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GEOLOGY AND PETROGRAPHY OF THE STENDEL PERLITE DEPOSIT, SOCORRO COUNTY, NEW MEXICO

By ROBERT H. WEBER

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ABSTRACT

A local sequence of late Tertiary-early Quaternary (?) volcanics in the western foothills of the Magdalena Mountains comprises several flow units of lithoidal rhyolite and rhyolite glass, with thin interbeds of tuff and breccia. Lithoidal rhyolite, at the base of the mapped section, is overlain by a tabular body of porphyritic perlite. The congenesis of the perlite and the rhyolite is demonstrated by their nearly identical chemical composition (water-free basis), phenocryst assemblage, and intimate to gradational contact relationships. The high viscosity of the perlite resulted in widespread brecciation of the mass during the flow stage.

The perlite was attacked by hydrothermal solutions, resulting in the development of zeolites (?), silica minerals, and montmorillonite as the principal products of the selective alteration of the glassy matrix. The phenocrysts show very little attack. Chemical analyses of unaltered and altered perlite, converted to a water-free basis, show that the $SiO2$ and $Al203$ contents were essentially unchanged during zeolitic (?) alteration, whereas $H20$, CaO, and MgO were added, and Na_2O and K_2O were partially leached. FeO was oxidized largely to Fe_2O_3.

Upward in the section two rhyolitic flow units with vitrophyric basal phases, and a separate lens of vitrophyre, are interbedded with pumiceous lapilli tuffs and vitric breccias. The tuffs also are locally altered.

Laboratory furnace tests of the perlite show that it will expand at moderate temperatures to a cellular product that may prove acceptable as a lightweight plaster aggregate. Utilization of the perlite will be impeded by the prevalence of zones of nonexpansible alteration minerals and spherulites, which eliminate 76 percent of the mapped segment of the deposit from consideration as a source of commercial-grade perlite.

INTRODUCTION

Perlite, the volcanic glass that may be expanded by appropriate heat treatment to a cellular material especially valuable for lightweight plaster aggregate, has become the basis for an industry of significant economic importance in New Mexico. The value of production in 1956 exceeded one million dollars. This report summarizes the preliminary results of one segment of a continuing field and laboratory study of perlite deposits of the State by the New Mexico Bureau of Mines and Mineral Resources.

The Stendel deposit was being prospected in 1950 when the mapping was undertaken, but to date has not been mined. It was selected for detailed study in part because of the variety of contained impurities which would affect its commercial utilization, should this be attempted. Field relationships show the perlite to be a tabular layer or lens within a sequence of rhyolite flows and tuffs. Chemical analyses of the perlite and associated rhyolite, when converted to a water-free basis, are essentially the same, although the two rock types have a markedly different appearance in hand specimen.

Although the commercial possibilities of this deposit may not be regarded as very attractive, it was believed that a careful petrographic investigation was warranted as a guide to interpretation and evaluation of other deposits.

The mapped portion of the Stendel deposit (plate 1) lies largely in section 14, and partly in section 23, T. 3 S., R. 4 W., in Socorro County, New Mexico. The area is within the western foothills of the Magdalena Mountains, on the west slope of a narrow ridge between Agua Fria Canyon, on the west, and Hop Canyon, on the east. It is reached via 5.3 miles of road extending southward from Magdalena, the shipping point on a branch line of the Atchison, Topeka & Santa Fe Railroad, All but the first 1.7 miles of road from Magdalena is rough and unimproved. The deposit area is characterized by steep slopes of moderate relief, with a variably sparse to dense cover of piñon pine, juniper, and mountain mahogany.

The writer was assisted briefly in the field by Donn M. Clippinger, and later by James W. Coombe, Expansion tests of perlite samples were made by Clippinger, using facilities generously provided by the Southwest Experiment Station of the U. S. Bureau of Mines, at Tucson, Arizona, F. J. Kuellmer, M. E. Willard, and M. S. Sun, of the State Bureau of Mines and Mineral Resources, kindly aided in X-ray diffraction analyses,

GEOLOGY

General Features

The regional geology of the area surrounding the Stendel deposit was not mapped as a part of this project, nor was the section of volcanic rocks treated herein correlated with that described by Loughlin and Koschmann (1942) in the northern Magdalena Mountains. It is the writer's impression that the sequence of rhyolitic volcanics exposed in the foothill belt west of the main mass of the Magdalena Mountains, and of which the rocks of the Stendel deposit are a part, is late in the total sequence of volcanic rocks of western New Mexico, Although definite proof of age is lacking, these rocks are believed to be late Pliocene or early Pleistocene, The Stendel deposit is only one of a number of occurrences of volcanic glass that are exposed in the region.

The vent (or vents) from which the perlite and associated rhyolitic rocks were erupted was not identified, but the perlite and closely related underlying rhyolite appear to represent a segment of the margin of a flow or volcanic dome. The area has been disturbed structurally since the eruption of these rocks; hence relationships are obscured by faulting, in addition to subsequent erosion and colluviation. The volcanic sequence in the deposit area has a general northeasterly dip. The steep slopes of the contacts between some of the units probably represent initial slopes rather than products of subsequent deformation.

Volcanic Sequence and Petrography

The accompanying geologic map (plate 1) shows that the volcanic sequence in the Stendel perlite deposit consists of three pairs of lithoidal rhyolite and rhyolite glass separated by thin units of tuff and breccia. An additional lens of vitrophyre appears to lie within the basal part of the uppermost tuff in the center of the mapped area, but contacts are obscured by cover. The perlite is on top of the lowermost rhyolite, whereas the two principal vitrophyre layers are at the base of the other two rhyolite units. Contacts between the glassy and lithic phases of each of the pairs are so intimate and tightly bonded as to suggest that each pair is a single eruptive unit rather than distinct flows separated by a significant time interval. The intervening tuffs also appear to be closely related to the flow pairs, thus furthering the implication that the entire sequence may have been erupted in a matter of days rather than during any appreciable unit of geologic time. The very close genetic relationship between the perlite and the underlying rhyolite is demonstrated by their nearly identical anhydrous chemical composition (table 1), the petrographic similarities of the phenocryst fraction, and the intricate, largely gradational contact between the two phases.

The total thickness of the volcanic sequence in the plane of the cross-section (plate 1) is a little more than 800 ft, Variations in the thickness of individual units, however, lead to a maximum aggregate thickness of nearly 1,000 ft. A thin veneer of slope wash and talus covers a part of the slope. The base of the section is concealed, but to the west of the mapped area volcanic conglomerate, vitric rhyolite, spherulitic glass and rhyalite, and an extensive mass of felsite were found in descending order, presumably below the mapped section.

Lower Rhyolite (Tr_1)

The lower rhyolite consists mainly of a gray, massive to convolutely flow-banded porphyritic aphanite, with a maximum exposed thickness of 170 ft. The basal contact is covered; hence relationships with underlying units were not determined. The contact with the overlying perlite at the southern end of the mapped area was drawn on the basis of a gradational change from stony rhyolite to perlitic glass. Toward the north, this contact is a highly irregular surface that is clearly marked by an abrupt change in lithology from Lithic, below, to vitric, above.

The manner in which the lower rhyolite was emplaced is not clearly indicated by its field relationships and internal structure. Its congenesis with the overlying perlite is amply demonstrated by the nearly identical chemical and mineralogic compositions of the two, as shown in Table 1, and by the lithologically gradational character of a portion of the contact between the rhyolite and the perlite. Structural features in the perlite, and the character of its contact with the overlying tuff, are particularly compatible with emplacement as a volcanic dome or flow. The same origin should also be applicable to the lower rhyolite,

TABLE 1. CHEMICAL ANALYSES, NORMS, AND MODES OF LOWER RHYOLITE, PERLITE, AND ALTERED PERLITE.*

	272-P19 Lower Rhyolite (Tr_l)		272-P51d Perlite (Tp)		272-P52a Altered Perlite	
	Natural	Recalculated to Anhydrous	Natural	Recalculated to Anhydrous	Natural	Recalculated to Anhydrous
$Si0_2$	75.04%	75.79%	73.10%	76.42%	67.65%	75.78%
Al_20_3	13.35	13.49	12.50	13.07	11.85	13.27
Fe_2O_3	1.01	1.02	.48	.50	1.18	1.25
FeO	.24	.24	.42	.44	.15	.17
MnO	.04	.04	.04	.04	.04	.04
MgO	.18	.18	.22	.23	1.03	1.15
CaO	.95	.96	1.03	1.08	2.82	3.16
Na_2O	2.88	2.92	2.99	3.12	.99	1.11
K_2O	5.15	5.20	4.76	4.98	3.34	3.74
TiO_2	.12	.12	.09	.09	.17	.19
P_20_5	.04	.04	.03	.03	.10	.11
H_2O+	.59	.00	3.70	.00	7.13	.00
H_2O-	.14	.00	.36	.00	3.75	.00
CO_2	n.d.		n.d.		.00	.00
S	n.d.		n.d.		.03	.00
Total	99.73%	100.00%	99.72%	100.00%	100.23%	100.00%

NORMS

Minerals	272-P19	272-P51d
Quartz	36.51%	36.78%
Orthoclase	30.90	29.58
Albite	24.80	26.33
Anorthite	4.77	5.62
Corundum	1.24	.53
Enstatite	.51	
Ferrosilite	-	.27
Magnetite	.47	.73
Hematite	.65	-
Ilmenite	.15	.16
Total	100.00%	

MODES

Minerals	272-P19	272-P51d
Quartz	6.34%	5.43%
Sanidine	1.35	4.05
Oligoclase (Ab70_81)	8.38	3.66
Biotite	1.34	.53
Hornblende	.52	.31
Magnetite	.16	trace
Matrix	82.80	86.02
Total	100.00%	100.00%

*H. B. Wiik, analyst; norms by M. S. Sun.

The typical massive variety of this rock consists of prominent phenocrysts of white plagioclase up to 6 mm in length, smaller glassy potash feldspar, rounded and embayed quartz, hexagonal plates of biotite, and prisms of hornblende set in a pale pinkish-gray cryptocrystalline matrix. Small, irregular vesicles are distributed randomly. Weathered surfaces are darker gray to brown. A chemical analysis, norm, and mode of the lower rhyolite are given in Table 1.

Microscopic study of thinsections reveals a microspherulitic, porphyritic texture, with a tendency for the phenocrysts to be grouped in clusters. Plagioclase, the most abundant of the phenocryst minerals, occurs as stubby euhedral to subhedral prisms, many of which are clustered and intergrown. Individual crystals range from 0.2 to 2.4 mm in length, whereas clusters range upward to approximately 6 mm. A few angular fragments are also present. Progressive zoning is prominent in many of the plagioclase grains. Carlsbad twinning is well developed, albite twinning is partially developed, and weak pericline twinning is visible in only a few grains. Many grains yield patchy to mottled extinction; a few contain abundant inclusions of the matrix. Crystal margins are largely intact, although a few show slight corrosion. Maximum albite-twin extinction angles of 1-1/2 degrees indicate median oligoclase. By analogy with apparently identical phenocrysts in the overlying congenetic perlite, however, it may be assumed that a similar range of Ab_{81-70} should characterize the approximate composition of the plagioclase in the rhyolite.

Sanidine occurs as clear individual and clustered, stubby euhedral prisms and angular fragments, a few of which contain matrix inclusions. 2V is very small, and extinction is sharp. Single crystals range from about 0.5 to 2.3 mm in length. There appears to be local replacement of plagioclase by sanidine.

Quartz is in part euhedral, but largely anhedral and rounded. A few angular fragments are present. Some grains are deeply embayed by the matrix. Extinction is sharp. Individual crystals range from 0.3 to 2.2 mm in diameter. A very small amount of quartz also occurs as a lining of vesicles, in which occurrence extinction is characteristically undulatory.

Biotite occurs as euhedral hexagonal plates ranging from 0.1 to 1.33 mm across. Pleochroism is variable in shades of pale olive, yellow-brown to opaque, and dark red-brown, owing to variations in the degree of oxidation. Optic angles also vary considerably, increasing with the degree of oxidation. Slight alteration of the rims of some grains to iron oxide is apparent.

Hornblende is of sparse occurrence as euhedral to anhedral prisms, with a size range of 0.2 to 1.0 mm, Pleochroism ranges from pale greenish-brown to yellow-brown to blood red. Extinction angles of approximately 1-1/2 degrees are indicative of oxyhornblende.

Magnetite is of sparse occurrence in the matrix and included in biotite as euhedral to anhedral grains from 0.08 to 0.20 mm in diameter. Zircon is rare as inclusions in biotite and plagioclase.

An aggregate of colorless microspherules ranging from 0.031 to 0.067 mm in diameter, with the majority about 0.045 mm, makes up the bulk of the matrix. The microspherulites have an approximate mean index of refraction of 1.512. Megaspherulites up to 1.2 mm in diameter are scattered randomly throughout the thinsections. They are brown by transmitted light and have a pronounced radial fibrous structure and obscure concentric growth rings. Small, irregular vesicles constitute approximately three percent of the matrix.

Segments of the lower rhyolite, particularly in the upper portion, differ in character from the massive variety by having a pronounced convolute flow structure, and larger and more abundant megaspherulites and vesicles. Vesicles ranging from a few millimeters to 15 cm in diameter are coated with a thin layer of hyalite and are partially filled with a flat-topped, banded layer of chalcedony and pearly-white opal. Wahlstrom (1941, p 557, fig 5) has illustrated similar cavity fillings from Specimen Mountain, Colorado. Colloform chalcedony forms overgrowths on white opal in some of the vesicles. The nearly horizontal attitude of the flat upper surface of the white opal in the larger vesicles provides an excellent indicator of the slight degree of tilting that has affected the lower rhyolite in its post-vesicle-filling history.

Other rock types that have been assigned to this unit for convenience in mapping include (1) a highly porphyritic, apparently quartz- and sanidine-free, medium brownish-gray flow-banded aphanite closely resembling the middle rhyolite (Tr2) that projects into the base of the perlite in the dikelike lobe in the southwestern portion of the area, and (2) the small isolated outcrop of highly spherulitic, subperlitic glass designated Tr_1?, below the main perlite outcrop. Quartz and sanidine are also apparently absent from this rock.

Perlite (Tp)

The unit with which this report is primarily concerned is a porphyritic perlite that crops out in a nearly continuous band through the mapped area, and beyond to the southeast. No traces of this unit were found north of the outcrops shown in Plate 1, and only fragmentary outcrops and float on the eastern (Hop Canyon) side of the ridge indicated eastward continuation of the mass beyond the limits of the map area. Although much of the lower contact is gradational with the underlying rhyolite, the upper contact with the overlying tuff is a sharply defined surface with negligible local relief. The attitude of the perlite is obscure, but the regional dip is believed to be about as shown in the section (plate 1), on the basis of which the exposed thickness ranges approximately from 175 to 230 ft. Dips of 2 degrees to the north shown by laminations in chalcedony-opal cavity fillings in the perlite indicate subsequent deformation.

The internal structure of the perlite is shown in Plate 2. Widespread brecciation and steep dips of flow bands are regarded as products of flowage of highly viscous glass close to the margin of the body. These features suggest that the mapped portion of the perlite represents the marginal segment of a flow or extrusive dome.

The prevailing fresh-rock type is a massive pale- to medium-gray porphyritic glass with vitreous luster. Phenocrysts, 1-4 mm long, of white to very pale-gray plagioclase, glassy potash feldspar, quartz, and minor biotite and hornblende, set in a matrix of very fine-grained perlitic glass, may be recognized with a hand lens. The perlitic structure is barely apparent to the unaided eye and has little effect upon the tendency of the rock to fracture subconchoidally.

In thinsection, the rock is vitrophyric and perlitic. Phenocrysts tend to occur in clusters. The perlite typically (see table 1) consists of phenocrysts of quartz, sanidine, plagioclase, biotite, and hornblende, in a matrix of clear, crystallite-free, highly perlitic glass, with a mean index of refraction of 1.496. Quartz occurs largely as rounded phenocrysts, 0.3-1.8 mm in diameter, that are deeply embayed by the matrix; a few grains have subhedral outlines. Curved fractures, similar to perlitic fractures in the matrix, are a common feature in the quartz. Veinlets, embayments, and partial rims of very fine-grained aggregates of a mineral with low birefringence and indices of refraction less than those of sanidine, are also present in the quartz.

Sanidine occurs as euhedral to rounded anhedral phenocrysts ranging from 0.2 to 1.4 mm in diameter. Individual grains commonly are clustered together. Optic normal sections yield nearly uniaxial negative interference figures. Embayments, partial rims, inclusions, and narrow veinlets of the low birefringent mineral aggregate mentioned above are also associated with the sanidine.

Plagioclase occurs as euhedral to angular anhedral grains ranging from 0.1 to 1.7 mm in diameter. Individual grains tend to form clusters and angular intergrowths. Weak zoning is present in some grains, wherein the cores are more calcic than the rims. Carlsbad, albite, and rare pericline twinning are also evident. Tsuboi indices of refraction indicate compositions ranging from median oligoclase to oligoclase-andesine (A1381_70). Some grains contain embayments and inclusions of the low birefringent mineral aggregate.

Phenocrysts of biotite and hornblende are minor constituents of the perlite. The biotite ranges from 0,2 to 0.8 mm across and is euhedral to subhedral, pale olive to pale brown and opaque, and locally embayed by the matrix; it exhibits a very small optic angle. Apatite inclusions in the biotite are sparse. Hornblende occurs as greenish-brown to brownish-green euhedral prisms that range from 0.1 to 1.2 mm in length. Maximum extinction angles reach 21 degrees. The hornblende also contains sparse apatite inclusions. Both hornblende and biotite in the perlite lack the visible effects of high-temperature oxidation that characterize these minerals in the lower rhyolite.

In addition to the typical perlite described above, several variants may be distinguished. Some segments of the mass are marked by dark bluish-gray, purplish-gray, and red lenticular streaks and narrow planar flow bands in a host of the more typical gray rock. Local zones, up to several tens of feet across, consist of mottled to uniform dark-bluish-gray, dark-brown, or nearly black glass, with a somewhat pitchy luster. These colored varieties are characterized in thinsection by abundant pale-green crystallites, of which trichites constitute the major fraction and margarites the minor fraction, Planar bands and irregular zones of spherulitic perlite have been differentiated on the accompanying detailed map, Plate 2. Reddish-brown megaspherulites ranging from less than 1 mm to more than 1 cm in diameter (the majority in the 2-3 mm size range) locally constitute up to more than 50 percent of the rock. Many of the spherulites have developed about phenocryst nuclei, of which only plagioclase shows slight local corrosion. Vesicles and spherulite-walled cavities, partially filled with opal and chalcedony, are relatively abundant in the more highly spherulitic zones. This relationship, as already noted, is also characteristic of the spherulitic phases of the lower rhyolite. In thinsection, the spherul Res are brown by transmitted light and exhibit well-developed radial fibrous structure. The fibers have parallel extinction and positive elongation. Concentric growth lines are prominent in some individuals. Trains of crystallites pass through the spherulites without interruption or deflection. The absence of deformation of the spherulites by flowage points to their origin after immobilization of the mass. Powder diffraction patterns of selected spherulites were obtained with a North American Phillips X-ray spectrometer, using Cu/Ni radiation. These showed that the spherulites consist of two components, cristobalite and feldspar. According to F. J. Kuellmer (personal communication, 11 June 1956) the feldspar is probably cryptoperthite.

Autoclastic brecciation has affected much of the perlite to an extent that ranges from slight to extreme (see plate 2). Where slightly developed, the rock has been broken without significant lateral displacement or rotation of the fragments. In its more extreme development, brecciation has resulted in pronounced lateral displacement and rotation of angular fragments, as shown by mixing of diverse color variants of perlite and angular discordance of flow bands in adjacent fragments. Individual fragments ranging from a fraction of an inch to several feet across are set locally in a finely comminuted matrix, which is in some places pumiceous. Small fragments may be pumiceous throughout, whereas larger blocks more commonly develop only a rim of vesiculation, thus demonstrating that vesiculation was preceded by brecciation. Although bands and irregular zones of brecciation are present throughout the deposit, there is a greater persistency and intensity of such features at the top. The irregular shape of these brecciated zones, the presence of some zones in isolated bodies that were apparently surrounded by unfractured perlite, and the greater persistency of brecciation at the top of the mass point to origin while the perlite was still plastic enough to yield by flow, where the rate of deformation was slow, but so viscous as to yield by fracture, where the rate of deformation was excessive.

The perlite was extensively altered following brecciation, as a result of which narrow seams a fraction of an inch in width, bands up to more than one foot in width, and zones as much as 300 feet across consist of material in which the glassy matrix of the perlite has been partially to totally converted to a crystalline aggregate (plate 2), The phenocrysts were largely unattacked. Where alteration was relatively slight, fractures were healed firmly by pale-buff to greenish-buff alteration products in parallel and anastomosing seams. A group of altered seams at the northern end of the deposit were formed in the walls of high-angle joints of northerly trend. Altered seams and bands up to several inches wide, which were apparently not fracture controlled, are locally in parallel alinement with spherulitic bands and flow banding. In some of the extensive zones of complete alteration to a hard, tough, pale-buff lithoidal mass, traces of prior brecciation have been obliterated almost entirely by the processes of alteration. Boundaries between fresh and altered perlite are locally sharp and regular, particularly along narrow seams and bands. Elsewhere they are diffuse and irregular, grading outward through a transitional zone in which alteration is confined to progressively narrower rims bordering perlitic fractures.

That alteration did not involve simple crystallization of the perlite is clearly shown by the chemical analyses of totally altered perlite and of fresh perlite in Table 1. A noteworthy gain in water content of 6.82 percent contrasts with the normal loss of water that accompanies simple devitrification of perlite to rhyolite. Significant changes in the proportion of all other major constituents, except silica and alumina, are also apparent when the compositions are recalculated to an anhydrous state. The principal cationic gains were lime (2.08 percent) and magnesia (0.92 percent). The principal losses were soda (2.01 percent) and potash (L24 percent). Combined weight-percentage gains of lime and magnesia (3.00 percent) are approximately balanced by weight-percentage losses of soda and potash (3.25 percent). On a molecular basis, the ratio of gains to losses is 1:1,57 ($CaO+MgO:K_2O+Na_9O$). Ratios of individual molecular oxides are 1 Ca0:0.32 MgO:1 K_2O:1.07 Na_2O. Indicated gains in titania and phosphate, though proportionately large, are quantitatively minor. Oxidation of ferrous iron to the ferric state in a ratio similar to that found in the underlying rhyolite is indicated also. Similar, though less pronounced, compositional changes will be noted in the alteration of a rhyolite pitchstone dike from the Isle of Arran, Scotland, if the analyses tabulated by Harris and Brindley (1954, p 820) are recalculated to an anhydrous basis. Alteration of the pitchstone glass to mordenite has resulted in pronounced hydration, a small loss in alkalies, a smaller gain in lime and magnesia, an increase in ferric iron, and no significant change in silica and alumina contents.

In thinsection, the altered perlite shows replacement of the original glassy groundmass by a microcrystalline assemblage of fibrous, spherulitic, platy, and mosaic aggregate minerals. The phenocrysts shows little or no alteration, except for irregular partial oxidation of biotite and hornblende to red pleochroic types. Slight alteration resulted in accentuation of the perlitic structure by controlled development of the alteration products along perlitic fractures. With increasing intensity in the degree of alteration, the perlitic structure was destroyed progressively. Alteration has resulted locally in the production of a microfluidal banding that is not apparent in adjacent areas of unaltered glass.

Preliminary attempts to identify the alteration minerals have been largely unsuccessful, owing to the microscopic size and nondefinitive optical properties of these minerals. Trains of globular grains and lenticular mosaic aggregates of a mineral that is brown by transmitted light and white by reflected light under low-power magnification, and green by transmitted light under high magnification, is of widespread (but quantitatively minor) occurrence in perlitic fractures and fluidal bands in the altered rock. Relief and birefringence are moderate, and the indices of refraction are greater than that of balsam. A colorless, low-birefringent fibrous mineral, with positive elongation and indices of refraction of approximately 1.474, is widespread as radial fibrous aggregates bordering fractures and fluidal bands of the green mineral. A third mineral of prominence in altered zones forms microcrystalline, flaky mosaic aggregates in the matrix,and euhedral rectangular plates that project into cavities. This mineral has very low birefringence, parallel extinction, cleavage paralleling the positive elongation, and indices of refraction of approximately 1.474. A few grains yield a very weak, unrecognizable interference figure. Extinction is commonly undulatory. Opal, chalcedony, and quartz that is cloudec with dusty inclusions are common as cavity fillings. Opal occurs in several varieties, among which are col loform hyalite; soft, frosty-white to buff aggregates resembling geyserite; and a white (pale brown by transmitted light) variety that shows highly undulatory strain birefringence and yields well-defined uniaxial negative interference figures.

X-ray powder diffraction spectrograms of the altered perlite reveal a number of strong reflections that are not present in the diffraction patterns of unaltered perlite. Attempts to correlate the d-values of these reflections with available published values have to date proved unsuccessful, but pronounced similarities with several zeolites were noted. X-ray diffraction and optical properties, bolstered by the chemical composition of the altered rock, strongly suggest that zeolites are probably the principal products of alteration.

The specific agency,of alteration has not been determined, but the character of the chemical exchanges involved, the formation of zeolites (?), montmorillonite, and silica minerals as alteration products, and the pattern of structural control and distribution of alteration point to mineral-charged hydrothermal solutions of volcanic affiliation as the responsible agent.

If one may judge from published accounts, zeolites are of far less common occurrence as hydrothermal alteration products of siliceous volcanic glasses than montmorillonite, kaolinite, sericite, and alunite. This well may be a function of the more limited stability ranges of the zeolites, as well as the more critical limits of solution composition and temperature required in their formation. Steiner (1953) has described the occurrence of ptilolite, with minor analcite and heulandite, as hydrothermal-alteration products of vitric rhyolite tuff and tuffaceous sandstone in an active fumarol ic- hot spring environment in the Wairakei area; New Zealand. Some doubt exists, however, as to the validity of the detailed comparisons made between the composition of the altered rock and that of fresh obsidian and ignimbrite in the neighboring area. Heulandit, (clinoptilolite) and analcite are among the prominent hydrothermal minerals in perlitic obsidian and lithoidal rhyolite in Upper Geyser Basin, Yellowstone National Park (Fenner 1936, pp 247-248). Bramlette and Posnjak (1933) have shown that clinoptilolite in beds of the Monterey group is a product of alteration of vitric volcanic ash, but the altering agency (weathering vs. hydrothermal) is not specified. Previous reference has been made above to the study by Harris and Brindley (1954) of the alteration to mordenite of glass in a rhyolite pitchstone dike in the Isle of Arran, Scotland. Their conclusion (p 824) that "zeolites as intermediate products in the breakdown of volcanic material, may be more common than is thought," merits reiteration.

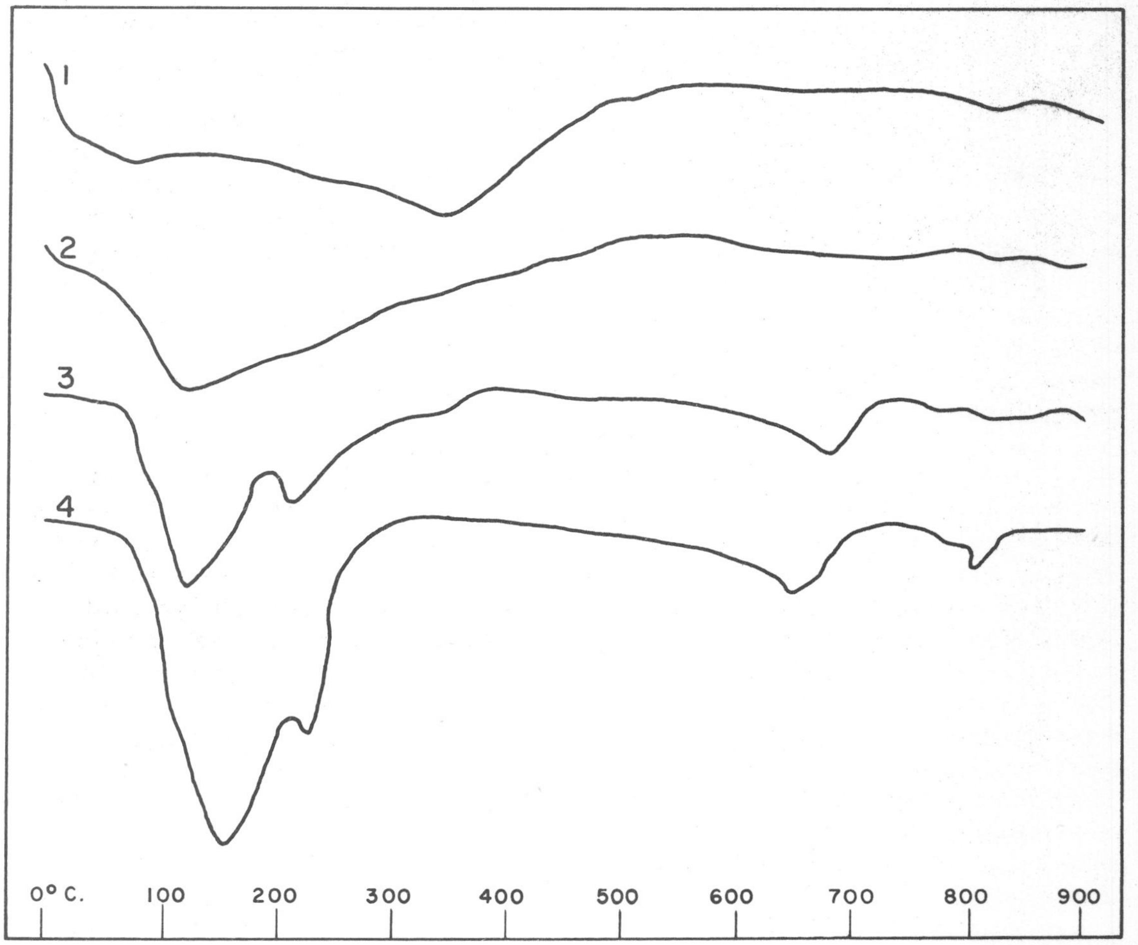
According to Lovering (1950), zeolites have been synthesized only in alkaline solutions. Kerr refers to experimental work by Noll (1936) indicating that zeolites form under more alkaline conditions than either montmorillonite or sericite. The persistence of fresh plagioclase phenocrysts throughout altered zones in the Stendel deposit supports the suggestion that alteration was effected by alkaline solutions (Steiner, 1953, p 11).

Figure 1.

DIFFERENTIAL THERMAL ANALYSES OF PERLITE AND ITS ALTERATION PRODUCTS

1. Sample 272-P51d, unaltered perlite.
2. Sample 272-P52b, zeolitic (?) alteration of perlite.
3. Sample 272-P54, montmorillonitic alteration of perlite.
4. A.P.I. Standard Clay No. H-23-a, montmorillonite from Chambers, Arizona.

Curve 1 was obtained with a galvanometer sensitivity setting of "high," whereas all other curves were obtained with a setting of "medium." Curve 1, accordingly, is amplified 3 times. Eberbach & Son Co. portable differential thermal analyzer.



In addition to the zeolitic (?) alteration described above, very minor amounts of montmorillonite have formed as a product of alteration of the perlite. Montmorillonitic alteration was recognized at only a few places, perhaps in part owing to the physical instability of montmorillonite in the outcrop, but probably largely owing to the relatively slight degree of montmorillonitization that took place. The mineral occurs as pale-green to pale-pink and white narrow seams and irregular patches bordering fractures in fresh perlite. Paragenetic and spatial relationships with zeolitic (?) alteration have not been determined. Bramlette and Posnjak concluded that clinoptilolite in the beds of the Monterey group was an intermediate product of alteration of vitric volcanic ash, with montmorillonite as the end product of the process (agency unspecified). Steiner (1953) proposed a reversed paragenesis for hydrothermal alteration at Wairakei, New Zealand, but the evidence cited does not appear to be conclusive.

Differential thermal-analysis curves of fresh perlite, zeolitic (?) altered perlite, montmorillonitic altered perlite, and a standard montmorillonite from Chambers, Arizona, are shown in Figure 1 for comparison purposes. The curves were drawn from manual records obtained with an Eberbach & Son Co. portable differential-thermal unit.

Narrow veinlets of grayish-red jasper are distributed sparsely throughout the perlite in the mapped area, as indicated in Plate 2. The jasper occurs both as simple veinlets and as anastomosing veinlets that cement narrow bands of brecciated perlite. Although emplacement was controlled at many places by fractures, there is a marked parallelism of most of the veinlets with flow banding in the perlite. Little evidence of replacement of perlite by jasper was noted in the course of this study, except for slight corrosion of the margins of altered breccia fragments.

Lower Tuff (Tt_1)

The perlite is overlain by a slope-forming sequence of pumiceous lapilli tuffs and tuff-breccias that are concealed largely by talus and slope wash. Isolated patches of the basal portion of the tuff crop out at widely separated places along the contact with the underlying perlite. The lower contact is a sharply defined interface between perlite and tuff along a comparatively smooth surface of low relief. Tuff fragments are impressed into, and firmly bonded to, the underlying perlite. The contact approximately parallels bedding in the tuff, dipping north to northwest at angles of from 13 to 20 degrees. The upper contact was seen only at one place; in the canyon near the northern end of the deposit, where the tuff is overlain by a flow (?) breccia of angular blocks of gray to nearly black vitrophyre along an eastward dipping contact. A lens of conglomerate composed of subangular to subrounded volcanic pebbles in a matrix of red silt is locally present at the contact. The total thickness of the lower tuff sequence may range approximately from 35 to 55 ft.

The tuff consists largely of lapilli and smaller quantities of ash, in which fragments of white to buff pumice predominate. The remaining fraction is composed of lapilli of pinkish-gray to red felsite and gray perlite; crystals of feldspar, quartz, and biotite; and local blocks of volcanic glass. The degree of induration ranges from weak to moderate, and the porosity is high. Bedding is generally poor, owing to poor sorting, but local intervals are sufficiently well bedded to permit accurate measurement of attitudes.

Pervasive alteration has affected most of the pumice and some of the nonvesicular glass fragments. Pumice fragments in a thin zone at the basal contact with the perlite have been replaced almost totally by coarsely crystalline calcite, cleavage faces of which extend entirely across individual lapilli, some of the latter being more than 1 inch across. Felsite fragments remain unaltered. Upward in the sequence, local alteration and leaching have converted the pumice fragments to a soft, pale-tan, very fine-grained crystalline aggregate, and have increased porosity by removal of the cores of the fragments. Adjacent fragments are partially cemented together by intergranular seams of opal and chalcedony.

Lower Vitrophyre (Tv_1)

A flow of conspicuously porphyritic glass forms a narrow band of outcrop, interrupted by several covered intervals, extending across most of the mapped area. The lower limit has been drawn *at* the contact of blocky vitrophyre flow (?) breccia with underlying pumiceous lapilli tuff. Lenses of tuff are also present in the lower portion of the vitrophyre in the canyon near the northern margin of the map. The upper limit is the contact between vitrophyre and an overlying lithoidal rhyolite flow. The vitrophyre and overlying rhyolite probably represent only textural variants of the same lava. Apparent thicknesses range from about 35 ft, in the plane of the cross-section, to about 75 ft, a thousand feet to the north. Attitudes are obscure throughout most of the outcrop, but the prevailing dip appears to be eastward at low angles. Near the northern tip of the mapped outcrop, strong, regular flow bands dip steeply north-northwestward.

The vitrophyre is largely massive above the basal breccia, but zones of planar flow banding are locally present. In the northern mapped segment, parting planes parallel to flow bands have resulted in a bedded appearance of weathered outcrops.

Abundant phenocrysts of white, glassy plagioclase, and less abundant euhedral plates of biotite, are set in a matrix of dark-colored glass. Most of the plagioclase crystals range from 1 to 3 mm in length, but a few reach a maximum of 6 mm. The glass ranges in color from dark gray to black, and grayish-brown to dark red. Blocks and smaller fragments of assorted colors are intermingled in the basal breccia zone. some fragments contain cores of different color from the rims. A tendency toward pitchy luster is most pronounced in red and black varieties. Crushed fragments of the black variety in immersion oils are a clear, smoky brown by transmitted light, and have a mean index of refraction of 1.503. Fine-grained perlitic structure is locally prominent.

The anhydrous composition of the vitrophyre should be equivalent to that of the middle rhyolite, inasmuch as the two rocks are only textural variants of a single eruptive unit. Therefore, the adjusted silica content of 74.5 to 75.0 percent in the middle rhyolite (see following section of text) is assumed to be equally applicable to the lower vitrophyre.

Middle Rhyolite (Tr$_2$)

A flow of porphyritic rhyolite directly overlying the lower vitrophyre forms resistant outcrops in the northern, central, and southern portions of the mapped area, The lower contact with vitrophyre is well exposed, but the upper contact with pumiceous tuff is largely covered, except at the northern tip of the area. The southern segment appears to dip gently eastward, whereas it is nearly horizontal in the central segment, and inclined steeply northwestward on the north. The apparent thickness ranges approximately from 0 to 260 ft. Abrupt thinning of the rhyolite at the head of the main canyon on the north may be ascribed to initial thinning over the lower vitrophyre, the contact with which dips steeply southward, or to a northwestward trending fault passing through the covered interval between the tuff and the rhyolite. Positive evidence of faulting was not observed; hence initial thinning was probably responsible.

The rhyolite is largely a massive prophyritic aphanite, with local zones of pronounced flow banding, Phenocrysts of abundant white plagioclase, minor biotite, and rare quartz are set in a brownish-gray, purplish-gray, and reddish-brown cryptocrystalline matrix. Weathered surfaces are buff or pinkish brown to reddish brown. The phenocrysts appear identical with those in the lower vitrophyre, but constitute a more variable proportion of the rhyolite. Small irregular vesicles, partially lined with minute quartz crystals and opal, are commonly present.

In thinsection, the rock is microspherulitic and porphyritic, with flow-banded structure. The mode of a typical specimen is as follows:

Phenocrysts			
oligoclase (Ab$_{81}$)	8.43	volume	percent
biotite	1.62	"	"
magnetite	0.64	"	"
In vesicles			
quartz and opal	2.26	"	"
Matrix	87.05	"	"
	100.00	"	"

Oligoclase occurs as euhedral to anhedral grains and clusters, in which individual grains range from 0.03 to 2.2, mm long, Progressive zoning, Carlsbad twinning, partial albite twinning, and rare pericline twinning are present. Many of the larger grains are intergrown and show mottled extinction. A sieve structure, with matrix inclusions, and moderate corrosion of crystal borders by the matrix are common. Apatite is sparse, and biotite rare, as poikilitic inclusions in oligoclase. Most of the biotite is present as euhedral plates and corroded, frayed particles ranging from 0.06 to 1.2 mm across. Pleochroism is pale yellowish brown to brownish olive and dark greenish black. Included grains of apatite and magnetite are sparse. Vesicles are lined or filled with quartz and minor amounts of opal. The matrix consists largely of microspherules ranging from 0.01 to 0.05 mm in diameter. Crystallites are abundant. Crude, sworled flow banding results from alinement of phenocrysts and segregation of crystallites, Powdered samples of two specimens of the middle rhyolite were fused in a carbon arc according to the principles outlined by Mathews (1951). Mean indices of refraction (1.513 and 1.515) of the resultant glasses indicate approximate silica contents of 69.0 percent and 68.5 percent, when plotted on a curve for New Mexico volcanic rocks compiled by M. S. Sun. Indices of refraction of fused samples of the lower rhyolite and perlite indicated silica contents 6.3 percent and 5.4 percent below those found in the chemical analyses. This may be due to the fact that the master curve was based largely on analyses of volcanic rocks of early to middle Tertiary age, whereas the volcanic rocks at the Stendel deposit are believed to belong to a younger assemblage of late Tertiary to early Quaternary age. The discrepancies cited should not be interpreted as representative of inherent inaccuracies of the method. A corresponding adjustment of plus 6 percent in the indicated silica contents of the middle rhyolite results in corrected values of 74.5 to 75.0 percent silica. The rock has accordingly been classified as a rhyolite despite the paucity of quartz and apparent absence of potash feldspar in the phenocryst fraction. A chemical analysis might, however, reveal a composition more characteristic of quartz latite than of rhyolite.

Middle Vitrophyre (Tv_2)

In the central portion of the mapped area, a small body of vitrophyre occupies an intermediate stratigraphic position between the middle rhyolite and the upper tuff. The outcrop pattern indicates that it has a lenticular cross-section in a north-south direction, with an apparent range in thickness of 0-75 ft. Lower and upper contacts are concealed by slope wash and talus; hence marginal relationships are indeterminate. It appears probable, however, that the mass originated as a narrow tonguelike flow, elongated in an approximate east-west direction, in a trough in the upper surface of the middle rhyolite.

The middle vitrophyre consists of black to red pitchy porphyritic glass lithologically similar to the lower vitrophyre.

Upper Tuff (Tt_2)

Most of the stratigraphic interval between the middle rhyolite, or middle vitrophyre, and the upper vitrophyre is screened by talus and slope wash from the higher cliffs. Several small outcrops indicate, however, that this interval is occupied by pumiceous lapilli tuff and ash. The basal contact with the middle rhyolite is poorly exposed at the northern margin of the area. The upper contact with overlying upper vitrophyre was seen only in a small outcrop in the head of the main canyon in the northern portion of the area, where it is marked by a sharply defined interface between tuff and vitrophyre. Total thicknesses probably range from approximately 60 ft, in the north, to 30 or 35 ft, in the south.

Exposed segments of the sequence reveal several lithologic variations. The northernmost segment is a well-indurated lapilli tuff composed of fragments of pale yellowish-gray, altered pumiceous glass and gray to red felsite. Crudely bedded tuff containing small lapilli of pale-gray to white pumice, sparse pale-gray perlite, and gray to red felsite, in a matrix of gray-buff ash, is exposed in the next outcrop to the south. Just below the upper contact with vitrophyre is a zone composed of pinkish-gray to grayish-red vitric ash containing angular fragments and thin sheets of dark gray perlitic vitrophyre and sparse felsite fragments.

Upper Vitrophyre (Tv_3)

A tabular vitrophyre flow forms a narrow, nearly continuous band of outcrop at the base of the cliff of upper rhyolite near the eastern margin of the mapped area. The basal contact with underlying upper tuff is sharp and distinct in the one small outcrop in which it is exposed. The upper contact with overlying upper rhyolite is locally less well defined, owing to interlayering of thin sheets of vitrophyre and lithoidal rhyolite in the upper portion of the vitrophyre, and the presence of a-nodular zone at the base of the rhyolite, in which nodules and blocks of vitrophyre are intermingled with vesicular rhyolite. Observed thicknesses range approximately from 40 to 60 ft.

The upper vitrophyre is lithologically very similar to the previously described lower vitrophyre. Further similarities are to be noted in its spatial relationships with an overlying flow of lithoidal rhyolite. Abundant phenocrysts of white plagioclase, minor quantities of hornblende and green biotite, and rare grains of quartz are set in a matrix of pale-gray to black glass that locally has a fine-grained, highly perlitic structure. Planar to convolute flow bands of contrasting shades of gray and black are commonly present in the basal portion.

In thinsection, the rock is vitrophyric, has a flow-banded structure, and yields the following mode:

Phenocrysts			
Plagioclase	12.07	volume	percent
Biotite	0.94	"	"
Hornblende	1.98	"	"
Magnetite	0.65	"	"
Matrix (glass)	84.36	"	"
	100.00	"	"

Most of the phenocrysts are perfectly euhedral and show less tendency to form clusters than in previously described units. Plagioclase is present in grains ranging from about 0.04 to 2.5 mm across, with a majority about 0.4 mm, showing Carlsbad, partial albite, and sparse pericline twinning. Progressive zoning is prominent in many grains. Abundant inclusions of glass are a common feature. Some of the larger grains contain segments that show mottled and undulatory extinction. Indices of refraction of crushed fragments indicate a composition ranging from median oligoclase to calcic andesine ($A6_{77-52}$). Pale yellowish-green.to dark brownish-green biotite occurs as euhedra 0.08-0.06 mm across, some of which contain inclusions of apatite. Pale-olive to brownish-olive hornblende occurs as euhedral prisms up to 1 mm in length. Sparse magnetite and a single rounded grain of quartz constitute the remaining phenocryst fraction. The matrix consists of nearly colorless glass, with a mean index of refraction of about 1.502. A fluidal banded structure is formed by segregation and alinement of trains of belonites.

The anhydrous composition is assumed to be equivalent to that of the upper rhyolite, for which "fusion indices" indicate an adjusted silica content of 73 percent.

Upper Rhyolite (Tr_3)

The uppermost unit of the volcanic sequence consists of a cliff-forming, largely lithoidal, porphyritic flow that forms the caprock of the ridge at the eastern margin of the mapped area. It directly overlies the upper vitrophyre along a slightly undulatory contact between rocks, below, that are predominantly vitrophyric and a nodular zone of mixed lithic and vitric phases, above.

The mass as a whole appears to dip generally eastward to northeastward at moderate angles, although local attitudes of flow bands show a wide range of variation. Only those attitudes representative of major segments of the upper rhyolite in the mapped area are shown in Plate 1. The northern segment of the mass is marked by synclinal opposition of flow structures, the axis of which trends northeast. Axes of smaller flow folds have a similar orientation. The bases of some flow layers in the lower portion of the rhyolite bear distinctive corrugations, the axes of which strike and plunge east-northeast in the southern portion of the mass, and northeast in the northern portion. These are clearly primary flow structures. Their orientation undoubtedly was determined by the direction of flow of the rhyolite lava, but the relationship is not clear. The general parallelism in orientation of the axes of corrugations and flow folds suggests that the flow in this area advanced in a direction normal to that delineated by the axes.

The original thickness of the upper rhyolite, before stripping of the upper surface by erosion, is unknown. The maximum remaining thickness is about 180 ft.

The prevailing rock type is a pinkish- to purplish-gray porphyritic aphanite that weathers reddish brown. The lower and upper portions commonly are marked by prominent flow banding that leads to flaggy weathering. Interlayering of vitric and Lithic bands is common in the lower one-third of the unit. The central portion is largely massive. Ellipsoidal gas cavities up to several inches across are locally conspicuous. Phenocrysts of glassy white plagioclase, biotite, and hornblende are generally less conspicuous and smaller (less than 1 mm) than those of the middle and lower rhyolites.

In thinsection, the rock is cryptocrystalline to vitric, porphyritic, and slightly vesicular. The mode of a specimen about 30 ft above the base is as follows:

Phenocrysts			
plagioclase	9.84	volume	percent
biotite	1.21	"	"
hornblende	1.80	"	"
magnetite	trace		

In vesicles	
opal, minor quartz	2.61 volume percent
Matrix	84.54 " "
	100.00 " "

Phenocrysts are almost identical with those of the underlying upper vitrophyre, except for a greater tendency to form clusters and the higher frequency of angular grains in the rhyolite. The plagioclase, accordingly, is assumed to have a range of composition similar to that in the vitrophyre (Ab_{77-52}). Biotite shows the effects of oxidation, with the development of pleochroism in shades of pale yellowish orange, dark olive brown, and red brown. Hornblende also shows variable oxidation to a variety near oxyhornblende, in which pleochroism ranges from brownish yellow to dark red, and the extinction angle of prismatic sections of some grains approaches zero. Most hornblende grains bear an alteration rim of opaque iron oxides; smaller crystal clusters are completely altered to opaque aggregates. Small, irregular vesicles are lined or filled with opal and minor quartz. The matrix consists largely of glass heavily clouded with crystallites that include dusty aggregates, globulites, and belonites. Bands and patches of cryptocrystalline to microcrystalline aggregates show general alinement with a crude planar flow structure. The matrix of specimens higher in the section is wholly cryptocrystalline to microcrystalline.

The mean index of refraction of the synthetic glassy fusion product of the upper rhyolite is 1.516, from which an adjusted silica content of 74 percent is inferred. The rock, accordingly, is classified as a rhyolite, although the observed features also characterize quartz latite.

Colluvium (Qc)

Slopes below the upper rhyolite are partially mantled with thin accumulations of unconsolidated detritus, which consists largely of slope wash and talus. Most of this material stems from cliff falls from the upper rhyolite and the vitrophyres. Several small areas at the western margin of the mapped area are veneered with undifferentiated upland alluvial gravels composed of a variety of volcanic rock fragments that are foreign to the sequence discussed herein,

PERLITE EXPANSION TESTS

A grab sample of perlite from the location pit at the northern end of the deposit was subjected to thermal expansion tests to determine its suitability for the commercial production of lightweight aggregate. The tests were performed by Donn M. Clippinger, using the facilities of the Southwest Experiment Station of the U. S. Bureau of Mines, at Tucson, Arizona.

The test procedures were those established by the U. S. Bureau of Mines. Pit-run perlite was crushed with rolls to pass a 10-mesh screen. Seven 25- to 30-gram splits

TABLE 2. EXPANSION TESTS OF STENDEL PERLITE.*

Furnace Tests of -10-mesh - +20-mesh Crude Perlite										
Bulk Weight lbs/cu ft		Furnace Temperature (˚C)	Retention Time (sec)	Color of Expanded Product	Cellular Texture of Expanded Product	Behavior in Furnace		Preheat Treatment		
Crude	Expanded						Temperature (˚C)	Treatment Time	Remaining H_20 (%)	Decrepitation (-20 mesh, %)
77.4	5.4	1100	7	white, mottled with Cream	very coarse	satisfactory	400	10 min.	3.49	4.5
77.4	10.2	1000	26	do.	very coarse	decrepitated	700	12 sec.	---	10.1
77.4	10.2	1100	14	do.	very coarse	satisfactory	450	10 min.	3.53	202
77.4	11.7	1050	8	do.	very coarse	satisfactory	600	10 min.	1.32	2.5
77.4	12.0	1050	5	do.	very coarse	exploded	none	none	4.62	41.2
77.4	18.2	925	20	do.	very coarse	decrepitated	none	none	4.62	17.1
77.4	27.5	1000	25	gray, mottled with cream	medium	satisfactory	450	10 min.	3.65	2.9

Sink-float tests using -20-mesh - +100-mesh crude preheated 10 min at 425˚C to water content of 3.13% gave the following results: Bulk weight, crude, 76.3 lb/cu ft; bulkweight, expanded, 5.5 lb/cu ft; furnace temperature, 1100°C; retention time, 4 sec; sink fraction, 12.5%, by weight.

Properties of crude perlite: Color, pale gray; density, 149.8 lb/cu ft; specific gravity, 2.4; total ignition loss, 4.62%; $-H_2O$ content, 0.46

*By Donn M. Clippinger.

the minus-10-mesh - plus-20-mesh fraction were expanded in a 1-inch Hastelloy-tube, vibrator-actuated electric furnace, at temperature steps ranging from 925°C to 1100°C. Several lots were given a preheating treatment in a muffle furnace, to reduce the degree of decrepitation during expansion. Bulk weights in a state of loose packing were obtained by pouring the aggregates carefully into a graduated cylinder. Expanded products were fractionated by sink-float in water, to separate expanded and unexpanded fractions. The results of these tests are shown in Table 2.

On the basis of these laboratory tests, which can be considered as only preliminary, it is concluded that the Stendel perlite is capable of yielding a commercial-grade lightweight aggregate when expanded by appropriate methods. Decrepitation properties indicate the need for preheating treatment, to minimize the production of fines during expansion. It is possible that a reduction in the coarseness of the cellular texture of the expanded product might result from different preheating and/or expansion treatment than that used in these tests. The production of an appreciable percentage of unexpanded particles is inevitable, owing to the abundance of phenocrysts in all portions of the deposit. The proportion of altered glass and spherulites in the crude feed will be reflected in a further increase in the percentage of unexpanded particles in the unclassified product.

COMMERCIAL POSSIBILITIES

The deposit has been opened by only a few shallow prospect pits and trenches, but outcrop exposures are sufficiently continuous across both the lateral and vertical extent to permit a reasonably accurate appraisal of its commercial possibilities. Mining by open-pit methods is feasible in a tract 300-350 ft wide, with a linear extent of over one-half mile. Except for local shallow patches of slope wash and talus, no overburden will have to be stripped west of the contact of the perlite with overlying tuffs. Access to the deposit can be facilitated readily by improvement of the existing dirt road.

As mentioned in the preceding section, the perlite shows moderately favorable response to conventional laboratory expansion tests. Additional tests on a laboratory scale, followed by testing on a pilot-mill scale, are essential, however.

Several types of impurity must be reckoned with in any consideration of the commercial exploitation of this deposit. Nonexpansible phenocrysts constitute approximately 11-14 percent, by volume, of the pit-run rock. Additional nonexpansible materials in altered and spherulitic zones make 76 percent of the mapped area of the deposit unsuitable for use. The shape and distribution of these zones (plate 2) will require selective mining of the perlite, if excessive dilution by nonexpansible material is to be avoided.

OWNERSHIP

An unpatented placer mining claim of 120 acres covers the NE¼SW¼, and the W½SE½ of sec. 14, To-3 S., R. 4 W. Designated as the Perlite claim, it is held by Mr. Roy

Stendel, of Socorro, New Mexico. The S½S¼ of sec. 14, and the E½W½ sec. 23, T. 3 S., R. 4 W., are reported to be patented homestead lands.

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