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PERLITE DEPOSITS NEAR THE DESCHUTES RIVER, WASCO COUNTY, OREGON

by

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See G.M.I S.P. No. 16

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INTRODUCTION

History: Since experiments in Japan many years ago (Kôzu, 1929) it has been known that certain types of volcanic glass would expand when heated abruptly. In 1928 students at the University of Nevada expanded perlite glass from a deposit in Bodie Canyon, between Aurora and Hawthorne, and in 1940 perlite was treated in a kiln at Las Vegas and used with gypsum to plaster a large building there.

In 1941, L.L. Boyer conducted some experiments on crude perlite near Superior, Arizona, and later in the same year tests were made by the Arizona Bureau of Mines[1] which showed that when crude perlite is crushed to 4-mesh and heated to around 1700° F. a loss in weight or nearly 4 per cent and an increase in volume of over 600 percent takes place. The rock, which is a natural glass with a water content of from 2 to 5 percent, "pops" like pop-corn, to produce a light colored frothy aggregate having physical characteristics which make it an excellent insulating, acoustic, and building material aggregate.

Samples of perlite has been collected for the museum of the Oregon Department of Geology and Mineral Industries in 1940, and other samples were submitted to the department by Mr. J.W. Staats of Maupin in 1944. Early in 1945, Mr. E.D. Zoradi, of Dant and Russel Inc., came into the Portland office of the department and was given the location of these and other samples of perlite from various localities in Oregon. As a result of his investigations, several plots of land were leased and claims located by Dant and Russell, and prospecting work was begun in the fall of 1945 on the deposit located north of Frieda Station.

1. Bull. 152, p. 35, 1944.

Geography: The Deschutes River Canyon has a depth of 3300 feet in the stretch adjacent to the area studied, where it has cut down through a great fold in the Columbia River Basalt and underlying rocks. The walls of the canyon drop in a series of great steps, formed by the flows of basalt and rhyolite and interbedded softer materials. East of the canyon the slightly dissected Shaniko surface (Hodge 1930) stretches for 25 miles eastward, and slopes away still farther to the north. West of the canyon and south of the mine, the mass of older rocks known as the Mutton Mountains rises to elevations of over 4200 feet, standing a thousand feet higher than the Shaniko surface of Columbia River basalt.

The north side of the Mutton Mountains is drained by Eagle Creek, which empties into the Deschutes River half a mile south of the mine at Frieda. Although having a drainage area of over 30 square miles, it is an intermittent stream, being dry for several months of the year. The flow of the Deschutes River above Crooked River "is more remarkably uniform than that of any other river in the United States comparable in size......at the mouth of the stream the maximum discharge is only six times the minimum" (Henshaw, 1914). A guaging station at Mecca, 25 miles upstream from the area mapped, recorded, in the period 1911-1926, between 3 and 4 million acre-feet of run-off per year, with January maxima not exceeding 12,100 and no August minima less than 3,170 acre feet. The annual precipitation is about 15 inches, although snowfall is greater in the higher part of the Muttom Mountains. The mean temperature range is from 45 to 52°. Climatically, the region is classified as dry steppe, with summer drought and cold winter.

The Frieda area is bare grassland, with an occasional oak and cottonwood in the canyons. Pine and fir occur higher up on the crests of the ridges.

Acknowledgments: The writer was assisted in the topographic mapping of the Lady Frances mine area by Mr. R.G. Bassett, then engineer at the mine. He is much indebted to Mr. Elda Zoradi, Mr. Pierre Hines, and Mr. Fred Gustavson for suggestions and discussions of the problems involved, and to Mr. Paul Schmidt for many courtesies during the period spent at the mine, which totalled 12 days. The base mine map for Plate 6 was also constructed by Mr. Bassett.

GEOLOGY

General Stratigraphy: Perlite deposits in Oregon generally occur within the Clarno formation, of Eocene (lower Tertiary) age. This series of andesitic, basaltic, and rhyolitic lavas with interbedded tuffs and ash is widespread in central Oregon (Hodge, 1931; Wagers, 1942) (See Plate 1 for general distribution) and rocks of equivalent age occur in several localities farther east in Oregon (Gilluly, 1937; Piper, 1939, p. 52; Bryan, 1929, p. 46) The Clarno is divided by a strong unconformity into a lower series, predominantly composed of andesitic tuffs, breccias and flows, and an upper series, mainly rhyolitic in lithology. In the Horseheaven area, 35 miles southeast of the mine, the lower series is 5,800 feet thick; in the Mutton Mountains the andesite below the unconformity is exposed for only 500 feet at the base of the section, while the overlying rhyolite is over 2,000 feet thick.

The base of the Clarno is exposed near the head of Hay Creek and Little Willow Creek east of Madras; near Mitchell; and near Muddy Creek Ranch, just west of the John Day River. The formation unconformably overlies slates, sandstones and conglomerates of Mesozoic age. The rocks near Mitchell are of Cretaceous age, elsewhere they are probably older. The Clarno is usually overlain by tuffs of the John Day formation (Oligocene) although younger rocks overlap in a number of places.

Perlite also occurs in eastern Oregon in rocks which are apparently later than Clarno age. In the Steens Mountains rhyolite flows and intrusives with perlitic selvages may be Pliocene (Fuller, 1931); in the Harney Basin perlite occurs in rocks assigned to the Danforth formation (Pliocene) (Piper, 1939, p. 47.)

The Clarno rocks of the Mutton Mountains have been mapped in detail by Wilkinson (1932), and more generalized maps of the area have been published by Hodge (1931, 1940, 1941). The generalized section, as abstracted from Wilkinson, is as follows:

Thickness	Description
50' (?)	Upper andesite flows and plugs, generally massive, iron gray to black, fine textured granular.
100'	Alkali-rhyolite (pantellerite), vesicular, light to dark gray, mottled.
500'	Rhyolite proper (subtype A), banded, gray, violet and fawn colors, aphanitic groundmass, with orthoclase and some quartz phenocrysts. Includes interbedded tuff layers not over 100' thick.
700'	Aphanitic rhyolite (lithoidite), massive, red colored, with perlite and obsidian beds, particularly at the top. Contains local interbedded pyroclastics, not over 50' thick.
150'	Trachyte, platy, aphanitic, gray color with iron0stained bands, overlain by a thin bed of black glass. In some places the entire flow is glassy (This is the main perlite zone).

0-500'	Agglomerate, varying from fine grained to breccia in size, red, cream and green colors. Contains interbedded tuff and ash.
100'	Rhyolite porphyry (nevadite), as lenses and dikes, aphanitic with microcrystals, gray to red in color.
	----------Strong disconformity----------
200'	Andesite, dense aphanitic to glassy, dark gray, green to black in color.

A reconnaissance geologic map of about 12 square miles was made of the area around Frieda Station (Plate 2), located at the north end of the Mutton Mountains on the Deschutes River about 9 miles south of the town of Maupin. A more detailed topographic and geologic map, on a scale of 200 feet to 1 inch (Plate 5), was made of about one-half square mile around the Lady Frances Mine, a thousand feet north of Frieda.

The 100 foot bed of rhyolite porphyry above the disconformity of Wilkinson does not appear near Frieda or along the north wall of Eagle Creek south and west of the Frieda although it occurs farther to the north and east, on both sides of the river. The agglomerate bed is only a few feet thick at the Lady Frances mine, but it thickens rapidly to the southwest, where half a mile up Eagle Creek steep attitudes within it indicate the presence of a buried cinder cone of considerable dimensions, composed of andesite breccias and yellow and red scoria, lapilli, and tuff. Five sections were roughly measured both up and down river from the mine and near the mine; these are presented on Plate 3. The perlite flow in which the mine is situated lies upon water laid tuffs, upon agglomerates, and in places upon the underlying andesite. Farther east and north there are two zones of perlite, separated by a rhyolite flow. A rough idea of the relationships if

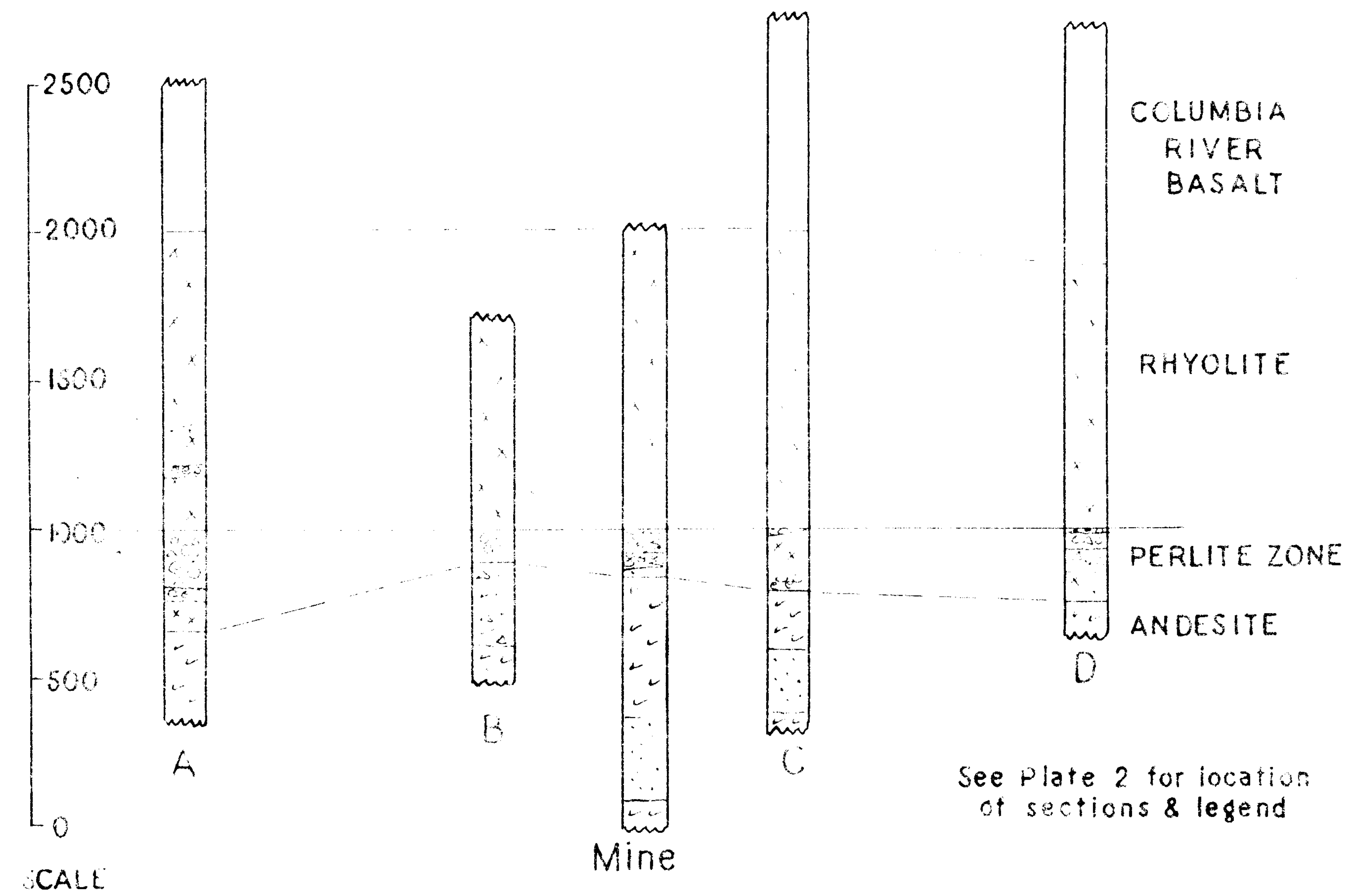

Plate 3 Generalized stratigraphic sections

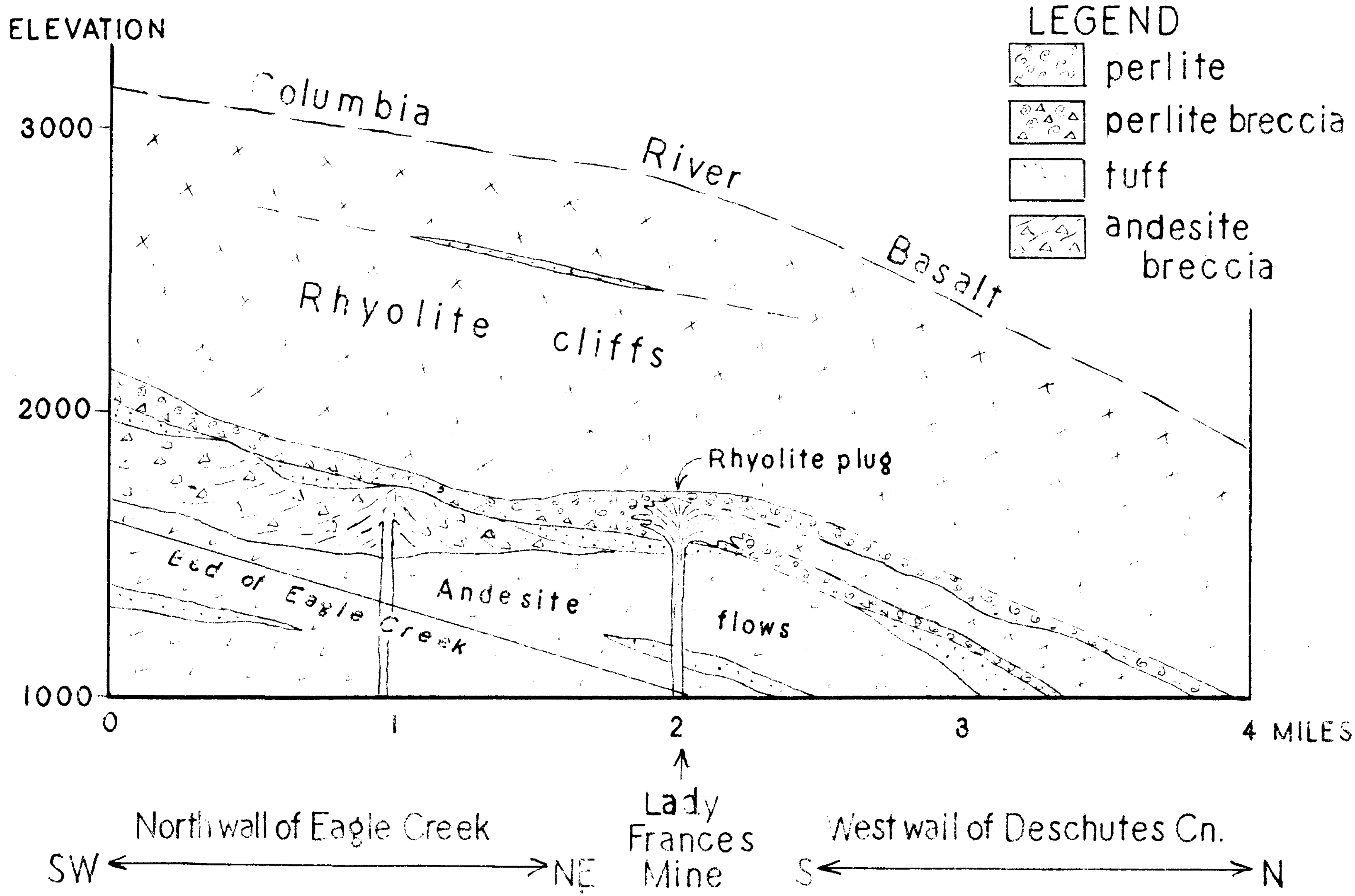

Plate 7 Diagrammatic cross section of Frieda district

is suggested by the diagrammatic cross section on Plate 7.

There are seven stratigraphic units distinguished on Plate 5, a geologic map of the area adjacent to the mine, which may be summarized as follows:

Thickness	Description
0-50'	Talus and soil cover
0-100'+	Recent alluvium, terrace, and landslide material
XXX	Dike, 50- to 150' thick, of gray, porous andesite, cutting entire Clarno and Columbia River basalt section.
900-1000'	Rhyolite, platy, banded, sometimes massive; gray to red color. Contains well defined flow structures, and near the base is often cavernous, with lithophysae and nodules containing agate.
0-140'	Perlite, blocky to splintery fracturing, light gray to nearly black in color; frequently contains well developed flow planes of lighter and darker material.
0-75'	Water-laid tuff and tuff breccias, varying from fine grained well bedded yellow tuff to a perlite agglomerate, consisting of round "pillows" of perlite in a vitric tuff matrix which grades into massive perlite above. Considerable alteration of both matrix and perlite by silicification, to form a greenish chalcedonic material.
	----------unconformity----------
500'+	Andesite breccias and flows, lapilli tuff, dark yellow to red, grading downward into andesite breccia and massive, blocky fracturing, usually vesicular and frequently amygdaloidal andesite.

Near the mine the various units are essentially flat lying, but the regional dip is to the north, and the perlite flow which is at an elevation of 500 feet above the river at the mine, dips below river level less than 2 miles north.

<u>Andesites:</u> The andesite flows occur in outcrops in the river bed just below the mine, and form prominent physiographic benches 400 feet above the river. They do not rise as high in the bed of Eagle Creek, but form low cliffs on either side of that stream for several thousand feet to the southeast. An interbed of green waterlaid tuff and overlying tuff breccia appears opposite the mine of the east side of the Deschutes. On Eagle Creek the lavas are overlain by several hundred feet of dark red to yellow and green tuff-breccia containing andesitic scoria, and lapilli of all sizes. These rocks weather into abrupt cliffs, pinnacles, and spires. Steep dips in this material strongly suggest the former presence of an andesitic cinder cone about a mile from the mouth of Eagle Creek. The lava varies from a black glassy augite andesite to a gray vesicular and frequently amygdaloidal lava. Both phases are porphyritic, with from 5 to 20% andesine phenocrysts, sometimes in two generations. A few crystals of hornblende occurs in the glassy phase. The groundmass of the glassy phase is 20 to 35% brown glass, 20% to 30% trachytic oligoclase, 15% to 20% augite granules, and 5% to 20% iron ores, the remainder being alteration products such as chlorite and limonite. The vesicular phase has a groundmass containing 20% glass, 15% iron ores, 3% augite granules; and 15% trachytic oligoclase-andesine. Amygdales, which make up 30% of the rock, contain, in order of formation, unidentified zeolites, interstitial chlorite, secondary iron ores, and chalcedony.

Tuffs and perlite breccia: Above the andsite and andesite breccias are found isolated beds of fine-grained, well bedded, water-laid vitric tuff, composed of minute shards of glass and perlite. At several localities up Eagle Creek the tuff is green and coarse granular, being composed of partially altered fragments of andesite and glass. Above the tuff there is usually a layer of perlite breccia, from a few feet to over 50 feet thick, overlain by massive perlite. At one locality a mile east of the mine great blocks of perlite breccia are imbedded in green tuff, which also contains angular and water-worn pebbles of basalt. The breccia is composed of rounded "pillows" of perlite in a matrix consisting of fresh to altered perlite tuff, containing angular fragments of the underlying andesite. Considerable secondary silicification of both perlite and tuff has taken place, with the formation of a pale green chalcedonic or plasma-like material. Some perlite fragments have rims of this siliceous material. Yellow unctious clay is not uncommonly present in the matrix. The rounded bodies of perlite frequently have smoothed and apparently striated surfaces.

Perlite: Blocky and splintery-fracturing light gray to nearly black perlite overlies perlite breccia, tuff, and andesite breccias, and underlies the rhyolite. In the Frieda district it crops out in three general areas (see Plate 5), at and near the mine, 2000 feet south in the north wall of Eagle Creek, and over the ridge to the northwest on both sides of "Land slide Canyon". These outcrop areas are believed to be connected beneath the soil cover, and perlite may be observed along the same zone for three miles to the southwest up Eagle Creek, and for two miles north along the west side of the river to where it dips below river level half a mile south of Nena Station. Perlite also occurs across the river to the east and in Sheep Mountain to the south. To the east and north two beds of perlite occur, with an intervening rhyolite.

At the mine portal the perlite is about 150 feet thick, but 400 feet south it is less than 30 feet thick, being replaced by bedded tuffs below and vitric tuffs above. North of the portal of the mine a plug of rhyolite 400 feet by 800 feet is bounded on both sides by perlite, and contains vertical, contorted, and steeply dipping flow planes. The contact between this plug and the adjacent perlite consists of interfingering lenses of perlite in rhyolite and rhyolite in perlite, the latter being parallel with flow planes in the perlite. On the south and west of the plug, where exposed in the mine workings, the flow planes dip gently away from the plug and then rise again, forming a peripheral synclinal structure (see Plate 6). The base of the perlite, where it overlies brecciated and tuffaceous rocks, dips north towards the plug. North of the mine portal the tuff and breccia is very thin, perlite resting almost directly upon andesitic breccias and flows.

At the south outcrop area perlite overlies perlite breccia which in turn overlies a thick section of andesite breccia. The perlite here is dark brown to black in color, breaks with a smooth blocky fracture, and consists of angular fragments of glass completely rewelded into a massive perlite, the only distinction between fragments and matrix being one of color. The angular and subangular fragments have a bluish gray color with reddish rims, the groundmass being a dark brownish black. In thin section the perlitic cracks appear, but are not abundant. The glass has an index of refraction of 1.505$\pm$ .002, which indicates that it has a silica content of about 71 percent (George, 1924), whereas the gray perlite with the splintery fracture at the main deposit has a refractive index of nearer 1.50, indicating a slightly higher silica content. Crystallites are sparse, consisting of lines of baculites. Fine iron ores are dusted throughout, frequently arranged in lines.

A generalized cross section showing the relationships of the perlite with adjacent formations in the Frieda area is given in Plate 7.

Rhyolite: Thick flows of rhyolite in excess of 1000 feet overlie the perlite. At the mine the contact is sharp, with the under surface of the rhyolite being grooved, indicating flowage over already cooled and solidified perlite. A mile up Eagle Creek and two miles down river, the contact is less definite, with blocks of perlite incorporated into a rhyolite breccia, and rhyolite fragments included sparsely in the perlite breccias. In these localities the lower 10 to 30 feet of the rhyolite is cavernous, with rounded lithophysal nodules developed on the walls of the cavities, which in places make up as much as 30 percent of the rock volume. The rhyolite above the perlite exhibits well defined flow structures, the banding due to varying color from lavendar to yellow, brown to red. In thin section the color bands are apparent under parallel light, but under crossed nicols they disappear, and the rock is seen to be an aggregate of radiating spherulites, composed of minute acicular crystals of quartz and orthoclase. The rock is made up of 15% well developed spherulites, 35% irregular interstitial spherulitic material, 20% interstitial quartz, 20% iron ores, 10% secondary limonite, and a few biotite flakes. Complete petrographic descriptions of the various types of rhyolite in the area are given by Wilkinson (1932).

Post-Clarno Rocks: Above the rhyolite series in the Mutton Mountains there is a relatively thin section of John Day tuffs, which do not appear within several miles of the mine, overlain by Columbia River basalt, which cap the crests of the ridges and forms the upland surface east of the Deschutes River.

Origin of Perlite: Perlite is "a glassy volcanic rock of rhyolitic composition with a marked perlitic structure" (Holmes, 1928), and perlitic structure consists of a system of convolute and spheroidal cracks, developed in natural glasses during cooling. Perlite contains from 2 to 4 percent contained water, and usually its chemical analysis shows that there is an excess of Na_2O over K_2O. Otherwise it is identical in composition to adjacent and related rhyolites, which usually contain less than 2 percent water and have an excess of K_2O (Fuller, 1935). Several characteristic analyses of perlites and rhyolites from the Steens Mountains of southeastern Oregon (Fuller, 1931) are given below:

PERLITES - RHYOLITES OF STEENS MTS.

	1	2	3	4	5	6	7
SiO_2	73.00	67.05	73.60	75.62	74.50	68.66	72.65
Al_2O_3	14.23	14.91	12.96	11.52	12.45	14.44	13.64
FeO	1.28	1.48	1.19	1.19	.83	1.28	.68
Fe_2O_3	.28	.92	.82	.82	.85	.80	.70
MgO	.24	.65	.20	.26	.28	.18	.60
CaO	1.25	2.44	.64	.62	1.82	1.96	.55
Na_2O	2.96	4.15	1.71	1.80	3.88	3.86	2.54
K_2O	4.86	3.04	7.27	6.50	4.27	3.28	5.70
H_2O (above 105° C.)	1.00	4.25	.80	.90	.66	4.80	1.50
H_2O (at 105° C.)	.60	.50	.40	.33	.30	.40	1.50
CO_2	none	none	none	trace	none	none	none
TiO_2	.18	.34	.30	.34	trace	.25	.10
P_2O_5	trace	.12	trace	trace	.07	trace	trace
S	none	trace	none	trace	.04	none	none
MgO_2	none	trace	none	none	trace	none	trace
Totals	99.88	99.955	99.89	99.90	99.95	99.91	100.16

1. Rhyolite
2. Perlite
3. Rhyolite
4. Spherulite
5. Rhyolite
6. Perlite
7. Rhyolite

Analyses by W.H. and F. Herdsman.

The origin of the various types of volcanic glass, and of perlite in particular, is still a topic of considerable controversy. Conditions requisite for the formation of thick deposits of glass seem to be 1) an acidic magma; 2) extremely rapid extrusion; and 3) extremely rapid solidification. Basic magmas are more fluid than intermediate or acid magmas, and upon extrusion tend to remain liquid long enough so that they can become crystalline except on their outer selvages. Acid magmas are viscous, and are generally erupted rapidly, often accompanied by explosions and the formation of breccia, tuff, and pumice. They may lose their combined water and cool rapidly, thus preventing crystallization. The difference in composition of the glassy margins and stony centers of acid rocks (more water and soda in the glass) has been attributed by several writers (Shand, 1943, pp. 37-38) to changes that have taken place since their formation, but this is not generally accepted by most geologists, who believe that the high water content, particularly, is an indication of the original high water content of the magma.

In the case of perlite, it appears to be a general rule that such deposits overlie water-laid tuff beds of a general similar composition, and are associated with explosive action. E.K. Zoradi, who has visited numerous deposits in the southwest, reports (oral communication) that in every case where the base of a deposit is exposed, it lies upon tuff beds or upon agglomerates or breccias of explosive origin. This is the case in the Frieda district, in the Steens Mountains (Fuller, 1931), in the Owyhee area (Bryan, 1928, p. 46), and in the Superior (Pinal County) area and in the Black Mountains of Mohave County, Arizona (Wilson and Roseveara, 1945). The only outstanding exception to this rule appears to be when perlite occurs as the chilled selvages of andesitic intrusions (Water, 1942).

In the Frieda area the presence of perlite reworked into the tuff beds, the apparent "pillow structure" in the base of the perlite breccias, the repetition of water-laid, tuffs below and above the perlite layers, and the degree of silicification and alteration of the breccias and portions of the perlites, suggest that the perlite extrusions took place beneath lakes of considerable depth, were, in face, sub-lacustrine in nature. It is not impossible that the high water content of the glass in perlite here at least, is due in part to water added during extrusion and while the brecciated mass was cooling. The brecciation and silicification would then be a result o f the interaction between the hot lava and the surrounding waters. It is also believed that the actual vent from which the perlite came is represented by the rhyolite plug just north of the mine portal, and that the excessive thickness of the perlite at this point is due to the proximity of the vent.

There are numerous thin rhyolite flows of composition similar to perlite in the same area which cooled slowly enough to crystallize. If lakes were present at the time of extrusion they might have been cooled rapidly enough to form perlites.

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