one can find a rhythmic layering in which the finer pumice particles lie beneath the coarser particles. This is referred to as inverted bedding and appears to be a characteristic feature of deposits of subaqueous origin. As many as six individual inverted beds have been found in one pumice layer and each bed apparently represents separate volcanic eruptions.

Although layers of reworked pumice are common in the Yellowjacket Spring area, they have not been mined extensively. However, they do contain appreciable quantities of pumice suitable for use as aggregate material. Most of the pumice fragments in the reworked layers are well rounded and differ in many respects from the angular fragments of the subaqueous material. The rounded pumice fragments are dirty, grayish-white in color and are slightly elongated in a direction approximately parallel to the lineation or elongation of the tubular openings in them. The pumice pebbles range from ⅛-inch to 2 inches in diameter and are loosely enclosed in a finer grained, pumiceous sand. The average size fragment is about a quarter of an inch. Typical sedimentary structures such as parallel bedding, crossbedding, deltaic bedding, and layers of sand and conglomerate are well developed. Many of the non-pumiceous, sandy layers are dark in color and consist of rounded grains of quartz, feldspar, biotite, and dark volcanic and metamorphic rocks. The conglomeratic layers are not continuous and consist of rounded pebbles of granite, dark mica schist, andesite, rhyolite and an occasional pebble of pumice. A thick layer of well rounded pumice occurs on the Crawford lease, about 600 feet southwest of the quarry. The reworked pumice layer is about 15 feet thick and lies near the base of the pumice sequence which is well exposed in the Crawford quarry. The following table gives a screen analysis of a sample taken across the entire layer of rounded pumice.

Screen analysis of reworked pumice from layer exposed in narrow ravine about 600 feet south of quarry on Crawford Lease, Mono County. Analysis by writer.

Screen size	Percent retained	Accumulative percent retained
¾-inch	3.2	3.2
½-inch	6.3	9.5
¼-inch	25.4	34.9
10-mesh	28.7	63.6
20-mesh	9.2	72.8
30-mesh	3.1	75.9
40-mesh	2.8	78.7
50-mesh	3.0	81.7
60-mesh	2.4	84.1
80-mesh	3.6	87.7
100-mesh	2.5	90.2
120-mesh	1.6	91.8
140-mesh	1.7	93.5
200-mesh	2.3	95.8
240-mesh	4.2	100.0

The eastern part of the Yellowjacket Spring area is partly covered by nuee ardente Bishop tuff of Pleistocene age. Much of the tuff is loosely consolidated and consists mostly of white, angular pumice fragments that range from $\frac{1}{16}$-inch to 3 inches in diameter and occur in a matrix of pale-pink pumicite. The pumice fragments constitute less than 15 percent of the tuff. Angular rock fragments of non-volcanic origin are present in small amounts and are usually not more than one inch in size. Angular grains of quartz, white and glassy sanidine, and black biotite are sparsely sprinkled throughout the matrix. The Bishop tuff in this area ranges in thickness from a few feet to 10 feet. It rests upon the pumice layers of subaqueous origin from which it is separated by a small erosional unconformity. Only a small amount of pumice has been mined from the nuee ardente tuff.

Several hundreds of thousands of tons of pumice for aggregate purposes has been obtained from deposits in the Yellowjacket Spring area. Some of the pumice was used in the construction of dwellings at the Paiute-Shoshone Indian Reservation near Bishop, and a bulk of it was shipped to markets in southern California.

White Rock Placer Pumice Deposit. Location: sec. 1, T. 3 S., R. 31 E., M. D. M., about 1¼ miles west of Yellowjacket Spring. Ownership: 200 acres are owned by H. A. Van Loon, Bishop, California. The deposit is at the southern end of Blind Spring Valley in land of low relief that is cut into by shallow ravines.

Two quarries, about ¼-mile apart, exist on this property, and have developed the same layer of subaqueous pumice. The pumice layer whose wide lateral extent is indicated by widely spaced test pits and quarrying operations, ranges in thickness from 8 to 12 feet. At the south quarry the layer is overlain by sandy pumiceous soil 1 foot to 6 feet thick (figs. 60, 61). Separating the pumice from the soil is a thin, irregular layer of white caliche. The pumice layer rests upon a pumiceous sandy soil and the whole sequence dips about 5 degrees eastward. The upper 2 feet of the pumice layer is made up of well rounded pumice pebbles and grains that range from ⅛-inch to 2 inches in diameter. At the north quarry, which is now inactive, the overburden is much thicker, well bedded, and contains several flat, lenslike bodies of conglomerate that consist largely of rounded pebbles of granite, andesite, dark mica schist, and an occasional pebble of pumice. Interbedded within the pumice layer are zones of reworked pumice.

In mining the pumice, the overburden was first stripped with a bulldozer. The exposed pumice was then moved to a bunker-type ramp by a drag scraper powered by an automobile engine. The pumice was loaded into trucks and hauled about 5½ miles to a plant where the pumice was passed through a screen with ½-inch openings. All oversize was discarded and the minus ½-inch material was stored in bins or hauled to Bishop where it was mixed with finer-sized pumice to make building blocks. The property was opened up during the middle 1940's and production came to a standstill in 1949.

Van Loon "Fines" East Pumice Deposit. Location: sec. 22, T. 3 S., R. 32 E., M. D. M., about 4 miles southeast of Yellowjacket Spring. Ownership: H. A. Van Loon, Bishop, California. The deposit is on flat-lying ground about 1¼ miles west of the eastern scarp formed by the resistant Bishop tuff. Exposures of the pumice are poor and the wide lateral extent of the pumice layers is indicated in the widely spaced test pits and abandoned quarries.

The pumice layer, which is of subaqueous origin, is about 10 feet thick, is flat-lying, and is overlain partly by brownish-gray, pumiceous soil and partly by loosely consolidated Bishop tuff. The pumice fragments in the pumice layer are white, angular, and range in size from dustlike particles to 4 inches in diameter. The pumice fragments in the overlying Bishop tuff are pinkish-brown, subangular, and range in size from $\frac{1}{16}$-inch to 2 inches in diameter. They are set in a matrix of pink pumicite which will all pass through a 100-mesh screen. Thin seams of caliche can be found cutting the pumice layer.

Mining was done in an open pit which in 1953 measured about 150 feet long, 100 feet wide, and 20 feet deep. The pit is abandoned and has not been worked since late in the 1940's.

Van Loon "Fines" West Pumice Deposit. Location: sec. 21, T. 3 S., R. 32 E., M. D. M., about 4 miles southeast of Yellowjacket Spring. Ownership: H. A. Van Loon, Bishop, California.

The Van Loon "Fines" West pumice deposit is located in the gentle rolling hills of the Volcanic Tableland, about 1 mile east of the moderately dissected hills which mark the eastern margin of the Benton Range (fig. 8).

The pumice is exposed in open pit mining operations, bulldozer cuts, test pits, and narrow, steep-walled ravines. The pumice appears to be widespread in distribution as indicated by the broad distribution of the exposures. The pumice is overlain by buff, sandy pumiceous soil covering which ranges from a few inches to 5 feet in thickness.

In the largest open pit, which measures about 100 feet long, 50 feet wide, and 30 feet deep, the following vertical section was measured on beds and layers which appear to dip gently eastward (fig. 62).

Thickness in feet	Description
2–3	Soil, sandy, pumiceous, dirty-brown in color.
4–6	Conglomerate, composed of flat, angular, and rounded pebbles of rhyolite, granite, andesite, and dark mica schist, poorly sorted, bedding fairly well defined.
15–18	Pumice, poorly sorted, considerable pumicite; poorly bedded; angular fragments are pink colored.
1–2	Pumice, angular, very little pumicite.
6+	Pumice, poorly sorted, no bedding, pink in color; considerable pumicite.

The section has been cut by several small normal faults which have displaced the layers by as much as 8 feet. Most of the pumice in the various layers is fine-grained and pale pink. It was used locally in the manufacture of building blocks, and trucked to Los Angeles and other distant places where it was also used for aggregate. The deposit was opened up during the early 1940's and was worked intermittently for the next few years before being abandoned in favor of other deposits much nearer to Bishop.

Estella Pumice Deposit. Location: sec. 6, T. 3 S., R. 32 E., M. D. M., about one-quarter mile southwest of Yellowjacket Spring. Ownership: Ted Schreiner, 4546 Lomita Street, Los Angeles 19, California.

The Estella pumice deposit is in the low rolling hills at the southern end of Blind Spring Valley. Actual exposures of the pumice are few and are in mining operations, test pits, and bulldozer cuts. The pumice is best exposed at the Estella quarry where it forms a layer that ranges from 50 to 60 feet in thickness. The areal extent of the pumice is not known, but as it is similar to pumice well exposed in mining operations and on steep hillsides at the Crawford Lease, about a mile and a half southeast, it is reasonable to assume that the pumice layer underlies at least 2 to 3 square miles here.

The pumice layer dips about 5 degrees eastward and consists of numerous thin beds of pumice and pumicite locally interbedded with reworked pumice and pebbly sands. Most of the pebbly sand beds are associated with the pumicite beds, are discontinuous, and ordinarily are less than 2 feet in thickness. The pumice beds range from 1 foot to 5 feet in thickness. The pumice fragments are angular, white, and lie mostly within the range of dustlike particles to fragments 3 inches in diameter. Silica sand is more abundant in the pumicite than in the pumice.

Mining at the Estella deposit was started in the late 1940's and lasted for only a few months. It consisted of removing the soil overburden with a bulldozer and then scraping the pumice downhill to a stockpile with a dragline. Several hundred tons of pumice were removed from a pit which in 1953 measured about 15 feet wide, 50 feet long, and 5 feet deep. The pumice was mined for use as aggregate in the manufacture of lightweight building blocks.

Snoeshoe Pumice Deposit. Location: sec. 12, T. 3 S., R. 32 E., M. D. M., about 2 miles southeast of Yellowjacket Spring. Ownership: Ted Schreiner, 4546 Lomita Street, Los Angeles 19, California. Ten acres of this property are under lease to G. N. Crawford, Bishop, California, who has sub-leased to William LeVeck, Box 216, Anaheim, California.

At the Snoeshoe pumice deposit a thick sequence of pumice beds is exposed in an extensive bench-cut mining operation in the low rolling hills at the southern end of Blind Spring Valley (fig. 64). The pumice beds range from a few inches to several feet in thickness, and are separated by layers of crossbedded sandy pumice that also range from a few inches to a foot or more thick. The pumice fragments in the pumice beds are angular, and in the crossbedded layers they are well rounded. In mining the pumice no attempt has been made to separate the two types.

In mining the pumice, the overburden of dirty brown pumiceous soil ranging from 1 foot to 4 feet thick was scraped back from the bench faces. The pumice beds were then opened up by several bench cuts, each 100 feet long and about 10 feet above the other, and the pumice was pushed and hauled to a hopper-like storage bin above the screening plant. From the bin the pumice was carried by a belt conveyor to a trommel screen where the plus 1 inch materials were separated from finer sizes and discarded. The minus 1 inch pumice was loaded directly into trucks to be used as aggregate in making concrete blocks. Property was opened up in the early 1940's and closed down in 1948.

Brewster Pumice Deposit. Location: sec. 21, T. 3 S., R. 32 E., M. D. M., about 4 miles southeast of Yellowjacket Spring. Ownership: R. W. Dean, C. L. Gilland, and J. C. Andahl, Bishop, California; leased to Acme

Pumice Company, 183 Spring Street, Fontana, California. Thomas R. Brewster, president.

The Brewster pumice deposit is in some gently rolling hills low on the east side of the Benton Range, Mono County. The pumice at the Brewster deposit is in a layer about 20 feet thick that is well exposed in several widely spaced test pits which indicate a wide lateral extent of the pumice. The layer dips eastward at a low angle and is overlain by sandy, pumiceous soil about 3 feet thick. The pumice fragments are angular, poorly sorted, pink to white in color, and range from material that is dustlike to fragments 2 inches in diameter. Most of the material is actually pumicite as at least 80 percent of it is minus 10-mesh. About 30 cubic yards of quarry-run pumice yields 1 cubic yard of plus ⅜-inch pumice.

The deposit was opened during the middle 1940's and closed in 1950. The pumice was mined from an open pit which in 1950 measured about 100 feet wide, 150 feet long, and 8 feet deep. A bulldozer was used to remove the soil overburden and to push the pumice to a hopper-like bin. From the bin the pumice was carried by belt conveyor to an inclined screen where the plus 1-inch pumice and stones were separated from the pumice. The pumice was loaded into trucks, for use as aggregate in making building blocks.

Mathieu Pumice Deposit. Location: sec. 31, T. 2 S., R. 32 E., M. D. M., about 1,000 feet north of Yellowjacket Spring. Ownership: One mining claim owned by the Mathieu Brothers, Benton Station, California.

The Mathieu pumice deposit is in the low rolling hills that border on the southeast part of Blind Spring Valley. The pumice occurs in a layer which dips eastward about 10 degrees. Exposures of the pumice layer are few, but a partial sequence exposed in a small mining operation shows several pumice beds that range from 1 foot to 6 feet thick. The pumice beds are separated by thin beds of pumicite up to 1 foot thick.

Most of the pumice fragments are angular, although one thin bed of reworked pumice consisting of well rounded pumice fragments was found. The pumice is white and the fragments range in size from dust to as much as 2 inches in diameter. Silica sand is more abundant in the beds of angular pumice than in the reworked pumice. In addition, the pumice contains phenocrysts of sanidine, quartz, and biotite.

The pumice is overlain by soil that ranges from a few inches to 2 feet thick. This property was in operation for about one year during the latter part of the 1940's. The pumice was mined with a bulldozer which pushed the pumice to a screening plant where minus 1-inch aggregate was produced for use in making lightweight building blocks.

Rae-Spencer Pumice Deposit. Location: sec. 28, T. 2 S., R. 32 E., M. D. M., about 1,000 feet northwest of the Mathieu ranch house. Ownership: William Rae and C. E. Spencer, Hawthorne, Nevada.

An extensive layer of pumice, averaging about 18 feet in thickness, is exposed in several partly caved tunnels and bulldozer cuts on the Rae-Spencer property which is in the low hills along the southeastern side of Blind Spring Hill. The pumice layer is overlain by loosely consolidated Bishop tuff that ranges from 1 foot to 6 feet thick, and rests upon a dirty-brown rocky soil. The pumice layer in the tunnels (fig. 63) which are about 40 feet above the bed of a nearby shallow stream, dips gently southeastward. About 300 feet west of the portals to the tunnels there is a northeasterly trending fault which has tilted the pumice layer eastward to a dip of 15 degrees.

The pumice layer consists of several distinct pumice beds ranging from 1 foot to 12 feet in thickness. Most of the mining was done in the thickest or 12-foot bed which consists of white, angular pumice fragments that range from dust-sized particles to as much as 3 inches in diameter. Phenocrysts of glassy quartz are common in the pumice, and angular fragments of rhyolite, andesite, and dark mica schist are present but rare. The pumice beds that overlie and underlie the main pumice bed range from 1 to 3 feet in thickness and contain more silica sand than the main pumice bed.

Mining operations started on the Rae-Spencer property in 1924 by Paul Splane and continued almost continuously until 1945 when all operations ceased. Most of the pumice was mined underground although several thousand tons were obtained from surface open pits. Access to the pumice was through six parallel tunnels, each extending into the main pumice bed for at least 300 feet. The room and pillar mining system was used extensively throughout the entire operation. Following mining, the pumice was separated into several sizes and shipped to markets in southern California for use as an aggregate in the manufacture of lightweight building blocks and concrete.

Large reserves of pumice remain, but they probably would have to be removed by open pit mining methods if the mine were to be reopened and operated economically.

Bishop-Laws Area

The Bishop-Laws area is in Mono and Inyo Counties. It includes a part of Owens Valley and extends along the west slope of the White Mountains southward from Sacramento Canyon to Black Mountain, a prominent peak located about 8 miles northeast of Big Pine. The area also embraces the southeastern part of the Volcanic Tableland, a plateau of welded rhyolite tuff some 300 square miles in areal extent located at the north end of Owens Valley, a few miles north of Bishop.

The Bishop-Laws area includes at least 8 deposits of pumice, of which only three are being operated. Two of these deposits are on the edge of the Volcanic Tableland, and the third is low on the west slope of the White Mountains.

Most of the pumice mined in this area has been quarried from deposits of subaqueous origin; substantial amounts also have been obtained from deposits of nuee ardente origin. The pumice occurs in extensive layers that range from a few feet to several tens of feet in thickness. Deposits of the nuee type are well exposed along the southern and southeastern margins of the Volcanic Tableland, about 5 miles north of Bishop, and are confined mostly to a layer of loosely consolidated Bishop tuff, about 30 feet thick that commonly is overlain by a denser phase of the Bishop tuff. The layer actually contains more pumicite than pumice, and the material ranges from dustlike particles to well-rounded pumice lumps as much as 4 inches in diameter. The pumice is pale, pinkish-brown in color and contains scattered phenocrysts of quartz and sanidine.

Subaqueous pumice is particularly abundant along the west slope of the White Mountains; also, along the east margin of the Volcanic Tableland, about 4½ miles north of Laws. At the Volcanic Tableland deposits the pumice is directly overlain by loosely consolidated Bishop tuff.

The pumice layers along the west slope of the White Mountains are interbedded with layers of fanglomerate which in some places are as much as 20 feet thick. Here the pumice layers range in thickness from 20 to 30 feet and show exposed lengths of as much as several hundreds of feet. The pumice layers consist of numerous beds of pumice interbedded with thin beds of pumicite and silica sand. The pumice fragments are angular, white, and range from 1/16-inch to 3 inches in diameter. All of the silica sand is finer than ⅛-inch and similar, in its mineral content, to the silica sand found in the Blind Spring Valley and Yellowjacket Spring areas. Bedding is prominent and the general dip is toward the west and southwest from 2 to 10 degrees.

A pumice layer exposed on the east edge of the Volcanic Tableland, about 4½ miles north of Laws is about 15 feet thick. It is overlain by loosely consolidated Bishop tuff and lies upon crossbedded deltaic sands and gravels (figs. 69, 70) of unknown thickness and extent.

Van Loon "Fines" Pumice Deposit. Location: secs. 8 and 18, T. 6 S., R. 33 E., M. D. M., about 5 miles north of Bishop, California. Ownership: H. A. Van Loon, Bishop, California, owns 540 acres.

The Van Loon "Fines" pumice deposit is located along the southern margin of the Volcanic Tableland. The pumice layer is poorly exposed. At the Van Loon pit it is overlain by loose pumice soil about 2 feet thick, and dense Bishop tuff which forms abrupt cliffs about 100 feet north of the pit. As exposed in a cliff about 2 miles west of this property, the same pumice layer is horizontal, is about 30 feet thick and is underlain by well-bedded pumiceous sands and gravels. At the Van Loon pit the layer is rather fine-grained, and contains material that ranges from angular, dustlike particles (pumicite) to rounded lumps as much as 4 inches in diameter. The finer portion is pale, pinkish-brown in color, whereas the larger lumps of pumice are grayish and have a thin coating of pinkish pumicite. Phenocrysts of quartz and sanidine are common in the lump pumice and also occur as scattered grains through the entire bed.

Mining for pumice on this property was started during the middle 1940's and has been continuous since then. The pit, in 1955, measured about 250 feet long, 250 feet wide, and 10 feet deep.

Mining is by bulldozer. First the loose pumice soil is scraped away, thus exposing the pumice which is scraped up and pushed directly into a bin (fig. 68). From the bin the pumice passes through a vibrating screen which separates the minus ½-inch material from the plus ½-inch material. The plus ½-inch material is discarded, whereas the minus ½-inch material is loaded into trucks and hauled to Bishop to be used as aggregate in the manufacture of building blocks and slabs, or sold to other pumice users.

Insulating Aggregates, Inc., Pumice Deposit. Location: secs. 32 and 33, T. 5 S., R. 33 E., M. D. M., on the west side of Hamil Valley, about 6½ miles north of Laws, Mono County, California. Ownership: The property, formerly owned by California Quarries Company (Tucker, 1927, p. 403) consists of 900 acres owned by Insulating Aggregates, Inc., Andrew Boyd, Bishop, California, and operated by L. V. Menefee, P. O. Box 215, Bishop, California.

The pumice at the Insulating Aggregates, Inc. deposit, which is located along the southeastern margin of the Volcanic Tableland, occurs in a flat-lying layer which ranges in thickness from 12 to 15 feet and has an exposed length of 2 to 3 miles (fig. 69). The pumice is overlain by loosely consolidated Bishop tuff which ranges in thickness from a few feet to 75 feet. Here the Bishop tuff is buff colored, whereas the main pumice bed is grayish-white with a local tinge of pink near the contact with the Bishop tuff. The pumice layer lies upon stream sands and gravels which, because of their internal structure and bedding, resemble deltaic sediments. The pumice layer shows well-developed inverted bedding and consists of several pumice beds that range from a few inches to several feet in thickness. The pumice fragments are angular, grayish-white and range in size from 1/16-inch to 2 inches in diameter. Both pumicite and silica sand are present in thin beds.

Chemical analysis of pumice and silica sand from the quarry of the Insulating Aggregates, Inc., Mono County.

	(1)	(2)
SiO_2	60.10	80.72
Al_2O_3	13.56	12.67
Fe_2O_3	3.30	0.06
FeO	ndt	ndt
CaO	4.96	0.77
MgO	0.72	tr
Na_2O	2.00	2.33
K_2O	0.68	3.45
TiO_2	tr	ndt
H_2O+ / H_2O-	12.87	tr
MnO	0.14	ndt
P_2O_5	ndt	ndt
SO_3	1.83	ndt
Cl	none	ndt
	100.16	100.00

(1) Pumice from quarry of Insulating Aggregates, Inc., Mono County. A aly is by Smith-Emery Company.
(2) Silica sand, waste discarded at processing plant of Insulating Aggregates, Inc., Mono County. Analysis by Smith-Emery Company.

Pumice was mined at this property as early as 1927 (Tucker, 1927, p. 403) when pumice was produced for use in making soap and cleansing compound, in stucco work, cement, and in acoustic plaster by the California Quarries Company. How much before this date was the property being quarried is not known. The property has, however, been in continuous operation since that date and the present operation, the Insulating Aggregates, Incorporated, is still producing pumice for plaster aggregate.

The large quarry adjacent to the plant has been closed down and the pumice is now coming from another large quarry which is located about 1000 feet south of the plant. The new quarry is along the south side of a small east-trending ravine. It has a quarry face which measures about 1100 feet long and an average of about 12 feet high. The overburden overlying the pumice layer at the new pit is loosely consolidated tuff that ranges from 1 to 20 feet thick.

The pumice is mined by open-pit methods. The overburden is stripped away with a bulldozer and the pumice is trucked to a plant (fig. 71) located near the pit. The plant contains 21 units consisting of screens, dryers, separators through which the pumice passes before the final product is bagged. Marketed aggregate products include interior insulating plaster, exterior stucco and insulating plaster, acoustical and abrasive materials. Chemical additives are mixed with the pumice to make some of the acoustical and insulating plaster aggregates.

Electric power is supplied by a 50 kilowatt Waukesha generator, using butane for fuel. Plant capacity is 70 tons per day.

Sacramento Canyon Pumice Deposit. Location: sec. 3, T. 5 S., R. 33 E., M. D. M., at the mouth of Sacramento Canyon, about 2½ miles northeast of the Maron Ranch. Ownership: Joseph B. Smith, Laws, California.

The pumice at the Sacramento Canyon deposit which is situated at an elevation of about 5300 feet on the west slope of the White Mountains occurs in a poorly exposed layer of unknown thickness and extent which is interbedded with fanglomerate material. Bedding is well developed in the pumice layer which dips 45 degrees southeastward. The layer consists of several pumice beds interbedded with thin beds of silica sand and pumicite. The pumice fragments are white and range in size from 1/16-inch to 2 inches in diameter. They contain scattered phenocrysts of quartz and sanidine and angular fragments of rhyolite in very minor proportions. The property was opened up to pumice mining during the middle 1920's and was operated intermittently until the early 1940's.

The pumice was mined from a pit which in 1948 measured about 100 foot square and 6 to 10 feet deep, with a scraper which moved the pumice to a small storage bin. From the storage bin the pumice passed through a screen and all plus ⅝-inch material was discarded. The minus ⅝-inch pumice was trucked to Bishop to be used as aggregate or cleaned and made into ground pumice.

Comstock Pumice Deposit. Location: sec. 11, T. 5 S., R. 33 E., M. D. M., about 2 miles northeast of the Maron Ranch. Ownership: Hallie Comstock, Bishop, California.

At the Comstock pumice deposit which is situated at an elevation of about 5500 feet on the west slope of the White Mountain a pumice layer ranging in thickness from 12 to 22 feet is interbedded with fanglomerate material. Both upper and lower contacts with the fanglomerate are angular unconformities (fig. 66). The bedding in the pumice layer dips 10 degrees southeast, whereas the overlying fanglomerate dips gently toward the west. The overlying fanglomerate is as much as 20 feet thick.

The pumice layer is well exposed in mining operations (figs. 65, 67) and shows typical subaqueous features. The bedding is prominent and of the inverted type. The pumice layer contains several beds of silica sand that indicate repeated volcanic outbursts. Near the top of the pumice layer several beds of pumiceous sand exist and the pumice is admixed with various proportions of fanglomeratic material.

The pumice fragments are angular, white, somewhat softer than the pumice in the Yellowjacket Spring area, and range from $\frac{1}{16}$-inch to 3 inches in diameter. The following table is a screen analysis of quarry-run pumice from the Comstock pumice deposit. The average size of pumice fragment is about ⅛-inch.

Screen analysis of quarry-run pumice from the Comstock pumice deposit, Mono County, California. Analysis by the writer.

Screen size	Percent retained	Accumulative percent retained
¾-inch	2.0	2.0
½-inch	4.4	6.4
¼-inch	10.8	17.2
10-mesh	22.4	39.6
20-mesh	29.9	69.5
30-mesh	13.4	82.9
40-mesh	6.4	89.3
50-mesh	3.7	93.0
60-mesh	1.8	94.8
80-mesh	1.7	96.5
100-mesh	0.8	97.3
120-mesh	0.5	97.8
140-mesh	0.5	98.3
200-mesh	0.9	99.2
240-mesh	0.8	100.0

The Comstock pumice deposit was opened to mining in 1941 and was operated for the next 2 years before temporarily closing down. Most of the pumice output during this period was shipped East for ground pumice. The property was again opened in 1945 but operated for only a few months and produced pumice for building blocks. Excessive overburden seems to have been one of the causes for the latest shut-down.

The deposit was mined with a bulldozer which stripped back the fanglomerate overburden. The pumice was scraped up from several pits of which the largest measured about 300 feet long, 50 to 75 feet wide, 30 feet deep at the deepest end, and pushed to a bin. From the bin the pumice passed first over a ⅛-inch screen to remove all silica sand and then through a set of 12-inch rolls adjusted to crush to minus ⅝-inch size. The crushed pumice was stored in a bin where it was loaded into trucks for hauling to Bishop and other markets in southern California.

Jamieson Pumice Deposit. Location: sec. 17, T. 8 S., R. 34 E., M. D. M., near the base of Black Mountain on the east side of Owens Valley, about 7 miles north of Zurich, a siding on the Southern Pacific Railroad. Ownership: The property consists of one mining claim owned by Alexander Jamieson, Bigpine, California, and leased to W. H. Frey and Associates, Los Angeles, California.

The Jamieson property contains the southernmost deposit of pumice of the White Mountains, and is situated at an elevation of about 4400 feet on the steep west slope of Black Mountain, a prominent peak on the western part of the White Mountains. It contains a pumice layer that ranges in thickness from 6 to 10 feet and is interbedded with fanglomerate. The entire sequence dips gently toward the west (fig. 72). Several pumice beds are present which range from a few inches to several feet in thickness. Interbedded with the pumice are thin beds of pumicite and silica sand. The pumice fragments are white, angular, and range from 1/16-inch to 1½ inches in diameter. Phenocrysts of quartz and sanidine are common, and these two minerals also constitute a large portion of the so-called silica sand which comprises about 20 percent by weight of the pumice layer.

The Jamieson pumice deposit was opened up during the middle 1940's and was in operation for a few months only. The mining was from an open pit which in 1948 measured about 75 feet long, 30 to 40 feet wide, and 5 feet deep. The mine-run pumice was hauled to a screening plant near the pit where the pumice was separated into the following sizes: minus 1½ inches, plus ⅜-inch, and minus ⅜-inch (Norman and Stewart, 1951, p. 109).

Oasis Pumice Deposit. Location: T. 6 S., R. 37 E., M. D. M., near Westgaard Pass Road, about 3¼ miles south of the Mono County line. Ownership: Francis E. Patton and F. S. Longley.

At the Oasis deposit the pumice occurs in a layer of unknown thickness and extent. The layer has been exposed in a pit which in 1949 measured 20 by 30 feet from which only a small amount of pumice was mined. The pumice fragments are angular, white in color, and are admixed with considerable amounts of silica sand.

Very little information is available regarding the dates of this operation and the location of the markets.

Coso Range Area

The Coso Range is in the southwestern part of Inyo County. It is a broad north-trending mountain range, about 36 miles long, 22 miles wide, and is bordered on the north by Owens Lake and the Inyo Mountains, on the east by the Argus Range, on the south by Brown Valley, and on the west by Rose Valley and the towering Sierra Nevada.

The Coso Range has a central core of granitic and metamorphic rocks which is overlain by a sequence (starting at the bottom) of (1) alluvial gravels, (2) tuffs and lake beds, and (3) andesitic and basaltic lava flows. The alluvial gravels and overlying tuffs and lake beds are referred to as the Coso formation (Schultz, 1937, p. 79) which is said to be late Pliocene or early Pleistocene in age. The pumice deposits are in the tuffs which are well exposed on the north, west, and south flanks of the range. Most of the pumice mining, however, has been carried on in deposits on the western and southern flanks of the range.

In the Coso Range area active volcanism ceased only several thousand years ago. Here, flows of basalt and andesite, thick accumulations of lacustrine sediments and pyroclastic rocks, domes of perlite, and thick mantles of loosely consolidated tuff lie upon a basement complex of deeply eroded granitic and metamorphic rocks (plate 3). At least two types of pumice tuffs exist in this area—tuffs of (1) subaqueous and (2) nuee ardente origin. The pumice in each type is similar in many respects, and each has been used principally for aggregate for pre-cast and monolithic concretes. Most of the pumice produced in this area, however, has come from deposits of the nuee ardente type.

Tuffs of subaqueous origin are well bedded and contain several beds of pumice separated from one another by layers of gray, moderately well consolidated sand (fig. 82). The pumice beds range in thickness from 1 foot to 15 feet, and in places the beds have an aggregate thickness of 100 feet. The pumice fragments are grayish-white in color and range in size from ¼ inch to 2½ inches. Deep brown plates of biotite are common; needles of hornblende and subhedral crystals of quartz and potash feldspar are rare. Scattered irregularly throughout the tuff are rounded to angular boulders of fresh granite, andesite, and dark mica schist.

The following section was measured on a steep hill face, a few thousand feet northeast of the pumice pit in sec. 13, T. 21 S., R. 37 E., M. D. M.

Section of tuffaceous rocks exposed on a steep hillside about 750 feet north of the Lucky Lager pumice pit, east ½ sec. 13, T. 21 S., R. 37 E., Coso Range, Inyo County, California.

Thickness in feet	Description
	Top
175–200	Hornblende andesite, porphyritic, brown to grayish in color. In several flows which dip 5° to 7° W. and strike N. 10° E.
50–60	Andesite agglomerate and breccia.
20–25	Tuff, sandy, brownish-gray in color.
15	Andesite agglomerate and breccia. Fragments angular and range in size from 1 inch to 3 feet. In gray tuffaceous matrix.
50–60	Tuff, sandy, buff colored.
85–100	Tuff, light gray. Pumice fragments range in size from ¼ inch to 2 inches. Crystal fragments are quartz, feldspars, hornblende, and biotite; lithic fragments include abundant andesite and rare granite.
20–25	Andesite tuff breccia, brownish-gray. Angular fragments range in size from 1 inch to 1 foot. In tuffaceous matrix.
5–7	Tuff, sandy, well consolidated, cream colored.
30	Tuff, gray, well consolidated. Contains numerous fragments of hard, gray pumice. Bedding well developed.
10	Tuff, light creamy-white; crystal-lithic-vitric; well bedded. Source of pumice production. Bottom not exposed.

At pumice pits in secs. 35 and 36, T. 21 S., R. 38 E., M. D. M., there is exposed a partial sequence which includes the following:

Sequence of pumice tuffs and tuffaceous sedimentary rocks exposed pumice pits on the Dauna pumice deposits, Coso Range, Inyo County, California.

Thickness in feet	Description
	Top of sequence.
5–10	Soil covering, pumiceous in part, loosely consolidated.
20–22	Tuff, pumice; pumice fragments well bedded, angular, grayish-white, range in size from $\frac{1}{16}$ inch to 2½ inches. Bedding inverted.
8–10	Tuff, pumice, fine-grained, grayish-white. Considerable silica sand in lower portion; well bedded and grades downward into tuffaceous sandstone.
2	Sandstone, tuffaceous, gray, well bedded with thin beds of silt and silica sand.
10–11	Tuff, pumice, white; rounded pumice fragments range in size from $\frac{1}{16}$ inch to 3 inches, inverted bedding. Thin silica sand beds in lower portion.
11–13	Sandstone, loosely consolidated, gray to buff, fine-grained, silty in layers.
3	Sandstone, loosely consolidated, gray to buff, coarse-grained, pebbly in part.
17+	Tuff, pumice, white, bedding poorly defined. Pumice fragments angular, and range in size from $\frac{1}{16}$ inch to 2½ inches. Bottom of sequence not exposed.

The nuee ardente tuffs are well exposed in open pits in secs. 13, 14, 23, and 24, T. 21 S., R. 38 E., M. D. M., where current mining operations are being carried on. These nuee ardente tuffs are near surface deposits and are covered by a soil mantle that ranges in thickness from a few feet to 10 feet (fig. 75). The bedding is poorly defined and dips gently westward. The actual thickness of the tuff is not known, although the working face in one large pit shows a section of loosely consolidated pumice as much as 30 feet in thickness. Among the interesting features of these tuffs are the boulders that are scattered indiscriminately throughout the section. These boulders range in size from 4 inches to 4 feet. They are angular to rounded, and are composed predominantly of hornblende andesite and rarely of granite and dark mica schist. Each boulder, no matter how large or small, is surrounded by a zone of bleached white pumicite which ranges in thickness from $\frac{1}{4}$-inch on the small boulders to 12 inches on the large boulders. These rims of pumicite are probably caused by the building-up of volcanic dust on the boulders as they were carried along with the mass of on-rushing pumiceous cloud (fig. 76).

The pumice fragments in these nuee ardente deposits are grayish-white in color, angular, and range in size from $\frac{1}{16}$-inch to $2\frac{1}{2}$ inches in diameter. Bombs up to 6 inches in diameter are rare. Crystals of biotite, hornblende, and feldspars are present in the pumice. Near the base of the exposed section are several dirty-gray layers. These layers are lenticular and range in thickness from $2\frac{1}{2}$ to 4 feet. Since they exhibit poorly defined bedding and correspond closely in appearance to the soil presently covering the tuff, it is assumed that they are soil horizons and indicate several periods of pumice deposition.

Chemical analysis of the pumice from the nuee ardente tuff from the Coso Range area shows some features that are not consistent with similar types of pumices found farther north in Mono and Inyo counties. The following analysis is by Smith-Emery Company, Los Angeles, California, and indicates that the pumice is not rhyolitic but andesitic in composition. This is further indicated by the scarcity of quartz and potash feldspar.

Chemical composition of the pumice from the nuee ardente tuff of the Coso Range. Analysis by Smith-Emery Company.

SiO_2	60.30
Al_2O_3	16.26
Fe_2O_3	2.80
FeO	
TiO_2	.60
CaO	5.74
MgO	3.98
Na_2O	1.95
K_2O	0.06
Loss on Ignition	7.82
SO_2	None
P_2O_5	None
Bentonite (clay)	None

Pumice Deposits

Crownite Corporation Pumice Deposits. Location: secs. 13, 14, 15, 21, 22, 23, 24, 26, 35, and 36, T. 21 S., R. 38 E., M. D. M., in the southern part of the Coso Range, about 6 miles northeast of Coso Junction. Ownership: The property consists of 17 claims grouped as follows (fig. 9): (1) Ray Gill No. 7, (2) Ray Gill Nos. 11, 13, and 53, (3) Ray Gill No. 31, (4) Ray Gill Nos. 51 and 52, and (5) Donna Group (Donna Nos. 1, 2, 3, and 4). These claims are owned by the Crownite Corporation, H. Fogwell, president, and Robert Huber, general manager, 6363 Wilshire Boulevard, Los Angeles, California.

Much of the pumice mining in the Coso Range area has been carried on by the Crownite Corporation, formerly Desert Materials Corporation. Although much of the early production for these deposits was obtained from the Donna pumice deposits in sec. 35, T. 21 S., R. 38 E., the present pumice is mined from the Ray Gill No. 31 pumice deposit in the northeast corner of sec. 24, T. 21 S., R. 38 E. Other pits in secs. 15, 21, 22, 35, and 36, T. 21 S., R. 38 E., have yielded small amounts of pumice.

Ray Gill No. 7. The Ray Gill No. 7 pumice deposit is in the center of sec. 21, T. 21 S., R. 38 E. It occurs on a south trending spur which rises about 350 feet above the floor of the open pit (see fig. 10), and is about 8 miles from the processing plant at Sykes, a siding on the Southern Pacific Railroad.

The pumice at the Ray Gill No. 7 deposit occurs in a tuff layer interbedded with tuffaceous sediments of the Plio-Pleistocene Coso formation. Granitic basement rocks are exposed in the deposit, but the actual contact was concealed beneath soil overburden. The pumice layer and associated tuffaceous sediments strike N. 45° E., and dip about 20 degrees northwestward. The layer ranges in thickness from 5 to 45 feet, but averages about 12 feet. Overburden consists of pumiceous soil about 2 feet thick.

The pumice tuff is moderately consolidated and consists principally of pumice fragments and minor amounts of pumicite. Rounded cobbles of red granite, hornblende andesite, and dark mica schist are common. The pumice fragments are angular, light-gray to white, and range from $\frac{1}{8}$ inch to 2 inches in diameter. Phenocrysts of black biotite and glassy feldspar are commou in the pumice; crystals of black hornblende are rare.

The Ray Gill No. 7 pumice deposit has been developed through bulldozer cuts, trenches, shallow shafts, and drill holes. There are 22 drill holes within the limits of the claim which show an average of about 11 feet of pumice per hole. Some of the holes did not intersect the pumice layer whereas several drill holes encountered as much as 45 feet of pumice tuff (see fig. 10).

Much of the pumice mining on the Ray Gill No. 7 pumice deposit was by open pit methods and was done in 1946 and 1947. The pumice was mined from an open pit, which in 1955, measured about 500 feet long, 100 feet wide, and 10 feet deep. A bulldozer was used to remove the overburden and the pumice was mined with a dragline which loaded the pumice directly into trucks.

The pumice was used as aggregate in making lightweight building blocks.

Ray Gill Nos. 11, 13, and 53 Pumice Deposits. The Ray Gill Nos. 11, 13, and 53 pumice deposits are situated in secs. 21 and 22, T. 21 S., R. 38 E., M. D. M. (see fig. 10). They are on the south slope of a spur which rises about 600 feet above its southern base, and are 8 miles from the processing plant at Sykes siding.

The pumice at the Ray Gill Nos. 11, 13, and 53 deposits occurs in a pumice tuff layer interbedded with tuffaceous lake deposits. The sequence of pumice tuff and tuffaceous lake deposits rests unconformably upon friable, deeply weathered granite. The sequence strikes N. 40° E. and dips about 20 degrees northwestward. Exposures of the pumice layer are rare, but as much as 15 feet in depth of pumice was encountered in open cuts on Ray Gill

No. 11 and an equal amount in the small open pit on Ray Gill No. 53 indicate at least 10 feet of pumice.

The sequence of pumice tuff and tuffaceous lake deposits (Plio-Pleistocene Coso formation) is cut by a small north-trending normal fault. The amount of movement is not known, but from the relative positions of the pumice layer on both sides of the fault, the displacement in a vertical direction was probably no more than a few tens of feet.

Overburden consists of pumiceous soil which ranges from 1 foot to 3 feet thick.

The pumice layer consists principally of pumice fragments and minor amounts of rounded boulders and cobbles of hornblende andesite, red granite, and dark mica schist. Angular grains of glassy quartz, black biotite, and feldspar constitute the crystalline portion that represents a few percent of the pumice tuff layer. The pumice fragments are angular, light-gray to white in color, and range from ⅛ inch to 2 inches in diameter. Phenocrysts of glassy feldspar and black biotite are common in the pumice.

The Ray Gill Nos. 11, 13, and 53 pumice deposits have been developed on a limited scale through a small open pit on the Ray Gill No. 13 and shallow test pits and open cuts on the other two deposits.

Although no pumice has been produced from these deposits since 1947, they contain, as indicated by the limited exposures and development, at least 100,000 tons of pumice suitable as aggregate for lightweight building block.

Ray Gill No. 31 Pumice Deposit. The Ray Gill No. 31 pumice deposit lies in parts of secs. 13, 23, and 24, T. 21 S., R. 38 E., M. D. M., although the Ray Gill Claim includes part of sec. 14 also (see fig. 11). The deposit occurs in a small broad valley at an elevation of 4890 feet, about 10 miles from the processing plant at Sykes siding.

The pumice at the Ray Gill No. 31 deposit occurs in layers of pumice tuff of nuee ardente origin. The pumice tuff layers are essentially flat-lying and range in thickness from 1 foot to at least 28 feet.

They are separated by thin layers of pumiceous soil, and the repeated appearance of the pumiceous soil indicates more than one period of pumice deposition (fig. 75). The pumice is overlain by a soil covering that ranges from 2 to 10 feet thick. The soil is loosely consolidated and easily removed.

The pumice fragments are white, angular, and range from $1/16$ inch to 6 inches in size. The average size of pumice fragments is about ½ inch. Phenocrysts of black biotite, black hornblende, and glassy feldspar are moderately common in the pumice. Scattered at random throughout the pumice layers are angular and rounded boulders of hornblende andesite, granite, and dark mica schist that range from 4 inches to 4 feet in diameter. Each boulder, regardless of size, is surrounded by a rim of white pumicite which ranges from ⅛ inch to 12 inches in thickness, the larger boulders having the thicker rims of pumicite.

The deposit is cut by several small normal faults of unknown displacement that strike roughly northwestward.

Screen analysis of quarry-run pumice from main open pit on Ray Gill No. 31 pumice deposit, Coso Range, Inyo County, California. Analysis by author.

Screen size	Percent retained	Accumulative percent retained
1¼ inch	9.78	9.78
¾ inch	10.00	19.78
½ inch	24.85	44.63
¼ inch	17.17	61.80
4 mesh	11.30	73.10
8 mesh	10.87	83.97
14 mesh	5.87	89.84
30 mesh	6.30	96.14
50 mesh	1.37	97.51
100 mesh	1.30	98.81
140 mesh	0.79	99.60
200 mesh	0.40	100.00

The Ray Gill No. 31 pumice deposit is the main source of pumice for the Coso Range area. This deposit has been developed through extensive open cuts and open pits (figs. 74, 77, 78). A total of 45 vertical drill holes were drilled into the deposit. Eleven holes did not show any pumice; the remaining 34 holes showed a thickness of pumice ranging from 1 to 27 feet. Apparently only a few of the holes were drilled to depths beneath the lowest pumice layer, since subsequent mining operations have shown the pumice sequence to be as much as 35 feet in thickness.

Overburden is removed and hauled away from the stripped area by caterpillar drawn Tourneaupulls. The pumice is mined with a dragline and loaded into trucks for hauling to the processing plant at Sykes Siding.

Ray Gill Nos. 51 and 52 Pumice Claims. The Ray Gill pumice claims numbers 51 and 52 are located in secs. 23 and 26, T. 21 S., R. 38 E., M. D. M., about 10 miles from Sykes siding (see fig. 11).

Pumice is not exposed at the surface on the Ray Gill pumice claims 51 and 52. Loose pumiceous soil covers the surface, but the widespread occurrence of pumice float and the abundance of angular pumice fragments in mounds surrounding badger holes indicates that the pumice occurs not too far beneath the surface of the ground.

The pumice obtained from badger mounds on the Ray Gill pumice claims 51 and 52 is very similar to the pumice which occurs in the nearby Ray Gill No. 31 pumice deposit.

Donna Pumice Deposits. The Donna pumice deposits are located on four pumice claims, Donna Nos. 1, 2, 3, and 4, located in sec. 35, T. 21 S., R. 38 E., M. D. M., about 10 miles from Sykes siding (see fig. 12). The pumice deposits are on a moderate south-dipping slope of an east-trending ridge of granite and appear to have been deposited in a shallow stream basin whose configuration was similar to the present topography (fig. 79).

The pumice at the Donna deposits occurs in a sequence of pumice tuff layers interbedded with layers of pumiceous sand that dips gently south. The base of the sequence is not exposed in any of the mine workings nor can the pumice be found in contact with the granite which is well exposed at several places near the open pits. However, on the basis of exposures in the mine workings, the sequence is at least 85 feet thick. In general, there are two layers of pumice tuff beds separated by a persistent layer of fine-grained pumiceous sand about 14 feet thick. The top tuff layer ranges up to 50 feet thick, and the bottom tuff layer, although not completely exposed, is at least 17 feet thick. The pumice is overlain by loosely consolidated pumiceous soil which ranges in thickness from 5 to 10 feet. The pumice in the upper tuff layer is both angular and rounded, light-gray to white in color, and ranges in size from $\frac{1}{16}$ inch to 3 inches (fig. 80). Phenocrysts of black biotite, black hornblende, and glassy feldspar are moderately common in the pumice. Thin interbeds of silica sand, tuffaceous sandstone, and silt can be found in the upper tuff layer, especially in the bottom portions of the pumice layers. The silica sand is fine- to medium-grained and consists of glassy quartz, glassy feldspar (both potash and soda-lime), black biotite, and stumpy needles of black hornblende. It is estimated that the silica sand and interbeds of silt and tuffaceous sandstone (not including the thick layer of pumiceous sandstone that separates the tuff layers) constitute at least 10 percent by weight of the upper tuff layer.

The pumice in the lower pumice tuff layer is white and occurs in angular fragments that range from $\frac{1}{16}$ inch to $2\frac{1}{2}$ inches in diameter. Phenocrysts of glassy feldspar, black biotite, and black hornblende are moderately common in the pumice. There is, however, a general absence of silica sand in the lower pumice tuff layer, and this is a good point in favor of this layer even though it is covered by at least 14 feet of loosely consolidated pumiceous sandstone. Several small faults cut the pumice but do not displace it appreciably (fig. 82).

The pumice at the Donna deposits has been well exposed in drill holes, test pits, shallow shafts, and deep open pits. A total of 19 drill holes were sunk to test the thickness and extent of the pumice. Pumice was encountered in 11 of the holes and the other 8 were bottomed in the soil overburden. None of the drill holes were deep enough to encounter the bedrock, and many of them were stopped in the thick layer of pumiceous sandstone which caved the hole and stopped the drilling.

All the mining at the Donna pumice deposits was by open pit methods from two pits, the larger of which is (measured in 1955) about 400 feet long, 100 feet wide, and 50 feet deep. The smaller pit is about 200 feet long, 40 feet wide, and 35 feet deep.

Pumice mining was started at the Donna pumice deposits in 1946 and continued through the middle of 1948. During this short period the output of pumice was more than 50,000 tons, the bulk of which was used in making lightweight concrete.

At the plant the mine-run pumice is first passed over a 3-inch grizzly to remove the boulders of andesite, mica schist, and granite. The minus 3-inch material then passes to closed circuit of vibrating screens and roll crusher to produce various sizes of pumice according to product desired. The coarser grades are stored on the ground in the yard and the finer material is stored in bunkers. The following products are produced at the plant:

Product	Size in inches	Yards per hour
Pea gravel	$-\frac{3}{8} + \frac{1}{8}$	85
Block aggregate	$-\frac{5}{16}$ to pan	85
Gunite aggregate	$-\frac{3}{16}$ to pan	40-45
Plaster granule	$-\frac{1}{8} + \frac{1}{16}$	—
Plaster sand	$-\frac{1}{8}$ to pan	45
Special sand	1 and $\frac{3}{4}$	110-115
Pozzolan	$-\frac{1}{8}$ to pan (reground for pozzolan)	

California-Nevada Building Materials Producers Pumice Deposit. Location: sec. 19, T. 21 S., R. 38 E., M. D. M., on the southwestern slope of the Coso Range, about 4 miles northeast of Coso Junction. Ownership: R. H. Thompson, Mayfair Hotel, Inyokern, California; leased to California-Nevada Building Materials Producers, D. B. Chester and Associates, 3723 Wilshire Boulevard, Los Angeles, California (Norman and Stewart, 1951, p. 107).

The pumice at this deposit occurs in tuffs of subaqueous origin that are well exposed on the north side of a small canyon. The pumice fragments are grayish-white in color, angular in shape, and range in size from $\frac{1}{8}$-inch to 2 inches in diameter. The pumice was mined and hauled to a small plant near Coso Junction where aggregate pumice was produced. This property is idle now, but was in operation during the late 1940's.

Inyo Pumice Corporation Deposit. Location: sec. 19, T. 21 S., R. 38 E., M. D. M., on the southwestern slope of the Coso Range, about 2 miles southeast of Haiwee Powerhouse. Ownership: property consists of two claims owned by William J. Petty, P. O. Box 21, Inyokern, California; leased to Inyo Pumice Corporation, N. W. Baum, president, 11314 S. Luitweiler Road, Whittier, California (Norman and Stewart, 1951, p. 108).

The pumice at the deposit of the Inyo Pumice Corporation occurs in a layer of creamy-white, angular fragments that range in size from $\frac{1}{4}$ inch to 2 inches in diameter. The layer which has an exposed thickness of 30 feet is overlain by a well-cemented, cream-colored, sandy tuff. Both the pumice and tuff are parts of a thick section of pyroclastic rocks that dips gently westward. In 1948 the property was opened for mining, but was in operation for only a few months.

Round Mountain Pumice Deposit. Location: sec. 30, T. 21 S., R. 38 E., M. D. M., on the southwestern slope of the Coso Range, about 3 miles southeast of the Haiwee Powerhouse. Ownership: Three placer claims owned by Henry Babineau, 6204 Woodward Avenue, Bell, California (Norman and Stewart, 1951, p. 108).

The pumice at the Round Mountain deposit occurs in a lenticular layer of unknown thickness in a section of tuffs and tuffaceous sediments that dips gently westward. In the center of an open pit where considerable pumice has been mined, the pumice layer has an exposed thickness of 20 feet. The pumice fragments are angular in shape, white in color, and range from $\frac{1}{4}$ inch to 2 inches in diameter. The pumice is loosely consolidated and is quite easily mined after the overburden of variable thickness is stripped away.

Mining operations were started in 1949 and the pumice was mined with tractor with a hydraulic dozer which pushed the loose pumice into a hopper. A vibrating screen powered by a 6-horsepower gasoline engine separated the pumice into the following sizes: minus $1\frac{1}{2}$ inches, plus $\frac{3}{8}$ inch, and minus $\frac{3}{8}$ inch. This property was inactive in 1955.

Lucky Lager Pumice Deposit. Location: sec. 13, T. 21 S., R. 37 E., M. D. M., on the southwest slope of the Coso Range, about $1\frac{1}{2}$ miles southeast of the Haiwee Powerhouse. Ownership: Eight placer claims are owned by William J. Petty, P. O. Box 21, Inyokern, California; leased to Henry Babineau, 6204 Woodward Avenue, Bell, California.

At the Lucky Lager pumice deposit, pumice is mined from a layer of tuff which lies near the base of a sequence of pyroclastic rocks (see fig. 85). The sequence dips westward between 5 and 7 degrees, and consists of interbedded pumice tuff, tuffaceous sedimentary rocks and tuff-breccia, all part of the Plio-Pleistocene Coso formation. The tuff layer at the open pit rests upon andesite breccia and is overlain by rocky talus which ranges from a few feet to 10 feet thick. Although the thickness of the pumice bed is not known, thicknesses up to 30 feet were exposed in test pits and mining operations (fig. 85). The pumice fragments are creamy-white in color, angular in shape, and range in size from $\frac{1}{16}$ inch to 2 inches in diameter. Pumice bombs up to 8 inches across are not rare.

The pumice is mined from an open pit which in June 1955 measured about 300 feet long, 50 feet wide, and a face about 30 feet high.

The pumice is mined with a bulldozer and used mainly as aggregate in building blocks.

Volcanic Cinders (Scoria) Deposits

Three producers mine volcanic cinders in the Coso Range area. Two of them are located on the south slope of Red Cinder Mountain (fig. 87) and the third, a more recent producer, on unnamed cinder cone about 2 miles northeast from Red Cinder Mountain. Red Cinder Mountain is a typical volcanic cone and rises about 500 feet from its base, which is about 1 mile in diameter, to an elevation of 3945 feet. The unnamed cinder cone is considerably smaller than Red Cinder Mountain. It rises about 180 feet above its circular base and attains an elevation of 3623. It measures about 2500 feet in diameter across the base. Both cinder cones are in the southern part of Rose Valley, about 3 miles north of Little Lake, Inyo County.

The volcanic cinders are basaltic in composition and contain small lath-shaped labradorite crystals set in a groundmass of fine-grained labradorite and augite, and some dark-brown basaltic glass.

The accompanying table, which gives the chemical analyses of Red Cinder Mountain volcanic cinders and an average of 56 basalts from world-wide occurrences indicates that the volcanic cinders from Red Cinder Mountain are basaltic in composition even though they contain appreciably more soda and potash than is common to basalts typical of volcanic centers containing calc-alkaline andesites, dacites, and rhyodacites.

Chemical analysis of volcanic cinders from Red Cinder Mountain, Inyo County, California, and the average of 56 chemical analyses of basalts from world-wide occurrences.

	(1)	(2)
SiO_2	50.90	51.35
Al_2O_3	18.24	18.04
Fe_2O_3	7.77	3.40
FeO	—	5.70
CaO	9.58	10.07
MgO	5.73	6.01
Na_2O	4.90	2.76
K_2O	2.20	0.82
TiO_2	1.79	1.10
H_2O+	0.22	0.45
H_2O-	0.71	—
MnO		0.16
P_2O_5		0.16

(1) Basaltic cinder from Red Cinder Mountain, Inyo County, California. Analysis by Tripplet and Barton, Inc. (Norman and Stewart, 1951, p. 111).
(2) Basalt, average of 56 analyses, cited after Nockolds, 1954, p. 1021.

In general the cinders are loosely consolidated, dark reddish-brown in color, and range from $\frac{1}{8}$ inch to 6 inches in diameter (fig. 89). Volcanic bombs are local constituents and large lumps of agglutinated cinders can be found (fig. 90). The latter ordinarily are broken up during the mining and screening.

Actual thickness of the cinders in the mine areas is not known although cinders have been mined to a depth of about 50 feet. Overburden is thin and consists essentially of loose cindery soil.

Much of the land that contains the volcanic cinders was withdrawn from entry for any minerals by Executive Order No. 6206, July 16, 1933, which was issued to protect the water supply of the Los Angeles metropolitan water district. However, Public Land Order No. 499, effective September 15, 1948, modified order 6206 to permit location and entries for non-metallic minerals only in the following listed lands (Norman and Stewart, 1951, p. 111): secs. 18, 19, T. 21 S., R. 38 E., M. D. M.; S$\frac{1}{2}$ sec. 30, T. 22 S., R. 38 E., M. D. M.; N$\frac{1}{2}$ sec. 31, T. 22 S., R. 38 E., M. D. M.

On September 15, 1948, all of the open portions of secs. 30 and 31 were staked by C. D. Ray and Associates, 1932 East Maple, Glendale, California, Lafayette Morrison and Associates, 228 9th Street, Huntington Beach, California, and George Rouff and Henry B. Jarvis, Little Lake, California. The land was leased one-half to George Rouff and one-half to Henry B. Jarvis for separate operations.

Redlite Aggregates, Incorporated. Ownership: A subsidiary of Pioneer Pyrophyllite Company, Chula Vista, California, Ferrar Mathews and Dorothy Benner, 3032 Motor Avenue, Los Angeles, California; leased from George Rouff.

Dark reddish-brown volcanic cinders are mined by Redlite Aggregates, Incorporated, in a quarry (fig. 91) low on the south slope of Red Cinder Mountain, and hauled to the screening plant on the west side of U. S. Highway 395. The plant is on right-of-way land leased from the Southern Pacific Company.

The quarry in 1954 measured about 500 feet long, 300 feet wide, and 12 feet deep. Mine-run cinders are dumped on a 4-inch steel rail grizzly and into a 150-ton steel bin; oversize material consisting of volcanic bombs and firmly agglutinated cinders is rejected. The discharge from the steel bin passes by way of a 24-inch belt conveyor over a truck loading pit, discharges onto a second conveyor belt which is reversible, and feeds either to a closed circuit of screens and roll crusher or back into trucks at the loading pit (fig. 93). The following sizes are produced and stored in steel bins: $\frac{1}{8}$ inch to pan, $\frac{5}{16}$ to $\frac{1}{8}$ inch, and $\frac{3}{8}$ to $\frac{5}{16}$ inch. Plus $\frac{3}{8}$-inch material is either put through a roll crusher or stockpiled as aggregate for monolithic uses (Norman and Stewart, 1951, p. 112).

Cinder mining started on the property leased to Redlite Aggregates, Inc., in the late 1940's and has been more or less continuous since that time. The plant, which was opened shortly following the start of mining operations, has a discharge capacity of 50 tons per hour for block aggregate and 75 tons per hour for monolithic aggregate.

The volcanic cinders produced from this deposit are marketed in southern California and used primarily as aggregate in concrete.

Volcanic Cinder Company. Ownership: Henry B. Jarvis, P. O. Box 5, Little Lake, California.

Volcanic cinders are mined by the Volcanic Cinder Company from a quarry (fig. 88) low on the south slope of Red Cinder Mountain, near the quarry of the Redlite Aggregates, Inc.

The quarry is somewhat irregular in shape, but in 1954 measured about 500 feet long, 200 feet wide, and 30 feet deep. A Caterpillar tractor with bulldozer is used to mine and push the cinders to a screening plant (fig. 92) located only a short distance. The cinders are pushed over a 3-inch grizzly, and the undersize is carried on a belt conveyor to a $\frac{3}{4}$-inch grizzly. The oversize from these grizzlies is rejected, whereas the undersize material passes through a circuit containing screens and a roll crusher. Only one size of material is produced, minus $\frac{5}{16}$ inch, for block aggregate which is stored in a 150-ton loading bin and in the nearby storage yard.

Volcanic cinder mining operations started on property leased to the Volcanic Cinder Company late in the 1940's and has been continuous up to date. The screening plant was put into operation shortly following the opening of the quarry. The cinders are shipped to markets in southern California and used in the manufacture of concrete building blocks and monolithic concrete.

Trucks are loaded directly under the bin. The plant has a discharge capacity of 150 tons per 8-hour day, and the cinders are shipped either by truck or rail. Rail loading facilities are at Little Lake.

Splane Cinder Deposit. Location: south $\frac{1}{2}$ sec. 20, T. 22 S., R. 38 E., M. D. M., about 4 miles north of Little Lake, Inyo County. Ownership: Paul R. Splane, 13539 Hart, Van Nuys, California, has made application to patent the property which consists of a quarter section.

The deposit consists of basaltic volcanic cinders that form a volcanic cone which is about 2500 feet in diameter at the base and about 180 feet high. The volcanic cinders are loosely consolidated, angular, and range from $\frac{1}{8}$ to 4 inches in diameter. They have a wide range of color from orange-red to black.

The cinders are mined from a fan-shaped quarry on the north side of the cinder cone which, in June 1955, measured about 800 feet in a north-south direction and about 300 feet in maximum width (figs. 94, 95). There is no overburden on the flanks of the cone where quarrying is being done, but on the top of the cone a thin veneer of cindery soil covers the cinders.

A bulldozer is used to push the cinders downhill into the grizzly hopper at the plant, adjacent to the quarry.

The main unit of the mill is an electrically powered Pioneer portable mill, containing a 10 by 36-inch jaw crusher, a 20 by 32-inch roll crusher, and a 4 by 12-foot double-deck Overstrom vibrating screen. Two double-deck 3- by 12-foot Overstrom vibrating screens atop the storage bin separate fines from the finished product. The flow sheet for producing cinder block aggregate is as follows: Pit material is pushed through 8-inch grizzly openings by the bulldozer, and is conveyed by belt to the screen which has 3-inch and $\frac{5}{16}$-inch sieves. Material larger than 3 inches goes to the jaw crusher set at $1\frac{1}{4}$ to 2-inch opening and returned to the screen. Material between 3 and $\frac{5}{16}$-inch goes to the roll crusher set at about $\frac{5}{16}$-inch openings and is returned to the screen. Material smaller than $\frac{5}{16}$-inch is conveyed to the storage bunkers. The screens at the bunkers have $\frac{1}{4}$-inch sieves on the top deck, and 12-mesh on the lower deck. The material larger than $\frac{1}{4}$ inch (but with $\frac{5}{16}$ inch upper size limit) is binned separately from the grade between $\frac{1}{4}$ inch and 12 mesh, but the two size grades are blended for use as cinder block aggregates. Material smaller than 12 mesh is stockpiled separately although the strong desert winds commonly blow much of the finer sizes away.

The plant has a nominal capacity of 60 tons per hour and was operating at capacity in June 1955.

The plant turns out aggregate for concrete, roofing granules, and finely ground cinders for agriculture admixture. Most of the cinders are used however in concrete. The roofing granules, for use in built-up asphalt-based roofs, range from $\frac{1}{8}$ inch to $\frac{3}{8}$ inch in size. This material weighs about 41 pounds per cubic foot. "Shaddow rock" from $\frac{5}{16}$ inch to as large as $2\frac{1}{2}$ or 3 inches has been produced in minor quantities. Roof granules are sold in bulk in truckload lots; some are later sacked by distributors for sale. Most of the granules have been used in the Los Angeles and San Bernardino industrial areas but have been marketed as far away as Fresno and San Diego.

All material smaller than 12 mesh is sold for agriculture admixture where it is used as a soil conditioner. Its action is to hold the soil and keep it friable; little or no nutritive value is claimed.

The Splane deposit was opened up in the latter part of 1954 and has been in continuous operation since January 1955.

El Paso Mountains Area

The El Paso Mountains area is in eastern Kern County, about 30 miles south of the Coso Range area. Both pumice and pumicite have been mined in considerable quantities in this area from tuffs of the Ricardo (Pliocene) formation.

The Pliocene Ricardo formation is well exposed in the El Paso Mountains and consists of a series of continental and lacustrine sedimentary rocks containing tuffs and lava flows. The formation has a maximum thickness of 7000 feet, strikes northeastward, and dips northwestward about 18 degrees.

The pumice, although formerly mined for abrasive purposes, is now being mined as a source of aggregate and filler and comes from a layer of pumice of lapilli tuff. The lapilli tuff located near the base of the Ricardo formation has an exposed thickness of 50 feet and can be traced along its outcrop for at least 7 miles. Because of the lack of bedding and sorting and the presence of large blocks of lava, the tuff is considered to be subaerial in origin, perhaps nuee ardente. The pumice lapilli tuff grades upward into a well-bedded, sandy tuff of subaqueous origin. This sequence of pyroclastic rocks is overlain by a flow of basalt and andesite flow-breccia, and underlain by a layer of gravel composed of granitic pebbles (Dibblee, 1952, p. 27).

Pumicite (volcanic ash), locally referred to as "seismotite," of commercial quality was produced from tuff layers located near the base and middle of the Ricardo formation in Last Chance Canyon (fig. 96). The most extensive deposit of pumicite, however, occurs near the middle of the Ricardo formation which also includes beds of bentonite, sandstone, conglomerate, tuffaceous sediments and chert (fig. 96). The pumicite occurs in six separate layers, of which the most extensive has a maximum thickness of 9 feet and is traceable along its outcrop for about 7 miles. The pumicite is white, fine-grained, and consists essentially of small, angular glass shards. It is well bedded and subaqueous in origin.

Pumice Deposits

Black Mountain Pumice Deposit. Location: sec. 5, T. 29 S., R. 38 E., and secs. 31 and 32, T. 28 S., R. 38 E., M. D. M., on the southwest slope of Black Mountain north of Holly Camp. Ownership: Property consists of a group of placer claims owned by R. L. Meuer and Della Gerbracht, Randsburg, California.

A layer of pumice lapilli tuff, which underlies much of this property, occurs near the base of the Ricardo formation and is about 50 feet thick, dips 20° W., and has been exposed in several small pits from which only a few cubic yards of pumice have been quarried. The property has been idle since 1950.

Opal Mountain Deposit. Location: sec. 4, T. 29 S., R. 38 E., M. D. M., north of Last Chance Canyon, about 7 miles north of Saltdale, California. Ownership: Property consists of 160 acres owned by R. L. Meuer and Della Gerbracht, Randsburg, California.

Much of the property is underlain by a layer of pumice lapilli tuff which is about 30 feet thick. The tuff is moderately consolidated and requires some blasting in order to facilitate mining. The pumice fragments are grayish-white in color, angular in shape, and range from ⅛ inch to 2 inches in diameter. The property which was idle in 1955 was opened up during the middle 1940's and the total output of pumice was limited to a few tons.

Calsilco Corporation Deposit. Location: sec. 33, T. 28 S., R. 38 E., and sec. 4, T. 29 S., R. 38 E., M. D. M., just north of Last Chance Canyon, about 7 miles north of Saltdale. Ownership: Calsilco Corporation, George Reynolds, president, and H. A. Richardson, vice-president and manager, 2372 South Atlantic Boulevard, Los Angeles 22, California.

Most of the pumice for aggregate purposes that has been produced in the El Paso Mountains area has been obtained from this deposit. It now yields pumice which is ground and used for abrasive and filler purposes.

The pumice is produced from a 20-foot layer of consolidated pumice lapilli tuff which dips 20° W. The pumice fragments are white, angular, and range from ⅛-inch to ⅜-inch in diameter, and are firmly held in a white matrix of pumicite (volcanic ash) and small grains of glassy quartz and white feldspar. Near the top of the layer are numerous small, angular fragments of brownish-black andesite.

The pumice is mined from an open pit which in 1955 measured about 1600 feet long, 30 feet wide, and 15 feet deep (fig. 97). Blasting is required to break down the tuff which is then loaded into trucks by a ¾-cubic yard shovel. At the plant (fig. 98) located near the quarry, the tuff is passed through a closed circuit containing a hammer mill, a Williams roller mill, a ⅜-inch screen, and cyclone collectors. The finished products are aggregate pumice for insulating and acoustical plaster and ground pumice for cleansing compounds, wood filler, paint, and tooth powder (Tucker, et al., 1949, p. 250).

Pumicite (Volcanic Ash or "Seismotite") Deposits

Cudahy Packing Company Deposit. Location: secs. 5 and 8, T. 29 S., R. 38 E., M. D. M., on the west side of Last Chance Canyon, about 6 miles north of Saltdale. Ownership: Cudahy Packing Company, Los Angeles, California.

The Cudahy Company mined pumicite from layers of tuff near the middle of the Pliocene Ricardo formation. The pumicite layer is one of six pumicite layers that crop out near the top of a steep east slope of a northeasterly trending ridge made up principally of rocks of the Ricardo formation (fig. 96). The pumicite layers dip about 20 degrees westward and are interbedded with siliceous lacustrine sedimentary rocks which locally contain small bodies of bentonite. The pumicite layers range in thickness from a few feet to 9 feet, are thinly bedded, and crop out over a distance of 7 miles. The pumicite is white, fine-grained, compact, and consists essentially of small, angular, flat glass shards of rhyolitic composition.

The pumicite was mined from a 9-foot layer by underground methods. The room and pillar mining method was used and the pumicite was removed through several underground entries.

Following a primary crushing operation at the mine, the pumicite was hauled 8 miles to a processing plant near Saltdale, a siding on the Owenyo branch of the Southern Pacific Railroad, where it was made ready for shipment to plants manufacturing Old Dutch Cleanser.

However, after nearly 25 years of continuous operation, from 1923 to 1947, the Cudahy property was shut down. Many thousands of tons of pumicite were produced during this period of operation, but the encroachment of silica flour in the cleanser field and the demand for sources of raw materials nearer the manufacturing centers are probably factors which directly or indirectly brought about the shut-down of pumicite mining at the Cudahy properties in the El Paso Mountains area.

Shoshone Volcanic Ash (Pumicite) Deposit. Location: secs. 30 and 31, T. 22 N., R. 7 E., M. D. M., about one-quarter mile southwest of Shoshone, California. Ownership: Charles Brown, Shoshone, California, owns 480 acres which are leased to Western Talc Company, F. H. Savell, president, 1901 E. Slauson Avenue, Los Angeles, California (Norman and Stewart, 1951, p. 109).

A few hundred yards southeast of the settlement of Shoshone are some low terraced hills underlain mostly by nearly horizontal lacustrine sedimentary rocks of Quaternary age. A layer of grayish-white pumicite (volcanic ash) that averages about 12 feet in thickness forms a prominent unit in these beds. The pumicite layer (fig. 100) is flat-lying, and is overlain and underlain by sands and gravels which, locally, are cemented with siliceous material. The overburden is as much as 12 feet thick.

The pumicite layer (fig. 100) is thinly bedded with the beds ranging in thickness from $1/50$ inch to 4 inches. The pumicite is grayish-white in color and consists almost wholly of small, flat glass shards of rhyolitic composition.

FIGURE 73. Oblique aerial view of the southern Coso Range, Inyo County, showing pumice pits of the Crownite Corporation, 1—Ray Gill #31, 2—Ray Gill #13, and 3—Ray Gill #7, and the general geology in which plio-Pleistocene volcanic rocks consisting of flows and cinder cones of basalt (B), domes of perlite (in part obsidian) (P), and layers of lacustrine sedimentary rocks including pumice tuffs (Ls) rest upon a deeply eroded basement of pre-Cretaceous granitic and metamorphic rocks (Br). The pumice tuffs in the lacustrine sedimentary rocks represent the earliest periods of volcanic activity. The perlite was emplaced at a much later date as volcanic plugs, and the basalt flows and cinder cones probably represent a more recent volcanic activity. Alluvium (Qal) covers much of the geology and fills shallow, broad valleys. Observer faces northeast. Photograph courtesy of White's Studio, North Hollywood, California.

FIGURE 74. Oblique aerial view of the Crownite Corporation's Ray Gill #31 pumice pit, southern Coso Range, Inyo County. Here pumice for aggregate purposes is mined from tuff layers interbedded with tuffaceous sediments and overlain by alluvium (Qal). The tuff rests upon a deeply eroded basement of granitic rocks (Br). Observer faces east. Photograph courtesy of White's Studio, North Hollywood, California.

Figure 75 (above). Close-up of the pumice at the Ray Gill #31 pumice deposit, southern Coso Range, Inyo County. Scale is indicated by pick handle which is 12 inches long.

Figure 76 (below). Boulder of hornblende andesite (A) partly surrounded by a zone of white pumicite (P) in quarry at Ray Gill #31 pumice deposit, southern Coso Range, Inyo County.

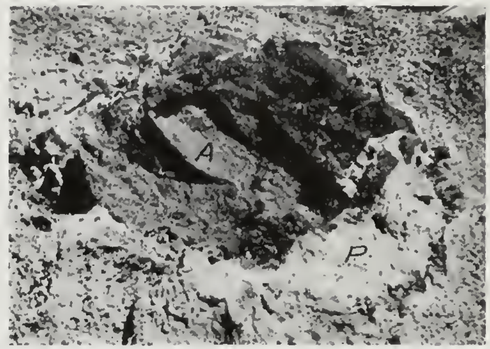

Figure 77. Mining pumice at the Ray Gill #31 pumice deposit, southern Coso Range, Inyo County. Observer faces northwest.

Figure 78. Panorama of Ray Gill #31 pumice pit, southern Coso Range, Inyo County. Pumice is mined from tuff layers (T) which are overlain by soil overburden up to 15 feet thick which is stripped away before the pumice is mined. Although actual contact between the pumice tuff and the bedrock is not observable, it is believed that the granitic rock (G), which constitutes most of the basement complex, immediately underlies the pumice tuff. Observer faces north.

Figure 79. Oblique aerial view of the southern Coso Range, Inyo County, showing several pumice pits of the Crownite Corporation, 1—Donna #3, 2—Donna #4, and 3—a pumice pit on Section 36, T. 21 S., R. 38 S., MDM., adjoining the Donna group of claims. Pumice (P) is mined from tuff layers of the plio-Pleistocene Coso formation which rests unconformably upon deeply eroded granitic basement rock (Br). Domes of perlite (Pe) were emplaced after the pumice was deposited, and a remnant of a low lapilli rim can be seen partly encircling the dome in the upper left-hand corner of the photograph. Alluvium (Qal) covers much of the geology and fills broad valleys. Observer faces east. Photograph courtesy White's Studio, North Hollywood, California.

Figure 80. Close-up of angular pumice of the upper layer at the Donna pumice mine, southern Coso Range, Inyo County. Scale is indicated by the 6-inch rule.

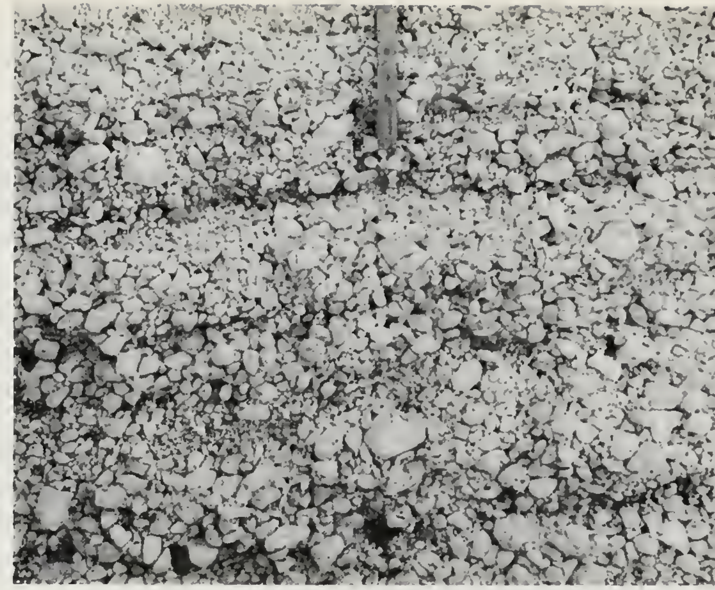

Figure 81. Rounded pumice of the upper pumice layer at the Donna pumice mine, southern Coso Range, Inyo County. Scale is indicated by the 6-inch rule.

Figure 82. Faulted pumice layer in the east quarry at the Donna pumice mine, southern Coso Range, Inyo County. The lower pumice layer (L) on the left side of the fault (F) has been faulted into place against the gray sandstone (S) and upper pumice (U) layers on the right side of the fault. Observer faces northwest.

Figure 83. West quarry of the Donna pumice mine, southern Coso Range, Inyo County. Rock in upper right-hand part of photograph is part of granitic basement complex. Observer faces northwest.

FIGURE 84. View of the southwestern part of Coso Range, Inyo County, showing location of pumice deposits: (1) Lucky Lager, (2) California-Nevada Building Materials Producers, and (3) Inyo Pumice Corporation. Pumice is mined from pumice tuff layers (T) interbedded with tuffaceous sedimentary rocks of the plio-Pleistocene Coso formation. This sequence of pyroclastic and sedimentary rocks rests upon andesite breccia and is overlain by later flows of andesite (A). Observer faces northeast.

FIGURE 85. Lucky Lager pumice mine, southern Coso Range, Inyo County. Quarry face above the figure is about 40 feet high. Dark rock in upper left-hand corner of the photograph is part of a flow of hornblende andesite which overlies the pumice, and the dark rock immediately above the pumice is consolidated talus derived from the overlying hornblende andesite. Observer faces northeast.

FIGURE 86. Crownite Corporation's pumice crushing and screening plant and storage facilities at Sykes siding, Inyo County. Much of the pumice stockpiled in the storage yard as shown in the photograph was used in the construction of several large office buildings in Los Angeles. Observer faces southwest. Photograph courtesy of White's Studio, North Hollywood, California.

FIGURE 87. View of Red Cinder Mountain, Inyo County, showing quarry and screening plant of the Volcanic Cinder Company (VC) and quarry of the Redlite Aggregates, Incorporated (RA). Red Cinder Mountain is a typical volcanic cinder cone made up of dark red volcanic cinders which are being mined and processed here and shipped to markets in California for use as aggregate in concrete building blocks and stucco. Dark colored rock in foreground is basalt flow. Observer faces northeast.

FIGURE 88. Quarry, Volcanic Cinder Company, Inyo County. Quarry is low on the south slope of Red Cinder Mountain, an extinct volcanic cinder cone near Little Lake. The cinders are loosely consolidated and easily mined. Observer faces northeast.

FIGURE 89. Close-up of volcanic cinders as exposed in the quarry of the Volcanic Cinder Company, Red Cinder Mountain, Inyo County. Crude sorting and the presence of volcanic bombs are characteristics of this deposit. Scale is indicated by pick handle which is 12 inches long.

FIGURE 90. Close-up of volcanic cinder agglutinate from the quarry of the Volcanic Cinder Company, Red Cinder Mountain, Inyo County. Masses similar to this are common in volcanic cinder deposits, and are usually broken up during the mining and screening operations. Scale is indicated by the 6-inch rule.

FIGURE 91. Quarry, Redlite Aggregates, Incorporated, Red Cinder Mountain, Inyo County. The quarry is low on the southeast slope of Red Cinder Mountain, an extinct Quaternary volcanic cinder cone near Little Lake. Observer faces northeast.

FIGURE 92. Screening plant, Volcanic Cinder Company, Red Cinder Mountain, Inyo County. Here the cinders are screened to size and loaded into trucks for shipment to distant markets. Observer faces northeast.

FIGURE 93. Screening plant, Redlite Aggregates, Incorporated. Volcanic cinders quarried on Red Cinder Mountain, Inyo County, about one-half mile to the east, are trucked to this plant where they are screened to size for shipment to distant markets. Observer faces northwest.

FIGURE 94. Splane volcanic cinder operation near Red Cinder Mountain, Inyo County. Cinders are mined from quarry (Q), processed at plant (P), and stored in steel bins (B) and storage yard (Y). Observer faces south.

FIGURE 95. Processing plant, Splane volcanic cinder operation, near Red Cinder Mountain, Inyo County. Observer faces northeast toward the Coso Range.

FIGURE 96. Lake beds in the Ricardo formation, Last Chance Canyon area, Kern County, which contain the layers of white pumicite (locally called seismotite). The dark rock in the foreground is andesite breccia. Observer faces west.

FIGURE 97. Pumice quarry of the Calsilco Corporation, Kern County. Pumice lapilli tuff (T) is overlain by tuffaceous sandstone (Ts) and andesite breccia (B). The scale is indicated by figure standing on the floor of the quarry. Observer faces north.

FIGURE 98. Crushing, grinding, and screening plant of the Calsilco Corporation, Kern County. At this plant pumice from the adjacent quarry is processed for plaster aggregate, filler, and abrasives. Observer faces southeast.

FIGURE 99. Pumicite operation at Shoshone, Inyo County. The pumicite (P) occurs in a series of Quaternary lake beds (Ql) which underly much of the valley near Shoshone. Resting Spring Range is in the background. Observer faces northeast.

Figure 100. Shoshone pumicite deposit, near Shoshone, Inyo County. The pumicite layer (P), about 10 feet thick, is overlain by a layer of buff-colored, moderately-well cemented tuffaceous sand (Ts) which must be removed before the pumicite can be mined. Observer faces northwest. Photograph by L. A. Wright.

Figure 101. Pumice breccia as exposed in the quarry of the Superlite Builders Supply Company's pumice deposit, Imperial County. The pumice fragments are angular to subrounded in shape, grayish-white in color, and range in size from 1/16-inch to 5 inches. Just above the pick the pumice is admixed with dark colored sands and gravels. Scale is indicated by the pick handle which is 12 inches long.

FIGURE 102. Tuffaceous sand and gravel that overlie the pumice breccia at the Superlite Builders Supply Company's pumice deposit, Imperial County. Scale is indicated by the pick handle which is 12 inches long.

FIGURE 103. Screening plant, Superlite Builders Supply Company, Imperial County. Here the pumice from the nearby quarries is screened and made ready for trucking to a block plant at Calipatria, Imperial County. Observer faces northeast.

FIGURE 104. Block plant, Superlite Builders Supply Company, Calipatria, Imperial County. Various sizes and shapes of pumice concrete blocks are manufactured at this plant. The pumice aggregate and portland cement are stored in the silos, and the blocks are made in automatically controlled machines. Observer faces southeast.

FIGURE 105. Quarry of the Williams Brothers pumice deposit, San Bernardino County. The quarry face is about 20 feet high, and there is exposed in it and the hillside behind the following sequence of volcanic and pyroclastic rocks: Rhyolite (R) grading downward into perlite (P) which rests upon tuffaceous perlite breccia (B). Below the rhyolite and perlite there is a thick succession of tuffs and tuffaceous sedimentary rocks. The massive tuff (T) is the principal source of the pumice at this quarry. Observer faces north.

Figure 106. Pumice processing plant at the Williams Brothers pumice deposit, San Bernardino County. Observer faces northwest.

Figure 107. View of volcanic cinder quarry on west slope of Mt. Pisgah, San Bernardino County. Flow in foreground is ropy or pahoehoe basalt. Observer faces east. Photography by Richard M. Stewart.

After the overburden is removed by bulldozer and scrapers, the pumicite is loaded into 20-ton trucks with a Caterpillar elevator loader and hauled to Western Talc Company's grinding plant at Dunn, a siding on the Union Pacific Railroad. At the plant the pumicite is either loaded directly into railroad cars, or dried, pulverized, and bagged for shipment to manufacturing plants.

Partial section of sedimentary rocks exposed in pumicite quarry at Shoshone, Inyo County, California.

Thickness in feet	Description
	Surface, top of section
4-6	Siltstone, clayey, siliceous, calcareous, thin-bedded, light-gray.
2	Siltstone, greenish-gray, tuffaceous and conglomeratic in part. Angular and rounded fragments of andesite, gray limestone, pink quartzite, and grains of quartz, feldspar, and biotite.
3-4	Siltstone, dull gray, more conglomerate than above.
4	Siltstone, gray, slightly crossbedded. Lower part is sandy and buff colored. Separated from underlying pumicite layer by slight erosional unconformity.
10-12	Pumicite, grayish-white to dead-white in color, very fine-grained and well-bedded. Bottom 10-12 inches of pumicite are firmly compacted and brecciated. Slight erosional unconformity between pumicite and underlying layer.
$1\frac{1}{2}$-2	Siltstone, light-gray, fine-grained, thin bedded, sandy in part, limy at base. Upper $\frac{1}{8}$-$\frac{1}{2}$ inch is very limy.
$1\frac{1}{2}$-2	Congromerate, loosely consolidated, sandy at top; consists of rounded to angular fragments of gray limestone, pink rhyolite, brown basalt, and gray andesite.
1	Sandstone, well compacted, dark-gray, limy in part.
2	Conglomerate, sandy, firmly consolidated; consists of rounded and sub-rounded fragments of blue-gray limestone, pink rhyolite, and gray granite.
	Base of exposure

Chemical analyses of two California pumicites (volcanic ash) which have been used extensively in the manufacture of scouring soaps.

	(1)	(2)
SiO_2	68.43	71.89
Al_2O_3	12.94	14.69
Fe_2O_3	1.22	ndt
FeO		
CaO	1.17	0.90
MgO	0.22	0.33
K_2O	2.15	3.18
Na_2O	3.50	4.86
H_2O (total)	9.81	4.86
CO_2	0.31	0.11
Cl_2	0.47	0.06

(1) Shoshone Pumicite. Analysis by Pacific Coast Borax Co.
(2) Cudahy Pumicite, Last Chance Canyon, Kern County; analysis by Pacific Coast Borax Co.

The Shoshone pumicite deposit was in operation as early as 1920 (Tucker, 1920, p. 297). The pumicite then was referred to as silica, and used for filtering and purifying oils at petroleum refineries on the West Coast. During the mid-1920's there was a change in the use of the pumicite from a filtering agent to an abrasive. Mining operations have been intermittent and depended largely upon the demand for this type of pumicite. During the latter part of the 1940's the average monthly output of pumicite was about 170 tons. In the early 1950's, however, mining of pumicite tapered off tremendously and the annual production now amounts to just a few tons. The demand for an abrasive which remains white when wet apparently has been one of the major factors effecting the change from pumicite to silica flour.

Mojave Desert and Colorado Desert

The Mojave Desert and Colorado Desert region includes a large part of southeastern California. It is bounded on the east by Nevada and Arizona, on the north by the Basin Ranges region, on the west by the Transverse and Peninsular Ranges region, and on the south by Mexico.

It is a desert region characterized by many mountain ranges separated by broad expanses of desert plains. The deposits of pumice, pumicite, and volcanic cinders are found in the volcanic rocks, principally in those places where there are thick accumulations of pyroclastic rocks.

The deposits of pumice and pumicite in the Mojave Desert and Colorado Desert region occur in tuffs of subaqueous origin. The volcanic cinders are mined from late Quaternary cinder cones which were built up by basaltic eruptions around central vents.

The pumice deposits that lie about 18 miles northwest of Barstow occur in a thick series of volcanic rocks of the Calico (Miocene) formation (Dibblee, 1952) and rest upon deeply-eroded Mesozoic granite. The volcanic rocks, which consist mostly of tuffs and rhyolite flows, strike northwest and dip moderately to the southwest.

A typical section of the volcanic rocks is exposed on a steep hillside a few hundred feet east of the Williams Brothers pumice quarry which is located about 18 miles northwest of Barstow.

Section of volcanic rocks of the Calico formation at Williams Brothers quarry, San Bernardino County, California.

Thickness in feet	Description
	Top of section
25	Rhyolite, spherulitic, with spherulites ranging in diameter from $\frac{1}{8}$ inch to 4 inches; purplish in color.
40	Perlite, massive, dark-gray to grayish-green, onion-skin and splintery fracture; mottled black and brown at base.
15	Perlite breccia grading upward into massive perlite.
10	Perlite, pumiceous, pink to gray in color.
40-45	Perlite breccia, pumiceous, grayish in color; fragments range in size from one inch to one foot.
40	Tuff, crystal-lithic-vitric; thin-bedded, grayish-white in color, angular perlite, rhyolite, and granite fragments average one inch in diameter; sandy in thin beds.
10	Tuff breccia, mostly light to dark-gray, angular perlite fragments to one foot in diameter set in fine pumice matrix.
20	Tuff, thin-bedded, sandy and contains considerable granite and perlite fragments. Gray in color.
15-18	Tuff, thin-bedded, sandy in upper two-thirds and considerable pumice in lower one-third; gray in color. Sandy zones are high in silica sand.
3	Tuff, well consolidated, well-bedded; grayish-white; pumice fragments range in size from $\frac{1}{8}$ inch to $\frac{1}{2}$ inch.
20-25	Tuff, moderately consolidated, well-bedded, grayish-white; angular pumice fragments range in size from $\frac{1}{8}$ inch to $\frac{1}{2}$ inch.
4	Tuff, hard, well consolidated but not welded; considerable rock fragments and silica sand.
30-37	Tuff, pumice-lapilli, loosely consolidated; white pumice fragments range in size from $\frac{1}{8}$ inch to $\frac{3}{4}$ inch. Pumice fragments coarsen upwards.

The pumice deposits along the southern shore of Salton Sea are localized around Obsidian Butte, a low mound which rises some 75 feet above a flat soil covered plain. Obsidian Butte actually is a low volcanic dome of vesiculated obsidian which has been covered incompletely by sands and gravels derived in part from the dome itself and in part from debris washed in by the waves and currents of Salton Sea whose waters once nearly covered the butte.

The pumice deposits are mostly subaqueous in origin. Volcanic activity started with an eruption of pumice which built up a low mound that was later intruded by the dome of vesiculated obsidian. Action of the waves of the prehistoric Salton Sea eroded the dome slightly and deposited on its flanks outward dipping beds consisting of well-rounded sands and gravels containing various proportions of pumice and obsidian.

The pumice fragments, which actually constitute no more than 40 percent of the surficial material, range from ⅛ inch to 10 inches in diameter. The larger pieces of pumice are rare, and the average fragment is about one inch in diameter. The remaining part of the surficial material consists of sands and gravels. Quartz, feldspar, pumice, and obsidian comprise the sand and pumice and obsidian constitute the clasts in the gravels.

Volcanic cinders have been produced from two cinder cones in the Mojave Desert and Colorado Desert region, and several undeveloped cinder cones exist in this region. Mt. Pisgah and Dish Hill, prominent landmarks in this part of California, are the late Quaternary cinder cones from which most of these cinders have been mined. Dish Hill is breached on its west side, whereas Mt. Pisgah stands as a symmetrical cone above a gently sloping apron of rough lava flows and collapsed lava tubes.

Pumice Deposits

Superlite Builders Supply Company Pumice Deposit. Location: sec. 32, T. 11 S., R. 13 E., S. B. M., on the east side of Obsidian Butte, about 9½ miles northwest of Calipatria, Imperial County, California. Ownership: Imperial Irrigation District; leased to Superlite Builders Supply Company, Paul Thomas, president, 3800 N. Central Avenue, Phoenix, Arizona; O. K. Barnhill, plant manager, Calipatria, California. Formerly held by Brand and Stevens (Tucker, 1920, p. 270).

Partial section of tuffaceous conglomerate and overlying beds of sands and gravels at the quarry of the Superlite Corporation pumice deposit, Imperial County, California

Thickness in feet	Description
	Top of section
10-15	Sands and gravels, well-bedded; fragments in gravels are sub-rounded and range in size from ¼ inch to 5 inches in diameter. An occasional large angular block as much as 2 feet in diameter is present. Sandy layers less common and contain angular and sub-rounded grains of quartz, feldspar, obsidian, and pumice, range in size from silt to ⅛ inch in diameter.
5-10	Pumice conglomerate, composed largely of sub-rounded and angular pumice fragments and substantial amounts of sand and gravel, especially in upper part. Pumice fragments are silvery-gray and range in size from ¼ inch to 5 inches in diameter. The sand is light red in color.
10	Pumice breccia, composed essentially of angular fragments of pumice and minor amounts of silica sand. Pumice fragments are silvery-gray in color and range in size from impalpable dust to 6 inches in diameter. Bottom not observed.

The Superlite Builders Supply Company mines pumice from pumice conglomerates on the northeast part of Obsidian Butte. The conglomerate dips about 20 degrees east and lies unconformably up the wave-eroded pumiceous obsidian of Obsidian Butte. A partial section of the pumice (fig. 102) conglomerate and overlying sand and gravel beds is well exposed at the quarry.

The material in all three zones in the section measured is loosely consolidated. As the sands and gravels overlie the pumice conglomerate and breccia, the pumice is commonly contaminated during mining operations. The pumice in the breccia (fig. 101) is very porous and coarsely vesicular, whereas that in the conglomerate is less porous and only moderately vesiculated. Most of the pumice produced in this area has been obtained from the pumice conglomerate (fig. 102).

The pumice is mined from irregular shaped open pits, the largest of which has a face about 250 feet long and 20 feet high. Pumice is trucked from the pits to a ramp on which there is a grizzly with 5-inch openings. The plus 5-inch material is discarded and the minus 5-inch passes into a steel bin below and, by way of a belt conveyor, onto two shaking screens, 1 inch and ⅛ inch. The minus ⅛-inch material, consisting largely of red silica sand, is discarded and the plus ⅛-inch material is fed by conveyor to a light rod grizzly. The plus one-inch material passes through a jaw crusher and combines with the fines from the light rod grizzly. These combined sizes pass via conveyor (fig. 103) to a double deck, 4 by 10 feet Allis Chalmers screen with openings at ⅜ inch and ⅛ inch. The material passing through these screens is largely silica sand and is discarded. The oversize from the ⅜-inch screen passes through a set of rolls adjusted to crush to ½ inch. The final product is all plus ⅛ inch and minus ⅜ inch and is used as aggregate in concrete blocks.

Pumice mining at Obsidian Butte was started around 1918 and by 1926 three operations, Brand and Stevens, California Pumice, and When-Miller-Underwood were producing pumice for abrasive and aggregate uses. From 1930 to 1935 the deposits were owned and operated by the Kalite Company, Los Angeles, California (Sampson and Tucker, 1942, p. 138). In 1935 the deposits were acquired by Chamberlain Company, Los Angeles, which operated the Obsidian Butte pumice deposits from 1935 until 1938. For almost 10 years pumice mining at Obsidian Butte was at a standstill, but early in 1949 the deposits were leased by the Superlite Corporation from the Imperial Irrigation District and were put back into operation. Since 1949 the Superlite Corporation has produced several hundreds of thousands of tons of pumice.

The pumice is trucked to block plants in Calipatria, California (fig. 104), and Phoenix, Arizona, where several different concrete products are manufactured.

Williams Brothers Pumice. Location: secs. 7, 8, 17, and 18, T. 32 S., R. 46 E., M. D. M., 5 miles east of Opal Mountain and about 18 miles northeast of Hinkley, a siding on the Santa Fe Railroad. Ownership: F. M. Williams, Star Route, Barstow, California, owns two claims and leases 80 acres from the Southern Pacific Railroad (Wright, et al., 1953, p. 190).

The Williams Brothers quarry is on the south side of a hill which rises several hundred feet above a south-sloping plain (fig. 105). Since 1947 it has yielded several thousand tons of pumice for use as aggregate in building blocks, plaster, and mortar. The area is underlain principally by Tertiary lavas and tuffs that rest upon deeply eroded Mesozoic granite. This series of volcanic rocks strikes northwest and dips southwest. The tuffaceous part of the section is at least 110 feet thick and includes several thin zones of pumicite as well as 10- to 20-foot beds of pumice tuff breccia. Most of the pumice has been mined from the lower part of the section where the tuff consists largely of loosely consolidated, angular pumice fragments ranging from $\frac{1}{8}$ inch to $\frac{3}{4}$ inch in diameter in a matrix of white pumicite (fig. 105).

Mining is by open pit from a pit which in 1955 had a face about 200 feet long and 40 feet high. A bulldozer is used to mine the pumice and push it to a screening plant. Blasting is used occasionally to break down the more consolidated portions of the tuff. At the screening plant (fig. 106) a trommel is used to produce two sizes, one ranging from $\frac{1}{2}$ inch to $\frac{3}{32}$ inch in diameter, the other less than $\frac{3}{32}$ inch (Wright, et al., 1953, p. 190). Property has been worked intermittently since 1952.

Pumicite Deposits

Santa Fe Railway Pumicite. Location: sec. 13, T. 5 N., R. 15 E., S. B. M., about 3.5 miles southeast of Siam, a siding on the Santa Fe Railroad. Ownership: Eight placer claims are owned by the Santa Fe Railroad.

In this area there is exposed a Tertiary (?) tuff overlain by flows of black basalt. The tuff is about 50 feet thick, dips gently toward the west, and appears to consist of alternating beds of pumicite, of which some are coarser than others. The best pumicite layer is about 8 feet thick and lies near the bottom of the tuff (Wright, et al., 1953, p. 189).

Volcanic Cinder Deposits

Dish Hill Volcanic Cinders. Location: sec. 16, T. 6 N., R. 10 E., S. B. M., on Dish Hill, near the Santa Fe Railroad at the old siding of Trojan between Siberia and Bagdad. Ownership: State of California owns section 16 as school land and has leased 160 acres to the Velvatone Stucco Products Company, 2066 Hyde Park Boulevard, Los Angeles, California.

Dish Hill is a breached volcanic cinder cone, about 500 feet high, which rests on granitic rocks. It probably was built up during late Quaternary time when several other volcanic cones in this region, such as Mt. Pisgah and Amboy Crater, were formed. The Dish Hill cone is composed of basaltic cinders which are scoriaceous and dark-red to black in color.

Blasting is required to break down the quarry face and the broken rock is fed by bulldozer into a conveying, crushing and screening system. Coarse aggregate is produced in two sizes, minus 1-inch plus $\frac{3}{8}$-inch and minus $\frac{3}{8}$-inch and plus $\frac{1}{16}$-inch. The minus $\frac{1}{16}$-inch material is further screened to a plus and minus 30-mesh fraction for plaster and stucco sand (Wright, et al., 1953, p. 187).

Mt. Pisgah Volcanic Cinders. Location: sec. 32, T. 8 N., R. 6 E., S. B. M., about 12 miles west from Ludlow and 2 miles south of Pisgah, a siding on the Santa Fe Railroad. Ownership: Harry F. Heather, 2365 Oak Knoll Avenue, Pasadena, California (one-half interest), Oscar Hoerner, 5211 Delaware Avenue, Los Angeles, California (one-quarter interest), and Fred A. Wilson, San Bernardino, California (one-quarter interest), own two 160-acre claims.

Volcanic cinders have been mined sporadically from Mt. Pisgah cone, and the Lava-Lite Company, operated by A. R. Hallie in 1948, produced cinders for aggregate purposes.

Mt. Pisgah (fig. 107) is a cinder cone which rises some 300 feet above the surrounding lava-covered desert. The cone is composed essentially of basaltic cinders and minor proportions of volcanic bombs. The cinders are scoriaceous, black to reddish-black in color, and range from $\frac{1}{4}$ inch to 4 inches in diameter.

After the cinder cone formed about a central vent, lava flows issued forth from near the base of the cone and spread out for many square miles covering the desert floor with frozen braided lava flows and collapsed lava tubes.

Cinder mining has been limited to the west side of the cone. A scraper operating downslope removed the cinders from a narrow trench-like gash on the cone and deposited them at a stockpile from which they were pushed by bulldozer to a screening plant which is now dismantled. Several sizes of cinders were produced and stockpiled near the plant. The property was idle in 1955.

Transverse Ranges-Peninsular Ranges

This region lies along the coast of southern California and extends from the Santa Ynez River in Santa Barbara County southeastward to the Mexican border. It is bounded on the northeast and east by the Mojave Desert-Colorado Desert region. The Transverse Ranges-Peninsular Ranges region includes nearly all of San Diego and Orange counties and large parts of Ventura, Los Angeles, and Riverside counties. It encompasses a great number of mountain ranges separated by longitudinal valleys. The various rocks, which range in age from pre-Cretaceous igneous and metamorphic rocks to late Tertiary sedimentary rocks, have been folded and later faulted by prominent faults whose trends parallel the northwesterly and westerly directions of the ranges.

Areas underlain by Tertiary and Quaternary volcanic rocks, especially tuffs and tuffaceous sedimentary rocks, are confined to small isolated patches of white and red tuffs near Jacumba, San Diego County (Brooks and Roberts, 1954); to lava flows and tuffs of the Glendora volcanic rocks (Shelton, 1955, p. 45) exposed in the foothills of the San Gabriel Mountains near Glendora and Pomona, Los Angeles County; basalt flows, breccias, and tuffs in the Santa Monica Mountains, Los Angeles County (Neuerburg, 1953, p. 15); and tuffs, tuffaceous sedimentary rocks and lava flows in Bouquet and Sand Canyons (Kew, 1924, p. 53; Jahns, 1940, p. 155-156; and Wallace, 1940), Los Angeles County

The tuffs and tuffaceous sedimentary rocks in the Bouquet and Sand Canyon area have been mined for roofing granules and chinchilla dust. Pumice and volcanic cinders for aggregate purposes are shipped into the Transverse Range-Peninsular Range region from deposits near Bishop and in the Coso Range.

Blue Cloud Chinchilla Dust Deposit. Location: sec. 32, T. 5 N., R. 15 W., S. B. M., in Bouquet Canyon, Los Angeles County, about 15 miles northeast of Saugus. Ownership: Blue Cloud Mineral Company, W. C. Harris, president, 519 8th Street, Newhall, California.

The Blue Cloud deposit (Gay and Hoffman, 1954, p. 552) is in a stratum of slightly altered tuffaceous sediment that lies between sandstones of the upper Miocene Mint Canyon formation. The tuffaceous stratum is about 6 feet thick, strikes N. 60° W., dips 30° southwest, and can be traced for about 1 mile in a northwesterly direction from Bouquet Canyon.

The tuffaceous sediment is friable and has a blue-gray color; such properties are favorable to its use as chinchilla dusting powder. The tuffaceous sediment is mined by open pit methods from a quarry which in 1952 had a face 40 feet long and 25 feet high. Blasting is required to mine the material which is removed with crowbars and wheelbarrow. Careful sorting is necessary to avoid contamination with overburden.

At the mill, which is situated at the deposit, the material is pulverized in a roll crusher and hammer mill passed through vibrating screens, dried and sterilized at 600° F. temperature in a rotating gas-fired kiln, and packaged in 50-pound paper bags for shipment. The screens are adjusted to maintain a desired particle size ranging between 20- and 200-mesh in the finished product.

The deposit has been operated since 1950 and by 1953 a production rate of about 50 tons a month was maintained. The local market for chinchilla dust is limited to several chinchilla farms in San Fernando Valley. In addition to the local market, the sacked dust is distributed throughout the Central States and to foreign markets.

Reynier Ranch Volcanic Ash Deposit. Location: sec. 35, T. 4 N., R. 15 W., S. B., on the west side of Sand Canyon, opposite Iron Canyon, about 6 miles east of Newhall, Los Angeles County, California. Ownership: Reynier Ranch Estate, operated by F. E. Walker and Sons, Box 277, Newhall, California (Gay and Hoffman, 1954, p. 688).

The volcanic ash on the Reynier Ranch occurs in tuff layers several feet thick in upper Miocene beds of the Mint Canyon formation (Wallace, 1940, p. 38). The tuff is well indurated, light grayish-white in color, and partly altered to clay. It dips about 30 degrees northwest and can be followed along its southwesterly strike for about 1 mile in Sand Canyon.

Mining was done in shallow pits distributed over an area several hundred yards long and several hundred feet wide. A total of several thousand tons was reported mined between 1937 and 1940, and sold to the Pioneer Flintkote Company for use as a surfacing on asphalt shingles and roofing (Oakeshott, 1955, p. c.).

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List of pumice, pumicite, and volcanic cinder deposits arranged by county.

CALAVERAS COUNTY

No.	Name of claim or mine	Owner (name and address)	Location Sec.	T.	R.	B&M
31	Peirano quarry	John Lemu, Angels Camp; leased to Jupiter Lumber Co., Deb Bentley and Hugh Preston, Hathaway Pines, California.	27	3N	13E	M.D.
32	Irvine quarry	Robert Irvine, Soledad, Monterey County, California.	25	5N	11E	M.D.
34	Warren pumice	H. D. Warren, Route 1, Box 295, Valley Springs, California.	29	10N	12E	M.D.

CONTRA COSTA COUNTY

No.	Name of claim or mine	Owner (name and address)	Location Sec.	T.	R.	B&M
24	Alvarnez, pumice	M. Alvarnez, Route 1, Box 589, Pittsburg, California. Leased to Pittsburg Pumice Industries, Route 1, Box 21, Pittsburg, California.	15	2N	1W	M.D.
25	Bailey Ranch, pumice	A. S. Bailey, Route 1, Box 163, Pittsburg, California.	23	3N	1W	M.D.

EL DORADO COUNTY

No.	Name of claim or mine	Owner (name and address)	Location Sec.	T.	R.	B&M
33	Sierra Placerite Corporation quarry	W. B. Willson, Route 3, Box 252, Placerville, California.	29	10N	12E	M.D.

HUMBOLDT COUNTY

No.	Name of claim or mine	Owner (name and address)	Location
	Weatherby Ranch pumice	Hanify Lumber Co., Eureka, California.	Four miles south of Elk River, Humboldt County.

IMPERIAL COUNTY

No.	Name of claim or mine	Owner (name and address)	Location Sec.	T.	R.	B&M
72	Superlite Builders Supply Co. pumice	Imperial Irrigation District. Leased to Superlite Builders Supply Co., Paul Thomas, president, 3800 N. Central Avenue, Phoenix, Arizona; general manager, Maurice Butterfield, P.O. Box 758, Calipatria, California.	32	11S	13E	S.B.

INYO COUNTY

No.	Name of claim or mine	Owner (name and address)	Location Sec.	T.	R.	B&M
48	Van Loon "Fines" pumice	H. A. Van Loon, Bishop, California.	8, 18	6S	33E	M.D.
52	Jamieson pumice deposit	Alexander Jamieson, Big Pine, California. Leased to W. H. Frey and associates, Los Angeles, California.	8	8S	34E	M.D.
	Oasis pumice	Francis E. Patton and E. S. Longley		6S	37E	M.D.
53	Crownite Corporation	Crownite Corporation (formerly Desert Materials Corporation), H. Fogwell, president, 6363 Wilshire Blvd., Los Angeles, California.	13, 14, 21, 23, 24, 25	21S	38E	M.D.

INYO COUNTY—Continued

No.	Name of claim or mine	Owner (name and address)	Location Sec.	T.	R.	B&M
54	California-Nevada Building Materials Producers pumice deposit	R. H. Thompson, Mayfair Hotel, Inyokern, California. Leased to California-Nevada Building Materials Producers, D. B. Chester and associates, 3723 Wilshire Blvd., Los Angeles, California.	19	21S	38E	M.D.
55	Inyo Pumice Corporation	William J. Petty, P.O. Box 21, Inyokern, California. Leased to Inyo Pumice Corporation, N. W. Baum, president 11314 Luitweiler Road, Whittier, California.	19	21S	38E	M.D.
56	Round Mountain pumice	Henry Babineau,6204 Woodward Avenue, Bell, California.	30	21S	38E	M.D.
57	Lucky Lager pumice	William J. Petty, P.O. Box 2, Inyukern, California. Leased to Henry Babineau, 6204 Woodward Avenue, Bell, California.	13	21S	37E	M.D.
64	Shoshone volcanic Ash (Pumicite)	Charles Brown, Shoshone, California.	30, 21	22N	7E	S.B.
65	Redlite Aggregates, Inc.	C. D. Ray, et. al., 1352 East Maple, Glendale, California. Leased to Redlite Aggregates, Inc., subsidiary of Pioneer Pyrophyllite Co., Chula Vista, California.	N½ 31	22S	38E	M.D.
66	Volcanic Cinder Company	C. D. Ray, Glendale; Lafayette Morrison, Huntington Beach; George Rouff and Henry B. Jarvis and associates, Little Lake, California.	S½ 31	22S	38E	M.D.
67	Splane volcanic Cinder deposit	P. R. Splane Company, 13539 Hart, Van Nuys, California.	S½ 20	22S	38E	M.D.

KERN COUNTY

No.	Name of claim or mine	Owner (name and address)	Location Sec.	T.	R.	B&M
58	Black Mountain pumice	R. L. Meuer and Della Gerbracht, Randsburg, California	32	29S	38E	M.D.
59	Opal Mountain pumice	R. L. Meuer and Della Gerbracht, Randsburg, California.	4	29S	38E	M.D.
60	Calsilco Corporation	Calsilco Corporation; George Reynolds, president, and H. A. Richardson, vice-president, 2372 South Atlantic Blvd., Los Angeles 22, California.	33	28S	38E	M.D.
61	Cudahy Packing Company "Seismotite" pumicite	Cudahy Packing Company, Los Angeles, California.	5, 8	29S	38E	M.D.
62	White Castle pumicite	F. D. Shuck, Glendora, California. Leased to W. M. LeVocks, Anaheim, California.	32	28S	39E	M.D.

List of pumice, pumicite, and volcanic cinder deposits arranged by county.—Continued.

No.	Name of claim or mine	Owner (name and address)	Location			
			Sec.	T.	R.	B&M
	KERN COUNTY—Continued					
63	Williams pumicite	Tom Williams, Randsburg, California.	32	28S	39E	M.D.
	LAKE COUNTY					
23	Coleman pumice quarry	V. V. Coleman, Lower Lake, California.	16, 17	13N	7W	M.D.
	LASSEN COUNTY					
16	Anderson Ranch pumice deposit	H. P. Anderson, Bieber, California.	24	37N	9E	M.D.
35	Red Rock pumicite	Galeppi family. Leased to P. F. Frund, 1709 Bridgeway, Sausalito, California.	2, 35	23N 24N	17E 17E	M.D. M.D.
	LOS ANGELES COUNTY					
73	Blue Cloud Chinchilla dust	Blue Cloud Mineral Co., W. C. Harris, president, 519 8th Street, Newhall, California.	32	5N	15W	S.B.M
74	Reynier Ranch volcanic ash	Reynier Ranch Estate operated by F. E. Walker and Sons, Box 277, Newhall, California.	35	4N	15W	S.B.M.
	MADERA COUNTY					
28	Pumice and Pumicite Mining Company	Mrs. Eva V. Erickson, Box 98, Friant, California.	1	11S	20E	M.D.
29	California Industrial Minerals Company	Forrest S. and Louisa M. Taylor, Friant, California.	1	11S	20E	M.D.
30	Ol' Rebel Minerals, Inc.	Mrs. C. H. B. Morrison, 140 Harvard Avenue, Fresno, California. Also, other properties leased from Edward A. Wagner, Friant, California.	36	10S	20E	M.D.
	MODOC COUNTY					
9	Weisman pumicite deposit	John Weisman, Alturas, California.	11, 14	43N	13E	M.D.
13	Great Northern Railroad	U. S. Department of Agriculture, Forest Service.	3	44N	5E	M.D.
	MONO COUNTY					
36	U. S. Pumice and Supply Co., Inc.	U. S. Pumice and Supply Co., Inc., 6331 Hollywood Blvd., Los Angeles, California. Property also leased from Frank Sam, Lee Vining, California.	18, 19 16, 21	1N 1S	27E 27E	M.D. M.D.
37	Sand Doon	Guy S. Way, Benton, California.	25, 26	1S	31E	M.D.
	MONO COUNTY—Continued					
38	Buckley pumice deposit	Tom Buckley, Benton Station, California. Leased to Clarence Comstock and Gordon Bacon, Benton, California.	10, 11	2S	31E	M.D,
39	Victory pumice	Mathieu Brothers, Benton Station, California.	14	2S	31E	M.D.
40	White Rock Placer	H. A. Van Loon, Bishop, California.	1	3S	31E	M.D.
41	Van Loon "Fine" east deposit	H. A. Van Loon, Bishop, California.	22	3S	32E	M.D.
42	Van Loon "Fine" west deposit	H. A. Van Loon, Bishop, California.	21	3S	32E	M.D.
43	Estella pumice property	Ted Schreiner, 4546 Lomita Street, Los Angeles 6, California.	6	3S	32E	M.D.
44	Snoeshoe pumice property	Ted Schreiner, 4546 Lomita Street, Los Angeles 6, California. 10 acres are under lease to G. N. Crawford, Bishop, California, and subleased to William LeVeck, Box 216, Anaheim, California.	17	3S	32E	M.D.
45	Brewster pumice property	R. W. Dean, C. L. Gilliand, and J. C. Andahl, Bishop, California. Leased to Acme Pumice Company, 183 Spring Street, Fontana, California, Thomas R. Brewster, president.	21	3S	32E	M.D.
46	Mathieu pumice	Mathieu Brothers, Benton Station, California.	31	2S	32E	M.D.
47	Rae-Spencer pumice deposit	William Rae, Hawthorne, Nevada.	28	2S	32E	M.D.
49	Insulating Aggregates, Inc. pumice deposit	Insulating Aggregates, Inc. Andrew Boyd, owner, and operated by L. V. Menefee, Bishop, California.	32, 33	5S	33E	M.D.
50	Sacramento Canyon pumice deposit	Joseph B. Smith, Laws, California.	3	5S	33E	M.D.
51	Comstock pumice deposit	Hallie Comstock, Bishop, California.	11	5S	33E	M.D.
	NAPA COUNTY					
18	Basalt Rock Company pumice deposit	Basalt Rock Company, Inc. Napa, California.	24	5N	4W	M.D.
19	Basalt Rock Company Mount George (King) pumice deposit	Basalt Rock Company, Inc. Napa, California.	24, 25	6N	4W	M.D.
20	Cicero pumice quarry	Frederica A. Pearl, Napa, California. Leased to C. Cicero, 849 South Jefferson Street, Napa, California.	24	6N	4W	M.D.

List of pumice, pumicite, and volcanic cinder deposits arranged by county.—Continued.

No.	Name of claim or mine	Owner (name and address)	Location Sec.	T.	R.	B&M
	NAPA COUNTY—Continued					
21	Pearl pumice quarry	Frederica A. Pearl, Napa, California. Operated by John Pearl.	24	6N	4W	M.D.
22	Walker pumice quarry	D. C. Walker, Napa, California.	26	6N	3W	M.D.
27	Wilson quarry	T. D. Wilson, 2651 Monticello Road, Napa, California. Leased to Lava-Lite Products Co., D. G. Saunder, manager, 209 12th Street, Vallejo, California.	19	6N	3W	M.D.
	SAN BERNARDINO COUNTY					
68	Williams Brothers pumice	F. M. Williams, Star Route, Barstow, California. 80 acres also leased from Southern Pacific Railroad.	7, 8, 17, 18	32S	46E	M.D.
69	Mt. Pisgah volcanic cinders	Harry F. Heather, 2365 Oak Knoll Avenue, Pasadena, California; Oscar Hoerner, 5211 Delaware Avenue, Los Angeles; and Fred A. Wilson, San Bernardino, California.	32	8N	6E	S.B.
70	Dish Hill volcanic cinders	State of California. Leased to Velvatone Stucco Products Co., 2066 Hyde Park Blvd., Los Angeles, California.	16	6N	10E	S.B.
71	Santa Fe Railway pumicite	Santa Fe Railroad	13	5N	15E	M.D.
	SAN LUIS OBISPO COUNTY					
26	Grey Eagle mine and Black Eagle claims (Formerly Francis Cleanser mine)	M. L. Francis, R. D. Box 253, Paso Robles, California.	21, 22	28S	15E	M.D.
	SHASTA COUNTY					
17	Liberty Bell mine	Frank Sarcletti, Joe Merciari, and Louis Dallatorre, all of French Gulch, California.	13	34N	8W	M.D.

No.	Name of claim or mine	Owner (name and address)	Location Sec.	T.	R.	B&M
	SISKIYOU COUNTY					
1	Thompson Pumice Company	Rodney Gordenker, R.F.D. 12A, Glen Ellen, California. Leased from R. N. Fouch, Jr., Tionesta, California.	22, 27, 34	44N	4E	M.D.
2	Mt. Hoffman pumice claims	F. L. Jamieson, J. C. Miller, and Dan Williams. Dan Williams lives in Salinas, California.	28, 29	44N	4E	M.D.
3	Boorman Pumice Products Company	Clarence, Carl, Leonard, and Irvine Boorman, P.O.Box 624, Klamath Falls, Oregon.	25 SW¼ 19	44N 44N	4E 5E	M.D. M.D
4	Glass Mountain Industries	Charles F. Van Dorn, Box 648, Klamath Falls, Oregon.	35	44N	4E	M.D.
5	U. S. Pumice and Supply Company, Inc.	U. S. Pumice and Supply Company, Inc., Sheldon P. Fay, president, 6363 Wilshire Blvd., Los Angeles, California.	33, 34, 35	44N	4E	M.D.
6	Skoria Star Brick Company	John Madsen, P.O. Box 711, Klamath Falls, Oregon.	26	44N	4E	M.D.
7	Volcanic Products Corporation	Paul Dalton, manager, Williams Bldg., Klamath Falls, Oregon.		44N	4E	M.D.
8	Pumice Stone mines	Richmond P. Hobson and associates, 6440 Madera Street, Long Beach 15, California.	13, 14, 23, 24, 26, 27	43N	2E	M.D.
10	Kegg	Ownership unknown. Leased to Southern Pacific Railroad.	5	44N	1W	M.D.
11	Soule Ranch	Ownership unknown. Leased to Southern Pacific Railroad.	24	44N	2W	M.D.
12	Copco Dam	Ownership unknown. Leased to California-Oregon Power Company.	29	48N	4W	M.D.
14	McCloud River Railroad	Ownership unknown. Leased to McCloud River Railroad.	36	41N	4E	M.D.
15	Hotlum cinder deposit	Shastalite Brick Company, Yreka, California; Fred W. Burton, president.	22	42N	4W	M.D.

List of pumice, pumicite, and volcanic cinder deposits arranged by region.

REGION I

MODOC PLATEAU-CASCADE RANGE-KLAMATH MOUNTAINS-BASIN RANGES (NORTHERN)

No.	Name of claim or mine	Owner (name and address)	Location				Remarks and references
			Sec.	T.	R.	B & M	
		Pumice					
1	Thompson Pumice Company	Rodney Gordenker, R.F.D. 12A, Glen Ellen, California; leased from R. N. Fouch, Jr., Tionesta, California.	22, 27, 34	44N	4E	M.D.	900 acres immediately north of Glass Mountain, Siskiyou County.
2	Mt. Hoffman pumice claims	F. L. Jamieson, J. C. Miller, and Dan Williams. Mr. Williams lives in Salinas, California.	28, 29	44N	4E	M.D.	960 acres on west and northwest sides of Glass Mountain, Siskiyou County.
3	Boorman Pumice Products Company	Clarence, Carl, Leonard, and Irvine Boorman, P. O. Box 624, Klamath Falls, Oregon	25 SW¼19	44N 44N	4E 5E	M.D. M.D.	On northeast side of Glass Mountain, Siskiyou County.
4	Glass Mountain Industries	Charles P. Van Doren, Box 648, Klamath Falls, Oregon.	35	44N	4E	M.D.	On top of Glass Mountain, Siskiyou County. Pumiceous obsidian used in making scouring blocks.
5	U. S. Pumice and Supply Co., Inc.	U. S. Pumice and Supply Co., Inc., Sheldon P. Fay, president, 6363 Wilshire Blvd., Los Angeles, California	33, 34, 35 3, 4	44N 43N	4E 4E	M.D. M.D.	Properties formerly held by John Madsen and Charles P. Van Doren of Klamath Falls, Oregon, and H. W. Free, Tionesta, California and the Christie Estate.
6	Skoria Star Brick Company	John Madsen, P. O. Box 711, Klamath Falls, Oregon	26	44N	4E	M.D.	One claim on top of Glass Mountain, Siskiyou County. Pumiceous obsidian used for making scouring blocks.
7	Volcanic Products Corporation	Paul Dalton, manager, Williams Bldg., Klamath Falls, Oregon.		44N	4E	M.D.	Lease large amount of land from Fouch and Christie Estate. Idle in 1953 (O'Brien, 1947, p. 458).
8	Pumice Stone mines	Richmond P. Hobson and Associates, 6440 Madera Street, Long Beach 15, California	13, 14, 23 24, 26, 27	43N	2E	M.D.	Property includes 2560 acres centered around Little Glass Mountain, Siskiyou County. Pumice occurs as loosely consolidated tuff covering the ground and ranging in thickness from a few inches to 10 feet.
9	Weisman pumicite deposit	John Weisman, Alturas, California	11 & 14	43N	13E	M.D.	Property formerly owned and operated by L. F. Foster, Alturas, California.
		Volcanic Cinders					
10	Southern Pacific Company Kegg	Unknown	5	44N	1W	M.D.	Volcanic cinders produced from cinder cones Material used principally as railroad ballast (Williams, 1949, p. 59).
11	Soule Ranch	Unknown	24	44N	2W	M.D.	
12	Copco Dam	Unknown	29	48N	4W	M.D.	
13	Great Northern Railroad	U. S. Department of Agriculture, Forest Service.	3	44N	5E	M.D.	Volcanic cinders produced from East Sand Butte, an extinct cinder cone. Material used principally as railroad ballast and bank widening.
14	McCloud River Railroad	Unknown	36	41N	4E	M.D.	Volcanic cinders produced from cone at Porcupine Port, Siskiyou County. Material used in railroad construction.
15	Hotlum Cinder Deposit	Shastalite Brick Company, Yreka, California; Fred W. Burton, president.	22	42N	4W	M.D.	Volcanic cinders produced from extinct cinder cone one mile east of Hotlum. Cinders used as aggregate for making building blocks (O'Brien, 1947, p. 458).
		Pumicite					
16	Anderson Ranch deposit	H. P. Anderson, Bieber, California	24	37N	9E	M.D.	20-foot bed of gray pumicite resting upon basaltic lavas. No production, and limited development work (Laizure, 1920, p. 511)
17	Liberty Bell Mine	Frank Sarcletti, Joe Merciari, Louis Sarcletti, and Joe Dallatorre, all of French Gulch, California.	13	34N	8W	M.D.	4-foot wide bed of pumicite lying between andesitic lavas and slate of the Bragdon (Mississippian?) formation. No pumicite produced (Laizure, 1920, p. 544).

REGION II. COAST RANGE

No.	Name of claim or mine	Owner (name and address)	Location				Remarks and references
			Sec.	T.	R.	B & M	
		Pumice					
18	Basalt Rock Company pumice deposit	Basalt Rock Company, Inc. Napa, California.	24	5N	4W	M.D.	Pumice for aggregate purposes was produced from massive tuff of unknown thickness. Property abandoned in 1946 (Davis, 1948, p. 173).
19	Basalt Rock Company Mount George (King) Pumice Deposit	Basalt Rock Company, Inc. Napa, California.	24, 25	6N	4W	M.D.	Pumice for aggregate purposes is obtained from a massive, poorly bedded tuff overlain by andesitic lava (Davis, 1948, p. 173).
20	Cicero pumice quarry	Frederica A. Pearl, Napa, California. Leased to C. Cicero, 849 Soutb Jefferson Street, Napa, California.	24	6N	4W	M.D.	Pumice for aggregate purposes was obtained from massive, poorly bedded tuff of unknown thickness (Davis, 1948, p. 174).
21	Pearl pumice quarry	Frederica A. Pearl, Napa, California. Operated by John Pearl.	24	6N	4W	M.D.	Pumice for aggregate purposes was obtained from a bed of grayish-white, massive, poorly bedded tuff (Davis, 1948, p. 175).
22	Walker pumice quarry	D. C. Walker, Napa, California.	26	6N	3W	M.D.	Pumice for aggregate purposes is obtained from pumice-lapilli tuff of unknown thickness (Davis, 1948, p. 176).
23	Coleman pumice quarry	V. V. Coleman, Lower Lake, California.	16 & 17	13N	7W	M.D.	Coarsely vesiculated obsidian is quarried for use as aggregate in plaster and concrete (Brice, 1953, p. 65).
24	Alvarnez pumice	M. Alvarnez, Route 1, Box 589, Pittsburg, California. Leased to Pittsburg Pumice Industries, Route 1, Box 21, Pittsburg, California.	15	2N	1W	M.D.	Pumice for aggregate purposes was produced from a massive, poorly bedded tuff interstratified with sandstone (Davis, 1951, p. 578).
25	Bailey Ranch	A. S. Bailey, Route 1, Box 163, Pittsburg, California. Leased to Diablo Pumibloc Company.	23	3N	1W	M.D.	Pumice for aggregate purposes was produced from a massive, poorly bedded tuff interstratified with sandstone (Davis, 1951, p. 578).
	Weatherby Ranch pumice deposit	Hanify Lumber Co. Eureka, California.	Four miles south of Elk River, Humboldt County, California.				White to creamy-white pumicite occurs in 2-foot bed overlain and underlain by clay. Idle (Laizure, 1925, p. 324).
		Pumicite					
26	Grey Eagle mine and Black Eagle claims (Formerly Francis Cleanser mine)	M. L. Francis, R. D. Box 233, Paso Robles, California.	21, 22	28S	15E	M.D.	Pumicite produced from a well-consolidated, fine-grained tuff layer 40 to 50 feet thick interbedded with sandstone and siliceous shales of the Santa Margarita formation (Franke, 1935, p. 461).
		Volcanic Cinders					
27	Wilson quarry	T. D. Wilson, 2651 Monticello Road, Napa, California; leased to Lava-Lite Products Co., D. G. Saunder, manager, 209-12th St., Vallejo, California.	19	6N	3W	M.D.	Black basaltic cinders mined from a 30-foot bed overlain by pumiceous tuff (Davis, 1948, p. 176).

REGION III. GREAT VALLEY

		Pumice					
28	Pumice and Pumicite Mining Company	Mrs. Eva V. Erickson, Box 98, Friant, California.	1	11S	20E	M.D.	Pumice for aggregate purposes is produced from a layer of tuffaceous sandstone which has a maximum thickness of 30 feet (Logan, 1950, p. 464).
		Pumicite					
29	California Industrial Minerals Company	Forrest S. and Louisa M. Taylor, Friant, California.	1	11S	20E	M.D.	Buff-colored pumicite is produced from a 20-foot bed of pumicite and used as insecticide carrier, in scouring soaps, manufacture of cement, and polishing agent (Logan, 1950, p. 463).
30	Ol' Rebel Minerals, Inc.	Mrs. C. H. B. Morrison, 140 Harvard Avenue, Fresno, California. Also, other properties leased from Edward A. Wagner, Friant, California.	36	10S	20E	M.D.	White to buff-colored pumicite is being produced from several beds of pumicite of variable thickness and used as insecticide carrier, in the manufacture of scouring soaps, cement, and polishing compounds.

REGION IV. SIERRA NEVADA

No.	Name of claim or mine	Owner (name and address)	Location				Remarks and references
			Sec.	T.	R.	B & M	
		Pumice					
31	Peirano quarry	John Lemu, Angels Camp, California. Leased to Jupiter Lumber Co., Deb Bentley and Hugh Preston, owners, Hathaway Pines, California.	27	3N	13E	M.D.	Firmly consolidated rhyolite tuff is quarried, crushed and used for aggregate in making "Tuftile", decorative gravel, road gravel, and terrazzo (Hill, 1953, private communication).
32	Irvine quarry	Robert Irvine, Soledad, Monterey County, California.	25	5N	11E	M.D.	Firmly consolidated, yellowish to buff-colored rhyolite tuff is quarried and sold as flagstone, garden stone, or used in making terrazzo (Hill, 1953, Private communication).
33	Sierra Placerite Corporation quarry	W. B. Willson, Route 3, Box 252, Placerville, California.	29	10N	12E	M.D.	Firm consolidated, yellowish to buff-colored rhyolite tuff is quarried and sold as flagstone, ashlar strips, garden stone, and used in the making of terrazzo (Hill, 1953, private communication).
34	Warren pumice	H. D. Warren, Route 1, 295, Valley Springs, California.	12	3N	9E	M.D.	Layers of pumice in the Miocene (?) Valley Springs formation mined for concrete aggregate.
		Pumicite					
35	Red Rock pumicite	Galeppi family. Leased to P. F. Frund, 1709 Bridgeway, Sausalito, California.	2, 35	23N 24N	17E 17E	M.D. M.D.	Beds of grayish-white pumicite of variable thickness are interbedded with beds of silt and tuffaceous sand. Some pumicite produced and sold under trade name of "Lassenite".

REGION V. BASIN RANGES

No.	Name of claim or mine	Owner (name and address)	Sec.	T.	R.	B & M	Remarks and references
		Pumice					
36	U. S. Pumice and Supply Co., Inc.	U. S. Pumice and Supply Co., Inc., 6331 Hollywood Blvd., Los Angeles, California. Property also leased from Frank Sam, Leevining, California.	18, 19 16, 21	1N 1S	27E 27E	M.D. M.D.	Vesiculated obsidian, referred to as dome pumice in this report, is quarried from tops of volcanic domes and used in the manufacture of scouring bricks.
37	Sand Doon	Guy S. Way, Bentoo, California	25, 26	1S	31E	M.D.	White pumice for aggregate purposes is mined from a flat-lying pumice bed of variable thickness.
38	Buckley pumice deposit	Tom Buckley, Benton Station, California. Leased to Clarence Comstock and Gordon Bacon, Benton, California.	10, 11	2S	31E	M.D.	White pumice for aggregate purposes was mined from a pumice bed of variable thickness. Idle in September, 1953.
39	Victory pumice	Mathieu Brothers, Benton Station, California.	14	2S	31E	M.D.	White pumice for aggregate purposes is mined from a 20-foot pumice bed.
40	White Rock Placer	H. A. Van Loon, Bishop, California	1	3S	31E	M.D.	White pumice for aggregate purposes was mined from an extensive pumice bed. Two large quarries now abandoned.
41	Van Loon "Fine" east pumice deposit	H. A. Van Loon, Bishop, California	22	3S	32E	M.D.	White pumice for aggregate purposes was mined from 10-foot pumice bed overlain by loosely-consolidated Bishop tuff. Property abandoned.
42	Van Loon "Fine" west pumice deposit	H. A. Van Loon, Bishop, California	21	3S	32E	M.D.	Pale pink pumice was mined from several quarries and used as aggregate for making building blocks. Idle in September, 1953.
43	Estella pumice property	Ted Schreiner, 4546 Lomita Street, Los Angeles 6, California.	6	3S	32E	M.D.	50- to 60-foot layer bed made up of several pumice beds interbedded with pumicite layers and conglomeratic sandstone layers was mioed for pumice aggregate. Idle in September, 1953.
44	Snoeshoe pumice property	Ted Schreiner, 4546 Lomita Street, Los Angeles 6, California. 10 acres are under lease to G. N. Crawford, Bishop, California, and sub-leased to William LeVeck, Box 216, Anaheim, California.	17	3S	32E	M.D.	Several pumice beds with aggregate thickness of 30 feet were mined by benches and the pumice used as aggregate for making building blocks. Idle in September, 1953.
45	Brewster pumice property	R. W. Dean, C. L. Gilliand, aod J. C. Andahl, Bishop, California. Leased to Acme Pumice Co., 183 Spring Street, Fontana, California, Thomas R. Brewster, president.	21	3S	32E	M.D.	Layer of pumice 20-feet thick, containing pink to white pumice fragments, is mined and the pumice used as aggregate. Idle in September, 1953.

REGION V. BASIN RANGES—Continued

No.	Name of claim or mine	Owner (name and address)	Location				Remarks and references
			Sec.	T.	R.	B & M	
		Pumice—Continued					
46	Mathieu pumice	Mathieu Brothers, Benton Station, California.	31	2S	32E	M.D.	White pumice fragments were mined from a pumice layer of variable thickness. Idle in September, 1953.
47	Rae-Spencer pumice deposit	William Rae, Hawthorne, Nevada	28	2S	32E	M.D.	Pumice for aggregate purposes was mined from an extensive layer averaging about 18 feet in thickness. Mining was by underground methods. Property idle in September, 1953.
48	Van Loon "Fines" pumice deposit	H. A. Van Loon, Bishop, California	8, 18	6S	33E	M.D.	Pale pinkish pumice for aggregate purposes is mined from an extensive layer of unknown thickness and used in making building blocks and precast slabs (Norman and Stewart, 1951, p. 110).
49	Insulating Aggregates, Inc., pumice deposit	Insulating Aggregates, Inc., Andrew Boyd, owner, and operated by L. V. Menefee, Bishop, California.	32, 33	5S	33E	M.D.	Extensive layer of grayish-white pumice is mined by open cut and the material is ground and made into plaster aggregate.
50	Sacramento Canyon pumice deposit	Joseph B. Smith, Laws, California	3	5S	33E	M.D.	White pumice for aggregate and abrasive purposes was mined from a layer of unknown thickness. Idle in September, 1953.
51	Comstock pumice deposit	Hallie Comstock, Bishop, California.	11	5S	33E	M.D.	Pumice for aggregate purposes was mined from a layer of variable thickness interbedded with fanglomerate. Several large quarries were opened and considerable pumice mined. Idle in Spetember, 1953.
52	Jamieson pumice deposit	Alexander Jamieson, Big Pine, California. Leased to W. H. Frey and associates, Los Angeles, California.	8	8S	34E	M.D.	Pumice for aggregate purposes was mined from a layer ranging in thickness from 6 to 10 feet (Norman and Stewart, 1951, p. 109).
	Oasis pumice deposit	Francis E. Patton and E. S. Longley		6S	37E	M.D.	Layer of white pumice of unknown thickness was prospected, but produced no pumice (Norman and Stewart, 1951, p. 109).
53	Crownite Corporation	Crownite Corporation (formerly Desert Materials Corporation), H. Thogwell, president, 6363 Wilshire Blvd., Los Angeles, California.	13, 14, 21, 23, 24, 25	21S	38E	M.D.	Extensive layers of pumice are being mined for aggregate pumice. Bulk of current production coming from quarry in section 24. (Norman and Stewart, 1951, p. 107).
54	California-Nevada Building Materials Producers pumice deposit	R. H. Thompson, Mayfair Hotel, Inyokern, California. Leased to California-Nevada Building Materials Producers, D. B. Chester and associates, 3723 Wilshire Blvd., Los Angeles, California.	19	21S	38E	M.D.	White pumice for aggregate purposes was produced from a subaqueous tuff of unknown thickness (Norman and Stewart, 1951, p. 107).
55	Inyo Pumice Corporation	William J. Petty, P. O. Box 21, Inyokern, California. Leased to Inyo Pumice Corporation, N. W. Baum, president, 11314 Luitweiler Road, Whittier, California.	19	21S	38E	M.D.	Creamy-white pumice has been mined for aggregate purposes from a layer of tuff about 30 feet thick (Norman and Stewart, 1951, p. 108).
56	Round Mountain pumice	Henry Babineau, 6204 Woodward Avenue, Bell, California.	30	21S	38E	M.D.	Pumice occurs in a lenslike layer of unknown thickness in tuffs and tuffaceous sediments. Pumice layer loosely consolidated and easily mined (Norman and Stewart, 1951, p. 109).
57	Lucky Lager pumice	William J. Petty, P. O. Box 21, Inyokern, California. Leased to Henry Babineau, 6204 Woodward Avenue, Bell, California	13	21S	37E	M.D.	Creamy-white pumice has been produced from a tuff bed of unknown thickness and used as aggregate in the manufacture of building blocks (Norman and Stewart, 1951 p. 110).
58	Black Mountain pumice	R. L. Meuer and Della Gerbracht, Randsburg, California.	32	29S	38E	M.D.	Pumice lapilli tuff has been prospected for pumice. No production (Tucker et al., 1949, p. 249).
59	Opal Mountain pumice	R. L. Meuer and Della Gerbracht, Randsburg, California.	4	29S	38E	M.D.	Consolidated pumice lapilli tuff has been prospected for pumice. Limited production (Tucker et al., 1949, p. 250).
60	Calsilco Corporation	Calsilco Corporation, George Reynolds, president, and H. A. Richardson, vice president and manager, 2372 South Atlantic Blvd., Los Angeles 22, California.	33	28S	38E	M.D.	Pumice for aggregate and abrasive uses is being produced from a bed of pumice lapilli tuff about 20 feet thick (Tucker et al., 1949, p. 250).

REGION V. BASIN RANGES—Continued

No.	Name of claim or mine	Owner (name and address)	Location				Remarks and references
			Sec.	T.	R.	B & M	
		Pumicite					
61	Cudahy Packing Company "Seismotite" pumicite	Cudahy Packing Company, Los Angeles, California.	5, 8	29S	38E	M.D.	White, fine-grained pumicite was mined from a 9-foot bed in the Ricardo (Pliocene) formation (Tucker, et al., 1949, p. 250).
62	White Castle pumicite	F. D. Shuck, Glendora, California. Leased to W. M. LeVocks, Anaheim, California.	32	28S	39E	M.D.	Layer of grayish-white pumicite of unknown thickness and overlain by basalt was prospected but did not produce very much pumicite (Tucker, et al., 1949, p. 251).
63	Williams pumicite	Tom Williams, Randsburg, California	32	28S	39E	M.D.	Extensive layer of pumicite about 50 feet was developed by open cuts. Idle in 1951 (Tucker, et al., 1949, p. 251).
64	Shoshone volcanic ash (pumicite)	Charles Brown, Shoshone, California	30, 21	22N	7E	S.B.	Flat-lying layer of grayish-white pumicite, about 12 feet thick interbedded with lacustrine sediments has been mined intermittently and the pumicite used in the manufacture of scouring soaps and cleansing compounds (Norman and Stewart, 1951, p. 109).
		Volcanic Cinders					
65	Redlite Aggregates, Inc.	C. D. Ray, et al., 1352 East Maple, Glendale, California. Leased to Redlite Aggregates, Inc., subsidiary Pioneer Pyrophyllite Co., Chula Vista, California.	N½ 31	22S	38E	M.D.	Volcanic cinders produced for aggregate purposes (Norman and Stewart, 1951, p. 112).
66	Volcanic Cinder Company	C. D. Ray, Glendale; Lafayette Morrison, Huntington Beach; George Rouff and Henry B. Jarvis, Little Lake. Leased to Henry B. Jarvis and associates, Little Lake, California.	S½ 30	22S	38E	M.D.	Volcanic cinders for aggregate purposes (Norman and Stewart 1951, p. 112).
67	Splane volcanic cinders deposit	Paul R. Splane Company, 13539 Hart, Van Nuys, California.	S½ 20	22S	38E	M.D.	New operation. Volcanic cinders for aggregate, roofing granules, and agricultural purposes.

REGION VI. MOJAVE DESERT-COLORADO DESERT

No.	Name of claim or mine	Owner (name and address)	Sec.	T.	R.	B & M	Remarks and references
		Pumice					
68	Williams Brothers pumice	F. M. Williams, Star Route, Barstow, California. 80 acres also leased from Southern Pacific Railroad.	7, 8, 17, 18	32S	46E	M.D.	Pumice for aggregate and abrasive uses is being obtained from a thick tuff layer interstratified with other tuffs that rest upon deeply eroded granite (Wright, et al., 1953, p. 190).
71	Santa Fe Railway pumicite	Santa Fe Railroad	13	5N	15E	S.B.	Developmental work was done on a layer of pumicite about 8 feet thick (Wright, et al., 1953, p. 189).
72	Superlite Builders Supply Co. Pumice	Imperial Irrigation District. Leased to Superlite Builders Supply Co., Paul Thomas, president, 3800 N. Central Avenue, Phoenix, Arizona; general manager, Maurice Butterfield, P. O. Box 758, Calipatria, California.	32	11S	13E	S.B.	Pumice for aggregate uses mined from tuff layers associated with sands and gravels (See also Tucker, 1920, p. 270).
		Volcanic Cinders					
69	Mt. Pisgah volcanic cinders	Harry F. Heather, 2365 Oak Knoll Avenue, Pasadena; Oscar Hoerner, 5211 Delaware Avenue, Los Angeles; and Fred A. Wilson, San Bernardino, California.	32	8N	6E	S.B.	Volcanic cinders used for aggregate (Wright, et al., 1953, p. 188).
70	Dish Hill volcanic cinders	State of California. Leased to Velvatone Stucco Products Co., 2066 Hyde Park Blvd., Los Angeles, California.	16	6N	10E	S.B.	Volcanic cinders for aggregate uses (Wright, et al., 1953, p. 187).

REGION VII. TRANSVERSE-PENINSULAR RANGES

No.	Name of claim or mine	Owner (name and address)	Sec.	T.	R.	B & M	Remarks and references
73	Blue Cloud chinchilla dust	Blue Cloud Mineral Co., W. C. Harris, president, 519 Eighth Street, Newhall, California	32	5N	15W	S.B.M.	Tuff layer mined and processed for chinchilla dusting powder (Gay and Hoffman, 1954, p. 552).
74	Reynier Ranch volcanic ash	Reynier Ranch Estate, operated by F. E. Walker and Sons, Box 277, Newhall, California.	35	4N	15W	S.B.M.	Indurated tuff mined and used as surfacing on asphalt shingles and roofing (Gay and Hoffman, 1954, p. 688).

TECHNOLOGY OF PUMICE, PUMICITE, AND VOLCANIC CINDERS

By F. Sommer Schmidt *

OUTLINE OF REPORT

Illustrations

INTRODUCTION

Pumice is a classic building material that has been used extensively for centuries in Europe as a lightweight aggregate. The Romans built the Pantheon and harbor works on the Tiber of pumicite and burned lime; substantial parts of German cities bombed in World War II were built of pumice concrete as well as many official buildings in Belgium and France that were constructed of pumice concrete in the last century. However, the use of pumicite and pumice in the United States, especially in our western states, is comparatively new.

Pumice, when used as concrete aggregate, is competitive with other lightweight aggregate materials and with conventional concrete aggregate. The use of pumice concrete is indicated when its additional cost is more than justified by its properties. Those properties that are advantageously divergent from conventional concrete and many so-called lightweight concretes include its weight, compressive strength, elasticity, fire resistance, and thermal conductivity.

Among the many advantages of pumice concrete are the following:

1. Light weight for its strength, yielding a saving in foundations and steel, also a saving in time and cost of construction.
2. Insulation value.
3. Flexural strength and resistance to shock.
4. Freeze-thaw resistance.
5. Vermin proof.
6. Low maintenance.
7. Fireproof.
8. Nailability and sawability.

Other lightweight aggregates of commercial importance used in California are diatomite, perlite, volcanic cinders, expanded shale (Rocklite, Haydite, and Airox), and vermiculite. Of these materials, those that have structural strength are expanded shale, volcanic cinders, and pumice. Each lightweight aggregate is best suited to certain purposes and there is a field of usefulness for each of them with overlapping competitive areas.

Properties of aggregate materials.

Concrete	Weight per cubic foot (pounds)	Compressive strength per square inch	Modulus of elasticity	Fireproof ratings	Thermal conductivity
Pumice	65 to 100	1,000 to 3,000	600,000 to 1,750,000	2 inches = 4 hours 4 inches = 5 hours	1.5 to 3.5
Volcanic cinders	95 to 120	1,000 to 3,000	1,500,000 to 2,500,000	unknown	3.5 to 5.0
Expanded shale	95 to 120	1,000 to 5,000	1,500,000 to 2,500,000	unknown	3.0 to 4.5
Sand and gravel	145 to 155	1,000 to 7,000	3,500,000 to 5,000,000	4 inches = 1 hour	12.0

Pumice is the lightest of the structural aggregates and probably the heavie t nonstructural aggregate used in any considerable quantity. That is to say, pumice concrete mixes may be designed to yield structural strengths at the lightest weights but the minimum weight of pumice concrete, even in very lean mixes, is in the heaviest range ordinarily specified for nonstructural fills.

Considering pumice concrete's two cardinal properties, namely, lightweight and low thermal conductivity, its major application is logical wherever one or both of these properties make a critical difference.

As a lightweight aggregate, pumice is used in (1) monolithic type of structures and (2) in masonry units, such as blocks and precast slabs. Monolithic concrete is plastic and masonry unit mixes are almost nonplastic. The nonplastic characteristic is necessary wherever concrete is ejected from molds prior to set; it offers some difficulty in compacting, but carries the advantage of very low water-cement ratios.

Pumice and pumicite has not only been used as aggregate materials, but also they have found utilization in abrasives, oil well slurries, pozzolans, as fillers in paint and rubber and plastics, and for insulation fills and filter media, in agriculture for soil conditioning and in hydroponics, and in sweeping compounds.

I wish to acknowledge my appreciation for the cooperation I have received from practically all the laboratories, pumice producers and manufacturers of pumice concrete in the states of California, Arizona and New Mexico, especially the unfailing and most valuable assistance of Philip Lockwood, concrete technician of Los Angeles, California.

* Consulting mining engineer, Los Angeles, California. Manuscript submitted for publication July 1950.

PUMICE AND PUMICITE

Technology

Shrinkage. Shrink cracks in concrete are primarily the result of the portland cement paste or matrix used, and are more or less universal in conventional concrete.

Shrinkage takes place as the concrete dries, the amount depending primarily upon volume change of matrix due to drying and upon the modulus of elasticity of the aggregate. However, the shrinkage of pumice concrete is due largely to an inherent trait of the cement and the capillary tension set up in both the pumice and cement by the water being evacuated from capillaries.

Cement, type No. 1, 5.5 sacks of cement per cubic yard of concrete that consisted of 5.5 cubic feet of silica sand, 14.0 cubic feet of fine pumice aggregate "Crownite," and 16 cubic feet of coarse pumice "Crownite."

There was no admixture; time in mixer was 20 minutes. Slump was 3 inches and K factor was 2.60.

Specimens of this concrete were placed in a controlled moisture room. At the end of 28 days the shrinkage was 0.00085 inch per inch; at the end of 49 days it was 0.00106 inch per inch; and at the end of 60 days it was 0.00105 inch per inch. The 28-day shrinkage was 81 percent of the 60-day shrinkage. After 60 days the specimens were dried to constant weight and cooled to room temperature. The average shrinkage

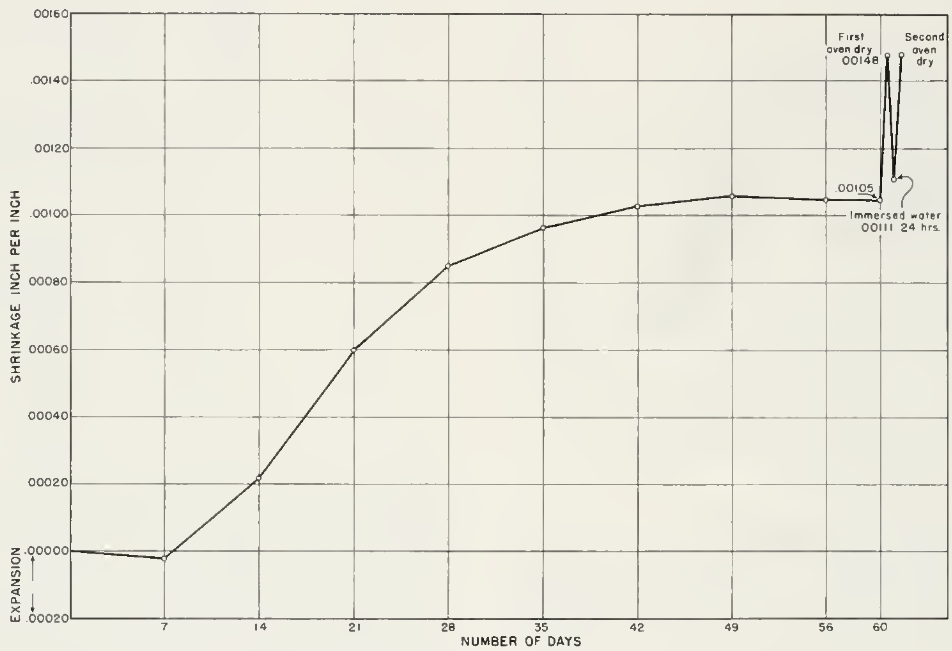


Figure 1. Shrinkage curve for monolithic pumice concrete. Data courtesy of Phillip Lockwood, Los Angeles, California.

Concrete containing aggregate that is 100 percent good pumice has a shrinkage of about 0.13 percent in 100 days (Klug et al., 1949), which amounts to 0.31 inch in a 20-foot continuity. If the contraction of conventional concrete is taken as 1.0, then the shrinkage of an ordinary pumice concrete devoid of natural sand would be about 2.0. The shrinkage of some of the other lightweight aggregates such as perlite, vermiculite, or diatomite would range around 4 to 5, and neat cement containing no aggregate would be approximately 8. The difference therefore between 2 and 8 is resistance of pumice aggregate to shrinkage.

Specifications for certain first class buildings in Los Angeles tolerated a shrinkage of only 0.06 percent in 60 days, an amount equivalent to the shrinkage in conventional concrete. This would be equivalent to 0.144 inch in the same 20-foot continuity; this specification was satisfied in some 28-day pumice concretes by replacing the pumice fines with natural sand.

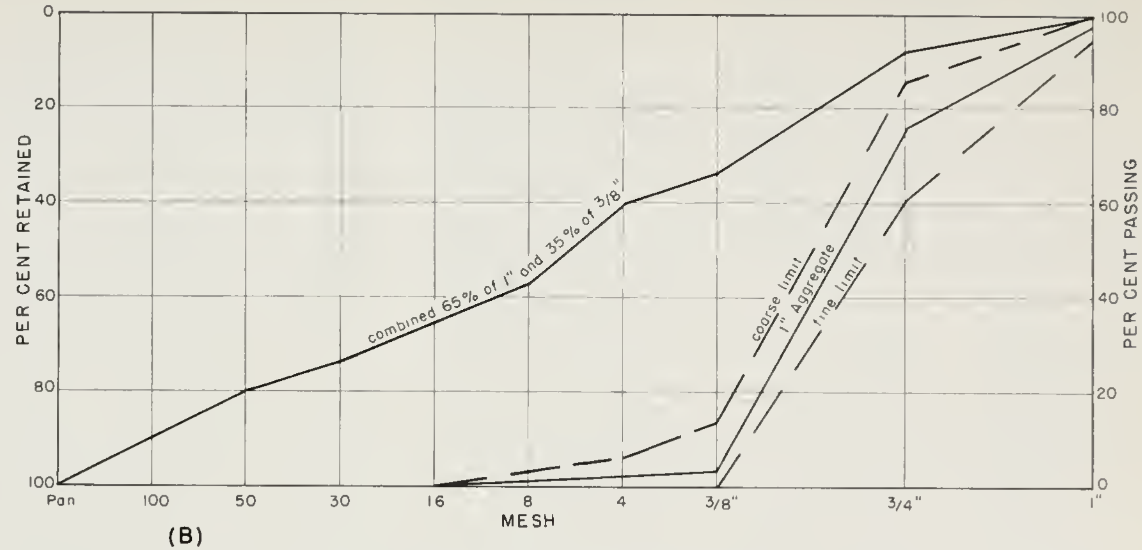
In a recent research project, six samples of pumice concrete were run under identical conditions. The mixture consisted of the following:

was 0.00148 inch per inch. The specimens were then immersed in water at 70°F for 24 hours, wiped dry and again tested, showing a shrinkage of 0.00111 inch per inch. Following this last treatment, the specimens were dried to constant weight and the shrinkage returned to 0.00148 inch per inch. It may be noted that after oven drying, following 60 days air drying, the shrinkage was 0.00148 inch per inch, and that after being immersed in water the volume of the specimens did not regain their former 60-day magnitude. In actual practice, however, the concrete will not shrink to the oven dry figure and the final permanent drying shrinkage appears to be the 49-day shrinkage value of 0.00106 inch per inch. Any variation from this figure should not be serious although the above data apply only to a particular mixture.

The causes of shrinking in pumice concrete are thought to be (1) contraction of cement gel upon hydrating, (2) the capillary tension due to the evacuation of water from capillary openings in the cement upon drying, and (3) capillary tension set up in the pumice aggregate by evacuating the water from the capillaries in the pumice.

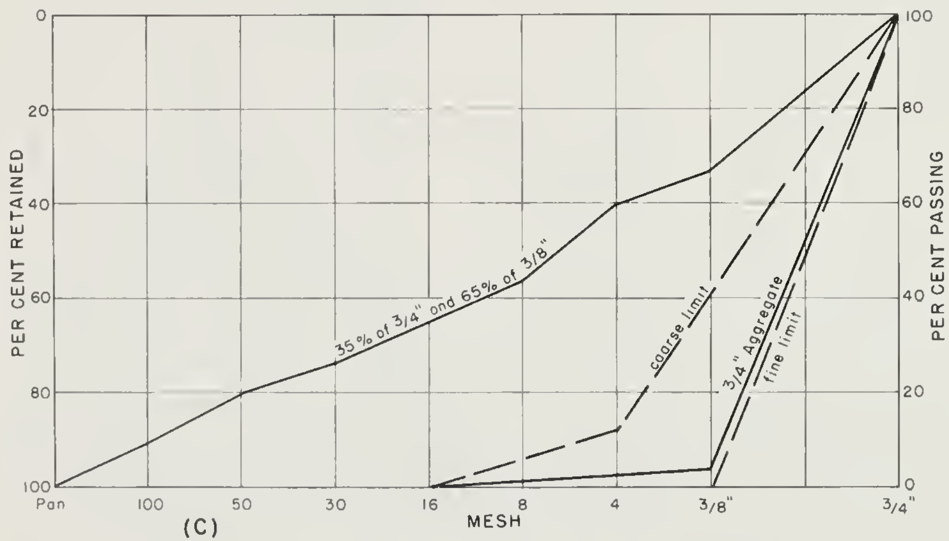
SCREEN ANALYSES USED IN GRAPHS			
PER CENT PASSING CUMULATIVE BY WEIGHT			
Mesh	3/8" Agg.	3/4" Agg	1" Agg
1"	100	100	97
3/4"	100	98	76
3/8"	100	4	3
± 4	90	2	2
± 8	66	1	1
± 16	53	0	0
± 30	40	0	0
± 50	30	0	0
± 100	15	0	0
Pan	0	0	0

(A)

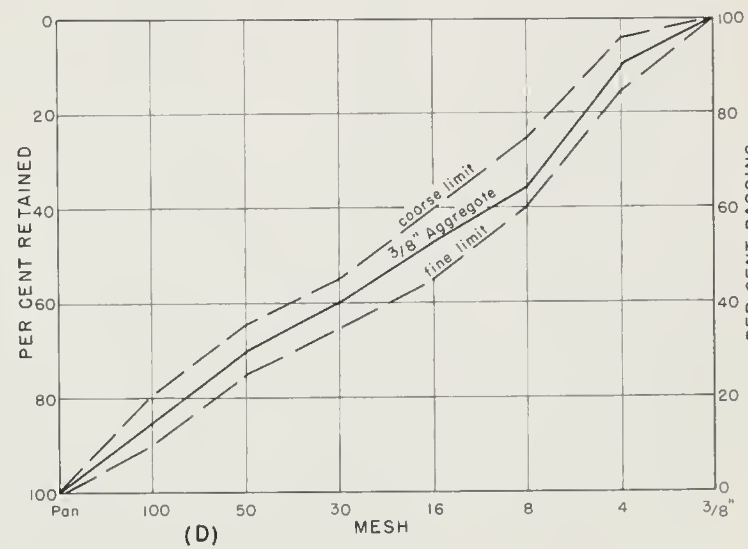


(B)

PER CENT PASSING CUMULATIVE BY WEIGHT										
35% 1" Agg.	0.00	0.00	0.00	0.00	0.00	0.30	0.70	1.00	26.60	33.90
65% 3/8" Agg.	0.00	9.70	19.50	26.00	34.50	42.30	58.50	65.00	65.00	65.00
100% Combined	0.00	9.70	19.50	26.00	34.50	42.60	59.20	66.00	91.60	98.90



(C)



(D)

FIGURE 2. Typical gradation curves of pumice aggregates for monolithic and masonry types of concrete. A, Screen analyses used in preparing the curves. B, Curves for monolithic concrete in which 35 percent of the aggregate by weight passes through a 1-inch screen and 65 percent passes through a ⅜-inch screen. C, Curves for monolithic concrete in which 35 percent by weight of the aggregate passes through a ¾-inch screen and 65 percent passes through a ⅜-inch screen. D, Curves for masonry concrete aggregate. Data courtesy of Phillip Lockwood, Los Angeles, California.

Research on pumice concrete, has shown that as much as 50 percent of the water of saturation can be evaporated with only a slight volume change in the concrete. However, following this initial loss in water, the concrete undergoes rapid changes in volume due to a combination of causes, mainly drying of cement matrix as absorbed water from aggregate is dissipated. Therefore, in pumice concrete as the initial water is removed from the coarse openings in the aggregate, the cement is still saturated and it is not until at least 50 percent of this contained water has evaporated that actual drying of the cement matrix initiates a capillary evacuation and a consequent compressive force which produces volume change in the concrete. In this process the shrinking cement matrix is in tension and the aggregate in compression. About 66 percent of the shrinkage takes place within the first 60 days for most pumice concretes at average atmospheric conditions.

Thermal contraction and expansion of pumice are nearly that of any portland cement concrete and steel so that no internal stress is thermally created. The thermal coefficient of expansion of pumice is 0.000006 inch per degree F. This is comparable to thermal coefficient of expansion of steel which ranges from 0.00000589 to 0.00000605 and most portland cement concretes fall in this range.

Chemical composition of the pumice has no known influence on its shrinkage.

Concrete made of pumice aggregate that had been heat treated had a lower shrinkage than concrete made with untreated pumice. When pumice is heat treated the volume of the particle is reduced about 10 percent and the saturated surface dry specific gravity increased from 1.55 to 1.70. Also, heat treated pumice absorbs less water than untreated pumice due to fusion closure of pores.

Although considerable research is needed in pumice concrete, the following procedures are suggested as favorable for reduction of shrinkage:

1. Minimum water cement ratio.
2. Optimum use of natural sand to replace the sand size in the pumice aggregate relative to maximum weight allowed.
3. Use of pumice which by actual trial and experimentation shows that it makes concrete with low shrinkage.
4. Better curing and especially more complete drying of masonry units before selling and integrating into structures.
5. Use of vacuum process and vibration where feasible to reduce amount of water.
6. Careful survey of the possibilities of using only such admixes as determined by actual trials.

Pre-Wetting of Aggregate. Pumice aggregate, like all porous aggregates, absorbs water. The time necessary for saturation varies directly with the particle size. For California coarse aggregate pumice, minus $\frac{3}{4}$ inch to plus $\frac{3}{8}$ inch, 9 minutes is required in the mixer; for fine aggregate, minus $\frac{3}{8}$ inch to pan, 3 minutes in the mixer.

Therefore, pumice concrete containing $\frac{3}{4}$-inch maximum aggregate and mixed for 9 minutes or more will not stiffen abnormally during placement, after discharge. Truck mixed concrete mixing time almost always exceeds 9 minutes. Pumice grout, containing $\frac{3}{8}$-inch maximum aggregate, mixed for 3 minutes will also display normal consistency characteristics. Pumice concrete containing $\frac{3}{4}$-inch maximum aggregate, mixed for less than 9 minutes will stiffen unless the coarse aggregate, $\frac{3}{4}$ inch plus $\frac{3}{8}$ inch, has been pre-wet.

To compute the amount of water necessary for saturation the following procedure is used: ascertain the percent by dry weight of absorbed moisture in the stockpile. Subtract this from 30 percent and the difference will be weight of water necessary to saturate the aggregate, to be added to free mixing water.

Vacuum Processing. The vacuum process of removing excess water is a well-standardized and recognized process. The water-cement ratio is reduced by extracting vehicular water normally used for workability. In the process a compacting pressure of 1500 lbs. per sq. ft. is created by 23 inches of vacuum process on pumice concrete that increases up to 20 percent in compressive strength have been obtained with a slight reduction in shrinkage. In addition, some of the research has shown that the vacuum process is effective in depth proportional to the time of application.

Curing. Basically, curing any portland concrete simply means supplying the concrete with moisture while maintaining temperature between 40° and 180° F. at normal atmospheric pressure. Much higher temperatures may be used in pressure chambers, however. The matrix (set portland cement paste) hydrates during curing. "Total hydration" and "ultimate strength" might be considered synonymous. Like nearly all chemical processes, the rate of cement hydration (or cure) is greatly accelerated by heat.

Pumice concrete shows curing characteristics similar to normal concrete because like most qualified aggregates pumice is inert and has no modifying effect on the matrix. However, the absorbed moisture in the pumice particles is "curing water" and until exhausted supplies the matrix internally. Therefore, it may properly be said that "pumice concrete cures itself" if the statement is qualified regarding temperature and the prevention of surface drying. This "self-curing" characteristic is typical of all concrete made with porous aggregate and its effect is proportional to the absorbed moisture.

Use of good, regular, accepted curing practice is indicated for pumice concrete. This is true in field cure or chamber curing of units.

Air Entraining. An air-entrainment agent is an artificial material which when admixed with concrete produces in the matrix many small, well dispersed, non-coalescing spheroids of air having diameters ranging from 0.003 to 0.05 inches (U. S. Bur. Reclamation, 1949, p. 36). "Darex," a triethanolamine salt of sulphonated hydrocarbon and "Vinsol Resin," which consists of the petroleum hydrocarbon insoluble fraction of a coal-tar hydrocarbon extract of pine wood are the most commonly used air-entraining agents.

The use of an air-entraining admix in concrete made with well-graded pumice aggregate is indicated only when minimum weight is desired and specified strength is low (typical requirements of nonstructural concretes).

In the structural strength range (compressive strength of 1500 to 3000 pounds per square inch) of pumice concrete, mixes should be designed for optimum density of the matrix. This means the lowest water-cement ratio practicable and least possible entrained air. The principle involved here is simple. Matrix strength has a much greater effect upon the strength of light concrete, with relatively weak aggregate, than it does upon the strength of heavier concrete using very strong aggregates.

The main advantage derived from air entrainment by concrete is increased resistance to the effect of freeze and thaw cycles. However, pumice concrete without air entrainment exhibits almost perfect properties in this respect.

Treating. In order to reduce the shrinkage of pumice concrete and yet retain the lightness of the concrete, pumice was treated by the following methods:

1. Pre-wetting the aggregate with a solution that coats the pumice and seals the openings, yet does not interfere with its bonding with the cement.
2. Heat treatment whereby the mouths to the openings in the pumice aggregate are closed or reduced in size, but still full of air.

Although both of these methods have been successful in the laboratory, they have not been applied commercially. Heat-treated pumice was used as an aggregate in tests performed by the U. S. Bureau of Reclamation (Housing and Home Finance Agency, 1949, pp. 3 and 10). The pumice fragments had been fused with a subsequent decrease in volume, and increase in density and strength. Concrete made from this treated pumice had at the end of 28 days a compressive strength of 3210 pounds per square inch and a shrinkage of 0.040 percent, i.e. a coefficient of .0004.

Aggregate Size Gradations. Many of the difficulties encountered in using pumice as an aggregate in concrete have been due in part to the grading of the material. In the work carried on by the U. S. Bureau of Reclamation the gradation of sand is expressed in terms of individual percentages retained on U. S. Standard screens that are designated by the numbers 4, 8, 16, 30, 50, and 100. The gradation for coarse aggregate is usually determined by screens having openings according to specifications for the particular job. On the other hand, the American Society for Testing Materials (Am. Soc. Testing Mat., 1949, p. 721) specifications for lightweight aggregates include all lightweight aggregate materials, and there is no distinction made between pumice, cinders, burned shale and slag. In addition, these specifications are based upon weight percent of material that will pass through the openings in the various screens. It is doubtful whether they are satisfactory for pumice aggregate since they are not based upon percent by volume and have a wide variation to certain size openings from 20 to 55 percent. Gradation specifications for pumice aggregate should be based upon volume because the apparent specific gravity of the different gradations may vary and the size of the particle is very important.

Size of standard Tyler screen openings.
(Tyler Company Catalog 53.)

Size and mesh	Inches	Microns
1 inch	1.050	25400
¾ inch	0.742	19050
½ inch	0.525	12700
⅜ inch	0.371	9525
No. 3½ mesh	0.263	5660
No. 4 mesh	0.185	4760
No. 6 mesh	0.131	3350
No. 8 mesh	0.093	2380
No. 10 mesh	0.065	1680
No. 14 mesh	0.046	1190
No. 20 mesh	0.0328	840
No. 28 mesh	0.0232	590
No. 32 mesh	0.0164	500
No. 48 mesh	0.0116	297
No. 60 mesh	0.0082	250
No. 100 mesh	0.0058	149
No. 150 mesh	0.0041	105
No. 200 mesh	0.0029	74

The apparent specific gravity of the particle increases with the fineness of the mesh because the finer material consists to a large extent of cell walls and not so much of the voids themselves.

Industrial Uses

The uses made of pumice and pumicite have been varied and numerous. The industrial uses of pumice and pumicite probably date back to the time of the Roman Empire when considerable quantities of these naturally occurring materials were used in various buildings and in harbor installations.

There are undoubtedly many more uses for pumice and pumicite yet to be realized. Modern research is rapidly developing new uses, perfecting old ones, and creating new and increased markets.

Abrasive

During World War II when imports of pumice were shut off from Italy, substantial amounts of abrasive pumice were obtained from deposits in Mono County, California.

However, one of the unique industries in California is the mining and processing of block pumice into scouring blocks. The pumice used in making scouring blocks is light to dark gray in color, has a silky luster, is frothy and very porous with openings ranging from long slender tubes to round pores. Crystals of quartz and feldspar are lacking. The pumice at the quarry occurs in angular blocks that are as much as 5 feet in diameter. Minor amounts of blasting are required to mine the pumice at Panum Crater, Mono County, California, where the pumice blocks are large and form an integral part of a pumice breccia. Elsewhere on the Mono Craters and at Big Glass Mountain, Siskiyou County, the pumice is simply mined by selecting loose blocks that form the upper crust of obsidian flows or

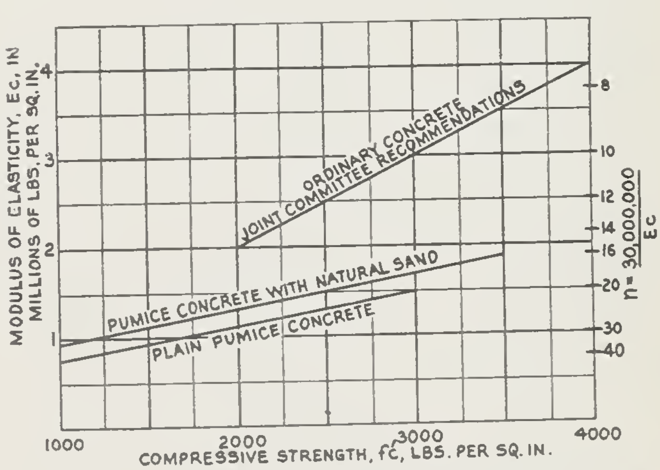


Figure 3. Relation of modulus of elasticity to compressive strength for plain pumice concrete and pumice concrete with natural sand. From Wagner, 1948.

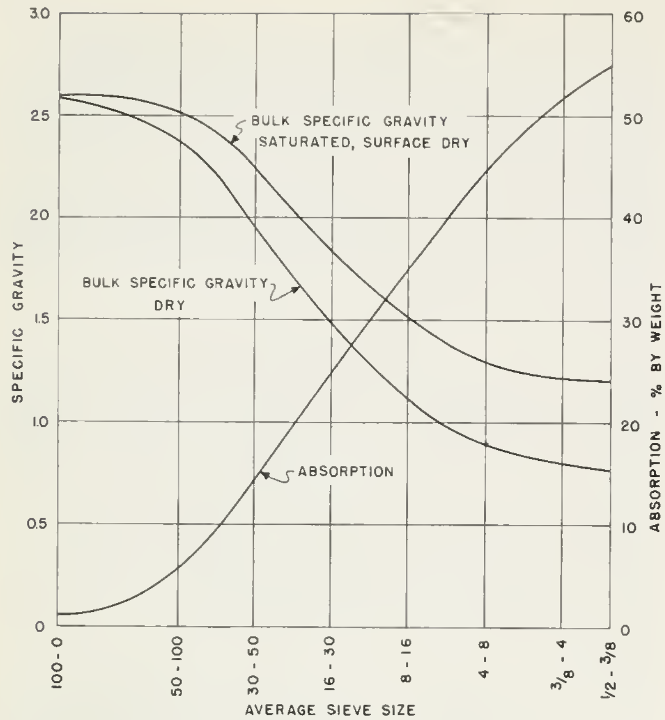


FIGURE 4. Relation of grain size to specific gravity and absorption for pumice concrete. Data from Wagner, 1948.

domes of vesiculated glass. Careful selection is made at the quarry to obtain pumice that will produce the highest quality of scouring blocks.

At the processing plant the pumice is cut into blocks of two sizes, 4 by 4 by 8 inches and 3 by 3 by 6 inches. The sawing of the pumice creates by-products ranging from 8-mesh to minus 325-mesh that are sold as abrasives. In addition, small angular fragments produced during mining operations are sold for abrasive rubbing blocks without squared surfaces.

Uses of ground pumice (after Hatmaker, 1932, pp. 6-7).

Grade	Mesh	Utilization
FFFF	Very finest air-floated powder	Extremely fine work.
FFF	—200	Finishing auto bodies and for certain kinds of soap.
FF	—160	Finishing auto bodies and for certain kinds of soap.
F	—140	Finishing auto bodies and for certain kinds of soap.
0	—100	Glass cutting and silverplate finishing.
0½	—80	Glass beveling and piano finishing.
0-¾	--	Glass beveling and piano finishing.
0-½ 1 1-½	—60 —50 —48	Grades 0½ to 1½ are used for rough rubbing in piano factories; in the manufacture of combs, pearl buttons, and mechanics' soap.
2	—40	Finishing certain kinds of pearl buttons.
3	—30	Finishing certain kinds of pearl buttons.
4	--	Coarse rubbing of hard materials.
7 10	From sand to pea sizes	Used in tumbling barrels. Used in tumbliog barrels.

Uses af lump pumice (after Hatmaker, 1942, pp. 6-7).

Grade	Description	Utilization
AA	Small, very finest quality	Automobile finishing
A	Little larger, almost same grade and quality as AA	Automobile finishing
WW		Finishing stone and marble
LIT	About 7 inches in diameter	Lithograph work
HP	Similar to LIT, inferior grade	Finishing leather
1717	Lightweight, in bags	Electroplating work
BD		Cleaning buffing wheels in electroplating industry

Ground pumice finds wide application as an abrasive agent. The finest grades are used chiefly for finishing silverware, watch cases, and other metal ware. The very finest grades which are air-floated are used in dental laboratories. Considerable amounts of ground pumice are used in scouring soaps, such as mechanics' soap, for polishing metals preparatory to electroplating, and for cleaning, cutting and beveling plate glass.

In addition, ground pumice is used in polishing high grades of wooden furniture and to a limited amount for polishing automobile bodies.

Lump pumice is used as an abrasive for rubbing down paint surfaces, for finishing leather, and in lithographic work.

Because of the fineness of pumicite, not very much of it is used in grinding. It does, however, find wide application as a polishing and cleaning agent in a variety of fields due to the angular nature of the individual particles. Some pumicite has been used as a substitute for ground pumice in electroplating with gold, silver and nickel, and in manufacture of pearl buttons. In addition, it has been used as an abrasive in tooth pastes and powders, and various kinds of metal polishes (Hatmaker, 1932, pp. 8-9).

Aggregate

Monolithic Concrete

In the making of monolithic concrete pumice is used in the same maner as sand and gravel in conventional concrete. It is poured into forms for buildings ranging from one story to the limit-height buildings erected in Los Angeles. The largest building constructed of monolithic pumice concrete in California is the Michelson Laboratory at the Naval Ordnance Testing Station, Inyokern, and contains 30,000 cubic yards of pumice concrete.

Monolithic pumice concrete has also been used in making buildings as a unit, such as the Tournalayer process where fabricated sections of homes are moved as a unit.

Monolithic pumice concrete is especially well adapted to construction where a savings in dead weight on foundations and in steel are important. While the cost for pumice aggregate for this purpose is greater than that for clean sand and gravel, it has been shown on several

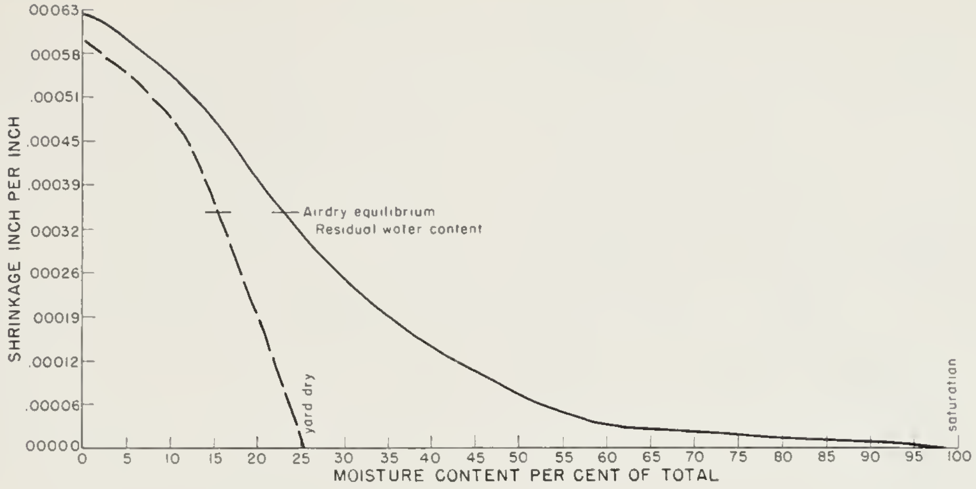


FIGURE 5. Curves showing relations between volume change and moisture content of concrete composed of volcanic cinders and sand. Data courtesy of W. Tonne, Wailes-Bageman Company, Los Angeles, California.

occasions that the savings in steel have more than compensated for the additional cost of the pumice.

Strength-Weight Ratio. The strength-weight ratio of pumice concrete is the ratio of the compressive strength to the weight. For example, the strength-weight ratio of a pumice concrete having a compressive strength of 3000 pounds per square inch and weighing 75 pounds per cubic foot would be 40.

The strength-weight ratio of pumice concrete varies with the strength of the pumice and the mix proportions of the concrete. In various all-pumice concretes this ratio was found to range from 13 to 47. However, when sand is added to the concrete there is a marked increase in weight commensurate with an increase in strength which results in a moderate increase in the strength-weight ratio for the sanded pumice concrete. This increase in strength-weight ratio of sanded pumice concrete or "doctored" concrete may suffer such penalties as (1) lower insulating and fire protecting properties, (2) an increase in modulus of elasticity proportionate to hard sand used, and (3) higher unit weight (Wagner, et al., 1950, p. 15). As compared to ratios ranging from 13 to 47 for all-pumice concretes, conventional concrete with a compressive strength of 3200 pounds per square inch and weighing 150 pounds per cubic foot has a strength-weight ratio of 21.3.

Lightweight concrete is justified when the savings effected more than balance any premium on its cost. In general, it might be stated that its use in tall structures is usually justified through its light weight and in low structures by the inherent insulation. The savings in structural steel on two buildings using 26,000 cubic yards of pumice concrete amounted to 2,000 tons, and the savings in dead weight of the buildings alone amounted to 22,900 tons.

Lighter foundation load is particularly important where sub-soil conditions show poor load-bearing ability. Sometimes lightweight concrete must be used, or a smaller building constructed; or, where the foundations of existing structures are good enough to support additional loads, lightweight concrete will allow larger additions.

There are other strengths of concrete that qualify pumice concrete for structural purposes in addition to compressive strength, but in all concretes these strengths vary in some ratio with the compressive strength. These strengths are (1) flexural or modulus of rupture, (2) bond, (3) tensile, and (4) shear.

Flexural Strength—Modulus of Rupture. The flexural strength of any concrete is expressed by the modulus of rupture expressed in pounds per square inch. In general, in conventional concretes of lower strengths, the modulus of rupture is usually 20 percent of the compressive strength, and in the higher strength concretes it is 13 to 15 percent of the compressive strength.

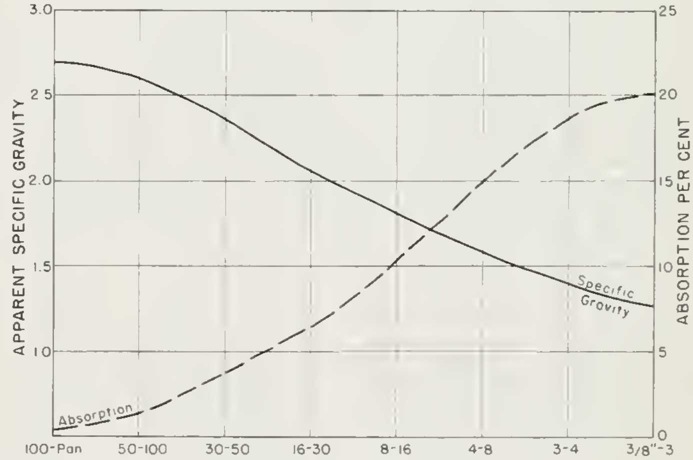


FIGURE 6. Curves showing relationship between grain size, specific gravity, and absorption of volcanic cinders (scoria). Data courtesy of W. Tonne, Wailes-Bageman Company, Los Angeles, California.

Change in length of untreated and vacuum-treated pumice concrete, with and without admixture

Data, Courtesy Raymond E. Davis, 1950

Type of concrete	Nominal cement content in sacks per cubic yard (Colton portland)	Admixture agent		Total water content per cubic yard (in barrels per cubic yard)	Water removed by vacuum (in barrels per cubic yard)	Percent changes in length			Percent changes in length										
						Untreated concrete			Untreated concrete				Vacuum-treated concrete						
		Type	Amount per sack of cement			7 days	14 days	28 days	60 days	100 days	6 months	1 year	7 days	14 days	28 days	60 days	100 days	6 months	1 year
Pumice and natural sand, 4 x 4 x 40-inch bars	5	None	----------	490	100	+0.(030	----------	—0.0205	—0.0590	—0.0800	—0.0950	—0.1010	+0.0020	—0.0060	—0.0240	—0.0585	—0.0760	—0.0880	—0.0930
		Plastiment	0.5 pound	480	90	+0.0035	+0.0010	—0.0200	—0.0605	—0.0800	—0.0940	—0.0990	+0.0025	—0.0015	—0.0215	—0.0580	—0.0745	—0.0865	—0.0915
		Suconem	4/5 quart	450	----------	+0.0055	—0.0030	—0.0240	—0.0625	—0.0860	—0.1055	—0.1125	-------	-------	-------	-------	-------	-------	-------
	7	None	----------	480	95	+0.0030	—0.0005	—0.0205	—0.0530	—0.0785	—0.0975	—0.6075	+0.0020	—0.0075	—0.0245	—0.0545	—0.0755	—0.0910	—0.0990
		Plastiment	0.5 pound	470	75	+0.0040	—0.0030	—0.0250	—0.0585	—0.0820	—0.1005	—0.1090	+0.0030	—0.0040	—0.0200	—0.0490	—0.0700	—0.0850	—0.0940
		Suconem	4/5 quart	440	----------	+0.0070	—0.0035	—0.0205	—0.0580	—0.0840	—0.1065	—0.1165	-------	-------	-------	-------	-------	-------	-------
Pumice and natural sand, 6 x 6 x 40-inch bars	5	None	----------	490	105	+0.0030	+0.0015	—0.0125	—0.0420	—0.0675	—0.0895	—0.1015	+0.0035	—0.0005	—0.0105	—0.0375	—0.0590	—0.0815	—0.0915
		Plastiment	0.5 pound	480	----------	----------	----------	----------	----------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
		Suconem	4/5 quart	450	----------	----------	----------	----------	----------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
	7	None	----------	480	90	+0.0055	+0.0010	—0.0105	—0.0375	—0.0580	—0.0835	—0.0995	+0.0050	—0.0025	—0.0130	—0.0350	—0.0545	—0.0785	—0.0920
		Plastiment	0.5 pound	470	----------	----------	----------	----------	----------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
		Suconem	4/5 quart	440	----------	----------	----------	----------	----------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------

Poured pumice concrete structures in California.

Date	Job	Location	Concrete yardage
1939	Pontoon bridge	Long Beach, California	1,500
1945	Administration building	U. S. Naval Ordnance Testing Station, Inyokern, California	7,000
1946	Housing unit-100 living units	American Potash & Chemical Corp., Trona, California	2,000
1946	Michelson Laboratory	U. S. Naval Ordnance Testing Station, Inyokern, California	30,000
1947	Factory building	Clayton Manufacturing Co., Rosemead, California	4,000
1947	Office building	Bell Telephone Building, Los Angeles, California	8,000
1947	Warehouses, shops, and motorpool.	U. S. Marine Base, Camp Pendleton, California	2,500
1947-49	Housing unit-520 two and three bedroom units	U. S. Naval Ordnance Testing Station, Inyokern, California	20,000
1948	Housing unit-250 two and three bedroom units	Mayfair Park, Chino, California	6,500
1948	Housing unit-200 two and three bedroom units.	Phillips Park Subdivision, Pomona, California	6,000
1948	Office building	General Petroleum Building, Los Angeles, California	12,000
1948	Office building	Rheem Manufacturing Company Office Building, Los Angeles, California	3,500
1949	College buildings	San Bernardino Junior College, San Bernardino, California	4,000
1949	Hangar and decks	Air Missile Testing Station, Point Mugu, California	700
1949	Office building	Prudential Life Insurance Building, Los Angeles, California	14,500
1950	Housing unit-250 two and three bedroom units (masonry).	George Air Force Base, Victorville, California	4,000
1952	Housing unit-1,000 two and three bedroom units.	Fort Ord, California	50,000

Pre-cast pumice concrete structural roofs in California.

Date	Job	Location	Concrete yardage
1947	Grandstand	Hollywood Park Race Track, Hollywood, California	1,500
1948	Office and store building	American Radiator and Standard Plumbing Co., Wilmington, California	3,000
1949	Office building	Hyperion Sewage P & B Building, El Segundo, California	500
1954	Industrial building	Fletcher Aircraft Bldg., Rosemead, California	1,200

Non-structural roofs of pumice concrete in California.

Date	Job	Location	Concrete yardage
1945	Miscellaneous buildings	U. S. Army Air Force at San Bernardino, California	2,500
1945-49	Miscellaneous buildings	U. S. Navy at Inyokern, Mojave, Pendleton, San Diego, California	5,000
1946-49	Office buildings	Bell Telephone Buildings (26 in all) in Southern California	1,000
1948	Parts building and precast louvers	General Motors Parts Building, Van Nuys, California	800

Bond Strength. A close relationship exists between compressive strength, bond strength, and tensile strength of concrete. Bond strength of any concrete, whether it is conventional or pumice, is a measure of the ability of the concrete to adhere to reinforcing steel.

Tests performed on pumice concrete of varying compressive strengths gave bond strengths comparable to those for conventional concrete of varying compressive strengths.

Typical comparison of ratios of compressive strengths to moduli of rupture of conventional and pumice concretes.

Conventional concrete			Pumice concrete		
Compressive strength (pounds per square inch)	Ratio	Modulus of rupture (in pounds per square inch)	Compressive strength (pounds per square inch)	Ratio	Modulus of rupture (in pounds per square inch)
1000	.230	230	903	.234	216
2000	.188	375	1270	.228	290
3000	.162	485	1618	.171	276
			1755	.184	324
			1768	.194	344
			1938	.192	370
			2066	.182	380
			2115	.165	350
			2230	.193	433
			2420	.169	411
			2560	.176	454
			2625	.144	377
			2718	.185	502
			3215	.160	516
			3278	.130	425

Comparisons of bond to compressive strengths of conventional and pumice concretes. After Abrams, 1925, in part.

Conventional concrete 28-day			Pumice concrete 28-day		
Compressive strength (pounds per square inch)	Ratio	Vertical bond strength (pounds per square inch)	Compressive strength (pounds per square inch)	Ratio	Vertical bond strength (pounds per square inch)
1000	.280	280	1366	.231	316
2000	.250	500	1755	.212	372
3000	.220	660	1800	.229	414
4000	.200	800	2420	.168	418
5000	.180	900	2560	.164	423
			3278	.140	461
			3215	.160	514

Tensile Strength. The compressive and tensile strengths of pumice concrete and conventional concrete are shown in the accompanying table. As the tensile strength in conventional concrete is about 10 percent of the compressive strength, it is clearly shown in this table that the tensile strength of pumice concrete compares favorably with that of typical conventional concrete.

The somewhat higher ratios of tensile strength in pumice concrete is usually attributed to the surface characteristics of pumice aggregate. The surface of pumice as seen under the microscope is composed of open pores. The cement matrix, apparently, can attain and maintain a superior bond to pumice aggregate compared to the bond possible to solid and relatively smooth surface of solid heavy aggregate.

Shearing Strength. Pumice concrete shows shear values in relation to its compressive strength that is adequate.

Comparison of compressive and tensile strength of conventional and pumice concretes.

Conventional concrete			Pumice concrete		
Compressive strength in pounds per square inch	Tensile strength in pounds per square inch	Ratio of tensile strength to compressive strength	Compressive strength in pounds per square inch	Tensile strength in pounds per square inch	Ratio of tensile strength to compressive strength
1000	110	11	1366	262	19.1
2000	200	10	1972	356	18.0
3000	275	9.2	2038	283	13.8
			2092	351	16.7
			2170	325	14.9
			2492	285	11.4

Comparison between pumice concrete and conventional concrete of double shear, ratio of shear to compression, and compressive strength.

Pumice concrete*			Conventional or heavy concrete**		
Double shear (pounds per square inch)	Compressive strength (pounds per square inch)	Ratio of shear to compression percent	Double shear (pounds per square inch)	Compressive strength (pounds per square inch)	Ratio of shear to compression percent
680	1755	.397	1180	950	124
728	2420	.300	1120	1270	88
752	2560	.293	1240	1310	95
822	3215	.391	1120	1360	82
			1310	2070	63
			1650	2620	63

* Data on pumice aggregate from Coso District, California, and supplied by courtesy of the Crownite Corporation report S.E. P-145329.
** From "Concrete plain and reinforced" by Taylor and Thompson, John Wiley, 1922.

Relation between compressive strength, weight of concrete K factor and heat transmission for conventional and pumice concretes.

Compressive strength (pounds per square inch)	Weight per cubic feet		K factor		Heat transmission, U 4-inch thickness	
	Pumice concrete	Conventional concrete	Pumice concrete	Conventional concrete	Pumice concrete	Conventional concrete
3500	110	115	3.50	13.0	.518	.928
3000	102	152	3.20	12.5	.495	.918
2500	90	150	2.70	12.0	.444	.907
2000	87	148	2.40	11.5	.409	.894
1500	75	145	1.95	11.0	.354	.883
1000	66	142	1.85	10.5	.340	.870

Elasticity. Elasticity is expressed by the modulus of elasticity which is the ratio of an increment of stress to a corresponding increment of deformation. Hence, the lower the modulus, the greater the elasticity. Elasticity in pumice concretes varies with different pumice concrete mixes and this variation is due largely to the difference between the elasticity of the pumice particles and the elasticity of the cement and sand factors. In general, the elasticity is greater with lighter weight concretes and decreases with the denser, stronger concretes. The modulus of elasticity for pumice concretes in general varies from 500,000 to 1,750,000, depending upon the mixture, strength and density of the concrete as compared with 3,000,000 to 4,000,000 for conventional concrete. Tests were performed on pumice concrete at the University of New Mexico where it was found that the modulus of elasticity for plain pumice concrete varied from 75,000 for a compressive strength of 1,000 pounds per square inch to 1,500,000 for a compressive strength of 3,000 pounds per square inch.

Also, within the same range of compressive strengths, pumice concrete containing natural sand had moduli ranging from 950,000 to 1,670,000 (Wagner et al., 1948, p. 125). Data on California pumice are practically parallel.

Relation of modulus of elasticity to weight and compressive strength of pumice concrete.

Compressive strength in pounds per square inch	Weight pounds per cubic foot air dry	Modulus of elasticity
1755	78.68	801,617
2420	90.23	945,721
2560	102.37	1,461,617
3278	92.40	1,529,799
3215	105.44	1,768,567

A high degree of elasticity is sometimes an advantage, especially when internal stresses in reinforced concrete are set up by extreme thermal gradients, shock, impact, seismic moments or other mechanical loads which would rupture a more brittle concrete. It permits the concrete to adjust itself to sudden and violent changes in expansion and contraction caused by con-

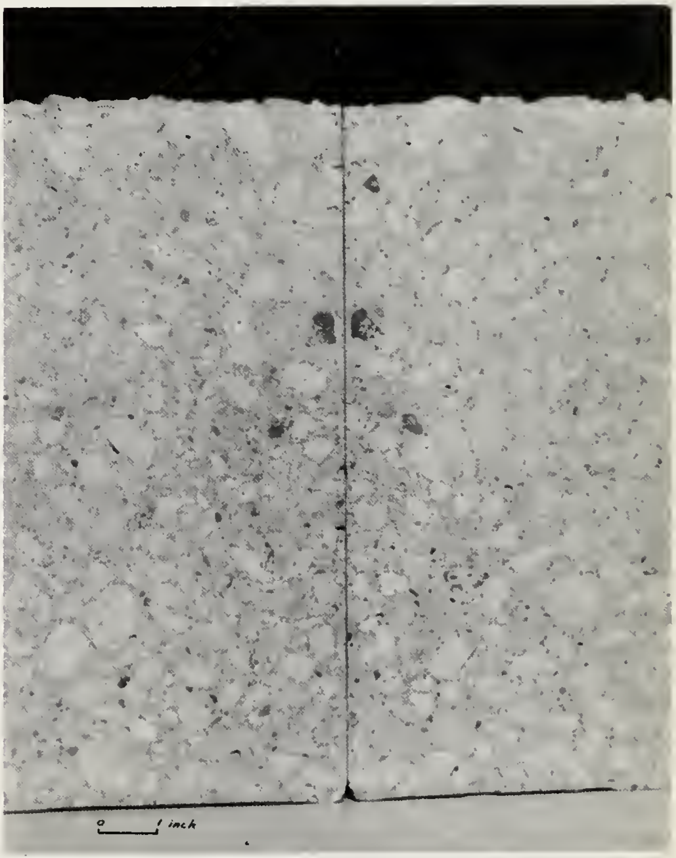


FIGURE 7. Cross section of cylinder of pumice concrete 6 inches in diameter, showing lack of segregation and uniform distribution of pumice aggregate. Cylinder contains no admix and had a compressive strength of 3000 P.S.I.

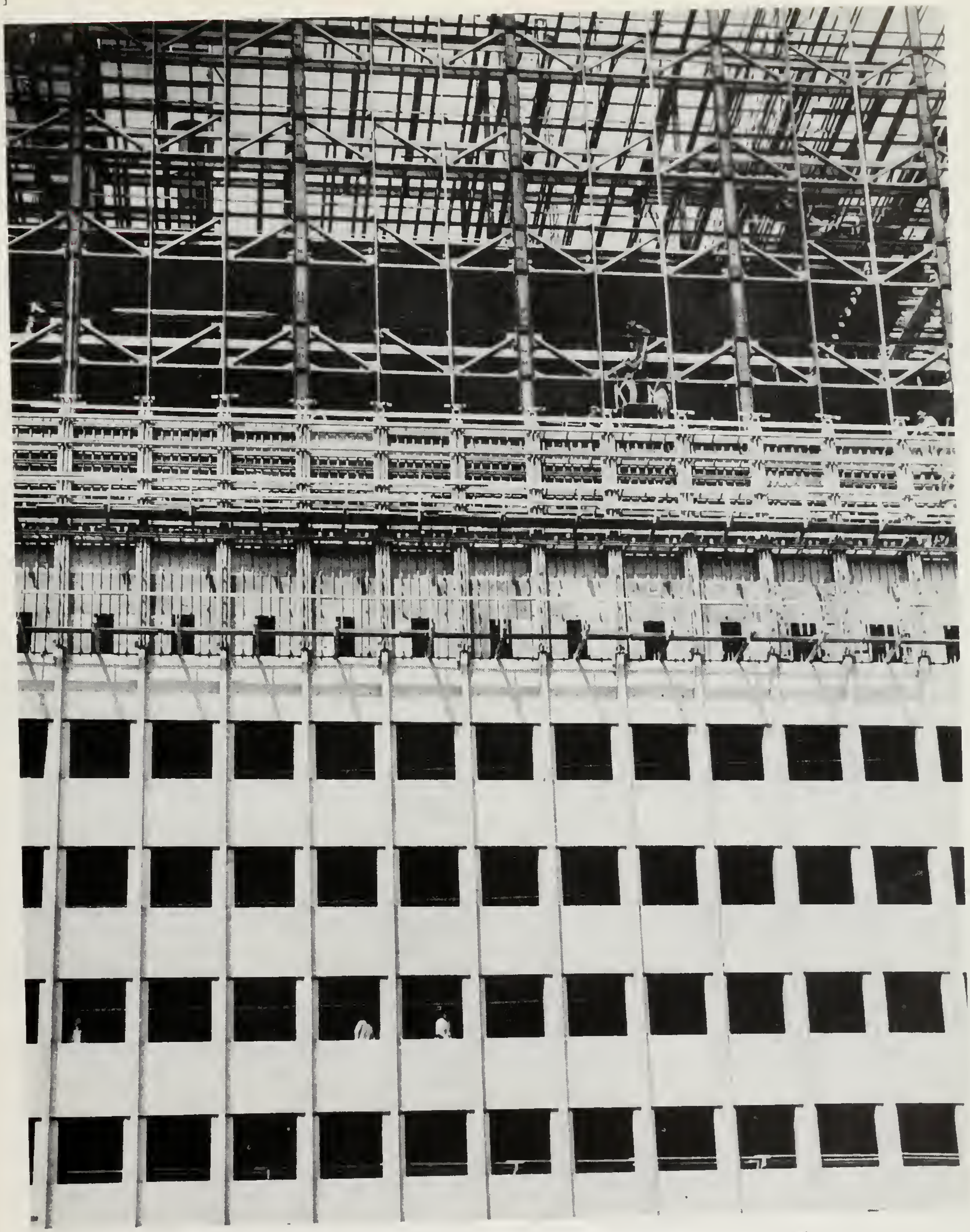


FIGURE 8. General Petroleum Building, Los Angeles, in process of construction; 12,200 cubic yards of pumice concrete were used in this building.

flagration. Houses constructed of pumice concrete in California, England, and Belgium, when subjected to a temperature of 1800°F, sufficient to melt and twist steel windows and door frames, and suddenly quenched by playing cold water directly upon the heated pumice concrete revealed practically no cracking or damage to the concrete.

A high degree of elasticity is also important in the use of pumice concrete in its dual role of structure and insulation, especially in such structures as kilns or refrigerated warehouses where steep temperature gradients and even the disintegrating effects of moving frost lines are continuously active.

Projectiles shot through military targets made of pumice concrete left perfectly clean holes with no spalling. The same experiments made with conventional concrete caused shattering of the target.

The overall ability of pumice concrete to resist shock due to elasticity was well demonstrated in Germany where houses made of pumice concrete resisted the bombings much better than those made of conventional concrete.

Insulation. The insulating factor of any material is usually termed the "K" factor which is expressed as the number of British Thermal Units (B.T.U.'s) per square foot per hour, per inch thickness, per degree Fahrenheit temperature gradient between two sides of a wall or block. The "U" factor is the B.T.U. per hour, per square foot per degree. Fahrenheit for any given number of inches of wall thickness. The lower the K factor the better the insulation. K factors are usually determined on oven dry samples. In actual practice, however, this is not the prevailing condition since contained moisture of the concrete depends to some extent upon relative humidity.

In general, the K factor increases with the density of the material and would be much higher for conventional concrete than for pumice concrete.

A slab of pumice concrete 1 inch thick weighing 75 pounds per cubic foot has six times the insulation value

Thermal conductivity or K factors of various types of building materials.

Material	K factor
Concrete, with cinder aggregate *	4.90
Concrete, with haydite aggregate *	3.73
Concrete, with limestone or gravel aggregate *	12.00
Corkboards *	0.30
Fiberboard *	0.33
Brick, common **	5.00
Plywood, ½-inch thick **	0.80
Plaster, gypsum **	3.30
Yellow pine, 25/32-inch thick **	0.80
Cement, mortar **	12.50
Concrete, sand and gravel aggregate **	12.50
Concrete, with pumice aggregate ** sanded	2.40
At unit weight of 83 pounds per cubic foot only *	1.95

* Portland Cement Association, Circular AC316.
** Federal Housing Administration Technical Circular No. 7.

Relations of compressive strengths of various lightweight aggregate materials to their respective K factors.

Material	Compressive strength in pounds per square inch	K factor
Rocklite concrete	2530	3.42
Perlite concrete	1000	1.40
Vermiculite concrete	500	1.40
Scoria concrete	2000	4.00

of a comparable slab of conventional concrete; a wall of pumice concrete 4 inches thick with a compressive strength of 2000 pounds per square inch would transmit less than half as much heat as a similar wall of conventional concrete.

Freezing and Thawing. Extensive tests were made by the U. S. Bureau of Standards and the U. S. Bureau of Reclamation (Housing and Home Finance Agency, 1949, pp. 13-16) on the freezing and thawing of various types of lightweight aggregate concretes. Although the tests were not identical in all respects, they checked each other and consisted in general of alternate freezing and thawing, and counting the number of cycles causing measured deterioration in elasticity. The U. S. Bureau of Standards established No. 100 for a perfect score, showing no failure, and gave pumice concrete the value of No. 90. A similar rating for pumice concrete was given by the U. S. Bureau of Reclamation.

Fireproof Characteristics. Three houses made of pumice concrete have been fired under controlled conditions for the purpose of determining the fireproof nature of pumice concrete. The houses were built in Belgium, England, and California, and in each house the fire was built inside with gasoline or oil-soaked wood and temperatures carefully noted by pyrometric cones and thermocouples. In one house the temperature reached 1800°F, in another steel windows and door frames warped out of shape, and in all three the sudden quenching by cold water showed no damage to the pumice concrete.

Well designed pumice concrete consistenly demonstrates twice the accepted value, of sand and gravel concrete, relative to fire rating. Pumice concrete not only maintains its rigidity under high heat, but protects structural members through its high insulating property which is equal to the highest of any of the lightweight aggregates that attain structural strength.

Absorption. All lightweight aggregate concretes are more absorbent than conventional concretes. Lightweight aggregate concretes derive their merit largely from aggregate porosity which is an inherent characteristic and one of the chief causes for higher absorption.

In pumice concrete, the addition of sand under certain conditions reduces absorption. The pore spaces and capillaries in the pumice aggregate are not of the same size, and those that are smaller require more time to absorb water so that a concrete which might ultimately absorb more water may not absorb as much in the same period of time.

Pumice on the whole does not make a porous concrete. One of the main reasons for this is because pumice, which is porous by nature, when mixed with water and cement loses its surface porosity due to sealing off of the pores by the cement. Therefore, when the pores are sealed there is little additional absorption of water by the pumice and after the concrete has set, the pores to a large extent lose their absorptive characteristic and thus minimize absorption.

If considerable sand is added to the concrete and no air-entraining agent used, there is little difference between the absorption of pumice and conventional concretes.

Relation between mix, weight of concrete and water absorption of New Mexico pumice concretes with and without sand.

Sample number	With sand	Without sand	Sacks cement per cubic yard	Weight pounds per cubic feet	Percent absorption 24-hours	Percent air entraining agent*
1a	0	X	5	80.7	25.4	5.0
2a	0	X	7	88.0	21.4	4.0
5c	X	0	5	96.6	14.7	6.5
6c	X	0	7	99.1	14.9	6.5
7d	X	0	5	107.5	11.4	6.5
8d	X	0	7	110.9	10.6	5.0
C	0	X	5	----	4.5	----
1A	0	X	4	78.0	28.9	3.75
2A	0	X	5	82.8	22.9	3.50
3A	0	X	6	84.0	22.5	4.00
4A	0	X	7	88.0	18.6	3.50
21FP	0	X	5	82.0	22.8	3.50
22FP	0	X	7	88.7	21.5	3.25
11D	X	0	5	94.9	14.5	6.25
12D	X	0	7	99.0	13.0	5.00
13E	X	0	5	108.0	10.6	5.40
14D	X	0	7	110.8	9.8	4.80

* Air entrainment agents Protex and Pozzolith. Data from Wagner, Wm. C., Gay, Walter E., and Reynolds, Dexter H., (1950), p. 30.

Nailability and Sawability. Nails driven into pumice concrete hold with the same degree of firmness as they do in soft wood. They can also be withdrawn from the pumice concrete with little spalling. In addition, pumice concrete can be sawed or drilled like hardwood.

Nonplastic Concrete and Masonry

All high production masonry and precast units which are ejected from molds immediately are made from nonplastic (very dry) concrete. Nonplastic concrete has no vehicular water and shows no tendency to flow or conform beyond assuming the angle of repose. It must be compacted entirely by force. Properly designed nonplastic concrete, if adequately compacted in molds by well-designed machines, may be ejected instantly without distortion or rupture.

Nonplastic concrete is rarely ever compacted to the same degree as plastic concrete. Also, the water-cement ratio in nonplastic concrete almost never exceeds the minimum for hydration. These two factors, to a certain extent, cancel each other in the matter of compressive strength. Hence, given cement contents in both plastic and nonplastic concrete yield strengths that are roughly in the same bracket. Economically, therefore, plastic and nonplastic concretes are very closely related. In terms of volume pumice aggregate has been used in the order of 70 percent for masonry production and 30 percent for monolithic uses in California while the percentage for masonry appears considerably higher in other regions where pumice is available.

The two cardinal advantages of pumice as an aggregate, namely, light weight and low thermal conductivity, have secured a large portion of the masonry aggregate market.

The slightly greater shrinkage of pumice concrete than some other concretes is of no consequence in masonry if good practice by the unit producer is observed. This good practice consists of drying the cured units to equilibrium with the relative humidity before delivery to the job. Subsequent volume change after this first drying is negligible.

Strength-Weight Ratio. The strength-weight ratio for masonry pumice concrete is somewhat lower than for structural monolithic pumice concrete, but it is within the range of strength required by masonry units. A standard pumice concrete block measuring 8 by 8 by 16 inches usually weighs when sold at the block yard from 26 to 30 pounds. It is made of pumice concrete that weighs from 80 to 90 pounds per cubic foot with a compressive strength ranging from 2000 to 2600 pounds per square inch. As the cross sectional area of the block is 50 percent air cells, the compressive strength must accordingly be divided approximately in half in order to obtain the 1000 pounds per square inch over the gross area required for Class A bearing walls, since all masonry units must meet code requirements. Similarly, monolithic pumice concrete weighing 85 pounds per cubic foot with a compressive strength of 2000 pounds per square inch would have a strength-weight ratio of about 24. One of the main reasons why there is not more strength per unit weight for masonry pumice concrete is that the mix is too dry to allow optimum compaction necessary for maximum strength to develop, yet the dryness of the mix is a requirement of the block machine.

The strength-weight ratio yields economy in foundations, cost of handling, manufacture, hauling and installation. The standard pumice concrete block, measuring 8 by 8 by 16 inches, has a wall surface of 128 square inches A wall made of pumice concrete blocks requires one-third less mortar than one made of concrete blocks, measuring 4 inches by 12 inches, having a unit wall surface area of only 48 square inches per block. One thousand square feet of wall surface requires 3,000 4- by 8- by 12-inch blocks and only 1,130 8- by 8- by 16-inch blocks. The cost per mason per square foot of wall surface is less for 8- by 8- by 16-inch blocks than for conventional concrete blocks because there are fewer joints for mortar.

Blocks 8 by 8 by 16 inches made with sand and gravel concrete weigh more than 40 pounds while pumice concrete may be designed to yield a weight as low as 22 pounds. However, a more economical mix design is usually used, yielding a block of equal strength weighing approximately 28 pounds using some natural sand.

Elasticity. Because of the elasticity and light weight of pumice concrete blocks, there is less breakage than with conventional concrete blocks. It is true that a wall made of pumice concrete blocks does not benefit to the fullest from the elasticity of the individual blocks because they are units bound together by mortar. However, this difficulty is overcome to some extent by using a bedding mortar that contains 50 percent pumice which imparts desirable characteristics to the mortar and produces more homogeneity in the wall both thermally and structurally.

In so far as insulation and freeze-thaw resistance are concerned, there are no differences between monolithic and masonry pumice concretes.

Fireproof Characteristics. Units made of masonry pumice concrete are naturally as fireproof as monolithic pumice concrete since the mortar that binds the blocks consists largely of pumice which is just as fireproof as the pumice aggregate. There is no tendency for the

FIGURE 9. American Radiator and Standard Plumbing Corporation building at Wilmington, California, in process of construction. The building occupies 15 acres and has a roof made of pre-cast pumice concrete slabs. Photographed by Rode Photo Service, Los Angeles.

blocks to separate as a result of high temperature. Pumice concrete blocks and other masonry members have been proven by tests to be more fireproof than conventional concrete blocks which have an acceptable fireproofing rating.

Absorption. The absorption of pumice concrete blocks is slightly greater than for conventional heavy concrete blocks. Although it is not as great as with some of the more porous lightweight aggregate concretes, well-graded pumice mixes have been and are now being used to produce lighter and less permeable units than any other lightweight concrete. It should be recommended that the outer surface of the wall be brush coated with a cement base paint. The cost for such an operation is nominal and the appearance of the job is greatly improved.

Permeability. Certain masonry units are intentionally made of a porous structure by machines that produce blocks containing from 15 to 20 percent voids. These voids are desirable for thermal insulation and acoustical advantages. A consequently greater permeability in this type of unit is no disadvantage as the unit is never exposed to the weather.

Block makers have many different ways of making and compacting their concrete, which results in variations in the permeability of their concrete blocks. Although the mix can be designed so as to reduce permeability, it may be done at the cost of other factors such as weight and insulation which might be more important.

Plaster Aggregate and Acoustical Granules

Pumice plaster aggregate and acoustical granules are produced by a few pumice producers in California. These materials are products of considerable research and experience and many of the details of their manufacture are not available for publication.

The Insulating Aggregates Company, Bishop, California, is one of the leading producers. At their quarry, which is in Mono County about 6 miles north of Laws, an extensive bed of white pumice is mined by stripping and moved with a HD-14 Caterpillar bulldozer to a processing plant adjacent to the quarry. The pumice is dried, screened, air tabled and passed through a Ding magnetic separator before being packaged in 2.25 cubic foot-bags that weigh 80 pounds when full.

In order to produce a precision product, especially acoustical granules all of which are minus 8 mesh and plus 30 mesh, very accurate screening is required. However, the sizes of screens used and the type of air-entraining agent added to the plaster aggregate are trade secrets. Although no air-entraining agent is added to the acoustical granules, one is added to the plaster aggregate to aid insulation, workability, sound control and reducing weight.

Plaster containing 60 percent pumice aggregate and 40 percent gypsum weighs about a third as much as an equivalent amount of standard gypsum hardwall plaster. One square yard of pumice plaster ½ inch thick weighs 14 pounds when dry as compared with a square yard of standard gypsum hardwall plaster ½ inch thick at 42 pounds. Therefore, the saving in weight when using pumice plaster for each 100 square yards is about 2,800 pounds.

The K factor for pumice plaster is very important and is not dependent entirely upon the nature of the aggregate, but also on the 12 to 16 percent dead air cells introduced by the air-entraining agent. The K factor for pumice plaster is 0.57 and that for standard gypsum hardwall plaster ranges from 3.0 to 3.5.

A test wall consisting of a 1-inch covering of Insulating Aggregates exterior stucco over metal lath, 2-inch by 4-inch studding, and an interior finish of ½-inch Insulating Aggregates interior plaster on $\frac{5}{16}$-inch plaster lath gave K and U factors respectively of 0.21 and 0.18.

Pumice is used not only as aggregates for plaster, but also in the manufacture of roof slabs in which portland cement substitutes for gypsum. A roof slab containing 4.5 cubic feet of pumice plaster aggregate to 1 cubic foot of cement gave the following test data:

Thickness	*U Factor*	*Weight per square foot*
2 inches	0.285	10 pounds
2.5 inches	0.228	12.2 pounds
3 inches	0.190	15 pounds

The 28-day tensile strength of the above mix was 163 P.S.I., and the compressive strength of another mix containing one part of cement to 4.5 parts of pumice plaster aggregate was 1048 pounds per square inch at the end of 28 days.

Agricultural Uses

Soil Conditioner. The functions of pumice in soils are to render the soil more porous and to improve aeration. The introduction of air into the soil even though the pumice is wet is very important. In both of these functions the pumice plays only a physical role and does not enter materially into the chemical processes of plant growth.

Considerable work has been done by the University of California at Los Angeles on pumice from Crownite Corporation's deposits in the Coso Range, and so far all results reported have been very good. The pumice has been used for the following purposes: rooting, propagation, potting, greenhouse tables, flats, turf culture, mulching, row crops, citrus and pasturage.

The most work has been done on turf culture, in both established turf and new installations. When spiking to aerify old turf, a top dressing composed largely of pumice may be raked in, and both aeration and soil conditioning are accomplished thereby. In new turf installations, or where it is practicable to roll back the old sod, pumice from 20 to 30 percent may be tilled into the subsoil, usually by rototiller. Roots will go down as far as the pumice is worked in, in some places more than 8 inches, a fact of particular value in mulching in hot dry areas. For this purpose a thickness from ½ inch to 2 inches is spread on the ground for insulation against heat and for moisture conservation. Turf and plants readily grow through this mulch. In many cases year round plant life has been achieved.

The accompanying tables show clearly the absorption, retention and exudation of pumice. These data place the values of absorption, retention and exudation at about optimum for the function of a soil conditioner. It means that, along with lightening heavy soils, it can introduce retention into light and sandy soils so that the nutrient does not leach below the plant roots. When

Absorption and retention of soluble foods in pumice.

Pumice	Weight of sample (in grams)	Treating chemical	Weight after being drained for 2 hours (in grams)	Weight after being air dried for 3 days (in grams)
Coarse (plus 4 mesh)	100	Phosphoric acid	136.3	116.0
Fine (minus 4 mesh, plus 10 mesh)	100	Phosphoric acid	140.8	117.0
Coarse (plus 4 mesh)	100	Liquid fertilizer	130.7	118.8
Fine (minus 4 mesh, plus 10 mesh)	100	Liquid fertilizer	135.8	121.7
Coarse (plus 4 mesh)	100	Distilled water	124.8	99.8
Fine (minus 4 mesh, plus 10 mesh)	100	Distilled water	138.5	99.6

Percent of soluble foods retained in air-dried impregnated pumice.

Pumice	Distilled water—percent retained	Liquid fertilizer	
		Nitrogen percent retained	Phosphoric acid percent retained
Coarse (plus 4-mesh)	6.69	3.60	2.02
Fine (minus 4-mesh, plus 10-mesh)	7.69	3.68	2.16

Percentage of soluble plant foods removed from the air-dried impregnated pumice by leaching. All data courtesy of the Crownite Corporation, Inc. Based upon research by the Geo. W. Gooch Laboratories, Inc.

Leach	Distilled water Percent lost by leaching		Liquid fertilizer Percent lost by leaching			
			Nitrogen		Phosphoric acid	
	Coarse pumice	Fine pumice	Coarse pumice	Fine pumice	Coarse pumice	Fine pumice
First	2.70	4.06	1.48	0.69	1.46	1.26
Second	1.62	1.83	1.25	0.71	1.22	0.55
Third	1.06	0.81	0.56	0.35	0.61	0.28
Percent remaining in pumice	1.31	0.99	0.31	0.27	0.40	0.07
Percent of original amount remaining	19.6	12.9	8.5	13.4	10.9	3.2

mixed with mulch or fertilizer, pumice absorbs moisture, air, and nutrient and retains them safely against chemical combination with the soil, so that they remain available to the roots. The pumice then acts in three ways: (1) as a soil conditioner, (2) a retainer of moisture and nutrient, and (3) a feeding regulator, prolonging the availability of any given amount of fertilizer. This applies to any fertilizer, as the nutrient is invariably in solution to the roots.

The fact that half the porosity of the pumice is of a type that will retain air makes it an aerating material as well. Once the pumice is in the soil, it is permanent, as it tends neither to sink nor to float out; it is physically strong enough to resist breaking down by cultivation, and functions continuously, absorbing available moisture and nutrient and exuding them slowly. Hence, the cost of its application can be amortized over a long period of time in water and fertilizer savings.

The pumice itself is chemically inert. Its pH is neutral. Soil conditions, either acid or alkaline, may be rectified more permanently if the soil contains pumice, because pumice does not allow a large percent of the neutralizer to leach away.

In using pumice as a soil amendment, the data show that advantages are obtained with as low as 10 percent pumice, and in some fine horticultural soil conditioning, as high as 50 percent pumice has been used for bedding. For rooting in greenhouse tables, flats, and potting, much higher percentages are used, even up to 100 percent, and in indicated cases nutrient is added to the water. In mulching, approximately 50 percent pumice is used, and as this is worked into the soil, it should be logged so that the required percentage in a given plot would not be needlessly exceeded. In row crops the pumice is distributed between the rows and covered. Of course, it must be within reach of the roots. In row and field crops, from 15 to 20 percent pumice seems to be sufficient to obtain excellent results. This means that for every 5 or 6 inches of depth of cultivation, 1 inch of pumice should be used.

Hydroponics. Some very interesting results were obtained through the use of pumice in hydroponics in wooden tanks 9 inches deep, 4 feet wide, and 25 feet long. A solution containing 8 ounces of commercial grade potassium chloride, 8 ounces of ammonium nitrate, and 4 ounces of treble superphosphate dissolved in 50 gallons of water was added to the seed bed once each week until plant growth was well established. After plant growth became heavy, the solution was added twice each week and any solution not absorbed by the pumice was allowed to drain off. Light watering with clear water was required each morning to replace the moisture lost by evaporation and used by the plants. Tomatoes and corn were planted the 20th of March and the tomatoes bore fruit until the following November. One hundred tomato plants were planted 6 inches apart and in rows 25 feet long. Many of the plants attained a height of 13 feet.

Another seed bed 18 inches by 35 feet produced 143 ears of corn. After a successful growing season, only a slight amount of breakdown had taken place in the pumice, which acted only as a medium through which the plant roots grew, extracting the required chemicals.

Miscellaneous Uses

Insecticide Carriers. Although a small amount of ground pumice has been used as an insecticide carrier for dusting crops, no general market has been established. Considerable pumicite, on the other hand, is being used for insecticide carriers. Pumicite has pH values ranging from 5.4 to 8.9 and forms a suitable diluent for such active poisons as DDT, Rotenone, Pyrethrum, Cryolite, nicotine, sulfur, and arsenates, which are effective in destroying chewing insects (Moretti, L. R., 1947).

Rather rigid requirements are specified for insecticide dusts, diluents, and carriers. For pumicite, the dry screen analysis should be 90 to 99 percent passing 325 mesh (Watkins and Norton, 1947). Average particle size as well as the range of particle size should be controlled closely and the bulk density may vary from 35 to 45 pounds per cubic foot for ground dusting diluents to 60 pounds per cubic foot for airplane dusting diluents. The ground dusting diluents are lighter in weight because the relative distance between the dusting machine and the plant is a matter of only a few feet.

Most of the pumicite used in insecticides in California comes from deposits near Friant, Madera County, where the pumicite is mined and prepared for shipment to markets throughout the United States.

Oil Well Slurries. Recently, pumice has been used as a slurry component for oil well cementing. For this purpose pumice in the size of minus 200 mesh is mixed with portland cement in the ratio of 25 to 60 percent of the slurry. The percentage of pumice used depends upon such conditions as depth of hole, temperature, porosity of the formations being cemented, and general groundwater conditions. The slurry is introduced into the well casing at about 15,000 pounds per square inch pressure causing it to rise between the casing and the wall rock and thus cementing the casing in place.

Pozzolan. Substantial amounts of ground pumice and pumicite are used in the manufacture of two types of cement, pozzolan cement and tufa cement. Pozzolan cement was used by the Romans many centuries ago and consisted of pumicite (volcanic ash) and slaked lime in a ratio of 2 to 1. Tufa cement, on the other hand, is made by blending finely ground pumice or pumicite (minus 325 mesh) with portland cement of varying proportions (Lippincott, 1913). Tufa cement was used extensively in the construction of the Los Angeles aqueduct from Owens Valley, California. The pumice or ground pumiceous tuff was mixed with cement clinker on a 50-50 basis and ground at the cement mill. Also, since the construction of the Bay and Golden Gate bridges at San Francisco where pumicite was used as an admixture with portland cement, there has been increasing use and interest in pozzolan-portland cements.

Ground pumice and pumicite when added to portland cement exhibit excellent pozzolanic properties which lower the rate of heat of hydration, raise the ultimate strength, and increase resistance to corrosive waters—hence are extremely useful in construction of salt water installations. In addition, both ground pumice and pumicite, when added to portland cement, inhibit alkali reactivity.

Minor Uses. Some pumice is used in brick manufacturing, filtration, as filler in non-slip paints, and as absorbents. Small amounts of pumice have been mixed with silicates to make insulation in glass working furnaces (Lormand, 1921, pp. 171-172).

VOLCANIC CINDERS ("SCORIA")

Volcanic cinders or "scoria" are usually basaltic in composition and were formed through expansion of gases contained in basaltic lavas that issued forth onto the earth's surface. They are crystalline, although glassy in part, and made up of minute crystals of basic feldspars and pyroxene set in a cryptocrystalline groundmass of the same minerals.

Most of the volcanic cinders in California are dark reddish-brown to brownish-black and take their color from the oxidized iron in the constituent minerals. They vary in texture from coarse cellular to fine cellular; because the cell walls are usually thicker than in pumice, they have a higher specific gravity and bulk density. One cubic yard of crushed dry volcanic cinders weighs from 1,200 to 1,500 pounds as compared to 850 pounds for pumice.

Chemical analysis of volcanic cinders and pumice.

	Volcanic cinders *	Pumice **
SiO_2	50.90	70.38
Al_2O_3	18.24	15.82
Fe_2O_3	7.77	1.50
FeO	ndt	1.42
CaO	9.58	1.52
MgO	5.73	0.49
Na_2O	4.90	3.82
K_2O	2.20	3.92
TiO_2	1.79	ndt
H_2O+	0.72	
H_2O-	0.22	0.53

* Norman, L. A., Jr., and Stewart, Richard M., 1951, Mines and mineral resources of Inyo County, California: California Jou . Mines and Geology, vol. 47, no 1, p. 111.
** Typical pumice, average of 80 samples.

Technology and Utilization. Volcanic cinders make a structurally strong concrete, much stronger than pumice concrete. Because of the thick cell walls, cinders have a higher compressive strength than pumice and consequently make a concrete with less shrinkage. In addition, there is less water absorption than with pumice and a quicker loss of water by evaporation.

The insulation or K factor for concrete made with volcanic cinders varies from 2.45 to 3.5 relative to its unit weight as compared to 1.8 to 2.7 for pumice concrete of comparable strength and weight.

The accompanying data are typical of a product of a cinder block manufacturer in southern California who utilizes volcanic cinders from deposits located near Little Lake, Inyo County, California.

Screen analysis of volcanic cinders.

Size	Percent retained
Pass number 3-mesh and retained on number 4-mesh	6–9
Retained on number 8-mesh	25–35
Retained on number 16-mesh	15–25
Retained on number 30-mesh	15–20
Passing number 30-mesh	39–11

The dry loose aggregate weighs from 50 to 60 pounds per cubic foot has a bulk density of 1.7 to 1.9, and a K factor of 2.8.

Mixture	*Weight*
Cinder aggregate	1800 pounds
Washed concrete sand	700 pounds
Riverside portland cement	600 pounds

The concrete weighs 103 pounds per cubic foot and at the end of 28 days has a gross compressive strength of 1250 pounds per square inch and a net compressive strength of 2375 pounds per square inch. Heavily ejected blocks made of this concrete show no deformation, and are oven cured for 18 hours at temperatures ranging from 160° to 180° F. Total moisture absorption is 14 pounds per cubic foot or 14 percent. After air drying for 2 weeks there is about 4 percent moisture remaining.

FIGURE 10. Refrigeration wing of the Tecate Brewery, Tecate, Lower California, Mexico, under construction. Approximately 7000 cubic yards of pumice concrete were used on this project. Photograph by J. L. Carlson, North Hollywood, California.

Concrete blocks made from volcanic cinders have proven to be most satisfactory for both residential and industrial buildings, and large amounts of volcanic cinders are being used in highway construction and maintenance and as railroad ballast.

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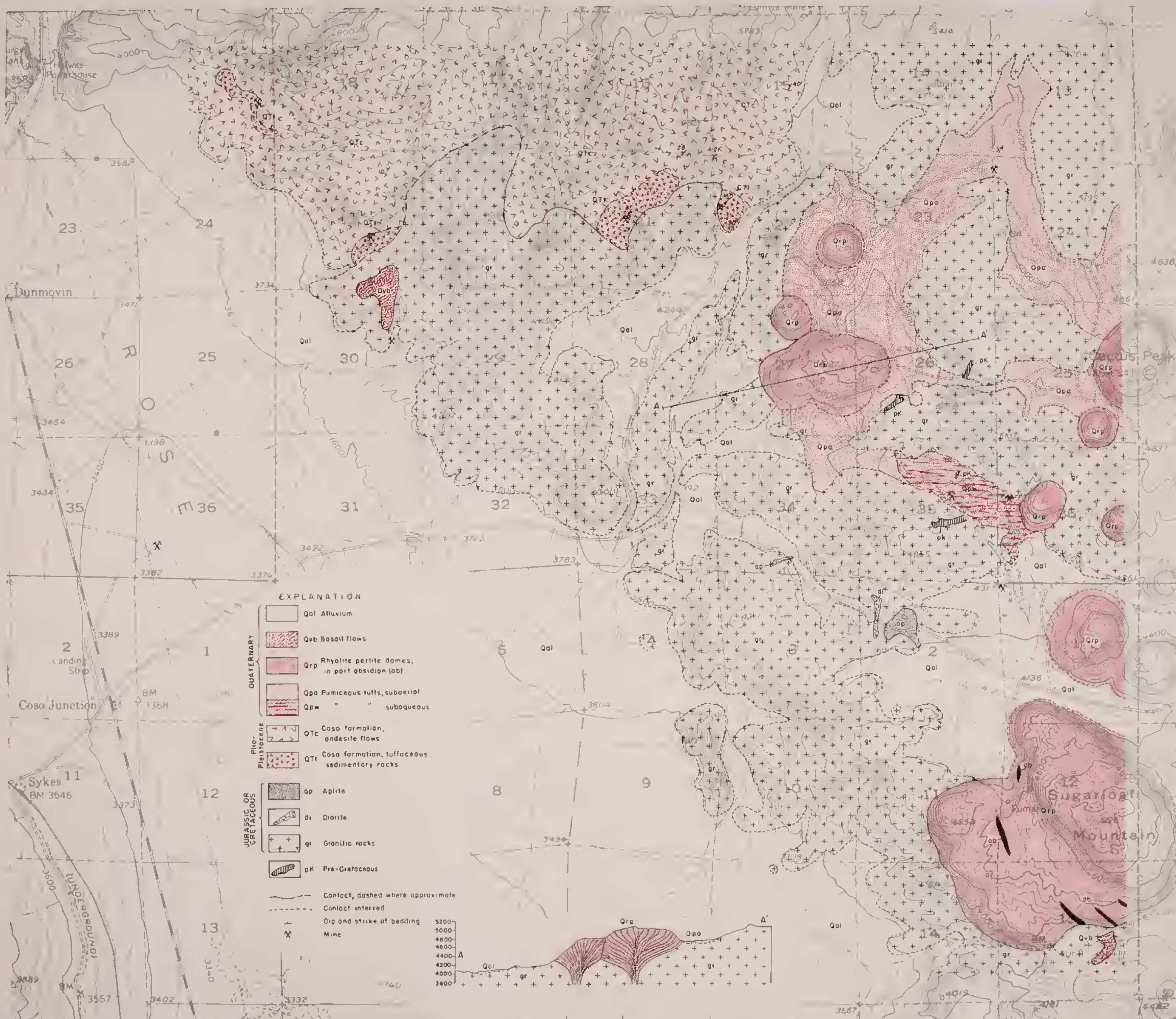
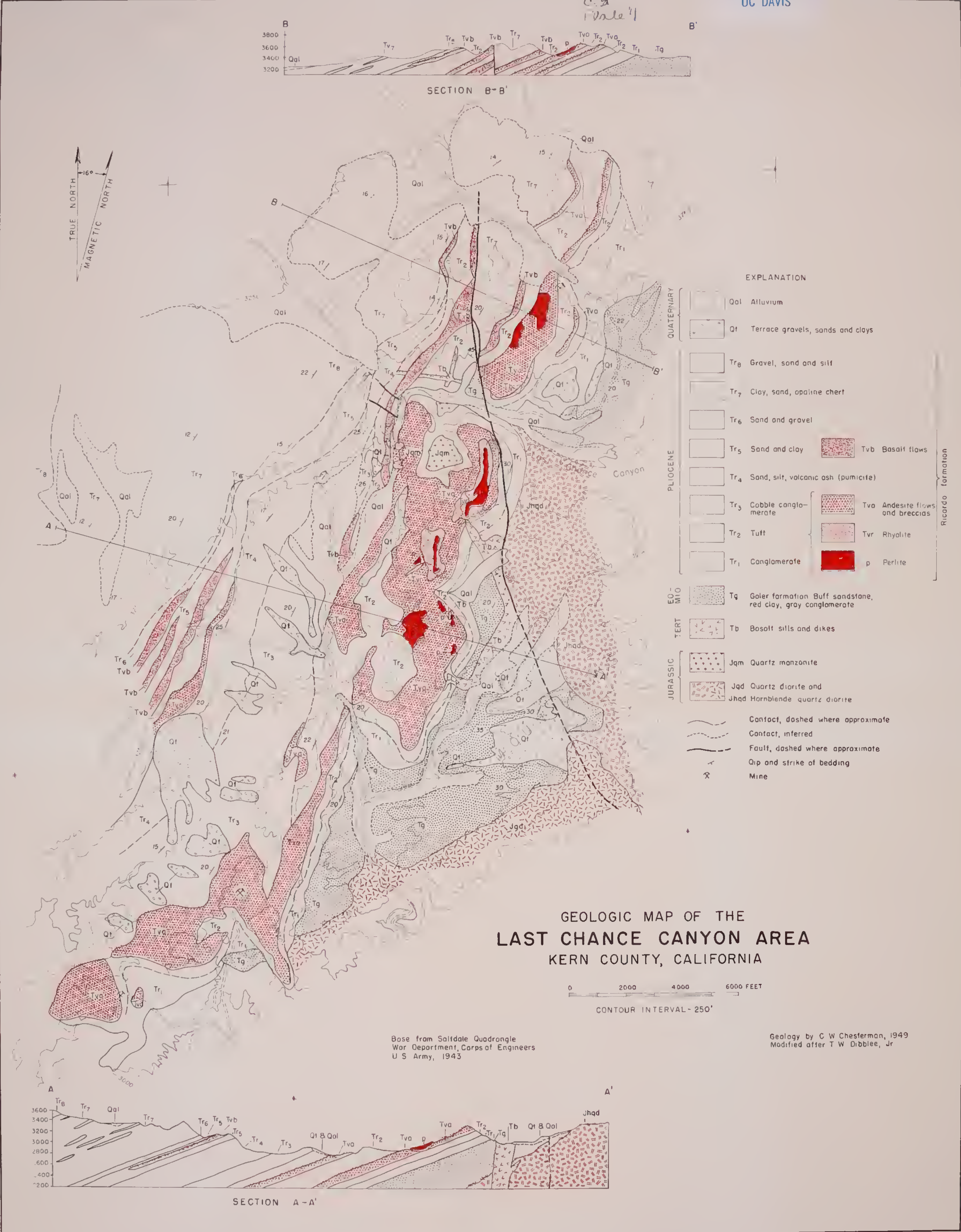


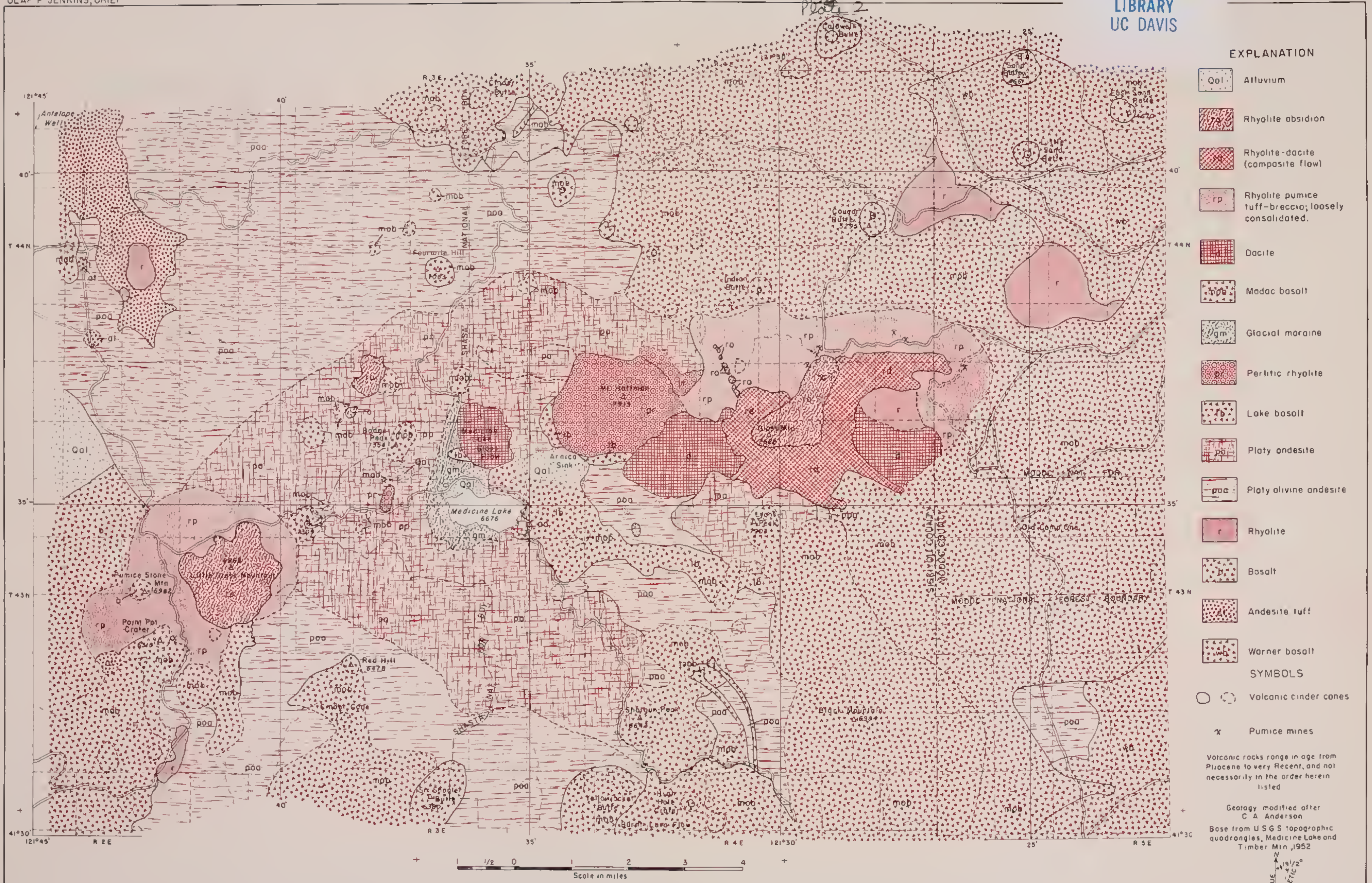
GEOLOGIC MAP OF THE COSO PUMICE AREA, INYO COUNTY, CALIFORNIA

0 3000 6000 9000 12000 FEET

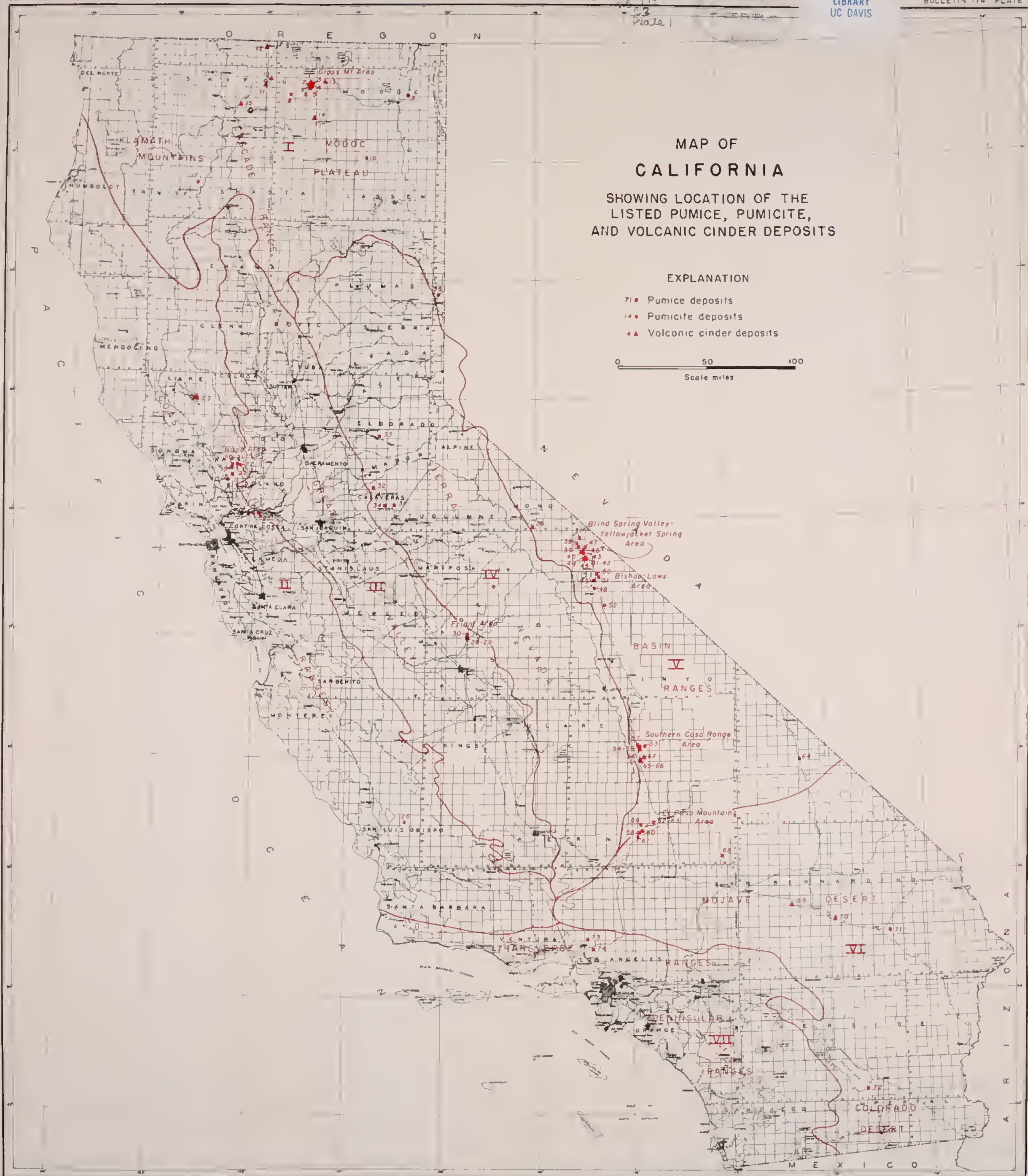
CONTOUR INTERVAL 40'

Geology by C. W. Chesterman


SECTION B-B'
GEOLOGIC MAP OF THE
LAST CHANCE CANYON AREA
KERN COUNTY, CALIFORNIA
0 2000 4000 6000 FEET
CONTOUR INTERVAL - 250'
EXPLANATION
QUATERNARY
Qal Alluvium
Qt Terrace gravels, sands and clays
PLIOCENE
Tr8 Gravel, sand and silt
Tr7 Clay, sand, opaline chert
Tr6 Sand and gravel
Tr5 Sand and clay
Tr4 Sand, silt, volcanic ash (pumicite)
Tr3 Cobble conglomerate
Tr2 Tuff
Tr1 Conglomerate
Tvb Basalt flows
Tva Andesite flows and breccias
Tvr Rhyolite
p Perlite
Ricardo formation
EO-MIO
Tg Goler formation Buff sandstone, red clay, gray conglomerate
TERT
Tb Basalt sills and dikes
JURASSIC
Jqm Quartz monzonite
Jqd Quartz diorite and
Jhqd Hornblende quartz diorite
Contact, dashed where approximate
Contact, inferred
Fault, dashed where approximate
Dip and strike of bedding
Mine
TRUE NORTH
MAGNETIC NORTH
Canyon
Base from Saltdale Quadrangle
War Department, Corps of Engineers
U S Army, 1943
Geology by C W Chesterman, 1949
Modified after T W Dibblee, Jr
SECTION A-A'



GEOLOGIC MAP OF THE MEDICINE LAKE AREA, SISKIYOU COUNTY


MAP OF
CALIFORNIA
SHOWING LOCATION OF THE
LISTED PUMICE, PUMICITE,
AND VOLCANIC CINDER DEPOSITS
EXPLANATION
Pumice deposits
Pumicite deposits
Volcanic cinder deposits
0
50
100
Scale miles
O R E G O N
N E V A D A
A R I Z O N A
M E X I C O
P A C I F I C O C E A N
Glass Mt Area
Napa Area
Blind Spring Valley-Yellowjacket Spring Area
Bishop-Laws Area
Friant Area
Southern Coso Range Area
El Paso Mountains Area
KLAMATH MOUNTAINS
MODOC PLATEAU
BASIN RANGES
MOJAVE DESERT
COLORADO DESERT
PENINSULAR RANGES
I
II
III
IV
V
VI
VII

BULLETIN 174 PLATE 1