Technical Papers Technical Papers

Tucker Hill perlite deposit, Lake County, Oregon

J.L. Wilson and D.L. Emmons

Abstract – *The Tucker Hill perlite deposit is located in the northwestern portion of the Devils Garden lava field in Lake County, south-central Oregon. The perlite occurs in the chill margin of a late Miocene composite rhyolite lava dome that exhibits distinct cooling zonation. The chill margin is composed of an outer glass envelope, which contains commercial-grade granular and vesicular perlite, and an inner glass envelope, which contains onionskin perlite of local commercial quality. Glassy rhyolite and rhyolite compose the lava dome core. The entire dome complex encompasses at least 5 km² (2 sq miles). Expansion tests in commercial-scale furnaces indicate that the perlites are suitable for a wide range of applications and compare favorably with commercial perlite ores. The large tonnage deposit appears competitive for markets in the midwestern and upper northeastern states, and the Pacific Northwest of the US.*

Introduction

The Tucker Hill perlite deposit is located within Lake County in south-central Oregon, about 80 km (50 miles) north of the California state line (Fig. 1). The deposit lies within portions of sections 24 through 27, 35, and 36, T. 34 S., R. 19 E., Willamette Meridian and Base Line. The nearest railhead is in Lakeview, 56 km (35 miles) to the south.

The perlite deposit is expressed as a northeast-trending, steepsided hill that rises more than 150 m (500 ft) in elevation above the flat lowlands of the adjacent Chewaucan Marsh (Fig. 2). Gently rolling and subdued topography characterizes the top of the elongate hill. The long axis of the hill is greater than 3.2 km (2 miles) in length and the width ranges from 0.8 to 1.6 km (0.5 to 1 mile). The Tucker Hill area is within the Cascade rain shadow and is characterized by a semiarid continental climate with hot and dry summers and cool winters. The property is within the upper Sonoran life zone and is vegetated by low brush, grass, and very sparse juniper trees.

Deposit history

A small portion of the Tucker Hill perlite deposit was originally discovered and staked in 1949 by a group of Oregon prospectors. Shortly after location, a 1.8-t

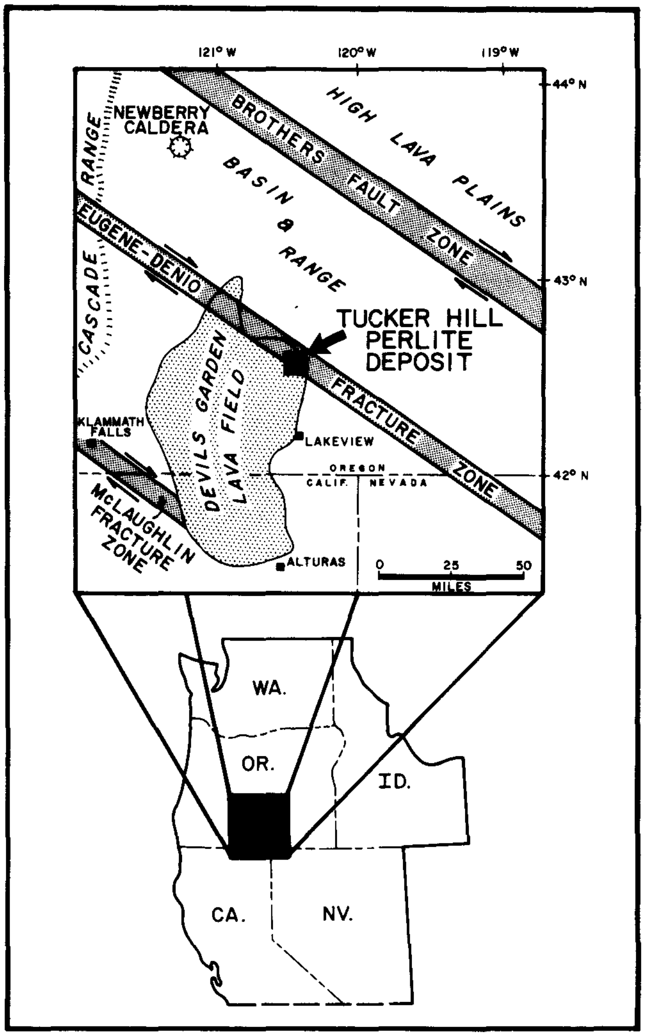

Fig. 1 — Index map and structural setting of the Tucker Hill perlite deposit

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(2-st) perlite sample was collected and crudely expanded in a fire assay furnace by the US Bureau of Mines in Tucson, AZ (Wagner, 1950). Expansion results on the classical "onionskin" perlite were favorable, and the property underwent a brief period of surface mining. Unfortunately, mining was conducted in a portion of the deposit that contains a high percentage of detrimental marekanite nodules (obsidian). Large adjacent areas of high grade perlite were apparently unrecognized. Mining quickly ceased and the claims became invalid in 1954.

In 1980, Tenneco geologists recognized perlite outcrops in the vicinity of Tucker Hill during a reconnaissance of adjacent Tenneco mineral lands. The perlite was found to be extensive and was staked in 1981. Most of the deposit is on lands administered by the US Bureau of Land Management. Lesser portions are on state lands and are held by State of Oregon prospecting permits. Tenneco geologists have since mapped, sampled, and tested the perlite with favorable results.

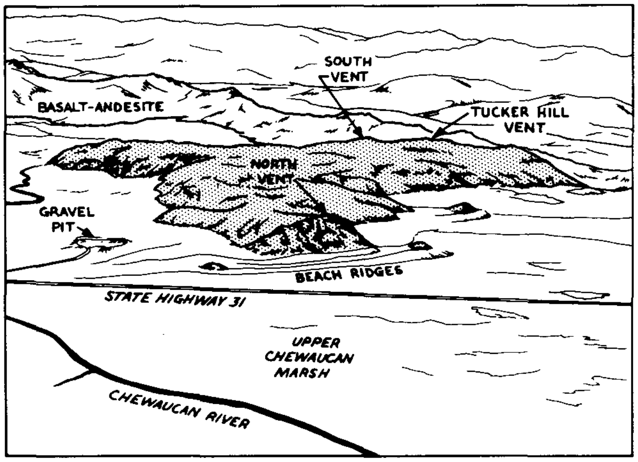

Fig. 2 — Sketch of the Tucker Hill lava dome (shaded midground) as viewed to the south. The Tucker Hill vent and north vent rise 150 m (500 ft) above adjacent flatlands. Exposed portions of the lava dome cover about 5 km^2 (2 sq miles).

Geologic setting

The Tucker Hill perlite deposit occurs in the northeastern portion of the Devils Garden lava field (McKee, Duffield, and Stern, 1983), which occupies a transitional zone between the Cascade Range to the west and the Basin and Range province to the east (Fig. 1). The lava field is 5 to 10 m.y. old (late Miocene to early Pliocene). It is composed largely of olivine basalt flows, minor andesite flows, and related rhyolitic domes, flows and pyroclastic rocks. Rhyolite is fairly abundant in the northern part of the lava field, but is nearly absent to the south. Tucker Hill is one of the late Miocene composite rhyolitic lava domes within the field. An obsidian sample from the dome has been age dated by K-Ar geochronology at 7.41 ± 0.19 m.y. (McKee and Walker, 1976).

McKee, Duffield, and Stern (1983) suggest that the basalt flows of the Devils Garden lava field isotopically resemble mid-oceanic-ridge basalt. They further suggest that the basalts erupted from the upper mantle through crust thinned by tectonic extension behind the Cascade Range volcanic arc. Rhyolites in the volcanic field, to include those of the Tucker Hill lava dome, are believed to have originated from a basaltic magma chamber as suggested by similar strontium isotope ratios and by common basalt-rhyolite associations observed worldwide (McKee, 1983).

Northwest-trending basin-and-range faults are the predominant structures in the region. The Brothers fault zone, to the north of Tucker Hill (Fig. 1), is interpreted as a right-lateral strike-slip fault zone that terminates the northwestern edge of the Basin and Range province (Lawrence, 1976). The less distinct Eugene-Denio and McLaughlin fracture zones are interpreted as similar structures. The Tucker Hill perlite deposit occurs within the Eugene-Denio fracture zone (Fig. 1).

Geology

General description

The Tucker Hill lava dome is essentially a package of cooling units related to several rhyolitic vents. These vents have extruded lavas through older, eastward-dipping basalt and andesite flows of the Devils Garden lava field. Figures 3 and 4 are schematic diagrams of the areal geology and a geologic cross section. A foliation (flow banding) formline contour map (Fig. 5) reveals three vent localities and associated flow directions. Additional vents are likely present. The vents are characterized by circular to elliptical foliation strike patterns with low angle inward dips, concentric rhyolite-perlite zonation, and circular to elliptical topographic expression (positive or negative). No significant faulting or tilting of the lava dome is evident from field observations to date. The flanks of the lava dome are covered by talus and Quaternary beach gravels from ancient Lake Chewaucan.

Volcanic zonation

The lava dome has distinct zonation similar to that described at the No Agua perlite deposit in northern New Mexico (Whitson, 1982). Zoning is largely the result of differential cooling that formed multiple units within an individual lava flow. Two major cooling zones are present — a chill margin and a rhyolite core. Vesicle abundance increases outward from the rhyolite core through the chill margin as the result of degassing and quenching of the once molten lava. Conversely, the abundance of feldspar crystallites decreases progressively outward. Figure 6 is a graphical representation of the general volcanic zonation.

Chill margin

The chill margin consists of an outer and inner glass envelope (Figs. 3, 4, and 6) and contains various perlite units. Classification of these perlite units is based on textural differences that resulted from variable degassing. Significant megascopic textural differences are present so as to permit differentation of onionskin (classical) perlite, granular perlite, vesicular perlite, and pumiceous perlite. This differentation is subject to some interpretation in the field. Microscopic examination of thin sections is helpful in supporting perlite classification. Figure 7 is a ternary diagram that roughly estimates the perlite compositional fields by volume of glass, crystallites, and vesicles. Hand specimens of granular to vesicular perlite and onionskin perlite are shown in Fig. 8. Contacts between perlite units are generally gradational over 1.5 to 6.1 m (5 to 20 ft). However, some sharp contacts are also present. Autobrecciation is locally common within all perlite units.

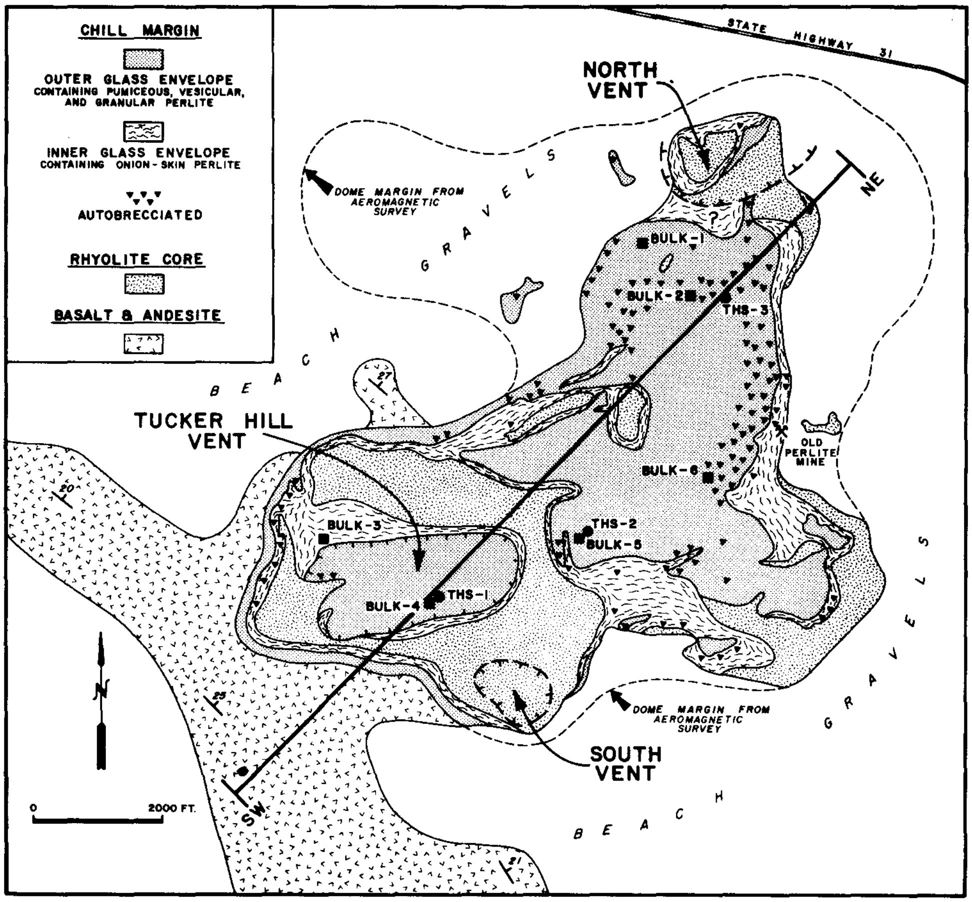

Fig. 3 — Idealized geologic map of the Tucker Hill lava dome as interpreted and simplified from outcrop map and aeromagnetic survey. Major samples sites are shown.

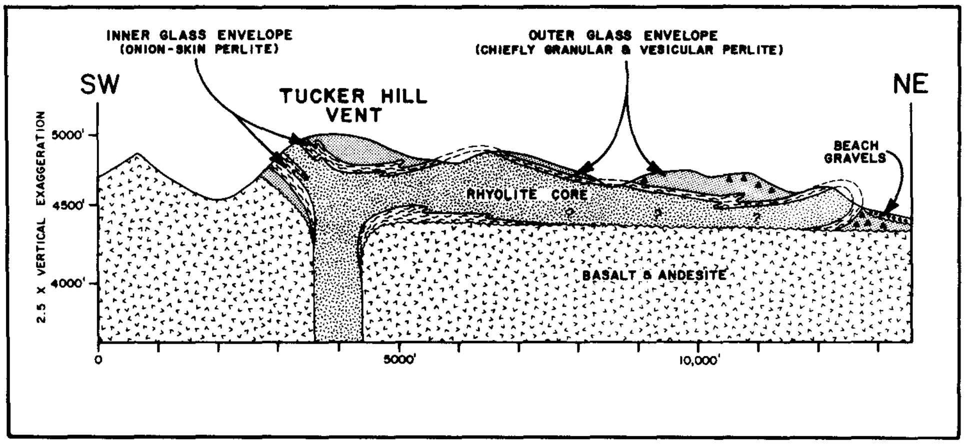

Fig. 4 — Inferred geological cross section through the Tucker Hill lava dome

The chill margin was originally obsidian that was converted to perlite as the result of secondary hydration by continued contact with meteoric waters (Friedman and Smith, 1958; Marshall, 1961; Friedman, Smith, and Long, 1966). Spherical fracture (perlite structure) within chill margin perlites are thought to be from strain developed during rapid cooling (Marshall, 1966) or developed by a volume increase during secondary hydration (Friedman and Smith, 1958). Erosion of the Tucker Hill lava dome has removed significant portions of the chill margin, particularly the outer glass envelope, exposing the rhyolite core (Fig. 4). However, large perlite resources still remain. Preserved portions of the chill margin are estimated to range from 15 to 75 + m (50 to 250 + ft) in thickness.

Outer glass envelope

The outer glass envelope consists of three distinct cooling units that grade inward from pumiceous perlite to vesicular perlite to granular perlite. Vesicle content ranges from about 5% to 30% by volume. Although untested by drilling, preserved portions of the outer glass envelope are estimated to range from 8 to 46 m (25 to 150 ft) in thickness.

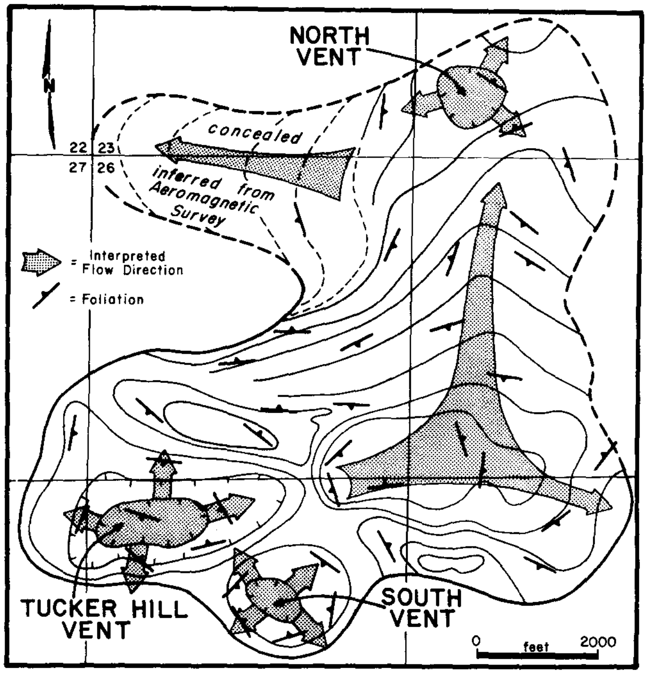

Fig. 5 — Foliation formline contour map showing interpreted vents and flow directions of the Tucker Hill lava dome. Additional vents are likely present.

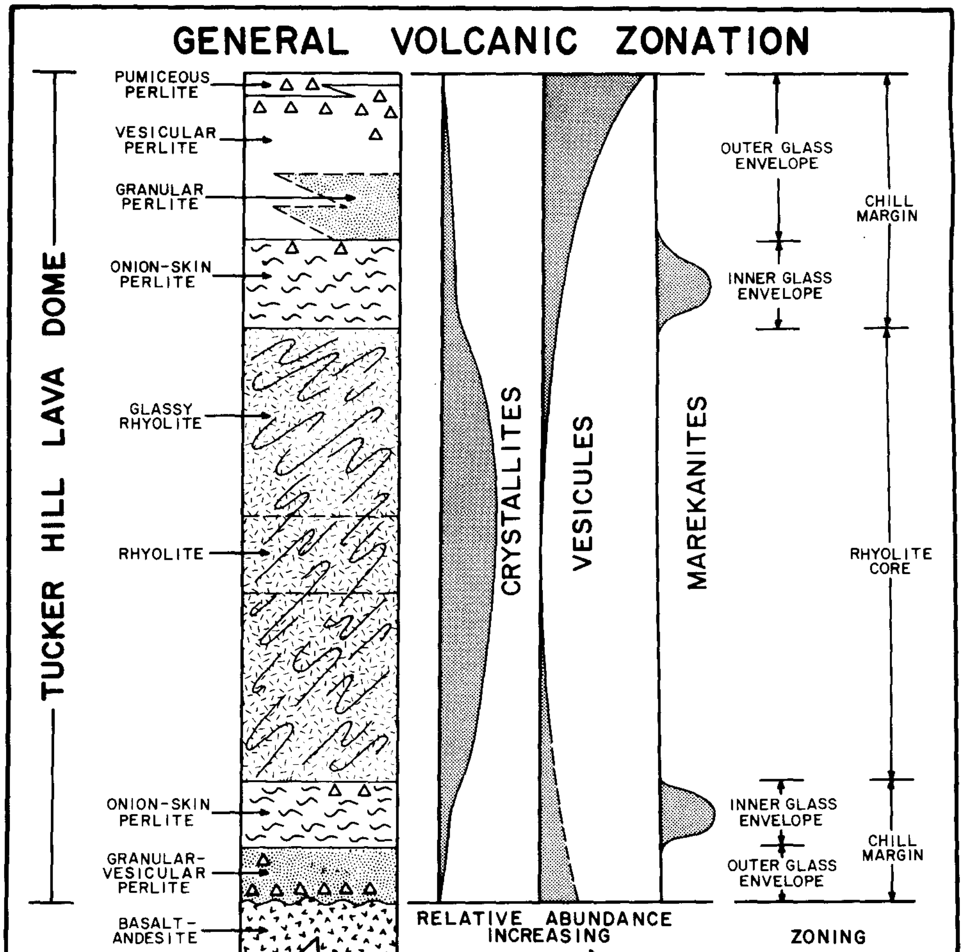

Fig. 6 — General volcanic zonation of the Tucker Hill lava dome. Contacts are typically gradational over 1.5 to 6.1 m (5 to 20 ft). Scales are relative.

Pumiceous perlite is frothy in appearance and occurs in sparse outcrops. Weathered surfaces are tan and fresh surfaces are very light gray. This low density unit is distinctly foliated, poorly indurated, and contains no conspicuous marekanite. Erosion has stripped much of the original pumiceous perlite skin from the lava dome, exposing underlying vesicular and granular perlite.

Vesicular perlite is a widespread transitional unit between pumiceous perlite and granular perlite and is abundant in outcrop. The unit is glassy with many elongate, wavy, partially collapsed vesicles (Fig. 9) and is typically devoid of marekanite. The perlite is tan to light gray on weathered surfaces and light gray on fresh surfaces. Vesicular perlite is distinctly foliated and is moderately to well indurated. Fracture surfaces normal to foliation may exhibit some onionskin texture.

Granular perlite exhibits a megascopic saccharoidal, fine-grained to medium-grained texture and faint to indistinct foliation. The unit is generally well indurated, tan on weathered surfaces, and light to medium gray on fresh surfaces. Disseminated to poorly layered marekanite nodules, 3 to 8 mm (0.1 to 0.3 in.) in diameter, typically comprise less than 1% of the granular perlite. Granular perlite (Fig. 10) is transitional between vesicular and onionskin perlite, although sharp contacts do occur. Fracture surfaces normal to foliation may exhibit some onionskin texture. Although granular perlite displays a characteristic sugary texture in hand specimen and in outcrop, it often resembles vesicular perlite when observed in thin section (Fig. 10).

Autobrecciated vesicular and granular perlite are locally abundant (Fig. 3). The autobreccias consist of angular, pebble, cobble, and boulder perlite clasts within an unaltered matrix of fine-grained perlite debris (Fig. 11). A small area was observed to contain red hematitic stain in the breccia matrix. The breccias are moderately indurated and locally well preserved. Crumble breccias likely formed along the steep, advancing flanks of the lava dome. Brecciation also occurred as the lava dome expanded and shattered its outer brittle skin.

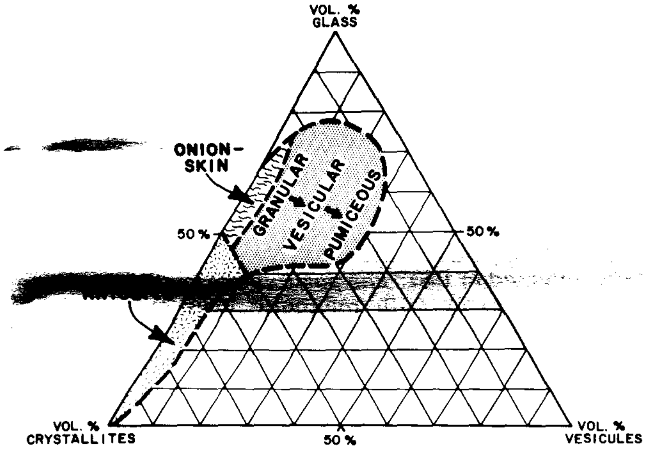

Fig. 7 — Estimated compositional fields of perlites and glassy rhyolite of the Tucker Hill lava dome based on a population of 60 thin section samples

Inner glass envelope

The inner glass envelope consists exclusively of onionskin perlite and associated marekanite and sporadic obsidian beds. This envelope is the most conspicuous marker horizon within the lava dome (Figs. 3 and 4). The onionskin perlite forms a somewhat concentric shell that is estimated to range from 8 to 30 + m (25 to 100 + ft) in thickness.

Onionskin perlite is medium to dark gray on fresh and weathered surfaces. The glassy unit is dense and typically contains 0% to 5% vesicles by volume. The perlite exhibits small to large spheroidal fractures like the skin of an onion (Fig. 12) ranging from <0.5 mm to 50 mm (<0.02 to 2 in.) in diameter. Foliation is commonly indistinct, but is locally well developed where onionskin perlite is transitional to glassy rhyolite of the rhyolite core. Black, subrounded marekanite nodules ("Apache Teardrops"), commonly 3 to 8 mm (0.1 to 0.3 in.) in diameter, comprise from 0% to 10% (typically <1%) of the onionskin perlite. Marekanite occurs as disseminations and in poorly defined layers parallel to flow banding. These obsidian nodules are particularly abundant in onionskin perlite along the eastern margin of the lava dome, and much less conspicuous along the western margin. Black obsidian beds are sporadically present in subcrop as indicated by trenches and local obsidian float. Onionskin perlite is poorly to moderately indurated and typically erodes to form slopes and prominant vertical columns.

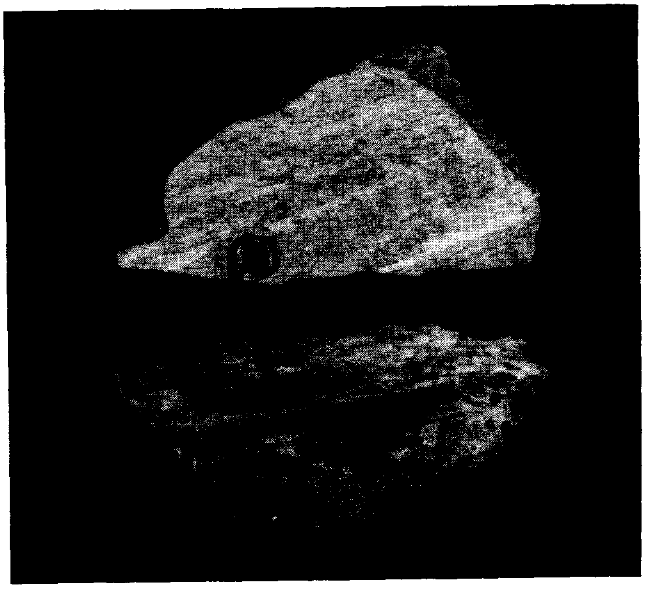

Fig. 8 — Hand specimens of medium-grained granular to vesicular perlite (top) and onionskin perlite with small concentric fractures (bottom). Both samples are moderately foliated.

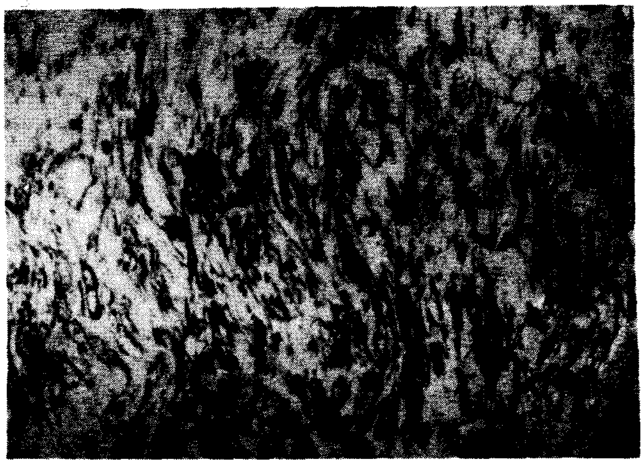

Fig. 9 — Photomicrograph of vesicular perlite showing wavy, elongate vesicules and indistinct, circular, perlitic fractures. Viewed in plane polarized light; field of view is 7 mm (0.3 in.).

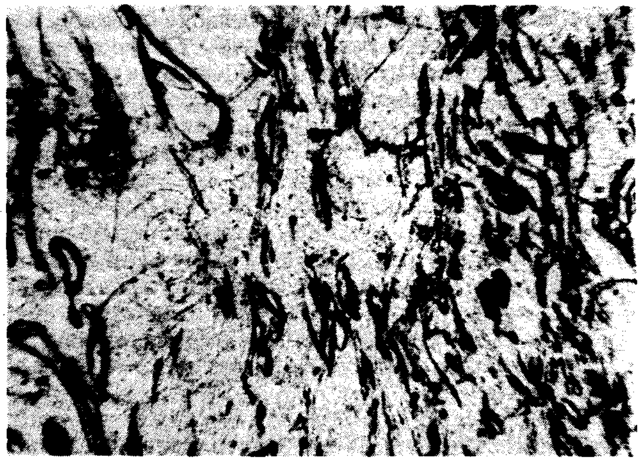

Fig. 10 — Photomicrograph of granular perlite, with indistinct, circular, perlitic fractures. Viewed in plane polarized light; field of view is 5 mm (0.2 in.).

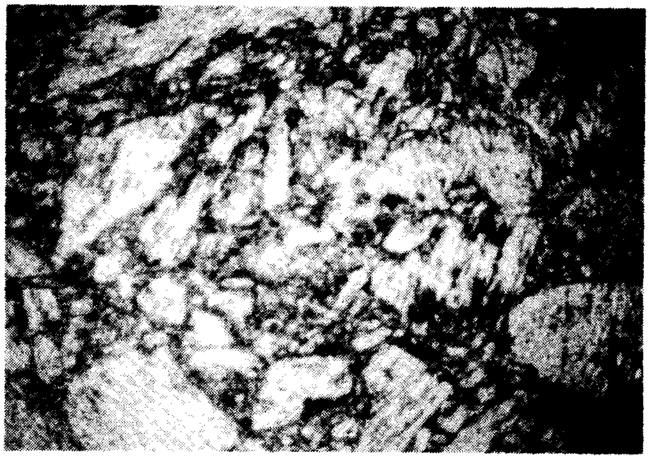

Fig. 11 — Photomicrograph of autobrecciated vesicular perlite with a matrix of fine, unaltered perlite. Viewed in plane polarized light; field of view is 5 mm (0.2 in.).

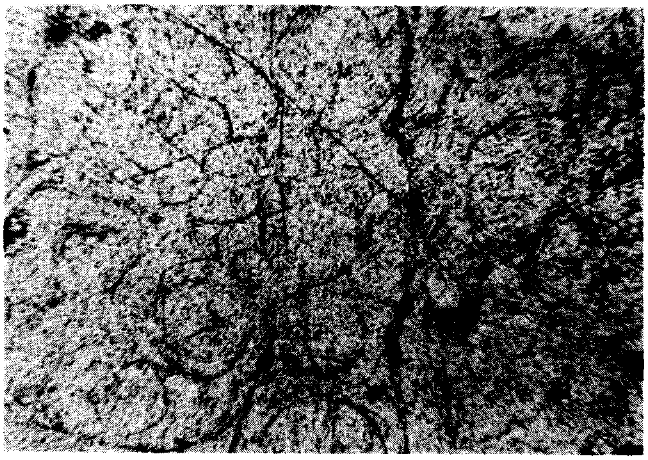

Fig. 12 — Photomicrograph of onionskin perlite showing circular fractures. Viewed in plane polarized light; field of view is 2 mm (0.08 in.).

Rhyolite core

The rhyolite core consists largely of flow-banded glassy rhyolite and a lesser volume of banded devitrified rhyolite. Insignificant granular and onionskin perlite layers occur sporadically within the rhyolite core and are not mapped. Contacts between the rhyolite core and the chill margin range from sharp to gradational over several meters. This contact is commonly marked by a topographic notch or bench.

Glassy rhyolite displays well developed flow banding that consists of light to medium gray perlitic laminae and brownish gray to pale red devitrified laminae, lithophysae, and blebs (Fig. 13). Visible devitrified material is a key diagnostic feature used to separate potentially economic perlite from nonperlite units. Glassy rhyolite is also characterized by abundant flow structures which include prominent, tight, overturned, parallel folds, chevron folds, and drag folds. Such folding is uncommon in the perlites of the chill margin. The resistant glassy rhyolite forms steep slopes and rugged cliffs.

Rhyolite occurs mainly in the vicinity of vents, particularly the North Vent. The colorful unit is commonly medium bluish gray to pale red. Flow banding is common as are tight, small-scale folds. Some rhyolite occurs in layers within the glassy rhyolite and remain undifferentiated.

Fig. 13 — Photomicrograph of glassy rhyolite showing light glassy laminae and dark devitrified laminae which are diagnostic of the rock unit. Viewed in plane polarized light; field of view is 6 mm (0.2 in.).

Aeromagnetic expression

The Tucker Hill lava dome is an area of pronounced magnetic highs as identified in Tenneco aeromagnetic data collected in 1981. The positive magnetic signature contrasts sharply with magnetic lows exhibited by adjacent basalt and andesite which are believed to be reversely polarized. Glassy rhyolite and perlite have low magnetic susceptibilities (<100 to 300×10^{-6} cgs units) which cannot explain the high magnetic response. Interpreted vent areas in the lava dome are closely associated with individual magnetic highs. It is perhaps reasonable to assume that rhyolite of a greater magnetic susceptibility underlies the dome vents at shallow depths and accounts for the positive magnetic anomalies.

Testing program

In 1982, three 180-kg (400-lb) vesicular to granular perlite samples were collected from three sites (THS-1, THS-2, THS-3) on top of the Tucker Hill lava dome (Fig. 3). The samples were shipped to four perlite expanders for expansion testing in commercial furnaces. The small amount of sample material allowed for brief tests at existing plant temperature settings and feed rates. Subsequent results were favorable and indicated readily-expandable, "lively" perlite (low temperature ore) with expanded densities ranging from 32 to 122 kg/m^3 (2 to 7.6 lb per cu ft). Whole rock analyses were also favorable and are compared to commercial perlites in Table 1.

Geologic mapping at a scale of 1:4800 and rock-chip grid sampling were conducted in mid 1983. Significant tonnages of perlite resources were identified. Grid sampling was assisted by a backhoe to get through local soil cover. Samples were submitted to the Colorado School of Mines Research Institute (CSMRI) for small-scale expansion tests at the Manville Corp. Research and Development Center in Littleton, CO. Test results from $-50/100+$ mesh raw perlite were favorable, with expanded perlite densities ranging from 23.6 to 63.6 kg/m^3 (1.47 to 3.97 lb per cu ft). Most samples had product recovery yields greater than 90% with baghouse dust between 3% and 7%. "Sinks" (unexpanded materials and shattered perlite bubble walls) typically ranged from 0.7% and 2.5%.

Table 1 — Whole rock analyses of some vesicular to granular perlite samples (THS-1, THS-2, THS-3) from the Tucker Hill lava dome (Fig. 3). World perlite mean values and typical commercial perlite values for the No Agua and Milos deposits are also listed.

Weight Percent	THS-1 (granular to vesicular)	THS-2 (vesicular)	THS-3 (vesicular)	World* Perlites	No Agua Perlite** New Mexico	Milos Perlite** Greece
SiO_2	74.9	74.2	74.2	72.71	72.1	74.2
Al_2O_3	11.7	12.6	12.4	13.21	13.5	12.3
Fe_2O_3	0.34	0.52	0.47	1.11	0.8	0.95
TiO_2	0.06	0.06	0.08	0.12	0.06	0.08
MgO	0.06	0.10	0.07	0.21	0.50	0.13
CaO	0.91	1.30	0.92	1.23	0.89	0.85
Na_2O	3.6	3.8	3.7	3.14	4.6	4.0
K_2O	4.3	4.5	4.6	4.12	4.4	4.4
H_2O+	3.1	3.3	3.2	3.43	3.0	2.8

* *From 106 worldwide samples (Naert, 1974, p. 72)*
** *(Kadey, 1983, p. 999)*

Table 2 — Expanded perlite products from six near-surface bulk samples (Fig. 3)
A = acceptable; M = marginal; NA = not acceptable

Sample No.	Perlite Type	Horticultural Grade	Loose-Fill Insulation	Insulation Board	Cryogenic Insulation	Plaster Grade	Acoustical Tile	Filter Aid
Bulk-1	Vesicular	M*	M*	A/M**	NA	A/M**	A**	M**
Bulk-2	Vesicular-Breccia	A*	A*	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested
Bulk-3	Onionskin	A/M*(?)	A*	Not Tested	A*	Not Tested	Not Tested	Not Tested
Bulk-4	Vesicular-Granular	A*	A*	A**	A**	A**	A**	A**
Bulk-5	Vesicular-Granular	A*	A*	A**	A**	A**	A**	A**
Bulk-6	Vesicular-Breccia	A*	A*	Not Tested	A*(?)	Not Tested	Not Tested	Not Tested

* *Independent expansion plant; Murdock and Stein VS-225 vertical furnace*
** *CSMRI/Manville Corp.; Murdock and Stein modified VS-50 vertical furnace (same height as VS-225)*

In late 1983, six 9.1- to 11.8-t (10- to 13-st) samples (Bulk-1 through Bulk-6) were collected from favorable areas of the lava dome (Fig. 3). The sample sites were blasted and then ripped by a bulldozer in an attempt to expose unweathered perlite. However, most samples exhibited various degrees of near-surface weathering. Samples ranging 2.7 to 4.5 t (3 to 5 st) were shipped to an independent perlite expansion plant for testing. Samples ranging 0.9 to 1.8 t (1 to 2 st) were shipped to CSMRI in Golden, CO, for various expansion tests in commercial scale furnaces. CSMRI again used Manville Corp.'s Research and Development Center. The purpose of this testing was to determine specific product line suitability of Tucker Hill perlite. Remaining sample material was stockpiled on site.

Bulk sample test results indicate that Tucker Hill perlite is suitable for a wide variety of expanded perlite products (Table 2). Upon crushing, all samples produced equidimensional particles essential for commercial processing, and most samples generated minimal fines (<75 μm or 200 mesh). Nearly all samples produced commercial quality horticultural and loose-fill insulation products. Vesicular to granular perlite appears acceptable for insulation board, cryogenic insulation, plaster, acoustical title, and filter aid, although some marginal perlite is also present. Marginal perlite can be upgraded by blending with acceptable material. Onionskin perlite and perlite breccia were not tested for all products, but may prove acceptable for a variety of applications. None of the perlite samples were tested for plastic and resin filler applications.

Perlite resources and markets

Resources of at least 18 to 36 Mt (20 to 40 million st) of vesicular to granular perlite and perlite breccia amenable to open-pit mining are inferred from geologic mapping of the Tucker Hill lava dome. A much greater tonnage may be present and can be verified only by drilling. Although present in large quantities, onionskin perlite is not presently considered as a resource due to local marekanite zones. However, "clean" onionskin perlite of commercial quality is probably present in large tonnages.

Tucker Hill perlite is within competitive range of markets in midwestern and upper northeastern states, and the Pacific Northwest to include northern California, Oregon, Washington, British Columbia, and Alberta. The deposit has potential for generating new market applications within the northwestern states. ■

Acknowledgments

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Design of permanent block stopping to resist strata convergence

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Abstract – *Conventional concrete block plastered with a cementitious coating is the most common material used in the construction of permanent stoppings to direct airflow in underground mines in the US. All mines experience various degrees of strata convergence depending on depth of overburden, geological conditions, and type of roof support employed. Strata convergence will cause cracks and joint openings in masonry stoppings, resulting in significant air leakage losses. Where strata convergence is severe, complete structural failure of the stopping can ultimately occur. Reconstruction of damaged or destroyed stoppings adds expensive overhead to mining operations, and even greater expenses are incurred from the additional fan horsepower required to overcome leakage losses.*

Ideally, a stopping should maintain high resistance to airflow while yielding to strata convergence. By properly incorporating a polyisocyanurate rigid foam material within the masonry block structure, stopping service life can be increased in mines experiencing strata convergence problems such as floor heave, roof loading, and lateral rib movement.

Introduction

One of the prime problems and concerns caused by convergence of the roof, ribs, and floor in underground mines is damage to ventilation control stoppings. Fractured or crushed-out stoppings and overcasts permit airflow to short circuit from intakes to returns. According to Kingery (1960), as little as 30% of the total quantity of air ventilating many underground mines reaches the last open crosscut. To provide a sufficient quantity of air at the working face for dilution of methane gas and float coal dust, additional fan horsepower must be supplied to compensate for air leakage through damaged or destroyed ventilation controls. Increased fan horsepower and the repair or reconstruction of ventilation controls obviously produce higher ventilation operating costs. Clearly, any stopping design concept that extends service life and reduces leakage will result in greater ventilation efficiency and lower operating costs.

Masonry stopping design

Stoppings are usually constructed of solid or hollow core masonry blocks. Two construction techniques are used: wet wall, where cement mortar is applied to all joints; and dry stack, where no mortar is used. To reduce air leakage through masonry stopping walls, the stopping faces are often coated with a cementitious sealant. As reported by Timko (1982), the sealant is usually enhanced with glass fibers and various additives to increase strength and adhesion. These are typically applied with a brush or trowel.

In mines with little or no convergence, a masonry block stopping may exist for years before maintenance becomes necessary. Air leakage first becomes evident around the stopping perimeter, especially the roof. It appears that the wood wedges, used to secure the stopping to the roof, dry and shrink, causing a fairly low resistance path for air to flow. In addition, as the pressure differential increases across the stopping, any degradation in the roof or ribs will gradually permit air leakage. The same problem can occur beneath the stopping. However, a properly constructed footing built beneath the stopping greatly reduces the potential for leakage.

Whenever convergence exists, masonry block stopping life is greatly reduced. A stopping may be damaged by roof, rib, or floor movement. The first indication that the stopping is under compression occurs when the mortar face sealant and possibly even the faces of the masonry block begin spalling from the stopping perimeter. This is followed by joint fracturing and destruction of masonry blocks near the area of maximum convergence. Once the blocks begin to crush under compressive load, the stopping has lost its integrity and can no longer be considered substantial by US Mine Safety and Health Administration (MSHA) standards. This can occur over months or may take place in a matter of days.

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