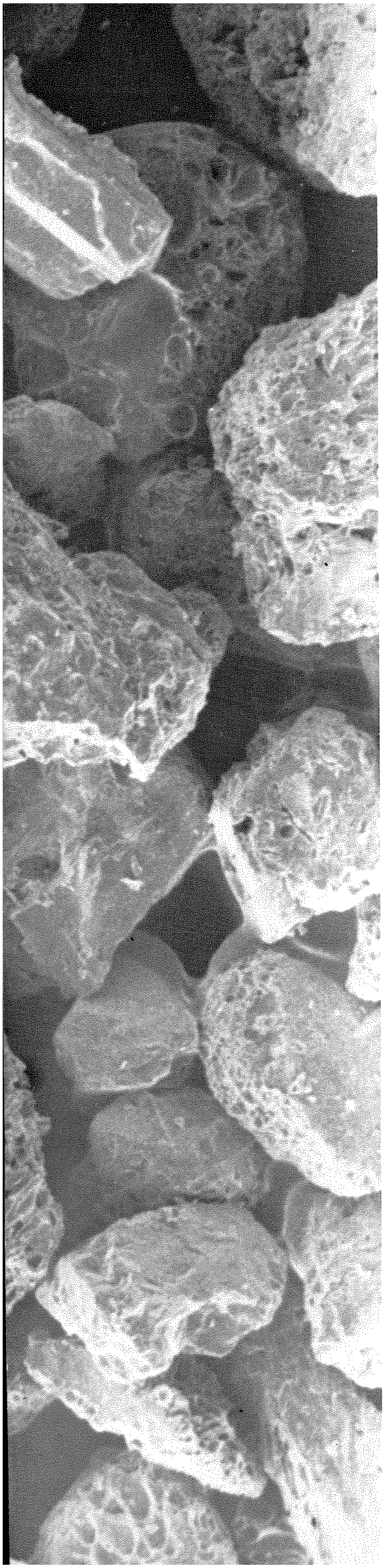

MOUNT ST. HELENS ASH— PROPERTIES AND POSSIBLE USES

By Wayne S. Moen and Glennda B. McLucas

Washington Department of Natural Resources
Division of Geology and Earth Resources

Report of Investigations
24

COVER PHOTO

Scanning electron photomicrograph of Mount St. Helens ash collected at Yakima, Washington, from the May 18, 1980, eruption of the volcano, X 150. Vesicular fragments are volcanic glass. Light-colored plagioclase feldspar crystal at upper left of photo is .5 mm in length (Photo courtesy of Dave Pevear, Western Washington University).

STATE OF WASHINGTON
DEPARTMENT OF NATURAL RESOURCES
BRIAN J. BOYLE, Commissioner of Public Lands
RALPH A. BESWICK, Supervisor

DIVISION OF GEOLOGY AND EARTH RESOURCES
VAUGHN E. LIVINGSTON, JR., State Geologist

Report of Investigations

24

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1981

For sale by the Department of Natural Resources, Olympia, WA
Price $5.00

FRONTISPIECE

Photomicrographs of Mount St. Helens ash, May 18, 1980, eruption, collected at Vantage, Washington.

These photographs reveal many facts about conditions in the Mount St. Helens magma chamber before and during the eruptive event of May 18, 1980. The presence of magnetite, hypersthene, feldspar, and quartz crystals in the ash demonstrates that crystallization was well advanced. Magnetite and hypersthene are minerals with high melting points that crystallize early in the history of a melt. Feldspar and quartz crystallize at low temperatures and represent the final stages in Bowen's Reaction Series which outlines order of mineral crystallization in a melt.

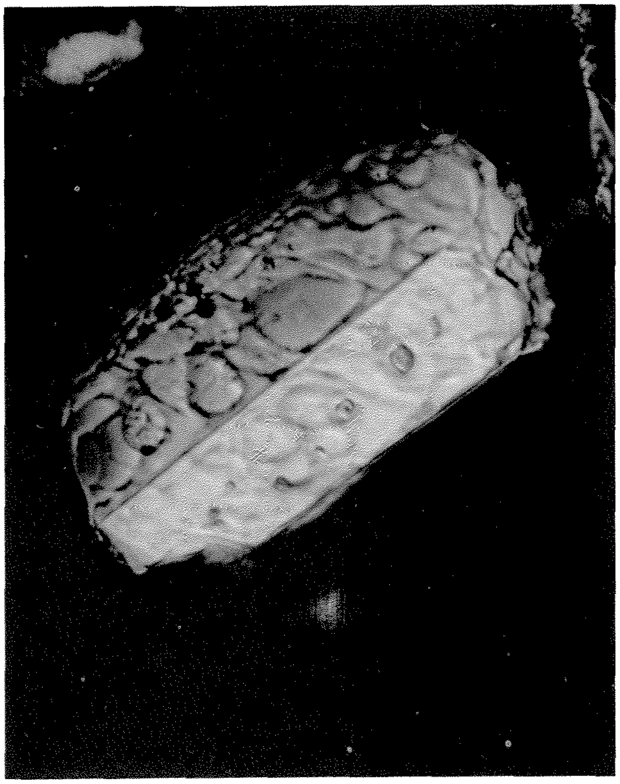
Often hypersthene and feldspar crystals are enclosed in vesicular glass jackets, also demonstrating that crystallization was in progress before they were explosively vented. The crystals were floating in liquid magma. When the magma was ejected, it cooled so rapidly that volcanic glass jackets formed around the crystals. Volcanic glass, by definition, represents average magma composition and is amorphous; that is, it has no regular internal arrangement of its atoms.

A. Plagioclase feldspar with Carlsbad twinning, enveloped in glass jacket with bubble-wall texture on surface, X 1500.

B. Plagioclase feldspar showing compositional zoning, 0.15 mm in length, X 1500.

C. Hypersthene crystal with magnetite and hypersthene inclusions, enveloped in glass jacket, 0.225 mm in length, X 1500.

D. Plagioclase feldspar showing compositional zoning, volcanic glass with microlitic magnetite inclusions, and hypersthene with crystallitic inclusions, enveloped in glass, X 1500.



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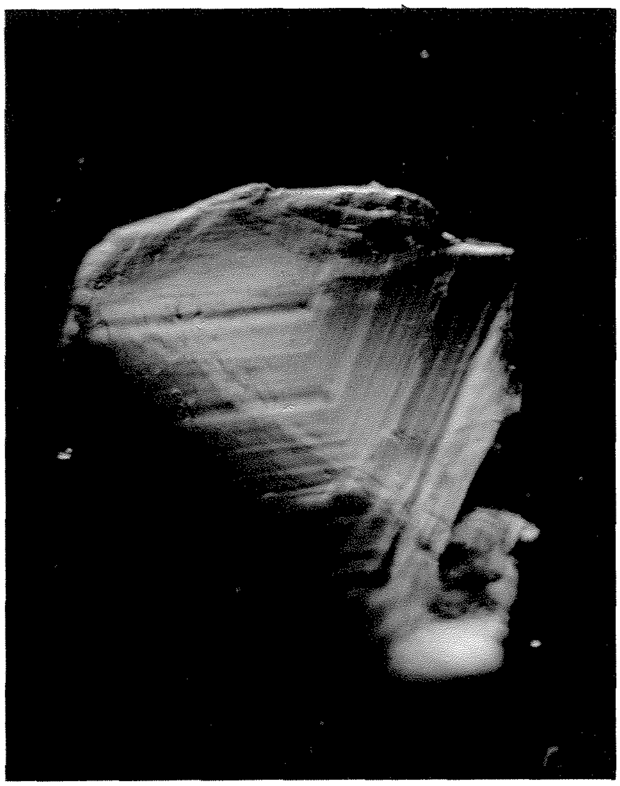

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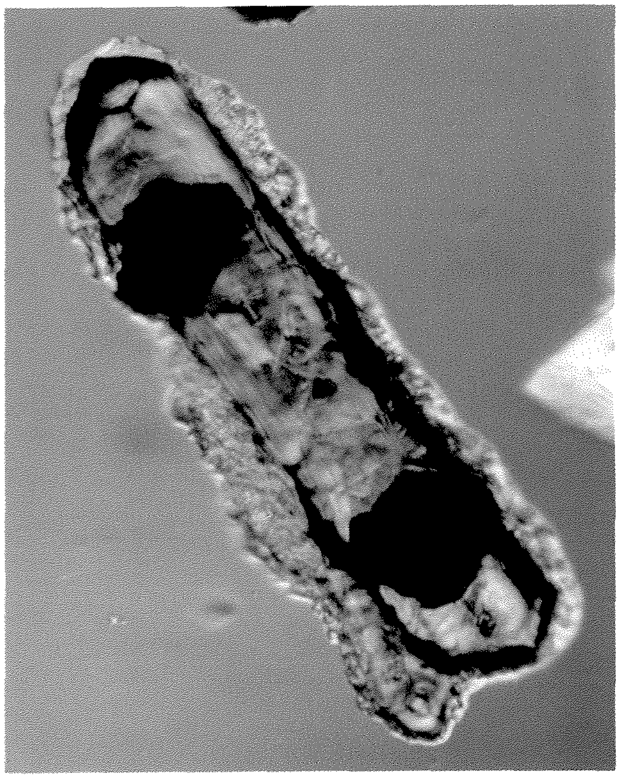

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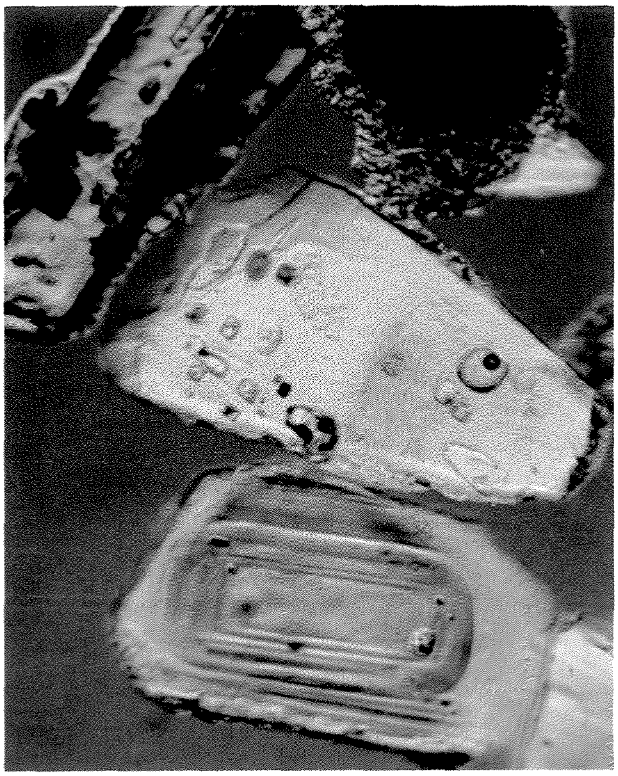

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III

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MOUNT ST. HELENS ASH—PROPERTIES AND POSSIBLE USES

By

Wayne S. Moen and Glennda B. McLucas

ABSTRACT

As a result of the May 18, 1980, eruption of Mount St. Helens, a total of about 0.33 cubic mile (195 million cubic yards) of volcanic ash fell on 49 percent of the land area of Washington State. The bulk of this ash, which in places was as much as 3 inches deep, fell mainly in Yakima, Grant, Adams, Whitman, and Spokane Counties of eastern Washington. As a result of cleanup operations in these counties, over 375,000 cubic yards of ash has been stockpiled, with the hope that it may have some use.

The ash consists chiefly of glass and plagioclase feldspar accompanied by accessory minerals such as pyroxene, amphibole, magnetite, and quartz. The ash is typically light gray and resembles portland cement in color and fineness. The bulk of eastern Washington ash falls in the 0.044 to 0.061 mm size range (325 to 250 mesh).

Several nonmetallic mineral-oriented companies have considered possible uses for the ash. These uses include: Abrasives, glass and ceramics, fillers, pozzolan, asphalt admixture, and fertilizer and insecticide carriers. Testing is in progress for a variety of these uses. To date, selling the ash as a souvenir of the eruption of Mount St. Helens has proven to be most profitable.

INTRODUCTION

On May 18, 1980, Mount St. Helens, after a dormant period of over 125 years, erupted violently sending over three-quarters of a cubic mile of volcanic ash into the atmosphere. This represented the first major eruption of a volcano in the contiguous United States since the eruption of California's Mount Lassen in 1914.

Shortly after the May 18th eruption of Mount St. Helens it was obvious that in eastern Washington vast amounts of volcanic ash had accumulated. This ash appeared to represent a new potentially valuable nonmetallic mineral resource, and within a few days individuals and mineral-oriented companies began investigating possible uses for the newly fallen ash. Although the ash covered up to 49 percent of the land area of Washington, only in about 30 percent of the state was the ash deep enough to be considered as a possible new mineral resource. Ash from 2 to 3 inches in depth covered the eastern Washington counties of Yakima, Grant, Adams, Whitman, and Spokane. Ash cleanup in these counties became a major problem and resulted in about 375,000 cubic yards of ash being stockpiled at various sites. Does this ash have any value—yes and no. To counties such as Grant and Adams, its value is negative, costing $5 to $9 per ton to remove. To enterprising souvenir merchants, who sold 1-ounce packets of ash for $1, its value is definitely positive. Investigations undertaken to date (1980) by Washington Division of Geology and Earth Resources and mineral-oriented companies indicate that the realistic value of the ash is low.

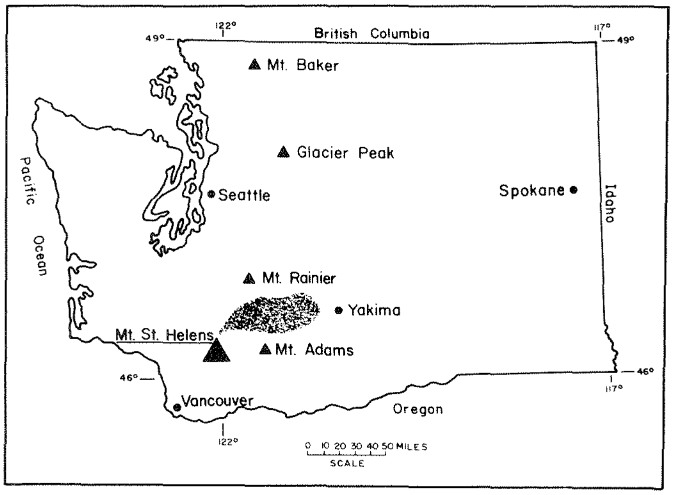

Figure 1.—Location map showing Mount St. Helens and other Quaternary volcanoes of Washington.

PURPOSE AND SCOPE

The purpose of this report is to present data accumulated to date (1980) by Washington Division of Geology and Earth Resources on ash of the May 18th eruption, with emphasis on possible uses of the ash and its availability. The section covering properties of the ash is presented with hope that investigators of possible uses of the ash will recognize certain properties which will in some manner make it valuable.

The report consists of three parts. Part I presents some physical and chemical properties of the ash; Part II reviews investigations undertaken to date to determine uses of the ash, as well as a review of these possible uses; and Part III relates to availability and limitations to use of the ash.

The writers found it impossible to include much valuable data within the main body of the report; as such, sample location data, screen analyses, and chemical analyses appear in appendices.

FIELDWORK

No more than 2 weeks of fieldwork was carried out in the preparation of this report. A total of 9 days was spent collecting ash samples throughout the state during the latter part of May. During mid-July, 5 days were spent visiting eastern Washington counties to determine the amount of ash that has been stockpiled, as well as to review ash cleanup problems with county agencies.

LABORATORY WORK

Work conducted at Washington Division of Geology and Earth Resources laboratory consisted of petrographic studies of ash samples, X-ray analyses, spectrographic analyses, screen analyses, density determinations, compaction tests, and ash acidity determinations. No chemical analyses were undertaken by the division. Photomicrographs of the ash were taken by Glennda McLucas at the laboratory science department of The Evergreen State College, Olympia, using a Coates and Welter scanning electron microscope and a Zeiss Universal Photoscope polarized-light microscope. Tests relative to uses of the ash were undertaken at the laboratories of the institutions and companies cited in the text.

ACKNOWLEDGMENTS

The writers of this report are grateful to many individuals, companies, and state and federal agencies that generously contributed much of the data used in this report. Without their help it would have been impossible to prepare this report within the allotted 30 days. Because of their help, many ash samples were obtained from areas inaccessible to the writers, and analytical data were made available which aided greatly in assessing the potential value of the ash. Special thanks are extended to the following individuals:

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U.S. Army Corps of Engineers, Seattle, Washington
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Other individuals and companies who aided in the preparation of this report are cited throughout the report and in the personal and written communications section at the end.

SUMMARY—MOUNT ST. HELENS ERUPTIONS, 1800 TO MAY 18, 1980

Mount St. Helens, prior to the 1980 eruptions, was one of the most picturesque Quaternary volcanic cones of the Cascade Mountains of Washington. Symmetrical in shape, snow covered throughout much of the year, and rising majestically 6,476 feet above Spirit Lake, it had long been a sacred mountain to Indian tribes of the region (fig. 2). Since the turn of the century it has been a prime recreation area of southwestern Washington. However, most people that visited the mountain were not aware that Mount St. Helens had been more active and more explosive during the last 4,500 years than any other volcano in the United States, excluding Alaska and Hawaii (Crandell and Mullineaux, 1978, p. 1). As recently as 1800 to the mid-1800's, Indians and early settlers of the region reported ash and steam eruptions from vents near the summit of the mountain; in one instance, lava flows and several mudflows were associated with these eruptions (Majors, 1980). From the mid-1800's up until the early 1900's, steam occasionally could be seen rising from fissures and small vents near the mountain's summit, but over the past 50 years the mountain had been relatively peaceful. On March

A. Spirit Lake, 1968 (photo by Don Miller).

B. Spirit Lake, July, 1980 (photo by Allen Fiksdal, Washington Division of Geology and Earth Resources).

Figure 2.—Mount St. Helens and Spirit Lake before and after catastrophic eruption of May 18, 1980.

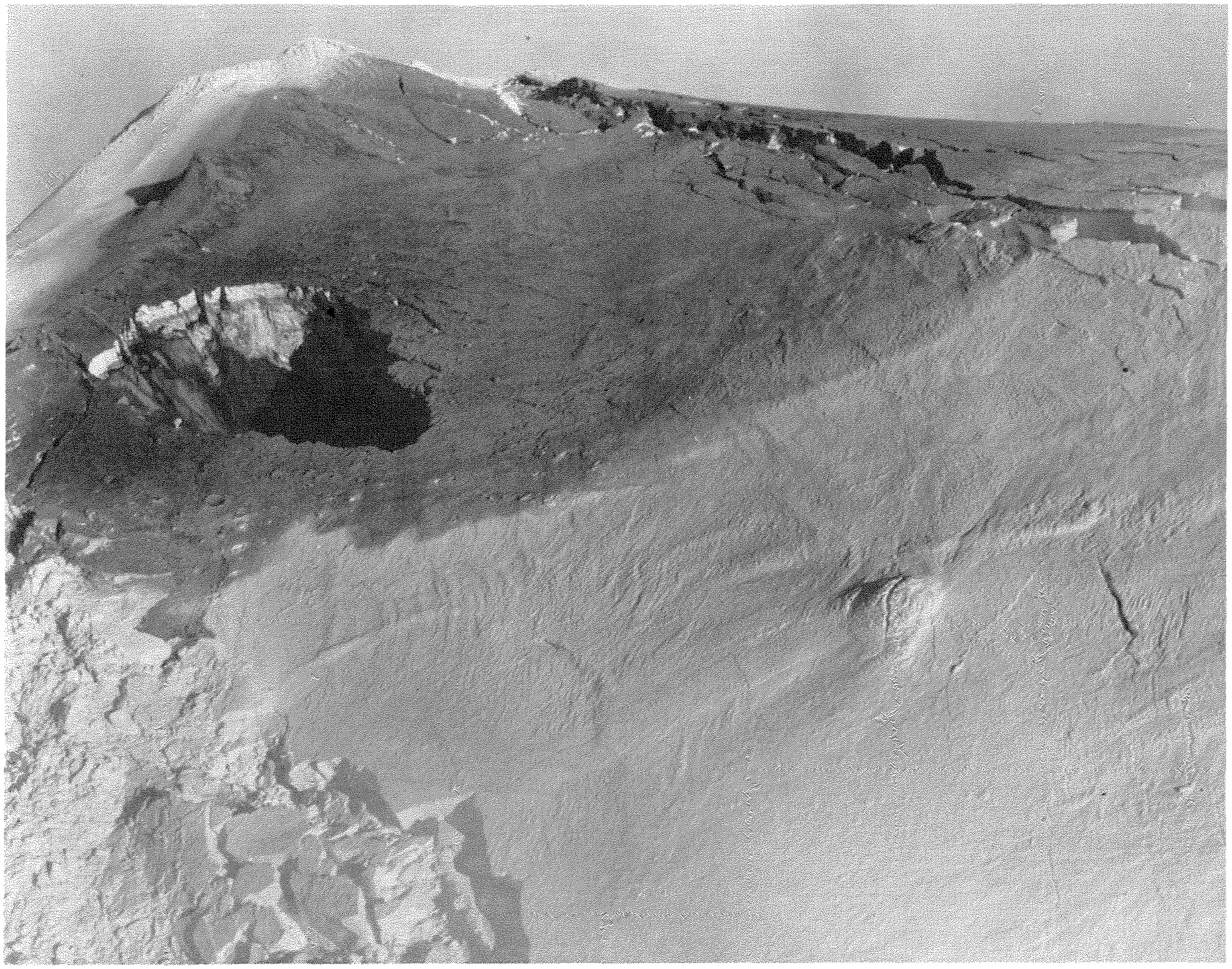


Figure 3.—Crater created by initial March 27, 1980, eruption of Mount St. Helens (photo by Jerry Thorsen, Washington Division of Geology and Earth Resources).

20th of this year the first significant seismic activity, consisting of a minor earthquake of 4.1 Richter magnitude, was recorded in the vicinity of Mount St. Helens. On March 27th, after continued seismic activity, the first eruption since the mid-1800's occurred. As a result of this eruption, steam and ash rose to elevations in excess of 16,000 feet from a newly formed vent on the north summit of the mountain (fig. 3). In weeks that followed, steam and ash eruptions became common and the snow-covered peak assumed a dark color from a cover of ash. As eruptions continued, the vent progressively grew to several thousand feet in diameter, a large bulge developed on the northern slope of the mountain, and harmonic tremors related to moving magma increased.

On Sunday May 18th at 8:32 a.m. Pacific daylight time, a gigantic landslide with a volume of 0.66 cubic mile occurred on the north slope of the mountain. This was immediately followed by a prodigious cannonlike blast to the north, and the eruption of steam and ash to around 45,000 feet into the atmosphere. At around 8:45 a.m., another major eruption sent ash and steam to elevations of 50,000 to 60,000 feet. On the north slope of the mountain, ash flows, pyroclastic flows, and mudflows slid down the mountain into Spirit Lake and valleys of the Toutle River (figs. 2 and 6). So directional was the initial blast of the eruption that occupants of a plane flying 1,000 feet over the summit of the mountain neither heard the blast nor encountered unusual air turbulence. Yet north and

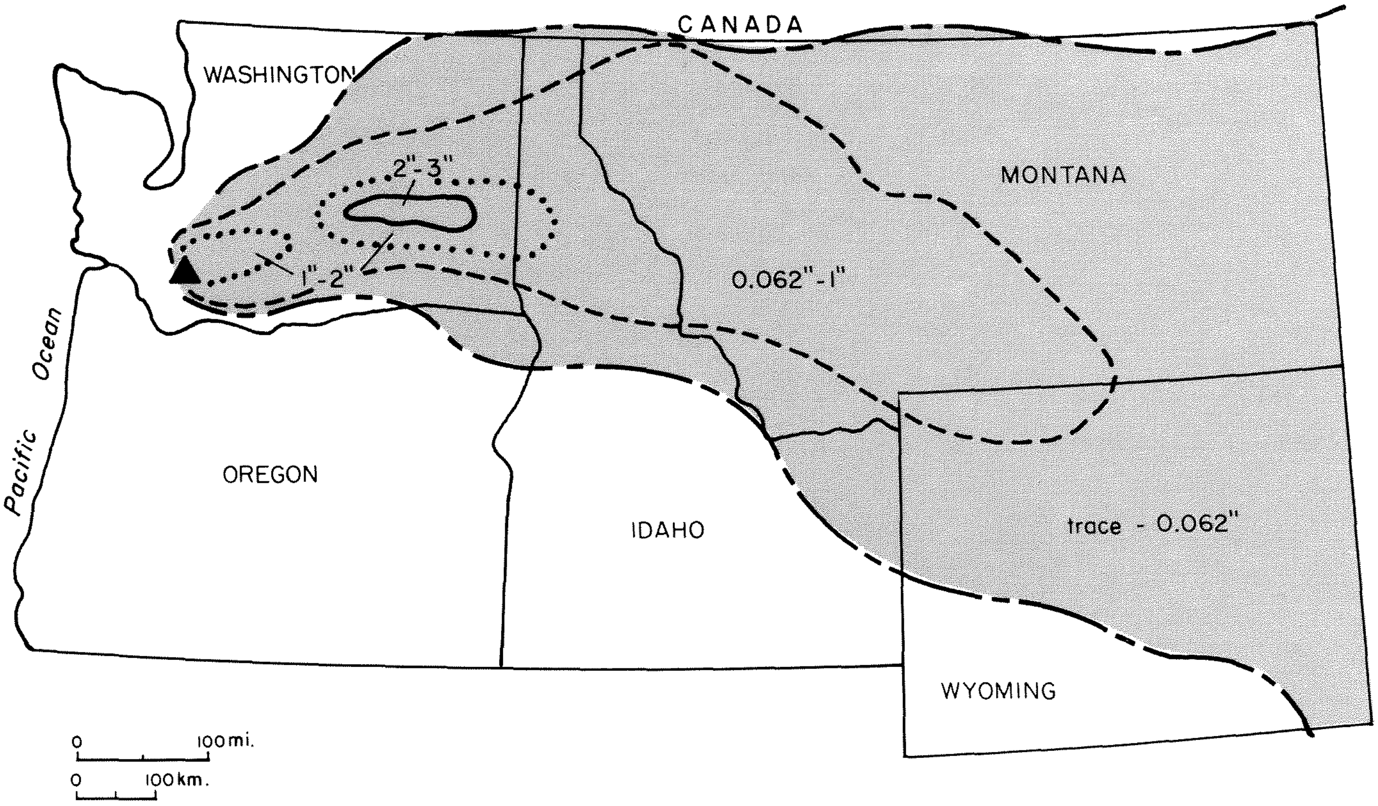


Figure 4.—Generalized Mount St. Helens ash fallout of May 18, 1980, eruption—Pacific Northwest states.

northwest of the mountain for as much as 18 miles, an area of total destruction existed, and 160 miles to the north-northwest in Victoria, B.C., the sound of the blast was heard. Within hours, the ash cloud had moved into eastern Washington; at 10 a.m. darkness descended upon Yakima; by 12:30 p.m. the ash had reached Moses Lake; and by 3:30 p.m., Spokane, which is 236 miles east of the mountain, was in darkness. By 5 p.m., the ash had traveled 400 miles east from Mount St. Helens and was falling in Missoula, Montana, as it continued its easterly route across the United States (fig. 4).

Numerous aerial surveillances on May 19th revealed the catastrophic power of the eruption; north and northwest of Mount St. Helens most trees had been ripped from the earth, stripped of their branches, and deposited like match sticks upon barren ash-covered terrain (fig. 5). For as far as 15 miles north from the mountain, trees were blown down and their foliage was destroyed; few creatures survived. At the foot of the mountain, crystal clear Spirit Lake was nothing more than a gigantic mud puddle, the surface of which was covered with thousands of delimbed trees, much of the lake having been displaced by mudflows and ash flows from the mountain (fig. 2).

Northwest and west of Mount St. Helens, valleys of the Toutle River no longer contained their beautiful stands of timber but were filled with thick accumulations of rock and mud (fig. 6).

Figure 5.—Tree blowdown 11 miles north of Mount St. Helens. Trade Dollar Lake in foreground (photo by Allen Fiksdal, Washington Division of Geology and Earth Resources).

East of Mount St. Helens, much of eastern Washington was covered by up to 3 inches of volcanic ash that resembled newly fallen snow. Travel on most roads came to a standstill, and ash cleanup became a major problem for counties that lay in the path of the ash fallout. A conservative estimate of the volume of ash that fell in Washington is one-third cubic mile (195 million cubic yards); 49 percent of the state received a trace or more of ash; and about 30 percent received one-eighth of an inch of more. Counties

A. North Fork of the Toutle River valley, August, 1968, looking southeast with Mount St. Helens in background (photo by Don Miller).

B. Debris-filled valley of North Fork of the Toutle River, July, 1980 (photo by Allen Fiksdal, Washington Division of Geology and Earth Resources).

Figure 6.—North Fork of the Toutle River before and after May 18, 1980, eruption of Mount St. Helens.

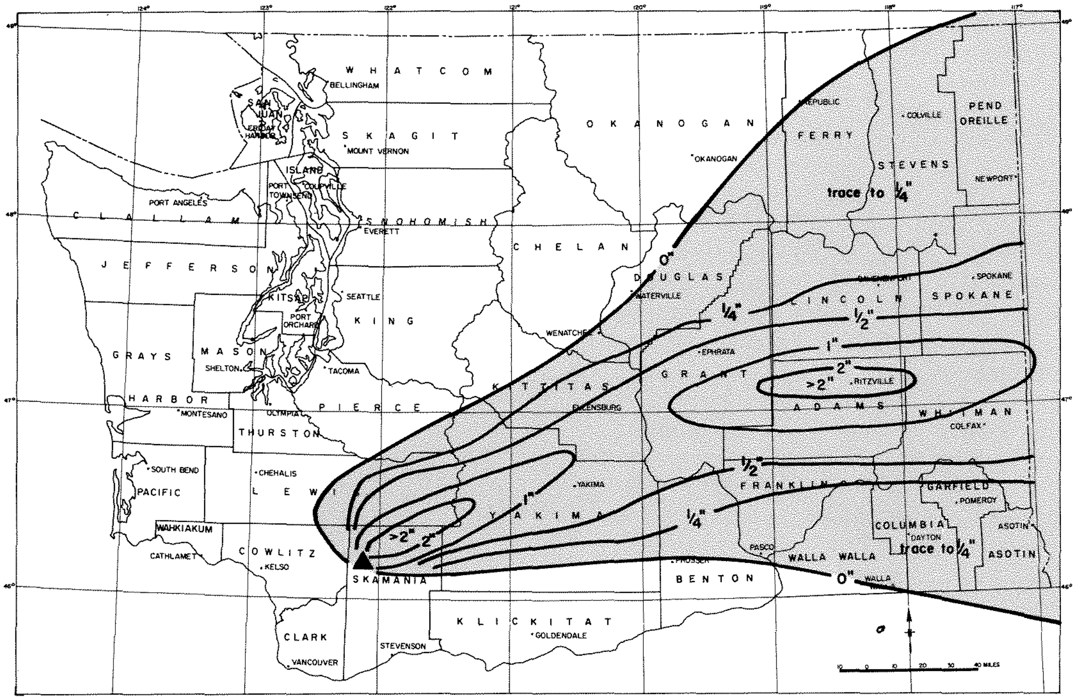


Figure 7.—Ash depths of Mount St. Helens, May 18, 1980, eruption—Washington State.

receiving the most ash were Yakima, Grant, Adams, Whitman, and Spokane. Up to three-quarters of an inch fell in Yakima; 2 to 3 inches fell in Moses Lake and Ritzville; and around one-half of an inch fell in Spokane (fig. 7). Adams County, which appears to have received most of the ash, has estimated their cleanup cost at $4.5 million, $300,000 of which was spent in the first 4 weeks. Ritzville, Adams County, estimates cleanup costs of $½ million, whereas at Moses Lake, Grant County, cleanup costs are set at $2.5 million.

PART I

PHYSICAL AND CHEMICAL PROPERTIES OF ASH FROM THE MAY 18, 1980, ERUPTION OF MOUNT ST. HELENS

By Wayne S. Moen

INTRODUCTION

Volcanic ash is defined as volcanic ejecta 4 mm or less in diameter. Although lapilli, which is ejecta 4 to 32 mm in size, fell in the vicinity of the volcano, the bulk of the ejecta that fell in Washington and other Pacific Northwest states is classified as ash. The physical and chemical properties of the ash that follow are based on 60 samples collected at widely distributed localities in Washington; all ash is from the May 18th eruption (see Appendix A). Although six other major ash eruptions have occurred since May 18th, the volume of ash from these eruptions is minor when compared to the May 18th eruption.

Volcanic ash of the May 18th eruption consists of composite ash falls composed of crystal, vitric, and lithic fractions. Volcanic glass, plagioclase feldspar, hypersthene, and magnetite predominate, and are accompanied by one or several accessory minerals. The ash is typically light-medium gray and very much resembles portland cement in color and fineness. About 90 percent of eastern Washington ash is in the .044 to .061 mm size range (325 to 250 mesh). Average properties of the ash appear in table 1.

MINERAL COMPOSITION

Ash samples examined to date by petrographic and X-ray analyses vary considerably in mineral composition. Minerals identified in order of decreasing abundance include glass, plagioclase, hypersthene, magnetite, hornblende, augite, sanidine, microcline, biotite, olivine, quartz, and cristobalite. In addition to these minerals, multimineralic particles are present in most ashes. The general range of the major constituents for eastern Washington ash is presented in table 2.

The anomalous nature of some ash is best illustrated by ash that fell 5 to 10 miles west of Vantage. In this area the ash was high in feldspar, hypersthene, and magnetite, and low in glass (see table 2, column C). This ash probably represents ash of the 8:45 a.m. eruption, which involved older andesitic rocks. The ash of the Moses Lake-Ritzville area was high in glass,

TABLE 1.-- Average properties of Mount St. Helens ash

Chemical composition (percent)

SiO_2	64	Na_2O	4.5	TiO_2	0.64
Al_2O_3	17.5	MgO	2	MnO	0.09
Fe_2O_3	5	K_2O	1.49	P_2O_5	0.18
CaO	5				

Mineral composition (percent)

Glass	75
Plagioclase feldspar	18
Multimineralic particles	5
Accessory minerals	2

Color	Acidity
Light gray	pH 5.2 to 7.2

Particle size

0.044 to 0.061 mm (325 to 250 mesh)

Density

Loose dry	0.88 g/cm^3 (55 lb/ft^3)
Compacted	1.29 g/cm^3 (80 lb/ft^3)

Compaction

Loose dry	40 percent at 10 psi 50 percent at 10,000 psi
Settled	11 percent at 10 psi 20 percent at 10,000 psi

Magnetism	Radioactivity
Slight to high	Insignificant

and low in feldspar and ferromagnesian minerals (see table 2, column B). This ash apparently represents ash of the 4:00 p.m. and later eruptions, which involved younger dacitic rocks.

Individual particles of eastern Washington ash occur as irregular glass shards containing bubble cavities, finely microcrystalline particles, tabular and semirounded particles, elongated crystals and crystal fragments, and platy fragments. Most particles contain inclusions in the form of dustlike specks, microlites, and crystallites. Bubble-wall texture and glass rinds occur on many crystal fragments (figs. 8 and 9).

Table 2.—Mineral composition of Mount St. Helens ash, May 18, 1980, eruption

	A (percent)	B (percent)	C (percent)
Glass	10 - 80	75	5
Feldspar	10 - 80	18	80
Ferromagnesian minerals	1 - 10	0.5	8
Opaque minerals	< 1 - 5	0.5	5
Multimineralic particles	5 - 20	5	2
Quartz	< 1 - 2	< 1	< 1
Miscellaneous minerals	1	1	1

A - Range of eastern Washington ash
B - Moses Lake-Ritzville ash
C - Vantage ash

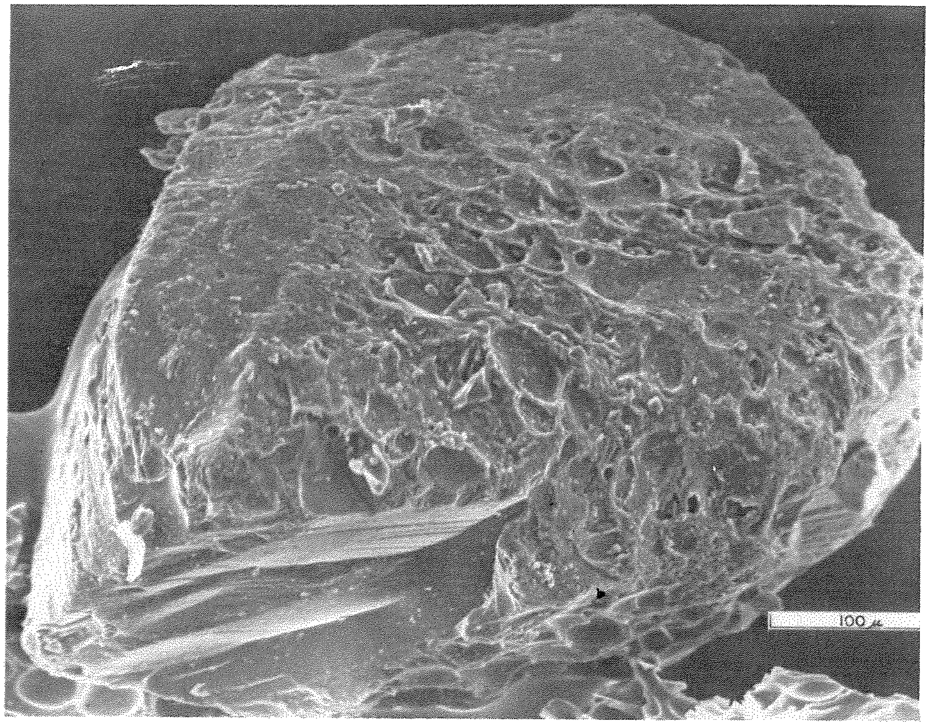
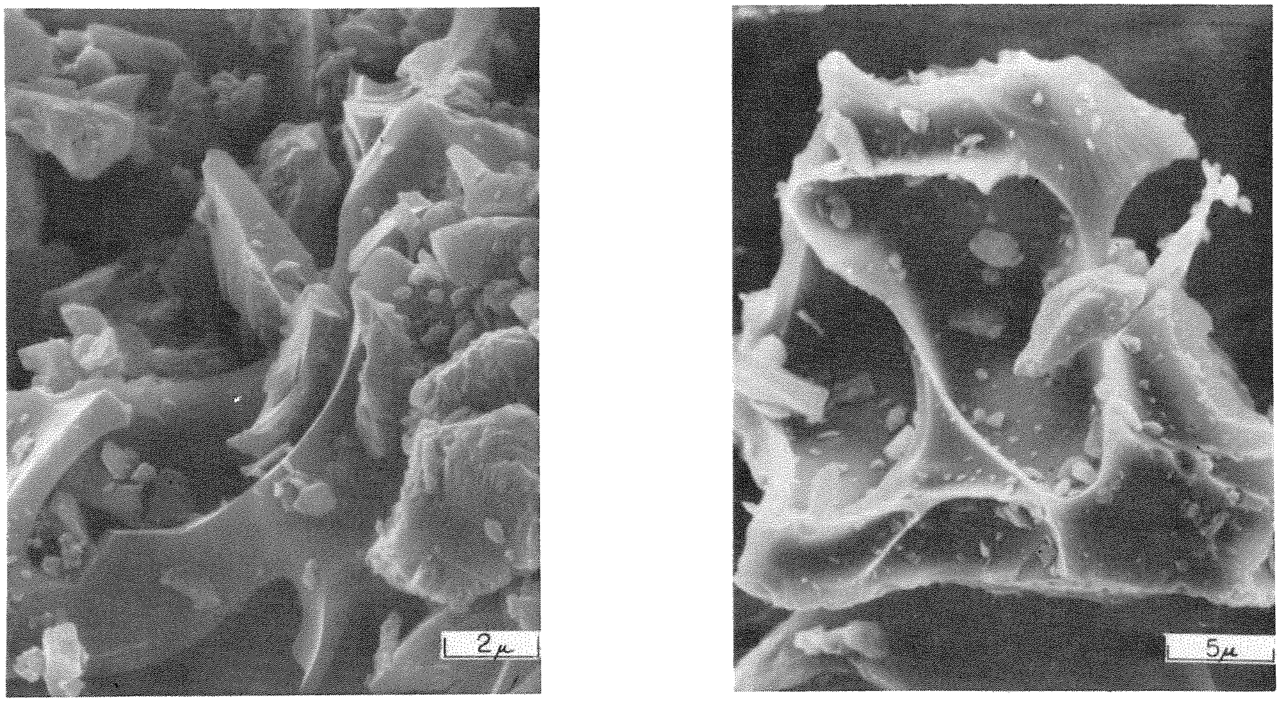
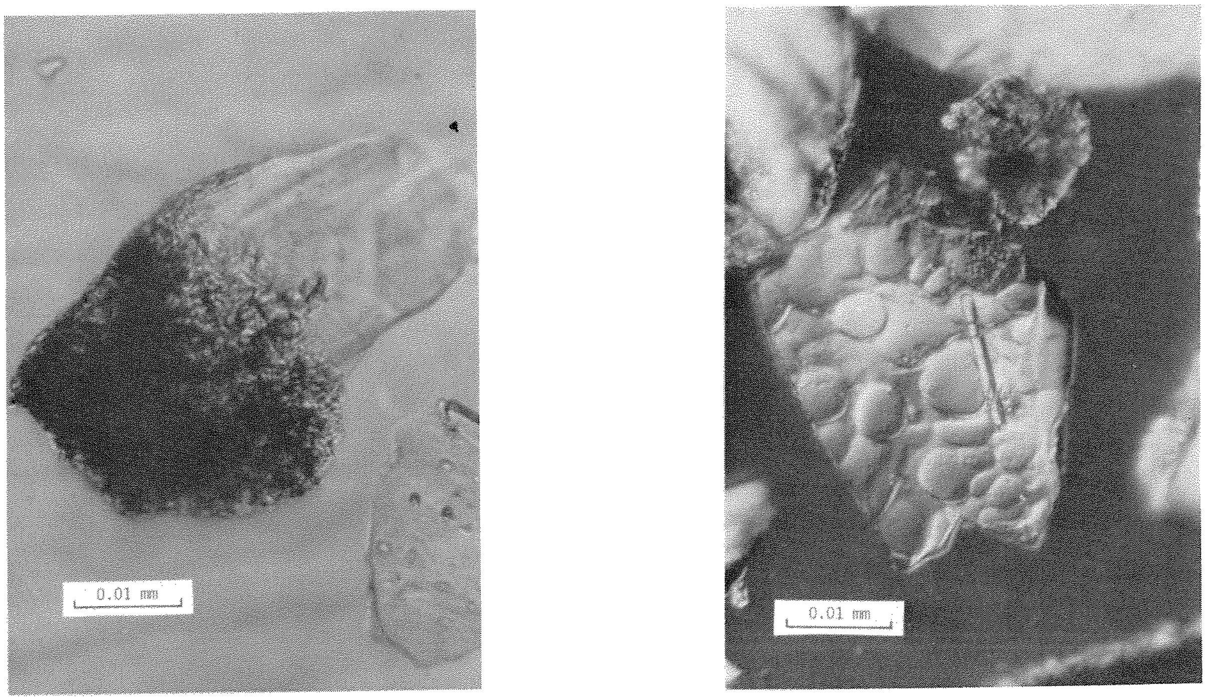


Figure 8.—Bubble-wall texture of glass rind on plagioclase feldspar crystal, X 300 (SEM photo courtesy of Dave Pevear, Western Washington University).



A. Splintery shards, X 6,900, SEM photo.

B. Vesiculated shards, X 3,200, SEM photo.



C. Dustlike inclusions of magnetite, X 1,750.

D. Feldspar crystal with glass jacket; note bubble- wall texture of glass, X 1,750.

Figure 9.—Volcanic glass of Mount St. Helens ash.

Some properties of the main constituents of the ash follow:

Glass

Most glass occurs as colorless to light-brown splintery vesiculated shards, and most always contains microlitic (dustlike) inclusions, from 1 to 5 microns in size, of plagioclase, hypersthene, and glass, as well as crystallitic and microlitic inclusions of magnetite. As one of the last constituents to solidify, it forms rinds on all other minerals of the ash (fig 9). Refractive indices of the glass range from *n* 1.502 to *n* 1.505, specific gravity averages 2.5, and hardness is in the 5 to 5.5 range. Chemical analyses of the glass show 73 to 76 percent silica, and 13.5 to 16 percent Al_2O_3 (Appendix C-3).

Feldspar

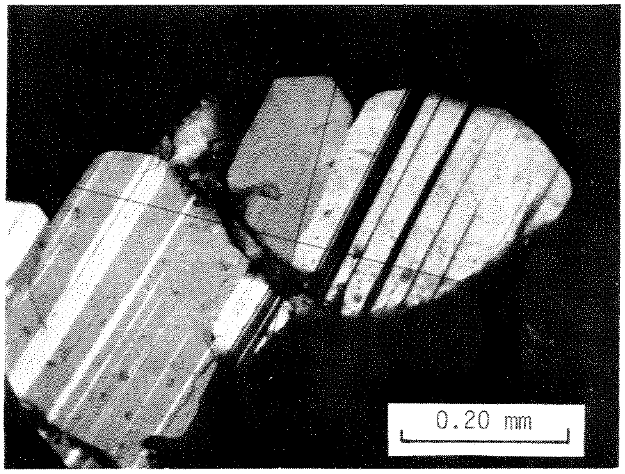
The feldspar of the ash consists almost wholly of plagioclase, ranging from andesine (An_{30}) to labradorite (An_{55}), with andesine predominating. It occurs as tabular to lathlike fragments that show Carlsbad and albite twinning, and compositional zoning (fig. 10). Many plagioclase fragments contain microlitic particles of magnetite, while others contain microlites of plagioclase and hypersthene. The orthoclase feldspars, microcline and sanidine, have been observed in several samples of ash, but in most they are absent.

Ferromagnesian Minerals

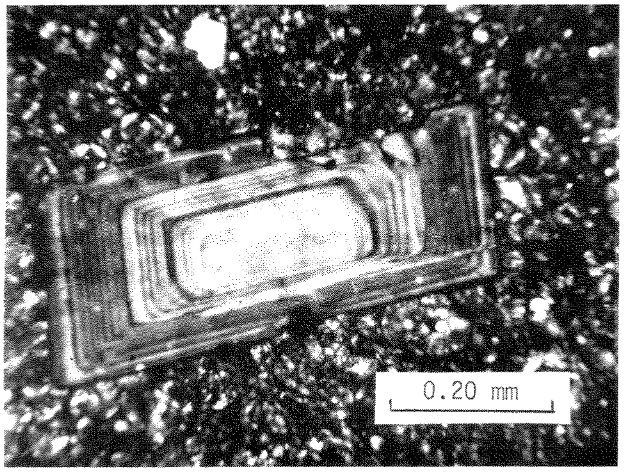
The most common ferromagnesian mineral is hypersthene, which has been noted in all ash samples. It occurs as greenish-brown crystals that almost always contain jackets of glass (fig. 11). Common inclusions in the hypersthene are microlitic hypersthene, and dustlike to crystallitic magnetite. Hornblende also is present in the ash, but only in minor amounts. Whereas up to 8 percent hypersthene is present in some ash, no more than 3 percent hornblende has been noted in ashes examined to date. It occurs as small dark-green tabular to platy particles. Because of the high iron content of the hornblende, it is classed as lamprobolite (basaltic hornblende).

Magnetite

Magnetite has been noted in all ash samples in amounts from 0.5 to 5 percent. Most commonly, it occurs as dustlike particles only several microns in diameter. However, crystals of magnetite up to 0.05 mm in diameter are present in some ash. It occurs as inclusions in all other components of the ash and comprises up to 30 percent of some plagioclase crystals and up to 60 percent of some glass particles (figs. 9 and 12). Spectrographic analyses of the magnetite shows that it is always titaniferous.



A. Polysynthetic twinning, X 90-crossed nicols.



B. Compositional zoning, X 90-crossed nicols.

Figure 10.—Plagioclase feldspar crystals.

Multimineralic Particles

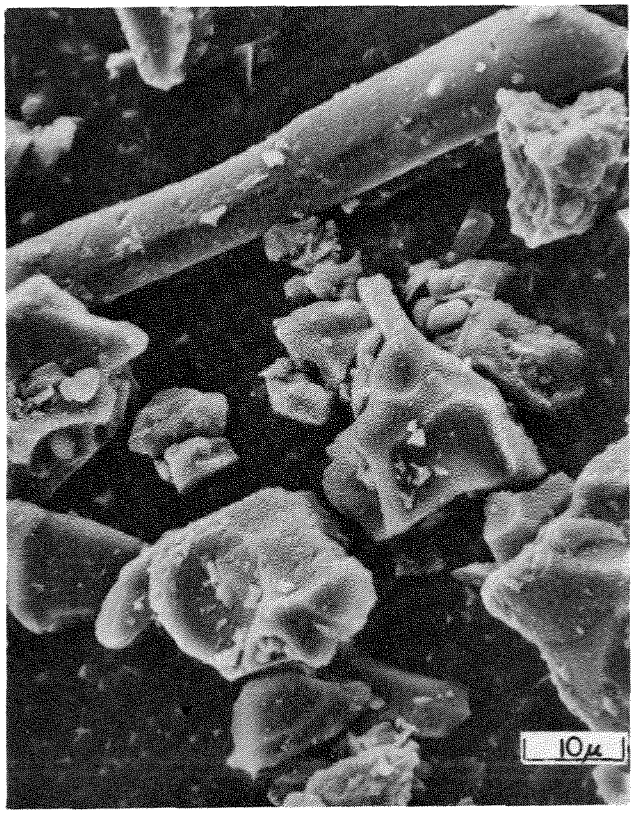
Multimineralic particles consist chiefly of glass fragments containing inclusions of plagioclase, ferromagnesian minerals, and magnetite (fig. 12). Most particles are irregular in shape or finely microcrystalline. The largest multimineralic particles exhibit trachytic texture consisting of microlitic crystals of plagioclase in parallel or subparallel arrangement.

Quartz

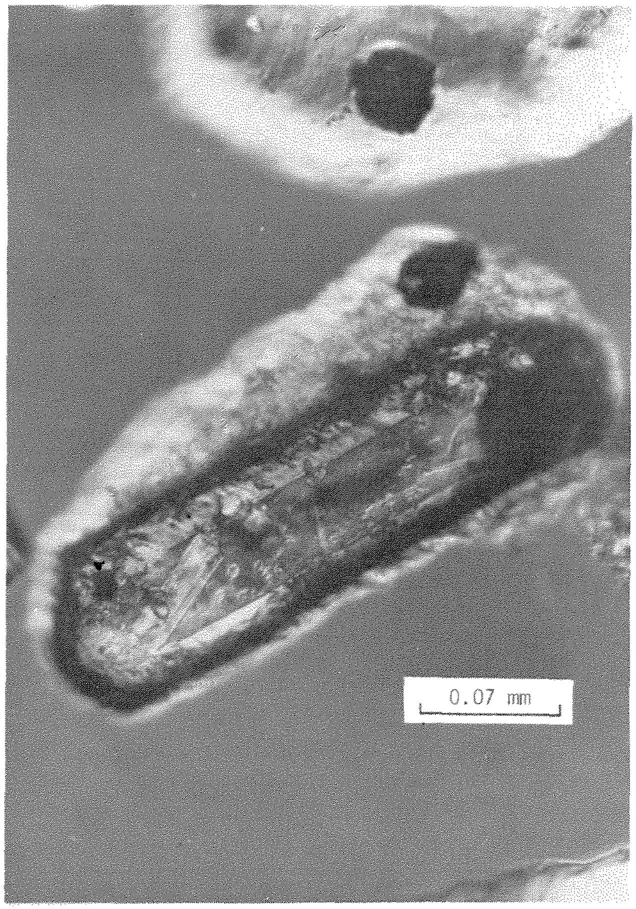
Although up to 5 percent quartz is present in some ash, the average is close to 1 percent. The quartz occurs as clear crystal fragments containing only minor inclusions. Some fragments as large as 0.25 mm in diameter are present, but the bulk of the quartz fragments is less than 5 microns in diameter. Because of the minute size of most quartz fragments, they are seldom visible under the petrographic microscope, and rarely detectable by X-ray analyses.

PARTICLE SIZE

The average ash particle is in the 0.044 to 0.061 mm (325 to 250 mesh) range (see Appendix B for screen analyses of ash). Particles as coarse as 0.25 mm (60 mesh) fell at Ahtanum, which is several miles west of Yakima, and most ash of eastern Washington contains around 2 percent of particles that are less than 5 microns in size; particles less than 1 micron have been measured with scanning electron microscopes. Particle size distribution is best illustrated by ash that fell along an easterly transect from Mount St. Helens to Lookout Pass on the Idaho-Montana border, 90 miles east of Spokane (fig. 13). This transect is about 340 miles in length and roughly parallels the easterly trending axis of the major ash fall of the May 18th eruption. At Ahtanum, the average particle size is 0.25 mm (60 mesh); at Moses Lake, which is 100 miles farther east, the average particle size is 0.061 mm (250 mesh); at Cheney and Spokane, about 236 miles from the volcano, the average size is also 0.061 mm (250 mesh); at Lookout Pass the ash averaged 0.044 mm (325 mesh). As can be seen in figure 14, particle size along the transect decreases moderately from Ahtanum to Moses Lake; from Moses Lake to the

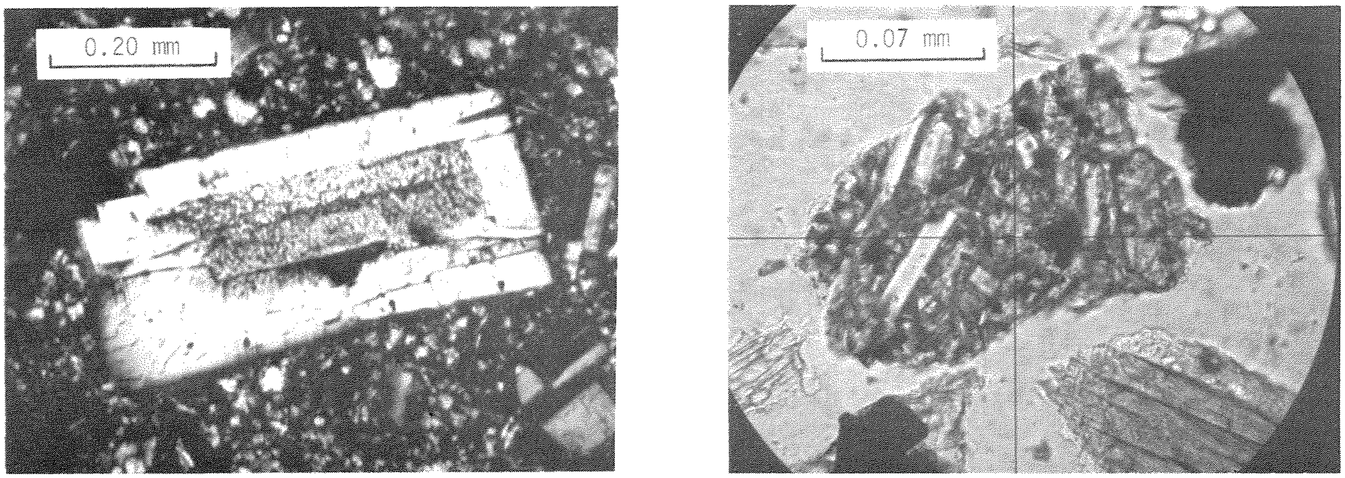


A. Elongated hypersthene crystal (0.07 mm in length) among glass shards, X 1,380, SEM photo.



B. Tabular hypersthene crystal (0.38 mm in length) with inclusions and glass rind, X 280-plain light.

Figure 11.—Hypersthene crystals.



A. Andesine showing dustlike inclusions of magnetite and glass, X 90-crossed nicols.

B. Multimineralic particle consisting of glass, plagioclase, hypersthene, and magnetite, X 280-plain light.

Figure 12.—Plagioclase and multimineralic particle.

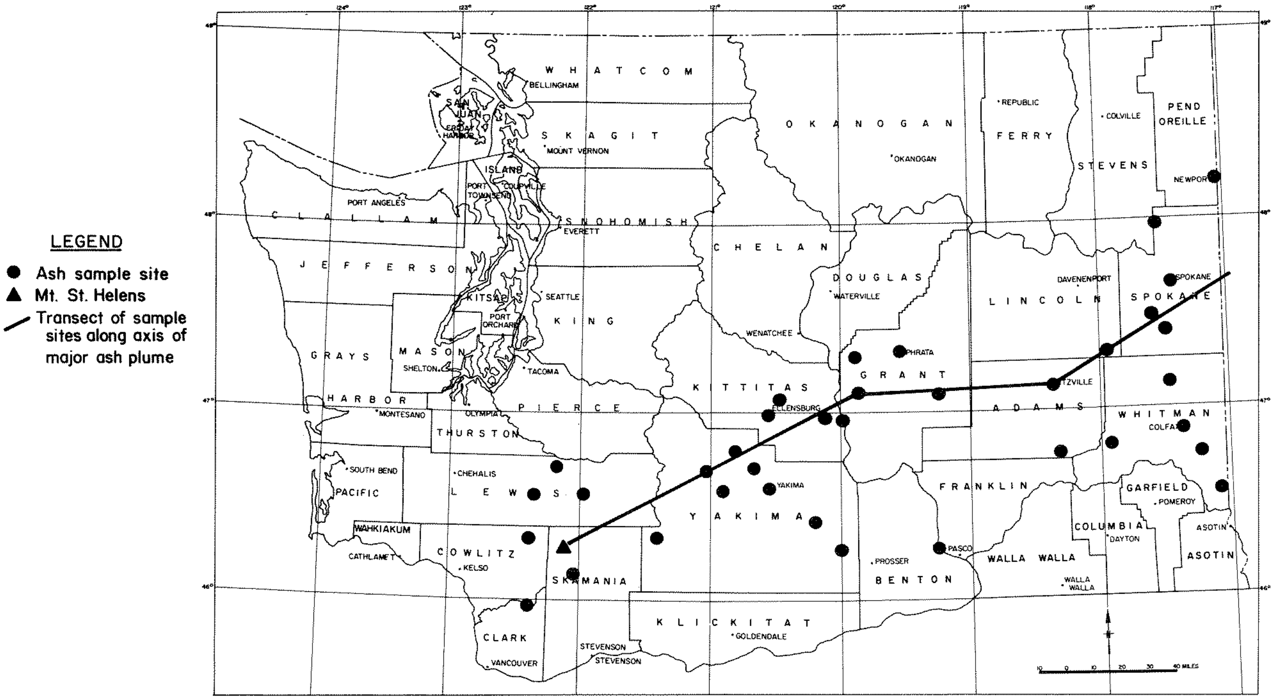


Figure 13.—Ash sample sites of Mount St. Helens ash—May 18, 1980, eruption.

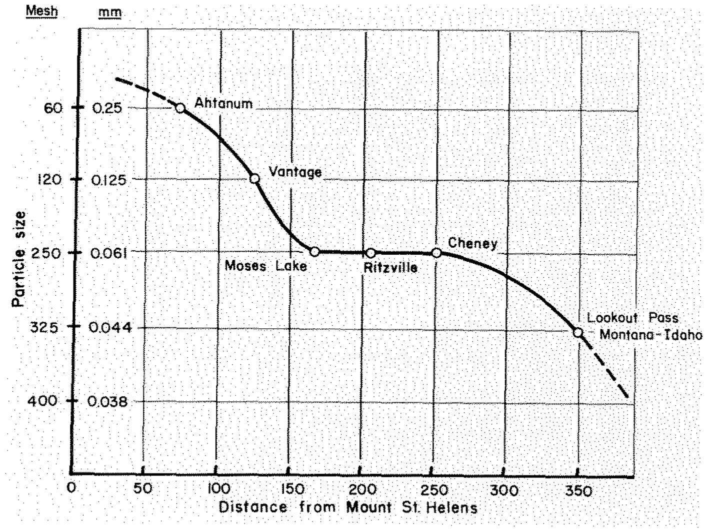


Figure 14.—Average ash particle size along Mount St. Helens—Lookout Pass transect.

Cheney-Spokane area the average particle size remains about the same; and from Spokane eastward to the Montana-Idaho border decreased gradually in size. Particle size distribution curves (fig. 15) of ash samples collected along the transect show normal curves with decreasing particle sizes as distances increase from Mount St. Helens, which one would expect from normal gravitational settling of coarse dense particles near their source. However, in several areas along the transect such as west Vantage, 125 miles from the mountain, and at Wallace, Idaho, 350 miles from the mountain, higher than expected amounts of coarse ash fell. This suggests that, rather than by normal air currents, some ash particles may have been transported by a sustained thermal plume to account for areas of coarse ash at great distances from the volcano. Other factors that appear to be related to variation in particle size are (1) turbulent air currents, and (2) rafting of coarse fragments by fine ash particle clusters (Ronald Sorem, personal communication).

COLOR

The color of the ash ranges from very light to medium gray (fig. 16). Its brightness ranges from 77 (Ritzville ash) to 40 (Vantage ash).[1] Its Munsell color range is from 10YR 5/1 medium gray (Vantage ash) to 10YR 8/1 light gray (Ritzville ash). Variations in the color of the ash are caused mainly by different amounts of black magnetite and dark-green to black hypersthene and hornblende. Ash with high glass-feldspar contents tends to be light gray, whereas ash containing up to 10 percent combined magnetite and

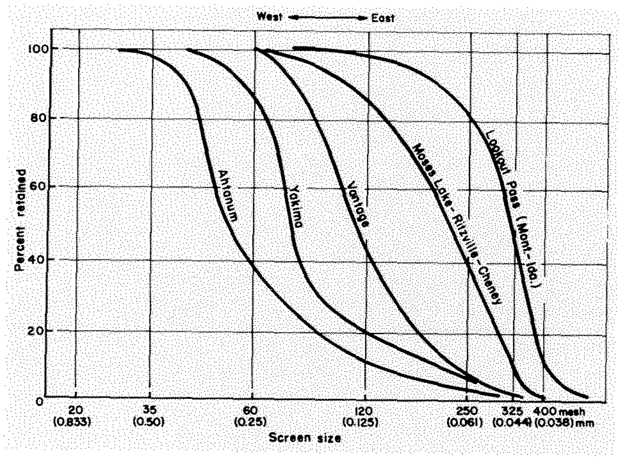
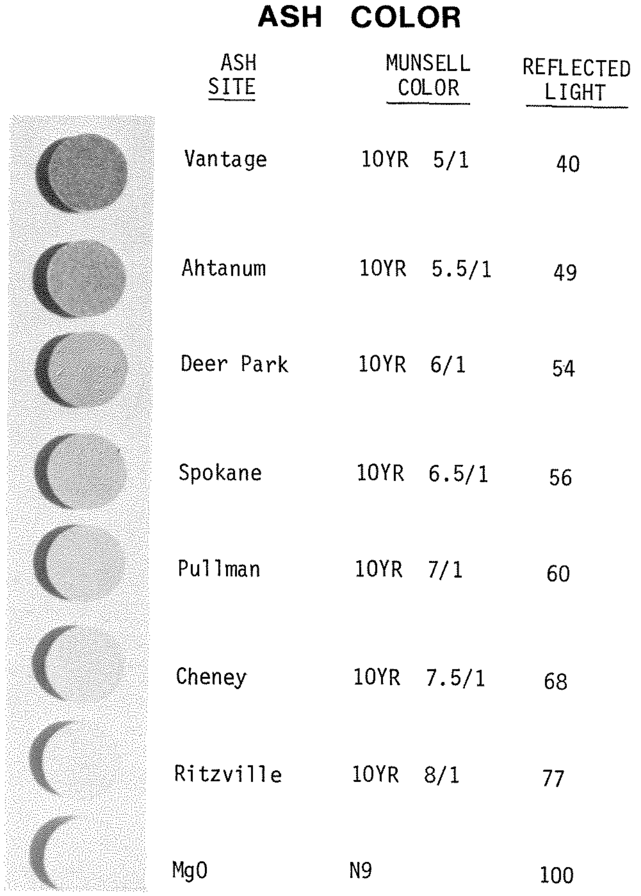


Figure 15.—Particle size distribution curves along Mount St. Helens—Lookout Pass transect.



ASH COLOR

ASH SITE	MUNSELL COLOR	REFLECTED LIGHT
Vantage	10YR 5/1	40
Ahtanum	10YR 5.5/1	49
Deer Park	10YR 6/1	54
Spokane	10YR 6.5/1	56
Pullman	10YR 7/1	60
Cheney	10YR 7.5/1	68
Ritzville	10YR 8/1	77
MgO	N9	100

Figure 16.—Color of selected ash samples.

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[1] Brightness (numerical value of reflectance to light, relative to MgO at 100 percent).

Table 3.—Weight percentages of major oxides in Mount St. Helens ash, May 18, 1980, eruption

	A	B	C	D	E	F	G
SiO_2	63.30	68.20	67.20	63.96	64.30	63.16	67.40
Al_2O_3	17.40	17.20	16.30	17.55	18.20	18.22	17.08
Fe_2O_3	5.59	4.22	3.76	4.79	4.20	4.69	4.79
CaO	5.74	4.77	4.20	4.92	4.80	5.24	3.27
Na_2O	4.49	4.42	4.52	4.62	4.80	4.06	4.21
MgO	2.80	1.61	1.48	2.08	2.00	2.30	1.16
K_2O	1.25	1.60	1.66	1.49	1.45	1.16	1.67
TiO_2	0.83	0.63	0.58	0.64	0.60	0.18	---
P_2O_5	0.33	0.37	0.37	0.18	---	0.14	0.18
MnO	0.092	0.067	0.064	0.090	---	Tr	Tr

A - Yakima ash (Fruchter and others, 1980, p. 1117).
B - Spokane ash (Fruchter and others, 1980, p. 1117).
C - Missoula ash (Fruchter and others, 1980, p. 1117).
D - Average of 25 samples in Washington.
E - Mount St. Helens pumice (Wozniak and others, 1980, p. 130).
F - Mount St. Helens hypersthene andesite (Verhoogen, 1937, p. 293).
G - Mount St. Helens dacite (Verhoogen, 1937, p. 293).

ferromagnesian minerals tends to be medium gray. Also coarse ash tends to be darker than fine ash. In general, the ash tends to be lighter in color the farther it is from Mount St. Helens. Ash that fell on the white snow of the mountain appears dark gray, whereas ash on the fields of eastern Washington appeared almost snow white.

CHEMICAL PROPERTIES

To date, numerous chemical analyses have been run on Mount St. Helens ash from many sites throughout the Northwest. Analyses show that the chemical composition of the ash is not much different than the chemical composition of ashes from past eruptions of the volcano. For comparison purposes, the composition of several ashes along the Mount St. Helens-Lookout Pass transect are presented in table 3. Also shown is the average of 25 samples at widely distributed sites in the Northwest, and analyses of pumice, dacite, and andesite from Mount St. Helens prior to the May 18th eruption. These analyses, and others, show a fairly stable SiO_2 and Al_2O_3 content across the state, but a progressive decrease in Fe_2O_3, TiO_2, and MgO as distance from the mountain increases. Small amounts of magnetite and ferromagnesian minerals at sites greater distances from the mountain accounts for the decrease in iron, titanium, and magnesium oxides. Based on norm calculations the chemical composition of the ash corresponds to rocks of dacitic composition.

In addition to analyses of common oxides in the ash, several samples have been analyzed for as many as 20 trace elements. Analyses of 10 common trace elements are shown in table 4. Also shown for comparison are element analyses for an andesitic rock, and analyses of certain elements for ashes of six eruptions of Mount St. Helens. As can be seen in table 4, concentrations of chromium, cobalt, and arsenic are slightly greater than that of an average andesitic rock. Because of high tourmaline contents of rocks in the vicinity of Mount St. Helens, boron is higher than average. Although the area, 7 to 12 miles north-northeast of St. Helens contains significant copper mineralization, the copper content of the ash is lower than that of an average andesitic rock. Trace element analyses of ash from six eruptions occurring from March 27 to August 7, 1980 (table 4 and figs. 17, 18, and 19) reveal only slight differences, with the exception of the July 22 eruption. Ash from this eruption showed zinc concentrations of around 10 times that of the other eruptions, whereas lead concentrations are up to 30 times as great as other eruptions. A slight increase in fluorine, antimony, and molybdenum also occurred in the July 22 eruption.

TABLE 4.-- Trace element concentrations of Mount St. Helens ash, 1980, eruptions (ppm)[1]

	A	B
Zn	57	84
Cu	36	60
B	30	5
Co	19	14
Cr	17	12
Ni	15	18
Pb	9	35
Mo	3	2
As	2	0.8
Hg	0.0097	0.015

A - Average of eight ashes, May 18th eruption (Fruchter and others, 1980, p. 1117)

B - Average andesitic rock (Fruchter and others, 1980, p. 1117)

	C	D	E	F	G	H
Cu	32	40	2	34	44	32
Pb	4	4	2	2	62	18
Zn	70	62	58	56	950	52
Mo	6	4	6	5	13	3
Cr	9	7	11	13	12	5
As	1	1	1	1	1	1
Sb	0.1	0.1	0.2	0.1	0.4	0.4
Fl	90	150	170	115	230	135

Ash Eruptions[2]

C - March 27
D - May 18
E - May 25
F - June 12
G - July 22
H - August 7

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[1] See appendix D for complete trace element analyses.

[2] Washington Division of Geology and Earth Resources samples, analyzed by Chemex Labs Ltd.

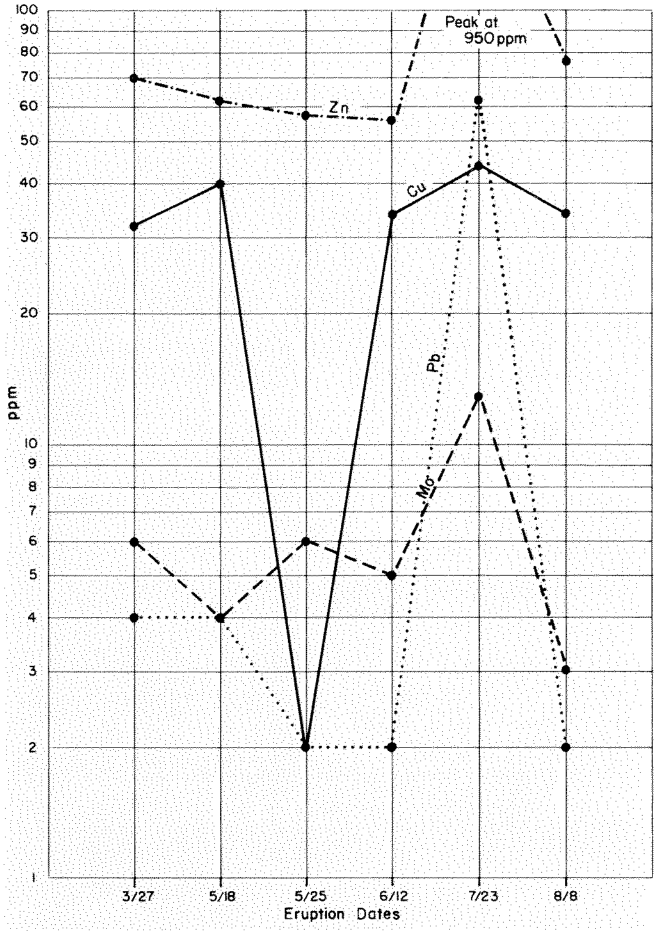


Figure 17.—Heavy metals content of ash from March 27 through August 8, 1980, eruptions.

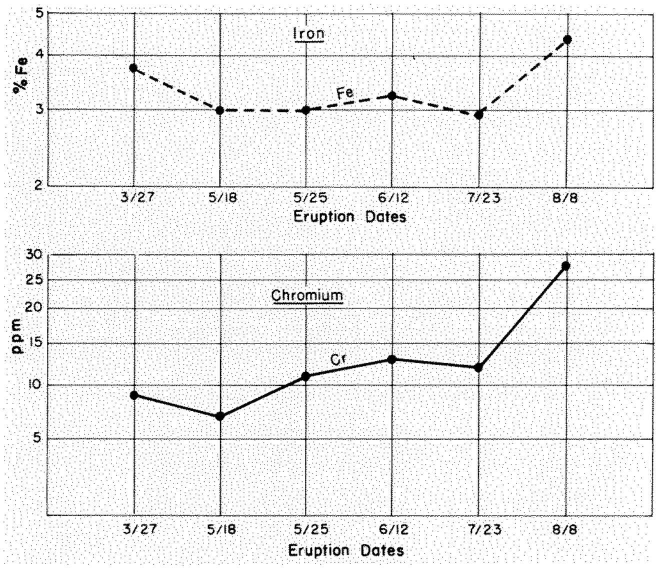


Figure 18.—Iron-chrome content of ash from March 27 through August 8, 1980, eruptions.

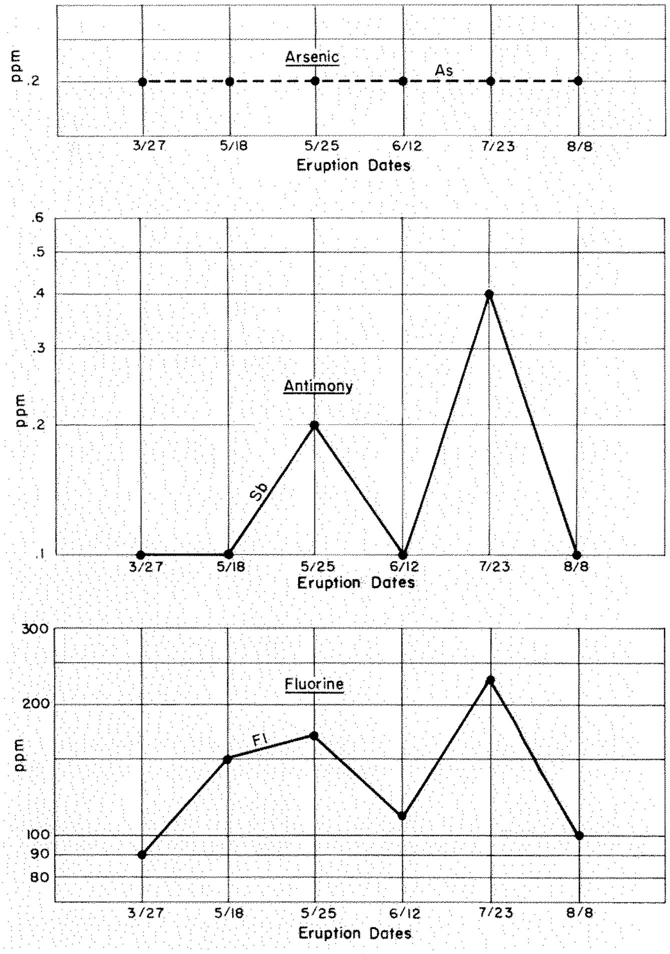
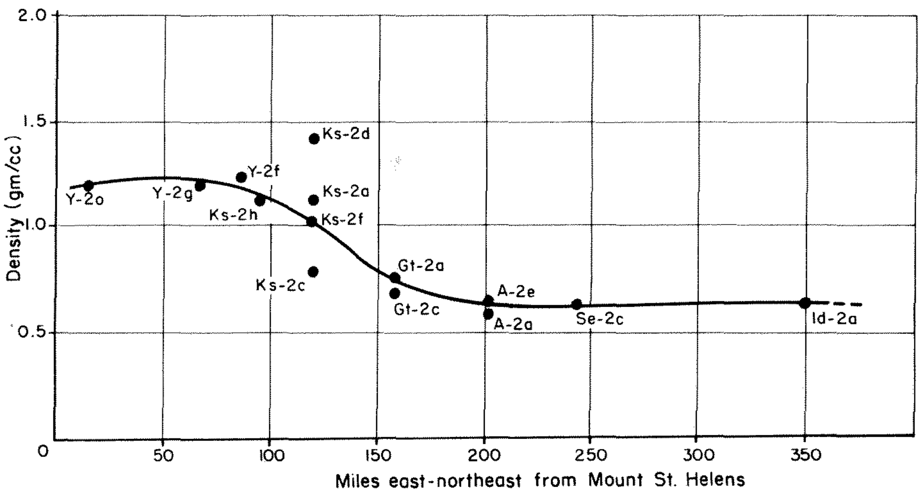


Figure 19.—Arsenic, antimony, and fluorine content of ash from March 27 through August 8, 1980, eruptions.

DENSITY

The density of Mount St. Helens ash of the May 18th eruption is quite variable and is related to the mineral composition of the ash. Dark ash, because of the presence of heavy minerals, such as magnetite, hypersthene, and hornblende, tends to be the most dense. Ash, which is low in these minerals but high in glass and feldspar, is the least dense. Dry unsettled ash in the 250-mesh range has densities of 0.62 to 0.90 g/cc. The density of compacted dry ash ranges from 1.2 to 2.55 g/cc. Water saturated ash (250 mesh) has an average density of 1.78 g/cc.

As can be seen in figure 20, the density of ash decreases as distances from Mount St. Helens increase, which is due mainly to fallout of the denser particles of the ash. In general, dry unsettled ash with densities of 1.10 to 1.22 g/cc fell within 100 miles of the mountain; 100 to 175 miles from the mountain the



Location	Sample no.	Density [1]	Miles from Mount St. Helens
Mount Adams	Y-2o	1.20	38
Ahtanum	Y-2g	1.20	66
Yakima	Y-2f	1.22	85
Ellensburg	Ks-2h	1.10	95
Ryegrass	Ks-2f	1.02	110
Vantage	Ks-2d	1.42	115
Vantage	Ks-2a	1.23	120
Vantage	Ks-2c	0.78	125
Moses Lake	Gt-2a	0.75	158
Moses Lake	Gt-2c	0.66	158
Ritzville	A-2a	0.57	202
Ritzville	A-2e	0.64	202
Cheney	Se-2c	0.62	244
Lookout Pass	Id-2a	0.63	340

[1] Densities are of dry unsettled ash along an east-northeast transect (see fig. 13) from Mount St. Helens to Lookout Pass, Idaho.

Figure 20.—Density of Mount St. Helens ash—May 18, 1980, eruption.

density of the ash ranged from 0.75 to 1.23 g/cc; and from 200 to 350 miles the density of the ash was in the 0.57 to 0.64 g/cc range.

SOLUBILITY AND ACIDITY

The average ash contains around 0.25 percent water-soluble salts, mainly as sulfates and chlorides in the form of sodium salts (Nellis and others, 1980, p. 14). The remainder of the water solubles are weakly conductive silicates and small amounts of fluorides and nitrates. The average concentrations of water-soluble salts in eastern Washington ash, as reported by Fruchter and others (1980, p. 1119), appear in table 5.

Fruchter and others (1980, p. 1119, table 5) also report on water-soluble and total concentrations of minor and trace elements of the ash. Several of the elements appear in table 6.

Water becomes slightly acidic when it comes in contact with the ash. On initial exposure to distilled water, pH values are slightly acidic, but approach neutral within a few hours (table 7). The acidity of water that has been in contact with ash is about the same or slightly less than that of rain or snow. Ranges of acidity of water leachates of many samples tested to date are from 5.2 to 7.2, the average being 6.5.

TABLE 5.-- Concentrations of water-soluble salts of 1980 Mount St. Helens ash (values in parts per million (ppm), by ion chromatography)

Salts	A[1]	B[2]
F^-	0.61	1.8
Cl^-	25	75
NO_3	1.7	--
SO_4	73	240
NH_4	0.59	--
PO_3	--	<1
Na_2	--	22

[1] Average for seven eastern Washington ashes (Fruchter and others, 1980, p. 1119, table 5).

[2] Richland ash (Taggert and Wahlberg, written communication).

TABLE 6.-- Water soluble and total concentrations of trace elements in 1980 Mount St. Helens ash (average of nine samples)

Element	Water soluble (ppm)[1]	Total (ppm)
Arsenic	0.3	2-3
Cadmium	0.01	3
Chromium	0.004	17
Copper	0.012	36
Manganese	0.57	770
Nickel	0.018	15
Lead	0.03	9
Zinc	0.098	53

[1] 10:1 mixture of distilled water and ash.

TABLE 7.-- Acidity of Mount St. Helens ash, May 18, 1980, eruption

Location	Acidity[1]
Cougar	5.5 - 6.5
Ahtanum	5.75 - 6.75
Yakima	5.8 - 6.45
Vantage	5.6 - 6.8
Ellensburg	5.5 - 6.5
Moses Lake	5.4 - 6.3
Ritzville	5.4 - 6.25
Cheney	6.45 - 6.55

[1] 1:1 mixture by weight of distilled water (pH 6.0) and ash; first figure represents initial pH, second figure represents pH after 24 hours.

CONDUCTIVITY

Power failures brought about by the coating of ash on high voltage insulators has resulted in testing of ash for its conductivity. Nellis and others (1980, p. 12) report that the ash is about 5 to 10 times more conductive than dirt from the Yakima Valley. Generally, the finer the ash, the more conductive it is. This is because smaller particles have more surface area per unit volume and can carry more volatiles than larger particles. The conductivity component of the ash, which influences flashover voltage on surfaces of insulators, is related to the equivalent salt deposit density (ESDD). The ESDD and equivalent salt for several ashes of the May 18th eruption is reported by Nellis and others (1980, p. 11, Table III).

MAGNETIC PROPERTIES

The presence of 1 to 5 percent by weight of magnetite makes much of the ash magnetic. The magnetite occurs as dustlike grains in the different

TABLE 8.-- Equivalent salt concentrations of 1980 Mount St. Helens ash

Location	Distance from Mount St. Helens	Equivalent salt (mg/100ml)	ESDD[1] (mg/cm^2)
Mount Adams	11 miles E	164	0.49
Silver Creek	43 " N	350	1.05
Yakima	84 " ENE	93	0.28
Sunnyside	106 " E	189	0.57
Midway	119 " ENE	132	0.40
Spokane	241 " ENE	127	0.38

[1] Equivalent salt deposit density.

minerals that comprise the ash (figs. 9 and 12), and very little of the magnetic fraction of the ash consists entirely of magnetite. In the case of Vantage ash, 12 percent of the particles by weight are strongly magnetic and can be separated by means of a common magnet. About 11 percent of this ash is weakly magnetic and can be extracted by magnetic separators, such as the Franz. Very fine-grained particles of magnetite are noted to collect on magnetic components of equipment, and in some cases, has caused electrical equipment to malfunction.

ABRASIVENESS

The presence of magnetite, feldspar, and ferromagnesian minerals, which have hardnesses ranging from 5 to 6.5 on Mohs scale of hardness, make the ash moderately abrasive. It readily scratches material such as paint, plastic, glass, and iron, and has proved to shorten the lifetime of bearings in many types of equipment that has come in contact with the ash.

ABSORPTION AND COMPACTION

The absorptive properties of the ash have yet to be fully investigated. Some ash has the ability to absorb up to 30 percent of its weight in water. Compaction tests reveal that loose dry ash in the 250-mesh range will compact to around 40 percent of its original thickness under only 10 psi; at 1,000 psi the ash will compact to about 50 percent; and at 10,000 psi it will compact to almost 60 percent. Compaction curves of several ashes appear in figures 21 and 22.

RADIOACTIVITY

Radioactivity has been detected in the ash but is no more than exists in average crustal rocks. To date, chemical analyses have not shown the presence of U_3O_8, and radioactive properties of the ash are not generally detectable by radiation detection instru-

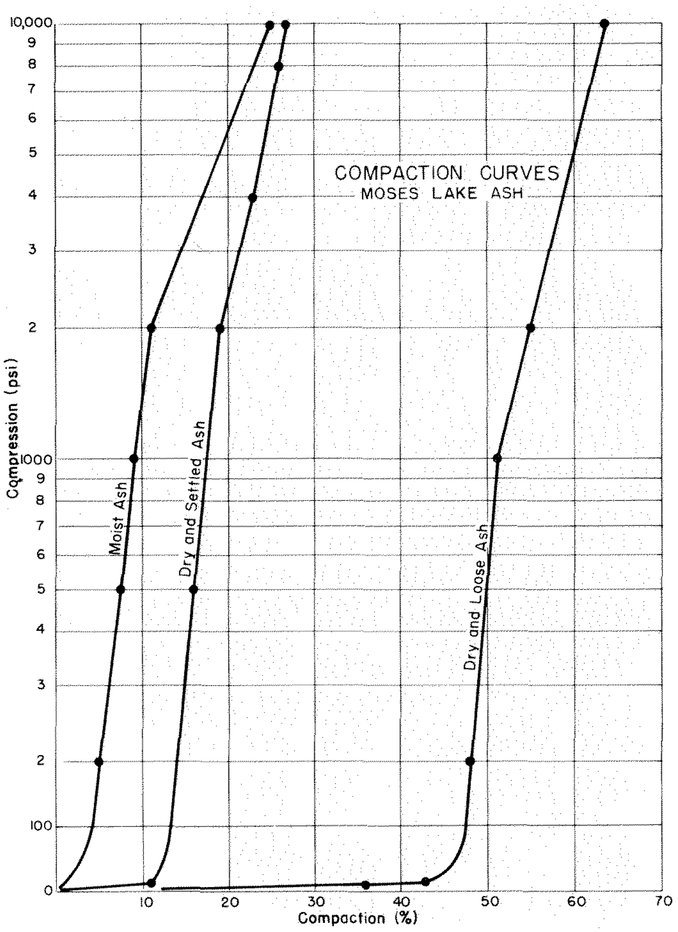


Figure 21.—Compaction curves—Moses Lake ash.

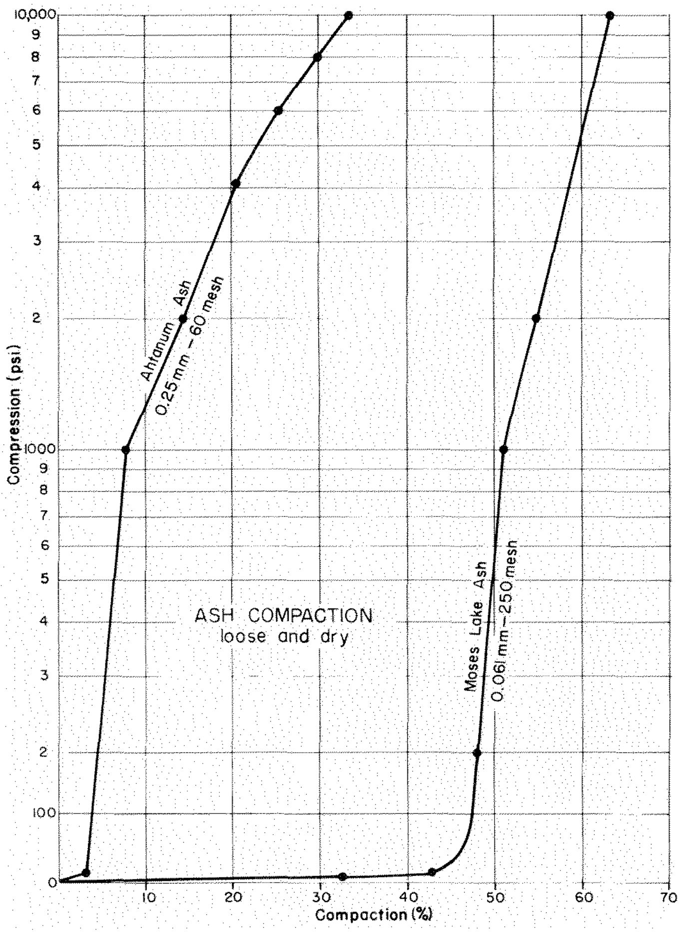


Figure 22.—Compaction curves—Moses Lake and Ahtanum ash.

ments commonly used in the field. Tests by Washington State Department of Social and Health Services Radiation Laboratory show the presence of short-lived radon, and long-lived thorium, radium, and potassium, with a gross alpha count of less than 15 pCi/g and a gross beta count of around 12 pCi/g.

PART II

POSSIBLE USES FOR MOUNT ST. HELENS ASH

By Glennda B. McLucas

INTRODUCTION

Although over 30 deposits of pumicite from volcanic eruptions of the past occur in the state (Carithers, 1946, p. 57), material from these deposits has not been utilized since 1957. Throughout the world, volcanic ash has been put to as many as 40 different uses (table 9); but to date, ash mined in Washington has been used only as (1) pozzolan, (2) scouring powder, (3) mechanics soap, and (4) dusting powder for brick molds. With the exception of pozzolan, it is doubtful that Mount St. Helens ash will be used in large amounts for the other mentioned uses, as the market for them is rather small. As such, it is best to consider uses that would require large amounts of ash, preferably within short distances of existing stockpiles in eastern Washington (see table 20). Uses considered to date (1980) for Mount St. Helens ash are presented in table 10.

TABLE 9.-- Past and present uses for volcanic ash

CONSTRUCTION

Pozzolan-cement concrete
Stabilized landfill
Ash-asphalt pavement and mineral filler
Lime-pozzolan-cement-aggregate pavement
Dust abatement
Lightweight aggregate
Acoustic and thermal insulation

FILLERS

Paper filler
Paint filler and extender
Linoleum filler
Plastics filler
Fireproof paint
Nonskid paint
Wallboard filler
Plaster filler

ABRASIVES

Grinding-wheel binders
Sand-blasting medium
Metal polish
Scouring powder
Mechanics soap
Substitute for jewelers rouge
Pearl button polish
Toothpaste filler
Rubber eraser filler

CERAMICS

Brick and tile body mixes
Pottery glaze
Ceramic glaze
Flux in glass
Television tube glass
High-voltage insulators

MISCELLANEOUS

Sweeping compound
Filter cell
Fertilizer and insecticide carrying agent
Noncaking agent
Waste treatment
Roofing granules
Dusting powder for brick molds
Electroplating gold, silver, and nickel
Nonsticking powder for tar paper products
Poultry grit
Welding rod coating
Absorbents

TABLE 10.-- Possible uses of 1980 Mount St. Helens ash

CONSTRUCTION

Pozzolan
Lightweight aggregate
Sewer lagoon lining
Stabilized fill
Ash-component pavement
Asphalt mineral filler

FILLERS

Paint, rubber, plastics, gypsum products, and linoleum

ABRASIVES

Sand-blasting medium
Grinding stones

CERAMICS

Bricks, glass, and glazes

MISCELLANEOUS

Waste treatment
Dust abatement
Filters
Carrying and nonsticking agents
Absorbents

CONSTRUCTION USES

Pozzolan

Since the time of ancient Greek civilization, volcanic ash (pumicite) has been used in the manufacture of cement. The Greeks used volcanic tuff, still used by modern builders, from the island of Santorin. Ancient Romans constructed the Roman Pantheon, Colosseum, and many other famous masonry structures with cement containing volcanic ash from Mount Vesuvius, quarried at Pozzouli, Italy. Through time, pozzuolana (pozzolan) became a general term for material, regardless of geologic origin, which possessed similar properties (Davis, 1949, p. 3).

Pozzolan is defined as an artificial or natural fine siliceous and aluminous compound which will, at atmospheric temperatures, form cementitious compounds upon combination with water and calcium hydroxide (slaked lime). During hydration of portland cement, calcium hydroxide is produced. It does not add any cementious properties to the concrete and is readily leached, resulting in porous, permeable concrete. By addition of a pozzolanic substance to cement, excess lime will enter into the chemical reaction, after the portland cement reaction is complete, to add more strength and impermeability to concrete. Silica in the amorphous form reacts more readily with calcium hydroxide than crystalline silica (quartz). Because of its high proportion of glass, volcanic ash makes an excellent pozzolan.

A 10 to 40 percent replacement of portland cement by pozzolan in concrete mixes imparts several advantageous properties to the concrete. The greatest benefit associated with this replacement is economic. Lime-pozzolan cement costs less than straight portland cement because pumicite does not require firing to high temperatures. Delivered portland cement averages $70 per yard; delivered pozzolan averages $50 per yard (1980 prices). Substitution of a yard of portland cement by a yard of pozzolan, therefore, involves a savings of $20 per yard (Fox, personal communication). Pozzolans have a lower specific gravity than portland cement; if used on a weight-replacement basis, a higher total volume of cement results. During construction of Priest Rapids Dam on the Columbia River, pumicite was mined from a local basalt flow interbed. Forty-three thousand tons of pozzolan were added to 142,500 tons of portland cement at a 30 percent reduction in delivered cost of portland cement (Klemgard, 1958, p. 18).

Other desirable properties of pozzolan-cement concrete are: (1) higher initial heat of hydration and lower ultimate heat of hydration than straight portland cement, leading to a reduction of the heat differential between interior and exterior portions of massive concrete structures and therefore a reduction in cracking; (2) up to 50 percent increase in tensile and compressive strength, especially in lean mixes, with maximum strength attained at 1 year; (3) a high degree of impermeability which increases with time and percentage of portland cement replacement (to 50 percent); (4) increased workability and decreased aggregate segregation, bleeding, and water gain, except with coarse, angular pumicites; (5) increased resistance to sulphates and weak acids in ground water and saltwater with increase in portland cement replacement (to 30 percent); and (6) reduction of expansive properties of concrete mixes containing high-alkali cement and reactive andesitic aggregates (Davis, 1949, p. 11-13).

On the negative side, some pozzolans with large, angular particles increase concrete water demand. Accompanying increased portland-cement requirements result in increased cost and reduced concrete strength. Additionally, pozzolan-cement concrete has higher dry shrinkage percentages than straight portland cement, and longer setting and curing times.

Impermeability and resistance to aggressive waters of pozzolan-cement concrete make it ideal for underground and underwater structure such as dams, piers, breakwaters, sewers, and foundations. Pozzolan-cement concrete was used in the construction of Bonneville Dam in the 1930's, as well as in every dam constructed on the Columbia River in the last 20 years, especially in the massive concrete sections (Staab, personal communication).

Portland Cement Association, the University of Washington's Civil Engineering Department, Pozzolanic Northwest, and the Seattle District, U.S. Army Corps of Engineers, have analyzed 1980 Mount St. Helens ash for its pozzolanic properties. Specifically, they examined the effect of ash in strength development of mortar cubes when ash is used as a partial cement replacement and as a partial substitute for sand; pozzolanic activity of the ash when mixed with lime or portland cement; and alkali reactivity by measuring mortar expansion. Tables 11 through 16 give the results of their investigations.

These analyses show that Mount St. Helens ash generates moderate pozzolanic activity. In combination with hydrated lime, the pozzolanic activity index at 7 days ranges from compressive strength failures of 139 psi (pounds per square inch) at Yakima to 632 psi at Spokane. The minimum ASTM requirement for

TABLE 11.-- Pozzolanic activity index with hydrated lime, Mount St. Helens ash, May 18, 1980, eruption

Ash locality	Compressive strength at failure (psi) [1]	Testing facility
Spokane (1)	493	Portland Cement Assoc.
(2)	632	Pozzolanic Northwest
Ritzville	542	Pozzolanic Northwest
Moses Lake	471	Pozzolanic Northwest
Yakima (1)	139	Portland Cement Assoc.
(2)	200	Pozzolanic Northwest
(3)	880	Army Corps of Engineers

[1] ASTM minimum at 7 days, 800 psi.

TABLE 12.-- Pozzolanic activity index with portland cement, Mount St. Helens ash, May 18, 1980, eruption

Ash locality	Percent control[1]	Testing facility
Spokane (1)	69	Portland Cement Assoc.
(2)	61	Pozzolanic Northwest
Ritzville	56	Pozzolanic Northwest
Moses Lake	69	Pozzolanic Northwest
Yakima (1)	38	Portland Cement Assoc.
(2)	35	Pozzolanic Northwest
(3)	69	Army Corps of Engineers

[1] ASTM minimum control at 28 days, 75 percent.

TABLE 13.-- Available alkalies, Mount St. Helens ash, May 18, 1980, eruption

Ash locality	Total Na_2O[1] (percent)	Na_2O (percent)	K_2O (percent)	Testing facility
Spokane	4.90	1.98	4.44	Pozzolanic Northwest
Ritzville	5.17	2.02	4.80	Pozzolanic Northwest
Moses Lake	4.56	1.99	3.90	Pozzolanic Northwest
Yakima (1)	2.03	1.89	0.21	Pozzolanic Northwest
(2)	5.42	4.35	1.63	Army Corps of Engineers

[1] Total Na_2O = (%Na_2O + 0.658 x %K_2O) ASTM maximum allowable Na_2O, 1.5 percent.

compressive strength failure at 7 days is 800 psi. The activity index increases with progressive distance from Mount St. Helens, a reflection of decreasing particle size. At Yakima, ash fineness is 721 cm^2/g as determined by Blaine apparatus at the research facilities of Portland Cement Association. At Spokane, ash fineness is 2,626 cm^2/g. Minimum ASTM specifications for fineness are 3,500 cm^2/g for type I-II portland cement and 5,000 cm^2/g for type III portland cement used in pre-stressed and cast concrete. Mineral character, chemical composition, and relative amounts of silica and other oxides are of secondary importance to degree of fineness in the pozzolanic reaction. Calcination (burning pozzolan with lime) and grinding increase the fineness and surface area of pozzolans.

Pozzolans reduce the expansive properties of concrete mixes containing high-alkali cement and reactive andesitic aggregates so common to the Northwest (Coombs, 1942, p. 288). A limit of 1.5 percent alkalies as Na_2O (%Na_2O + 0.658 X %K_2O) is required by ASTM specifications for portland cement when the purchaser requires low-alkali cement. Table 13 lists weight percentages of available alkalies for Mount St. Helens ash at various localities.

The primary criterion regarding suitability of the ash as a pozzolan is whether or not it meets all ASTM standards, listed in table 17. Composition of Mount St. Helens ash appears to be within acceptable ranges for pozzolanic material. With sizing and grinding, the

TABLE 14.-- Alkali reactivity tests, Mount St. Helens ash, May 18, 1980, eruption[1]

Control lab blend	(0.98 percent) alkali
Cement	400 g
Pyrex glass	900 g
Water	194 ml
Expansion (percent)	0.35 at 14 days
Expansion (percent)	0.43 at 5 months
Spokane ash and cement	
Cement	300 g
Ash	79 g
Pyrex glass	900 g
Water	194 ml
Expansion (percent)	0.12 at 14 days
Expansion (percent)	0.17 at 5 months
Yakima ash and cement	
Cement	300 g
Ash	85 g
Pyrex glass	900 g
Water	204 ml
Expansion (percent)	0.13 at 14 days
Expansion (percent)	0.18 at 5 months

[1] Campbell and Weise, 1980.

TABLE 15.-- Compressive strengths of Mount St. Helens ash, May 18, 1980, eruption (2 in. mortar cubes)

Ash locality	Lab blend	@ 7 days cure (psi)	@ 28 days cure (psi)	Testing facility
	Standard PCC[1] with type I portland cement	3,980	5,088	University of Washington, Civil Engineering Department
Spokane	80 percent cement/20 percent ash	3,280	4,150	Portland Cement Assoc.
	100 percent cement/20 percent ash	5,220	6,910	
Moses Lake	90 percent cement/10 percent ash	3,470	6,359	University of Washington, Civil Engineering Department
	80 percent cement/20 percent ash		4,589	
	70 percent cement/30 percent ash		5,107	
Yakima	80 percent cement/20 percent ash	2,430	3,120	Portland Cement Assoc.
	100 percent cement/20 percent ash	4,490	5,760	

[1] Portland cement concrete.

ash could be brought to acceptable fineness. Considering the variability of the ash in its physical properties from site to site, extensive testing would be required at each location before use would be considered.

The increased workability, slower setting time, and chemical stability of pozzolan-cement concrete allows its use in grouting. Fineness and low specific gravity of pozzolans enhance penetrating and pumping charateristics of pumped grout. The same reasons pozzolan-cement concrete is used in grouting apply to its use in the construction of mixed-in-place pilings and in prepared aggregate concrete (King, 1966, p. 8-15).

TABLE 16.-- Density and fineness, Mount St. Helens ash, May 18, 1980, eruption

Ash locality	Density (g/cc)	Blaine fineness (cm^2/g)[1]	Testing facility
Spokane	2.50	2,626	Portland Cement Assoc.
Yakima	2.67	721	Portland Cement Assoc.

[1] Minimum ASTM Blaine fineness 5,000 cm^2/g for type portland cement, 3,500 cm^2/g for type I-II portland cement.

TABLE 17.-- Standard specifications for fly ash and raw or calcined natural pozzolan for use as a mineral additive in portland cement concrete [1]

Chemical Requirements	
Total combined SiO_2, Al_2O_3, and Fe_2O_3 (minimum percent)	70.0
SO_3 (maximum percent)	4.0
Moisture content (maximum percent)	3.0
Loss on ignition (maximum percent)	10.0
MgO (maximum percent)	5.0
Available alkalies as Na_2O (maximum percent)	1.5
Physical Requirements	
Fineness:	
Amount retained when wet-sieved on 325-mesh sieve (maximum percent)	34.0
Pozzolanic activity index:	
With portland cement, at 28 days, minimum percent of control	75.0
With lime, at 7 days, minimum psi (kPa)	800 (5,500)
Water requirement, maximum percent of control	115
Soundness:	
Autoclave expansion or contraction (maximum percent)	0.8
Uniformity requirements:	
The specific gravity and fineness of individual samples shall not vary from the average established by the 10 preceding tests, or by all preceding tests if the number is less than 10, by more than:	
Specific gravity, maximum variation from average percent	5
Percent retained on 325-mesh sieve, maximum variation, percentage points from average	5

[1] ASTM American National Standard specification ANSI/ASTM c618-78 issued March 1, 1979.

Lightweight Aggregate

Lightweight aggregate is defined as any solid material used in the manufacture of concrete that weighs less than standard sand and gravel aggregate. Volcanic ash from Mount St. Helens averages 55 lbs/cu ft. while clean sand averages 90 lbs/cu ft. and gravel averages 100 lbs/cu ft. One cubic yard of concrete requires 1,800 lbs of ash versus 3,000 lbs of a conventional sand and gravel mixture. This results in a 25 percent weight reduction in floors, roofs, and columns, which permits less reinforcing steel, easier handling, lighter forms and foundations, and increased floor space (Capp and Spencer, 1970, p. 22).

Lightweight aggregate composed of volcanic ash and pumice has been used for many years in the structural and precast concrete industries. Concrete block and brick manufacture dominate the market, consuming 80 percent of total production. Lightweight concrete makes possible the design and construction of structural forms that would be impractical or impossible with use of heavier aggregate and allows concrete to be competitive with structural steel framing in high-rise buildings. The advantages of lightweight-aggregate concrete include: (1) substantial savings in construction costs due to reduced weight; (2) high weight-to-strength ratios; (3) thermal and acoustical insulation; (4) flexural strength and shock resistance; (5) impermeability; and (6) low maintenance costs (King, 1947, p. 3).

Properties of prime importance to lightweight aggregate are: (1) uniformity in all properties to prevent costly, time-consuming changes in mixing formulations; (2) color consistency, especially in exposed concrete products such as precast wall panels or concrete blocks; and (3) chemical stability to prevent deterioration of the product. The ready-mix concrete industry is accustomed to consistent, reliable aggregate supplies. They do not feel that the ash represents such a supply because of inconsistencies in particle size, color, and chemical composition. Due to ash angularity and abrasiveness, the industry is concerned about the impact of fine ash fractions on their mixing and handling machinery (Downing, personal communication).

Concrete block manufacture requires particle sizes from 6.4 to 0.074 mm; ASTM specifications for ready-mix concrete require 100 percent passing 4 mesh (16 mm), 20 percent passing 50 mesh (0.30 mm), and less than 2 percent passing 200 mesh (0.074 mm) sieves. Mount St. Helens ash from Yakima west to the volcano has the best aggregate potential because this is where it is coarsest, in the fine to medium sand range, with 70 percent retained on 60 mesh (0.25 mm) sieves.

If cement content is maintained, ash can be substituted for 25 percent of the weight of sand in concrete mixes, especially in lean concrete mixes. Using volcanic ash as sand replacement poses some problems, however. Concrete water demand could be high because of ash angularity leading to increased portland cement requirements, accompanied by increased costs and decreased product strength.

Sewer Lagoon Lining

The town of Othello in Adams County, Washington, has 25 acres of sewer lagoon (settling ponds) to which they intend to add another 25 to 50 acres. The lagoons are lined with bentonite to prevent leakage of organic waste through the underlying highly fractured basalt bedrock. When the May 18th ashfall occurred, the engineering firm responsible for design and construction of the proposed lagoons (Brown and Caldwell Engineers, Seattle) developed an interest in the feasibility of substituting ash for bentonite. Bentonite is an extremely fine clay mineral (montmorillonite) that, upon wetting, swells to 7 times its dry volume and becomes impermeable. It is imported from Montana or Oregon by rail and its installed price is 25 cents per square foot or $250 per ton. To be competitive, ash would have to be made available at 10 cents per square foot or $100 per ton (DeSteiger, personal communication). Ritzville, 50 road miles distant from Othello, is the nearest ash source.

Moses Lake-Ritzville ash compacts well, as shown in figures 21 and 22. Since the ash is composed of 75 percent vesicular glass, it is very angular; this property, combined with small particle size, should make the ash fairly impermeable if compacted with vibrating roller equipment. Brown and Caldwell personnel are gathering information on the physical and engineering properties of the ash to present to their construction subcontractors who will make the final decision regarding its use.

Ash-Component Pavement

As access is reestablished into the Mount St. Helens devastation zone, volcanic ash from the debris flows and mudflows along the major drainages will undoubtedly be incorporated into the construction of new roads as stabilized base material or as pavement aggregate and filler (Richardson, personal communication). With the large ash stockpiles in eastern Washington communities, potential also exists for the incorporation of ash in road construction projects in proximity to these sites.

The Federal Highway Administration has utilized volcanic ash sands as aggregate in the construction of asphalt roads near White River (Mount Hood vicinity), Oregon, and at Potato Hill on the Yakima Indian

Reservation, Washington. Ash sand (Mount Hood and Mount Adams ash, respectively) was mined and mixed on-site with asphalt, then applied directly to the soil road base. Because ash-asphalt mixtures are not highly abrasive-resistant, a thin cap of resistant aggregate chips was embedded in the top of the 6-inch ash-asphalt pavement (Richardson, personal communication).

Ash can also be used as asphalt mineral filler because the amorphous silica content counteracts the hydrophilic reaction of some aggregates (Richardson, personal communication). The major function of mineral filler is to provide cohesion in asphalt mixes and thereby increase stability and durability of the pavement. Mineral fillers work by increasing the surface area in an aggregate mix that has to be coated with asphalt. If these surfaces are compatible and easily coated with asphalt, increased pavement strength results; if they are highly susceptible to water, pavement failure results. Mineral filler must be uniform in grading and finer than 200 mesh (Zimmer, 1970, p. 49). Mount St. Helens ash has a chemical composition very similar to Trinidad asphalt, a filler that has been given excellent rating by the asphalt industry.

Natural pozzolans have also been used in conjunction with lime-cement-pozzolan-filler (LCPF) pavements. The LCPF mixture is combined with water to form a paste that is compacted with normal paving equipment to a relatively high-density mass that hardens to a rigid pavement with 1-year compressive strengths of 750 to 2,000 psi. Strengths for mixtures including portland cement are usually higher than those without.

LCPF pavements can be used as base or subbase material and range in thickness from 6 to 40 inches, depending upon the load they are designed to support. Their benefit is in support of the static load. Because they do not hold up to surface abrasion and are subject to infiltration of surface water, they are capped with 2 to 4 inches of a wearing surface (Barenberg, 1974, p. 180).

LCPF pavement was used by the Port of Portland in the construction of a runway at the Portland, Oregon, airport, and as pavements at Terminal 4, a steel-handling facility, and Terminal 6, a container-port facility in the Portland harbor. The Oregon pumicite was calcined and ground and plant-mixed with other components to careful specifications because a high-grade concrete was essential. However, for secondary access roads, such as those required for logging in the Mount St. Helens devastation zone, LCPF pavements could be mixed on-site. Laboratory testing of the ash will evaluate potential variations in acidity and grain size, or the potential presence of sulfides and organic material that could adversely impact the pozzolanic reaction or the long-term strength, durability, and dimensional stability of the pavement. As in the case of all road construction, laboratory analyses of the pozzolan and aggregate are vital, and in fact will soon be undertaken by the Federal Highway Administration's Materials Laboratory in Vancouver, Washington.

Stabilized Fill

Cleanup of Mount St. Helens ash in eastern Washington led to its disposal in hundreds of landfill sites, from a few yards to 103,000 cubic yards in volume. Small fills do not pose safety or environmental hazards, except as uncapped sources of windblown dust. The creation of several large fills, however, allows them to be considered in terms of the benefits, problems, and engineering considerations of stabilized fills in general. Dredging operations along the volcanic mud-choked lower Cowlitz and Columbia River channels have resulted in several large landfill disposal sites along their courses (fig. 23). The U.S. Army Corps of Engineers and the Federal Highway Administration are performing laboratory tests of the physical and engineering properties of this volcanic mud as fill material; results are pending.

The benefit of any fill is the disposal of an undesirable substance, such as the ash, and the elimination of a negative topographic feature, such as an abandoned quarry or a bog. The problems associated with any fill involving the use of fine-grained material are internal and external erosion, liquefaction, surface and ground water contamination, and slope instability. The physical properties to be considered when evaluating a substance for its use as fill material, therefore, are grain size, density, compaction characteristics, shear strength, and permeability.

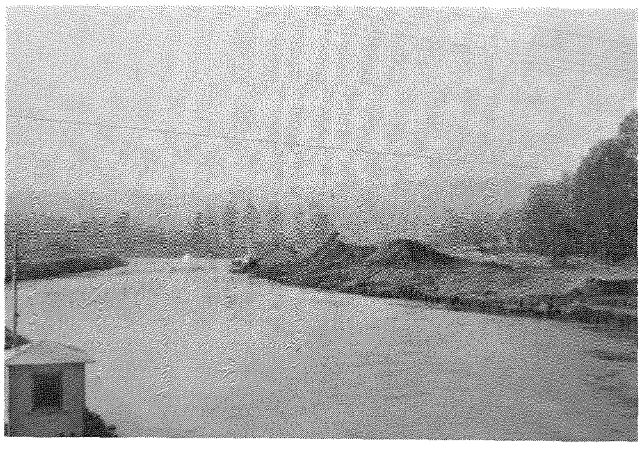


Figure 23.—Dredging operation along volcanic mud-choked Cowlitz River at Castle Rock, Washington.

Figures 14 and 15 show average grain sizes for ash from Yakima to Moses Lake-Ritzville. Yakima ash is a fine to medium sand with less than 5 percent passing the 250-mesh sieve. Moses Lake-Ritzville ash is a coarse silt with 38 percent passing the 250-mesh sieve. Density of the ash averages 0.88 g/cc (55 lb/ft^3) when loose and dry, 1.29 g/cc (80 lb/ft^3) when compacted and dry, and 1.8 g/cc (112 lb/ft^3) when water saturated. This places the ash in the size and density range of most conventional fill materials.

Due to angularity of ash particles, it compacts well (figs. 21 and 22), with Moses Lake ash showing the greatest initial compaction because of its fine grain size. Ash absorbs up to 30 percent of its weight in water; compaction curves show that it compacts best when wet. The ash can probably be compacted satisfactorily over a wide range of water contents, but shear strength will probably decrease substantially as maximum water-absorption percentages are approached. The ash has a natural cementing action in contact with water (even more so in the presence of hydrated lime), which greatly increases its compaction properties and strength, especially with time. Optimum compaction for the ash would be achieved by mixing it with lime and water, then compacting it with a vibrating roller to bring angular particles into maximum interlocking structure (DeSteiger, personal communication).

Permeability of ash decreases with compaction and increases with grain size; Yakima ash is more permeable than Moses Lake-Ritzville ash because it is coarser grained. Besides slight initial solubility in water, with an accompanying slight increase in pH (5.2 to 7.2 with an average of 6.5), the ash is essentially inert and does not undergo deterioration upon exposure to the atmosphere. During any pozzolanic activity, the small soluble content of the ash is tied up in the reaction; as such, water percolating through ash landfills is unlikely to pick up significant quantities of any chemical that could negatively impact surface or ground water supplies. Aside from the landfill in the wetlands adjacent to Moses Lake (see fig. 26), leaching of fines and soluble substances into water supplies does not pose a potential problem, as all other landfills are naturally well drained and above grade.

Problems arising from compacted fills include internal and external erosion and liquefaction. Internal erosion can be controlled by properly designed drainage and filter systems to ensure that fine material is not carried in suspension by percolating water. External erosion can be controlled with topsoil and vegetation. Liquefaction, the sudden decrease in shearing resistance caused by structural collapse of material due to sudden increase in pore pressure, can be avoided by ash compaction and placement in sites with low water tables.

None of the landfills in eastern Washington have had internal drainage or filter systems installed because of their low volume and location in well-drained landfill sites (with the exception noted in Moses Lake), and because they are situated in sparsely populated areas where they do not pose safety hazards that justify installation costs. Yakima installed an underground sprinkler system, at a cost of $35,000, to aid in ash compaction and dust abatement (see fig. 27). Most of the large landfills were covered, or soon will be, with 1 to 2 inches of topsoil and seeded to grass.

ABRASIVES

At least two grinding-wheel manufacturers have evaluated the potential use of Mount St. Helens ash in their products. Pacific Grinding Wheel Co., Marysville, Washington, has produced some promotional hones from a mixture of 15 percent ash and 85 percent aluminum oxide, clay, feldspar, and slip. Results of industry evaluations indicate that the ash is too soft and friable and has too low a melting point to be compatible with standard abrasives products.

Aluminum oxide, silicon carbide, and garnet predominate as abrasive materials; local demand is met by copper slag, a black, iron-rich, fused glass derived from local copper-smelting operations (Pritchard, personal communication). These abrasives approach diamond in hardness, while ash hardness on Moh's scale ranges from 5 to 6.5. Standard abrasives particle size ranges from 12 to 220 mesh, averaging 60 to 120 mesh. Industrial abrasives have densities ranging from 35 to 200 lbs/cu ft. depending upon the use for which they are intended. Density of Mount St. Helens ash is low by comparison, averaging 55 lbs/cu ft.

Friability is a measure of the number of fracture points associated with a substance. Ash particle surfaces are riddled with broken vesicles with sharp, thin, readily broken walls (fig. 9). The glass jackets that enclose many mineral crystals are readily separated upon impact. Even those feldspar crystals not encased by glass have well-developed cleavage that allows the mineral to break easily upon impact (Hackwell, personal communication).

Abrasives industries fuse all material at high temperatures in kilns. Rugged vesicular ash surfaces quickly fuse into a rounded blob that is essentially useless as an abrasive. The greatest potential use of ash in grinding devices is not as an abrasive but as a bonding agent for other abrasive particles, and as a matrix that holds them away from the wheel so that their cutting edges remain effective. Binding agents are usually composed of clay minerals that fuse into glass at temperatures from 600° to 4,000°F, depending on the substances involved. Tests have demonstrated that Mount St. Helens ash fuses at 1,800°F, a melting point too low to make it a viable replacement for established binding agents (Lamont, personal communication).

In the nuclear industry, it is essential that abrasive material be absolutely inert; for most industrial uses, however, slight chemical reactivity is unimportant. Most industries feel that the ash contains too many mineral inclusions and trace elements for it to be of use to them.

Siliceous material, mostly quartz sand and feldspar, has been used extensively in the past as sandblasting medium for cleaning buildings constructed with brick and natural stone. Legislation has limited the dry use of crystalline silica (quartz) for this purpose because of silicosis hazards. Although Mount St. Helens ash on the average contains less than 1 percent crystalline silica, and therefore does not pose an inhalation hazard, it does not appear to be a viable blasting medium because of its softness, friability, and small particle size. Blasting abrasives must be retained by a 50-mesh screen and most abrasives (such as garnet) are at least 36 mesh. Very little of the Mount St. Helens ash is this coarse. For more delicate polishing purposes, however, such as china and furniture finishing, artwork, and jewelry, the fine-grained ash in the 300-mesh range probably could be used in very limited tonnages. For this use the ash must be free of sharp, gritty particles like quartz or other impurities such as gravel fragments. The value of the ash for fine polishing purposes is the thin slightly curved shape of its particles which resist breakup in use down to very small sizes (King, 1947, p. 3).

The ash might also be used as granular material for sandpaper, although sandpaper manufacturers traditionally use much harder substances, such as aluminum oxide, and produce their own grains to ensure a uniform product. Past use has been made of pumicite as an abrasive filler in scouring powders, mechanics soap, and toothpaste. Color is an important consideration for these uses, however; the filler should be white when wet as well as dry.

CERAMICS

Bricks

The use of Mount St. Helens ash as an additive to building bricks and tiles does not appear to be promising. The Ceramics Department of the University of Washington, and Mutual Materials, a Seattle-based brick manufacturer, have investigated the use of ash for this purpose. Clay was tested with 15 percent additions of fine ash from Moses Lake and coarse ash from Portland, Oregon. The ash was mixed with water to a plastic state, then extruded into test bars, and dried and fired for 3 hours at 1,950°F or 2,050°F. From 10 to 18 bars were broken by 3-point loading to determine moduli of rupture. The conclusion reached by these investigators indicates that addition of the ash had little beneficial effect on the product and in some instances lowered dry brick strength. Sintering the ash with 10 percent clay bond turned it a dark brown color, but when 15 percent ash was added to brick clay, little color change was noticed (Whittemore, personal communication). Table 18 lists test results.

TABLE 18.-- Average modulus of rupture for ash-brick[1/] (psi)

Type of clay	Dry	Fired 1950 F	Fired 2050 F
Brick clay	481	1,502	1,787
Brick clay with 15 percent Moses Lake ash	275	1,441	1,973
Brick clay with 15 percent Portland ash	220	1,033	1,509

[1/] Whittemore, 1980.

The fact that the ash is not a clay, and therefore not plastic, prevents its use in the extrusion brick process. Clays in the Northwest tend to be nonplastic so that addition of ash would greatly increase this nonplasticity (Stumpff, personal communication).

Still another problem stems from the short firing range of the ash which makes the manufacture of a brick product difficult. Changes that take place during firing of brick are physical more than chemical. As brick temperature increases, binding material becomes viscous and, near the end of the firing cycle, the ash component vitrifies. The optimum condition involves a body mix that melts over a wide temperature range so that the proper amount of glass develops in the brick. Too much glass produces a soft, deformed brick; too little glass produces a weak brick (Stumpff, personal communication).

Fly ash bricks have been manufactured in the past at one third of the cost of clay brick. Because of low ash density, ash brick products weigh up to one-third less than clay bricks, resulting in reduced transportation and handling costs. Ash bricks also have excellent thermal and acoustical properties and are fire resistant and dimensionally stable (Reidelbach, 1970, p. 195).

Volcanic ash does not have application to manufacture of refractory bricks because of its chemical composition and low melting point. Most refractory brick is manufactured from a very pure combination of aluminum oxide (60 percent) and crystalline silica (40 percent). Refractory temperatures involving this mixture range from 2,000°F to 3,800°F, well above the 1,800°F ash melting point. Metallic trace elements are intolerable in refractory bricks above a few hundredths or tenths of one percent. No more than 0.05 percent iron oxide is tolerated because it acts as a flux, lowers the melting point of other brick constituents, and therefore defeats the refractory process and destroys the brick (Kelsey, personal communication).

Glass

Mount St. Helens ash has been considered for use in glass manufacturing by several Washington State companies. While it is being used in small volumes for novelty items, no realistic use has been found by commercial glass manufacturers. The ash is excellent for conversion to the glassy state because up to 80 percent of the ash is already composed of volcanic glass. Conversion to glass at lower temperatures is aided by addition of flux such as boric acid.

Mineralogical and chemical composition of the ash are the major factors considered by glass manufacturers. Feldspar acts as a flux in glass manufacturing and brings alumina (Al_2O_3) into the melt which increases workability, inhibits devitrification, and increases chemical stability. Clear bottle glass needs 2.0 to 2.5 percent alumina. Potash feldspars, such as orthoclase and microcline, are preferred by the glass industry over plagioclase feldspars, which predominate in the ash.

Iron oxide in the ash prevents its commercial application to glass manufacture by imparting, along with manganese, magnesium, and nickel, a dark brown to black color. Commonly not over 0.05 percent total iron as Fe_2O_3 is allowed in commercial glass manufacture. Even in amber glass, such as beer bottles, a maximum of 0.1 to 0.15 percent is tolerated. This color control is not possible with inclusion of ash in glass products. Other impurities in the ash, such as gravel particles, also interfere with the glass-making process by not melting completely and setting up stresses in the glass. Uniform particle size of glass-making substances is important because, if not uniform and well mixed, particles can aggregate and cause the glass to run (Dellwo, personal communication).

Glaze

Glazes are vitreous substances applied as coatings to finished pottery or enamelware. They are usually mixtures of silicates similar to Mount St. Helens ash, which is being used by artists in the state to glaze novelty pottery and ceramic items. The ash does not have potential for commercial glaze because of the same lack of color control that prevents its use by commercial glass manufacturers (Whittemore, personal communication). Iron content imparts a brown to black color that has artistic appeal, enhanced by association with the cataclysmic eruption of Mount St. Helens.

FILLERS

Fillers, or extenders, are used in great volume by industry for a wide range of purposes, mostly for the savings inherent in the use of cheap, readily available, bulk-replacement industrial minerals. Most fillers are inert silicates, very similar in physical and chemical properties to Mount St. Helens ash. For this reason, the possible substitution of volcanic ash for common fillers by Washington State industries was investigated. The most common users of filler materials are paint, rubber, plastics, gypsum products, and vinyl floor-covering manufacturers.

Paint Filler

The paint industry uses fillers in its products to increase their viscosity, flexibility, and durability, degloss or flatten the product, prevent settling and clustering of pigment particles and thereby achieve a continuous film with uniform reflection properties, improve brushing and flow, decrease cost of raw materials, change color or opacity, or effect a change in penetration (Hohn, 1951; Brooks, personal communication). Because it appears to have some of the necessary physical and chemical properties of paint fillers, Mount St. Helens ash was considered for this purpose.

The primary industry specification for paint fillers is chemical inertness because formulation problems can arise through use of substances, such as the ash, that contain reactive accessory minerals. Silicate fillers are preferred because they are chemically inactive in combination with paint emulsions, with the exception of magnesium silicates. The silicates that are commonly used contain as much as 99 percent SiO_2 while Mount St. Helens ash averages 64 percent. The presence of substantial accessory compounds in a filler such as the ash presents a situation so fraught with chemical problems that industry cannot afford to deal with them. The iron oxide content of the ash (5 percent average) poses problems in all paint products except those that use it as a primary pigment, or in oil-base interior paints that will not be subjected to excessive oxidation and discoloration (Brooks, personal communication).

Filler particle size is also critical. In general, flat paints require larger particles, and glossy paints require fine particles. Large particle size provides thicker film or "build" than fine particles. The average filler grain size is 2.5 microns with a maximum of 1.5 percent retention on a 325-mesh sieve. Diatomite, a commonly used filler, averages a 6-micron particle size with 3 percent retention on a 325-mesh sieve. Only the easternmost ash fall in Washington passes 325 mesh in sufficient quantities for use and would have to be processed to attain uniform grain size. Apparently ash particle angularity is not a critical factor; however, more rounded particles increase flowing ease or workability of paint and reduce abrasion on spray guns and other application and mixing equipment (Brooks, personal communication).

Filler porosity determines its absorptive properties, which in turn affects paint thickness, viscosity, and flow. Paint thickness, or body, increases with filler absorbency. Highly porous diatomite, for example, is used in thick-bodied latex paints. Because of high ash particle porosity and surface area, it approaches diatomite in absorbency.

Another carefully controlled filler specification is color, especially for use in white paint. Extender pigments have little light absorption and practically no light-scattering power when immersed in film-forming materials. They are essentially transparent and have refractive indices of *n* 1.45-1.70, equal to the film-forming substance (Hohn, 1951, p.1). Brightness ratings for the most desirable fillers are in the 90 range. Some use of materials in the high 80 range is allowed in colored paint and when filler volume is low. Reflected light values for Mount St. Helens ash range from 77 at Ritzville to 40 at Vantage (fig. 16); this fact alone would prevent its use in paint.

In summary, the primary reasons Mount St. Helens ash cannot be used as a paint filler/extender are its mineral impurity, dark color, and large, unsorted particles. It does have potential use as a nonskid additive, however, in the 40- to 60-mesh screen sizes and, because of its high heat capacity, ash could be used in the manufacture of fireproof paints. The same arguments against its use in paint apply to its use in paper products where color, purity, and particle size are critical factors.

Rubber Filler

Use of Mount St. Helens ash as a rubber additive was investigated because the rubber industry uses large quantities of silicate fillers such as talc, feldspar, and amorphous silica as reinforcing agents in their products. Addition of small quantities of these silicates, or carbon black, can increase the strength of rubber-filler mixtures 10 times over that of natural rubber. Unfortunately, high ash angularity counteracts these reinforcement properties so that its addition could result in an inferior product. In addition, ash rapidly abrades processing equipment (Vickers, personal communication). The most desirable rubber-paint filler particle shape is platy (talc and mica flakes), because this shape provides the best flow and handling properties (Shackelford, personal communication).

Ash abrasiveness makes it ideal for addition to rubber erasers, especially typewriter erasers, where abrasiveness is the desired property. However, no eraser industries exist in the Northwest and volume of abrasives used by the industry is small. Another possible use, which would take advantage of ash abrasiveness, is nonskid additive to rubber shoe soles or rubberized floor and deck paint. The Navy has used rubberized paint with ground-pumice filler to prevent skidding on ship decks.

Particle size and surface area are also important rubber-filler factors. Commonly used, jet-milled rubber fillers are a maximum of 40 to 50 microns (325 mesh) in size, and average between 1 and 5 microns. The average ash grain size is 61 to 125 microns; these large sizes would dilute rubber and reduce its quality (Vickers, personal communication).

Chemical composition of the ash is not a major deterrent to its use in rubber products, as it is essentially inert. Trace elements in the ash would require careful examination, however, as a few tenths of one percent of certain reactive elements such as copper, cobalt, or nickel can hinder curing time, aging, and rubber quality. In general, slightly alkaline or neutral fillers are preferred by the rubber industry, as acidity retards the curing process.

Plastics Filler

The plastics industry uses filler material in many of its products to add strength and stiffness. Those plastics that would make best use of Mount St. Helens ash are epoxy and polyester resin systems; ash angularity would create problems in all other systems. Particle angularity can be positive or negative, depending on intended product use. Angular particles make a resin thick or "thixotropic" because particles anchor themselves in the fluid. If slump resistance is the desired property, so is thixotropicity; if flowing ease is desired, thixotropicity is not. Filler inertness is important because reactive metals such as cobalt in the ash (9 ppm) can affect product stability (Vickers, personal communication).

Commonly used plastics fillers are limestone and silica flour (finely ground crystalline quartz) in the 2- to 30-micron range. Larger particle sizes make many plastic products grainy. Coarse ash particles can be used in casting of novelty items, such as ashtrays, or in synthetic marble countertops where low ash density (0.9 gm/cc) is an asset, and reduced surface area provides greater resin-wetting properties. Particle angularity does not pose a problem in this application because of less concern with flowing ease in casting operations. A mixture of ash particle sizes in the 30- to 80-mesh range are used because of the strength this mixture imparts to products. The biggest problem posed by ash in cast products is its monotonous gray color; the public demands a wide color range, and the most popular color is white (Blanchard, Winebrenner, personal communication).

Mount St. Helens ash also has potential for use with concrete epoxys because of its large particle size. In situations where it is necessary to bond new concrete castings to old, an epoxy with large-grained (60 mesh) fillers such as sand is used. Ash that fell between Yakima and Mount St. Helens complies with this particle size requirement (Martinez, personal communication).

Gypsum Products

In Australia, pumicite has been used in the manufacture of gypsum wallboard. Apparently ash does not pose any physical or chemical problems for use in wallboard, but the supply of gypsum in the western United States is plentiful and cheap so that there are no economic inducements to substitute other fillers such as Mount St. Helens ash. Additionally, manufacturers are concerned with equipment abrasion by ash dust, a much less severe problem with gypsum (House, personal communication).

The drywall adhesive, finishing compound, and texture-paint manufacturers in Washington State are interested in the potential use of Mount St. Helens ash in their products, but cite its gray color as a deterrent to use in any coating product, such as texture paint, that must be absolutely white. The ash would require sizing for this application because the industry requires very specific particle sizes, from 80- to 600-mesh (Bartlett, personal communication).

Linoleum Filler

The inlay vinyl industry uses fillers similar to the ash to make floor covering wear longer and to cut manufacturing costs. There are no linoleum industries in the Northwest, however, that could make use of the ash.

MISCELLANEOUS USES

Waste Treatment

Volcanic ash and fly ash have been the objects of scientific investigation for their effectiveness as adsorbents in the removal of inorganic phosphorus and organic pollutants from municipal sewage and polluted lakes. Phosphorus removal efficiency has been shown to vary from 0 to 82 percent for an influent phosphorus concentration of 10 mg/l, using volcanic ash as an adsorbent in 24-hour shaking-type batch tests. Additional contact time did not improve phosphorus removal efficiency. Increasing volcanic ash particle size resulted in decreasing efficiency of phosphorus removal (Hung and others, 1977, p. 1).

Acidity and the presence of calcium are the major factors in removal of phosphorus from substances; pH values of 4.8 to 5.4 will remove phosphorus from soil for example (Lucas, personal communication). Under the proper pH conditions, the lime components of ash precipitate phosphorus out of solution. Acidity of Mount St. Helens ash ranges from pH 5.2 to 7.2, with an average pH of 6.5.

For the first few days after the May 18th ash fall in Spokane, when the ash load in municipal sewer systems was high, sewer treatment personnel bypassed the main components of treatment plants and ran ash-laden sewage directly through primary clarifiers. As a result, total coliform level dropped to zero. The sheer mass of the ash, and its high specific gravity (2.6) relative to organic material, removed organic solids from suspension to a degree normally reserved for secondary waste treatment. Phosphorus in the sewage was adsorbed by the ash; normal treatment removed up to 85 percent, but the ash content caused 100 percent removal.

Volume of ash in the sewage ranged from 9 to 14,000 ppm; normal volume of organic material is 160 ppm. Apparently the extremely fine ash (to 0.3 microns), with a very large surface area per unit volume and high electrostatic energy, behaved as a net and scavenged organic material as it settled out of suspension.

Liberty Lake in Spokane County demonstrated an immediate drop of 1 to 1.5 pH units following the May 18th ashfall, accompanied by a 50 percent decrease in total phosphorus and a massive decrease in the volume of algae, undoubtedly due to scavenging by ash particles. The lake had a similar appearance following alum treatment in 1974 (Funk, 1980, p. 14).

In a practical sense, ash could not be used in sewage treatment plants for clarification purposes because its specific gravity would cause it to settle to the bottom of clarifiers and digesters where it would require mechanical removal. Use of volcanic ash to control plant nutrients in natural standing bodies of water with eutrophication problems, however, seems to warrant further investigation. Laboratory tests have demonstrated that with additions of ash (up to 10 g/l) no harm was done to fish populations; while water hardness was increased, it was still below hardness limits prescribed by Public Health Service drinking water standards.

Carrying and Noncaking Agents

Fertilizer and insecticide industries often use carrying agents to distribute, dilute, and gradually release chemical compounds to the environment. Some of these agents also double as noncaking agents. Because the glass fraction of Mount St. Helens ash is fine-grained and vesicular, its use for this purpose was examined.

Properties of greatest significance to insecticide and pesticide carriers are: (1) chemical stability; (2) high pH; and (3) large particle surface area. The most common carriers are talc, diatomite, micronized clays, and calcium silicates. Talc and diatomite are chemically stable agents. Apparently Mount St. Helens ash, in combination with insecticides and pesticides, is chemically active, which could lead to product decomposition and diminished shelf life (Lucas, personal communication). Ash iron-oxide content (5 percent average) is detrimental because it acts as a catalyst in the chemical breakdown of organic insecticide constituents. In addition, ash acidity (6.5 average) presents problems.

As particle size decreases, surface area, electrostatic attraction, and adsorbency increases. Substances, such as diatomite or volcanic ash with high porosity and surface roughness and small grain size, can store tremendous quantities of fertilizer and insecticide or pesticide in proportion to their grain size, and release them to the environment over an extended period of time.

Mount St. Helens ash does not have any value to the Washington State fertilizer industry because, due to high transportation costs, they no longer use carrying agents. Instead they either manufacture liquid fertilizer or combine dry fertilizer with filler material such as gypsum, talc, sewage sludge, vermiculite, or dolomitic lime that provide additional soil nutrients. The ash does not contain the necessary 12 percent magnesium or 95 percent calcium that industry demands. The fertilizer industry requires material with a maximum density of 60 lbs/cu ft and a grain size equivalent to BB shot (4 mm). Because the ash is denser and finer than these specifications, it compacts or segregates in mixing and therefore clogs the equipment used to spread it (Peterman, personal communication).

Filters

Volcanic ash has high particle porosity, surface area, and absorption properties that allow its use as a filtering agent. However, many filtering agents on the market, such as diatomite and bentonite, are superior to ash. In its natural state, diatomaceous earth has filtering properties very similar to ash; upon calcination, however, it becomes far superior. The major reasons for this are its decreased density, increased chemical stability, and very large internal porosity.

Diatomite has a wet density of 17 lbs/cu ft compared to 112 lbs/cu ft for wet St. Helens ash, a significant difference in light of the fact that heavy particles won't remain in suspension long enough to accomplish maximum filtration.

Diatomite is 99 to 99.8 percent pure SiO_2, while St. Helens ash averages only 64 percent, making it much less inert. Accessory ash minerals would prohibit its use in the food industry which carefully monitors even the 0.2 percent trace-element fraction of diatomite. Less critical uses such as water purification could tolerate less chemical stability.

Diatomite is famous for its internal porosity and permeability—the features that make it a superb filter. While ash has great porosity associated with its bubble texture, it lacks the open internal latticework of diatomite and therefore its filtering properties are reduced by comparison (Wyman, personal communication).

Dust Abatement

One of the most obvious problems generated by 1980 Mount St. Helens ash falls has been airborne volcanic dust generated by wind action on fine fractions of the ash. On roads and shoulders, traffic kept the ash in constant motion, resulting in low visibility, vehicle damage due to abrasive brake and clutch wear, and health problems associated with inhalation. On heavily traveled roads, the problem has greatly diminished; on rural and logging roads, however, the problem will persist for some time. Within hours after heavy rainfalls, the highly porous ash dries out and is subject to renewed wind action (Mahoney, personal communication). Hundreds of piles of ash, from a few cubic yards to 90,000 cubic yards in volume, have accumulated throughout eastern Washington as a result of cleanup operations. Most of these ash piles are uncovered, will remain so, and represent an ongoing airborne dust problem for municipalities in their proximity.

Various state and county public-works departments and the Federal Highway Administration have experimented with dust abatement compounds with varying degrees of success, including ash-lime mixtures, lignin sulfonate, and calcium and sodium chloride (see table 19). A dust palliative is a chemical compound that, when applied to a fine-grained substance such as volcanic ash on roadbeds and shoulders, penetrates that substance, then hardens to a durable, cohesive mass that prevents or retards regeneration of dust by traffic or the wind.

The most important properties of a dust palliative are low cost, ready availability, low environmental impact, and good penetration, durability, and cohesion. Because of its immediate on-site availability and soil-lime enhancement potential, the feasibility of using an ash-lime mixture was particularly attractive.

Volcanic ash in combination with hydrated lime and water generates a pozzolanic reaction which allows the mixture, when sprayed on an ash-covered gravel road or shoulder, to harden to a cementitious capping compound. Investigation of Mount St. Helens ash-lime mixtures by the Federal Highway Administration have indicated poor pozzolanic reaction, however, perhaps due to large ash grain-size or the low percentage of lime that will go into solution, even though separate studies of ash-lime-cement mixtures have indicated moderate pozzolanic activity (see tables 11, 12, and 15). Had the pozzolanic reaction been sufficient, an ash-lime mixture would have been a viable dust palliative equal to or better than the sodium and calcium chlorides, but substantially less effective than lignin sulfonate which has been given the best dust-abatement rating by all investigators. Penetration, cohesion, durability, and leachability of the ash-lime mixture are superior to the chloride compounds but inferior to lignin sulfonate. Environmentally the mixture is neutral and may even be beneficial in the addition of lime to soil (Ross, personal communication).

Absorbents, Nonsticking Agents, and Roofing Granules

High external porosity and surface area make volcanic ash absorbent. For this reason, it has been used as a sweeping compound to soak up substances such as oil from garage floors. In very fine fractions (325 mesh or finer), it has been used as a nonsticking agent to dust brick molds, composition roofing, and tarpaper. Angular ash particles in a mixture of sizes from 6 mesh to 40 mesh have been used for roofing granules to shield bituminous materials from sunlight and thereby prevent product deterioration. The public prefers a variety of colors, however, and the ash can only provide gray granules.

TABLE 19.-- Dust-abatement compounds[1/]

Product	Description	Cost ($)	Performance
Lignin sulfonate	Organic byproduct of sulfite wood-pulping process	0.19/gal	Penetration superior, especially in wet ash; leaches in moderate rainfall by 4 months; good fertilization properties; readily available and inexpensive; excellent cohesion
Ash-lime mixture	Pozzolan spray	120/ton	Exhibits poor pozzolanic activity, possibly due to large ash grain size; penetration, cohesion, durability, and leachability superior to chlorides but inferior to lignin sulfonate; readily available and inexpensive; provides soil-lime enhancement
Sodium chloride	Rock salt	85/ton	Good dust palliative because of good penetration and cohesion; easily leached by light rainfall; toxic to vegetation; corrosive to metal; inexpensive
Calcium chloride	32 percent salt solution	0.62/gal	Exhibits essentially the same palliative properties as sodium chloride; good penetration, cohesion, and durability; leaches easily
Coherex (Witco Chemical)	Resin-water emulsion	1.09/gal	Penetration poor; good cohesion; 3 to 6 months durability under light traffic; not toxic to plants; minimally effective as palliative
Esi-Bond	Plastic compound	5.55/gal	Not a penetration product, therefore doesn't perform well on roads; forms tough plastic film over surface making it a good palliative for ash stockpiles in eastern counties; not toxic to plants

[1/] Ross. 1980.

PART III

AVAILABILITY AND LIMITATIONS TO USE OF MOUNT ST. HELENS ASH

AVAILABILITY OF MAY 18, 1980, ASH

When evaluating the potential use of any mineral commodity, one of the most important factors to consider is availability. One of the most positive features of the May 18th ash fall is that upward of 375,000 cubic yards of ash are stockpiled in eastern counties and require no mining. When Mount St. Helens erupted on May 18th, 50 percent of the state was covered with ash. Most of this ash fallout was in the range of trace to ½ inch deep, an amount that did not require removal, and which was rapidly assimilated into the soil and surface runoff. The portion of the state covered with sufficient ash to warrant removal was probably around 10 percent (fig. 7). Even in the most heavily impacted areas, ash was only removed from buildings, roads, parking lots, and public grounds. On farmland it was tilled into the soil.

Quantities of ash sufficient for industrial use occur only in areas where ash fall was thick enough (2 to 3 inches) to be collected and stockpiled in large volume. The five eastern Washington counties where this was the case are Adams, Grant, Spokane, Whitman, and Yakima. County public-works departments disposed of the ash they removed from county roads in hundreds of small, widely scattered private landfills. Selection of original municipal dumpsites was dictated by expediency. In the haste of removing ash from vital facilities and roads (fig. 24), selection of permanent disposal sites was a secondary consideration. When time and common consensus allowed, however, attention turned to permanent interment of the ash. Table 20 provides information pertaining to the largest municipal ash disposal sites.

The largest stockpiles are in Ritzville, Moses Lake, Yakima, and Spokane. At Ritzville, an abandoned basalt quarry on the west side of town has been used as a disposal site and contains around 103,000 cubic yards of ash, part of which is contaminated with sand, gravel, and refuse (fig. 25). The surface of this stockpile has been seeded with grass.

The city of Moses Lake dumped 10,000 cubic yards of ash in a 1- to 2-acre site adjacent to Moses Lake (fig. 26), leading to a confrontation with the Washington State Department of Ecology that resulted in closure of the site. The second major site is adjacent to a city water tower (Reservoir 4) on the south side of town and involves 5 acres to a depth of 4 feet (32,000 cubic yards). The largest site (Milwaukee property) on the northeastern side of the city, involves 10 acres to a depth of 5 feet for a total of 80,000 cubic yards.

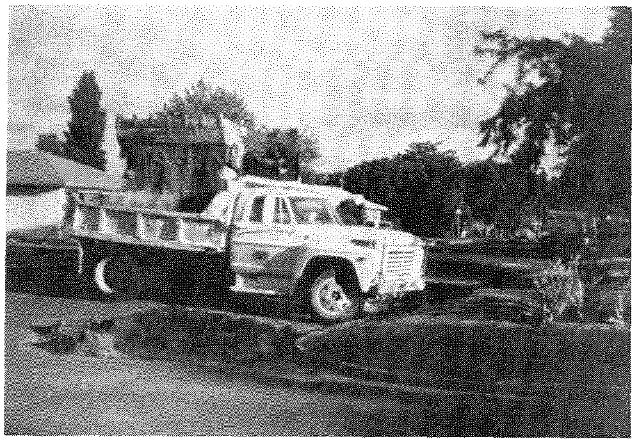


Figure 24.—Ash cleanup at Othello, Washington.

Yakima disposed of its ash in three major landfills. The largest represents 5 acres (15 feet deep), which contains 90,000 cubic yards of ash (fig. 27). The city installed a $35,000 underground sprinkler system, covered the fill with topsoil and grass, and converted the site to a municipal park (Chesterly Park). The second fill (40,000 cubic yards) was used to build up the county fairgrounds. In a practical sense, ash in these sites is unretrievable. The third site, near the airport, represents 20,000 cubic yards of ash that may be relocated due to a change of heart by the private party who volunteered the site.

The city of Spokane dumped its ash, along with normal refuse, in two municipal sanitary landfills, forever eliminating its retrieval. It is impossible to estimate the total number of cubic yards involved in these sites because new ash is being added daily from a variety of sources. Pullman disposed of most of its ash through the city sewer system and hauled the remainder to scabland tracts far removed from the city.

TABLE 20.-- Ash stockpile information

Locality	Volume (cubic yards)	Remarks
Ritzville Basalt quarry site Sec. 22, T. 19 N., R. 35 E.	103,000	2 to 3 acre site to 30 feet depth, uncovered; ash contaminated with sod, gravel, and refuse; retrievable
Moses Lake Reservoir 4 site Sec. 33, T. 19 N., R. 28 E.	32,000	4 to 5 acre site to 5 feet depth, uncovered; ash contaminated; retrievable
Moses Lake Milwaukee Property site Sec. 14, T. 19 N., R. 28 E.	80,000	Up to 10 acres to 5 feet depth, uncovered; ash contaminated; retrievable
Moses Lake Three Pond site Sec. 23, T. 19 N., R. 28 E.	10,000	2 to 3 acres to 5 feet depth, uncovered, closed to dumping by Washington Department of Ecology; ash uncontaminated; retrievable
Yakima Airport site Sec. 35, T. 13 N., R. 18 E.	20,000	2 to 3 acre site, uncovered, may be relocated; ash contaminated; retrievable
Yakima Fairgrounds site Sec. 29, T. 13 N., R. 19 E.	40,000	Ash unretrievable due to use as landfill to build up fairground infield
Yakima Chesterly Park Sec. 15, T. 13 N., R. 18 E.	90,000	Ash unretrievable due to use as landfill to create municipal park with underground sprinkler system

Figure 25.—Ash stockpile at Ritzville, Washington. Abandoned basalt quarry containing 103,000 cubic yards of ash.

Figure 26.—Moses Lake wetlands dumpsite containing 10,000 cubic yards of ash.

PRACTICAL LIMITATIONS FOR RECOVERY AND USE

While it is interesting to speculate on the possible uses of Mount St. Helens ash, in a practical sense there are few reasons to believe it will be used in significant volume. Probably the greatest deterrent to its use is the distance of ash stockpiles from existing markets. The margin of profit associated with use of industrial (nonmetallic) minerals is so narrow that transportation costs are a major consideration. Most industries that would consider using the ash are located in California. Even if these industries were in Spokane or Seattle, transportation costs would be prohibitive.

Another deterrent to use of the ash involves the attitude of residents in the most heavily impacted counties and towns. Initially these municipalities would have been delighted to have industries remove the ash, but no firm offer materialized. Now that the ash has been interred, at tremendous effort and expense, the towns are reluctant to have it resurrected, especially if there is any chance of a recurring dust problem. Yakima has converted its major ash landfill to a city park with an extensive $35,000 underground sprinkling system (fig. 27). A second major landfill occupies part of the Yakima fairground. These two sites are, therefore, permanently removed from industrial exploitation.

County public works departments disposed of ash that fell on roads in a great number of private landfill sites. Most of these sites are uncovered, widely scattered, and full of contaminants. Municipalities have disposed of the ash in large, centralized landfill sites and covered them, or plan to do so soon, with topsoil seeded to grass. With the exception of one stockpile in Ritzville, the ash is highly contaminated, containing sod and gravel which was scooped up with the ash, and refuse dumped by private parties.

Counties and municipalities are also reluctant to deal with the legal problems of ash ownership. If an industry purchased the ash, the question would be raised as to who is entitled to payment, and who would assume liability. Could Burlington Northern, owners of the old St. Helens summit, or the property owners on whose land the ash fell, claim payment? Or would payment pass to the counties or municipalities that cleaned the ash up and stored it on public land? These legal considerations would have to be resolved at additional expense and time.


Figure 27.—Yakima's Chesterly Park ash landfill. Five-acre site containing 90,000 cubic yards of ash.

Variations in ash particle size poses another problem for utilization. The ash is very poorly sorted and average grain size varies widely from place to place (figs. 14 and 15). Most industries that would consider using the ash require uniform and specific particle sizes. A 20 percent variation in particle size would cause so much variation in the properties of certain products (such as concrete) that its use would be detrimental. In order to obtain the necessary particle size, the ash would require processing such as air classification, calcination, and grinding. The extreme angularity of the ash particles would also negatively impact its use in some products, particularly pozzolan-cement concrete.

While all May 18th, 1980, ash contains the same suite of minerals, the relative proportions of constituent minerals vary widely at different locations. In general, composition responds to normal gravitational settling models for volcanic ash with a decrease in heavy, dark ferromagnesian minerals with progressive distance from the vent. If mineral content and chemical composition were critical factors, the user industry would have to deal with these differences.

Ash iron-oxide content negatively impacts its usefulness in the ceramic, pre-cast concrete, and paint industries because it imparts an undesirable black to brown color to products. Even in products where these colors are tolerable, such as beer bottle glass and building brick, the iron content has to be very carefully controlled and the nature of magnetite dispersal, as crystallitic and microlitic inclusions in other minerals, prevents this control.

APPENDIX A

Sample Locations

Sample locations of May 18, 1980, ash collected by Washington Division of Geology and Earth Resources and others appear in figure 28. Sample numbers represent county abbreviations, numeral designations for eruptive events, and sequence of samples collected at each site. For example, sample number Se-2g signifies that the sample was collected at Spokane (Se), represents the second eruption (2), May 18, 1980, and represents the seventh (g) sample of ash collected at Spokane.

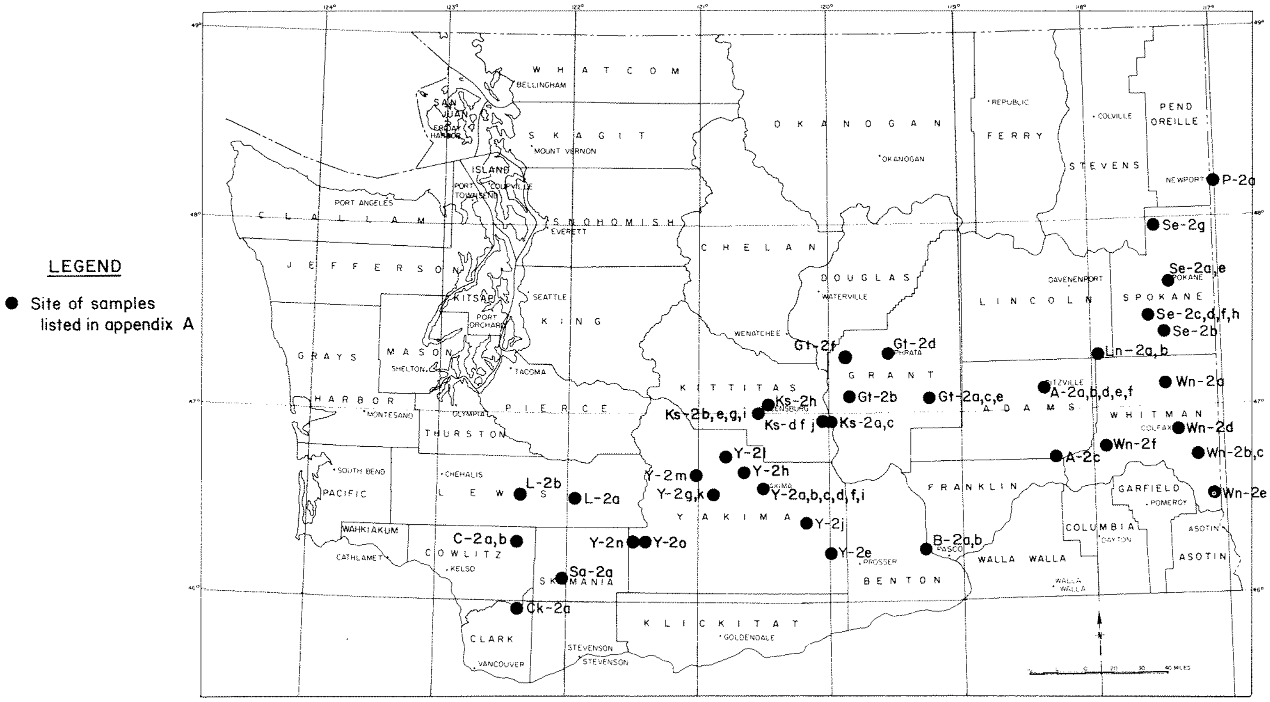


Figure 28.—Sample locations of Mount St. Helens ash—May 18, 1980, eruption.

Appendix A

SAMPLE LOCATIONS, MOUNT ST. HELENS ASH, MAY 18, 1980

Sample no.	County	Town	Legal description	Collected by	Collection date
A-2a	Adams	Ritzville	Sec. 23 (19-35E)	T. Robinson	
A-2b	Adams	Ritzville	Sec. 23 (19-35E)	W. Henning	5-19-80
A-2c	Adams	Washtucna	Sec. 28 (15-36E)	DGER Staff	5-22-80
A-2d	Adams	Ritzville	Sec. 23 (19-35E)	DGER Staff	5-21-80
A-2e	Adams	Ritzville	Sec. 23 (19-35E)	DGER Staff	5-31-80
A-2f	Adams	Ritzville	Sec. 22 (19-35E)	DGER Staff	7-28-80
B-2a	Benton	Richland	(9-28E)	DGER Staff	5-21-80
B-2b	Benton	Richland	(9-28E)	Ron Walcker	6-19-80
Ck-2a	Clark	Chelatchee	Sec. 12 (5-3E)	DNR Staff	
C-2a	Cowlitz	Camp Baker	Sec. 25 (10-2E)	C. Jones	7-27-80
C-2b	Cowlitz	Camp Baker	Sec. 23 (10-2E)	C. Jones	7-27-80
Gt-2a	Grant	Moses Lake	(19-28E)	T. Robinson	
Gt-2b	Grant	George	Sec. 6 (18-24E)	T. Robinson	
Gt-2c	Grant	Moses Lake	(19-28E)	DGER Staff	6-8-80
Gt-2d	Grant	Ephrata	Sec. 16 (21-26E)	R. Walcker	6-19-80
Gt-2e	Grant	Moses Lake	(19-28E)	R. Walcker	6-18-80
Gt-2f	Grant	Quincy	(20-24E)	W. Tucker	6-16-80
Ks-2a	Kittitas	Vantage	(17-23E)	T. Robinson	
Ks-2b	Kittitas	Ellensburg	(18-18E)	T. Robinson	
Ks-2c	Kittitas	Vantage	(17-23E)	DGER Staff	5-31-80
Ks-2d	Kittitas	Vantage Hill	(16-22E)	DGER Staff	5-31-80
Ks-2e	Kittitas	Ellensburg	(18-18E)	O. Green	6-2-80
Ks-2f	Kittitas	Ryegrass	(17-21E)	DGER Staff	5-31-80
Ks-2g	Kittitas	Ellensburg	(18-18E)	R. Clark	
Ks-2h	Kittitas	Ellensburg	(18-19E)	T. Klein	
Ks-2i	Kittitas	Ellensburg	(18-19E)	State Patrol	5-19-80
Ks-2j	Kittitas	Ryegrass	(17-21E)	DGER Staff	7-28-80
L-2a	Lewis	Randle	Sec. 20 (12-7E)	DGER Staff	
L-2b	Lewis	Mossyrock	Sec. 12 (12-3E)	DNR Staff	6-3-80
Ln-2a	Lincoln	Sprague	Sec. 23 (21-38E)	T. Robinson	
Ln-2b	Lincoln	Sprague	Sec. 23 (21-38E)	DGER Staff	5-19-80
P-2a	Pend Oreille	Newport	Sec. 24 (31-45E)	DNR Staff	
Sa-2a	Skamania	7 miles SE St. Helens	(7-6E)	DNR Staff	

Appendix A —Continued

Sample Locations—Continued

Sample no.	County	Town	Legal description	Collected by	Collection date
Se-2a	Spokane	Spokane	(25-44E)	T. Robinson	
Se-2b	Spokane	Spangle	Sec. 4 (22-43E)	T. Robinson	
Se-2c	Spokane	Cheney	Sec. 33 (24-41E)	G. Alf	
Se-2d	Spokane	Spokane	(25-44E)	R. Clark	
Se-2e	Spokane	Spokane	(25-44E)	DGER Staff	5-19-80
Se-2f	Spokane	Cheney	Sec. 13 (23-41E)	DGER Staff	5-19-80
Se-2g	Spokane	Deer Park	Sec. 2 (28-42E)	DNR Staff	
Se-2h	Spokane	Spokane	(25-44E)	M. Freeman	
Wn-2a	Whitman	Thornton	Sec. 27 (19-43E)	T. Robinson	
Wn-2b	Whitman	Pullman	(14-45E)	T. Robinson	
Wn-2c	Whitman	Pullman	(14-45E)	DGER Staff	5-18-80
Wn-2d	Whitman	Colfax	Sec. 14 (16-43E)	T. Robinson	
Wn-2e	Whitman	Uniontown	Sec. 7 (12-46E)	T. Robinson	
Wn-2f	Whitman	LaCrosse	Sec. 2 (15-39E)	DGER Staff	5-19-80
Y-2a	Yakima	Yakima	(13-17E)	N. Campbell	5-18-80
Y-2b	Yakima	Yakima	(13-17E)	N. Campbell	5-18-80
Y-2c	Yakima	Yakima	(13-18,19E)	E. Rogers	
Y-2d	Yakima	Union Gap	(12-19E)	R. Washburn	
Y-2e	Yakima	Sunnyside	(10-22E)	R. Reimer	5-19-80
Y-2f	Yakima	Yakima	(13-18,19E)	R. Clark	
Y-2g	Yakima	Ahtanum	Sec. 14 (12-14E)	DNR Staff	5-30-80
Y-2h	Yakima	Cowiche	(14-17E)	R. Clark	
Y-2i	Yakima	Yakima	Sec. 6 (12-18E)	DNR Staff	5-19-80
Y-2j	Yakima	Zillah	Sec. 35 (11-20E)	J. Schmeirer	
Y-2k	Yakima	Ahtanum	(12-16E)	DGER Staff	7-28-80
Y-2l	Yakima	Naches	Sec. 35 (15-16E)	DGER Staff	7-17-80
Y-2m	Yakima	Rimrock	Sec. 29 (14-15E)	DGER Staff	7-17-80
Y-2n	Yakima	Yakima Indian Reservation	Sec. 30 (10-11E)	B. Burton	5-23-80
Y-2o	Yakima	Yakima Indian Reservation	Sec. 34 (10-11E)	B. Burton	5-23-80

APPENDIX B

Screen Analyses

The following screen analyses of ash from widely distributed localities in Washington are representative of ash from the May 18, 1980, eruption of Mount St. Helens. These samples were used in determining the physical and chemical properties of the ash as reported on in this report. Portions of several of these samples were also submitted to nonmetallic mineral-oriented companies for investigations of potential uses of the ash. Results of these investigations were used in part II — Possible uses of Mount St. Helens ash. Sample sites appear in figure 28.

Appendix B

SCREEN ANALYSES FOR MAY 18, 1980, MOUNT ST. HELENS ASH

Sample no.	Location and legal description	Screen analyses by weight (Tyler standard screens, percent retained on screens)					
		No. 60 (0.250 mm)	No. 115 (0.124 mm)	No. 250 (0.061 mm)	No. 325 (0.044 mm)	No. 400 (0.038 mm)	Pan (-400 mesh)
Y-2g	Ahtanum Sec. 14 (12-14E)	64.3	26.2	5.5	3.1	0.6	0.2
Y-2d	Union Gap (12-19E)	72.3	16.2	7.2	3.9	0.3	0.2
Ks-2a	Vantage (17-23E)	0.1	58.8	35.3	4.0	0.8	1.0
Gt-2a	Moses Lake (19-28E)	0.1	20.7	41.3	32.1	5.3	0.4
A-2a	Ritzville Sec. 23 (19-35E)	0.1	14.8	47.0	33.1	4.4	0.6
Se-2c	Cheney Sec. 33 (24-41E)	0.1	22.2	44.5	28.6	3.6	1.0
Se-2e	Spokane (25-44E)	0	2.5	71.3	21.0	3.9	1.2
P-2a	Newport Sec. 24 (31-45E)	1.2	0.8	7.9	50.3	6.7	33.1
Id-2a	Lookout Pass Idaho-Montana Border (48-6E)	0	1.2	18.3	46.6	21.9	12.0
Se-2g	Deer Park Sec. 2 (28-42E)	11.9	0.4	17.8	46.3	3.8	19.9
Wn-2a	Thornton Sec. 27 (19-43E)	1.0	2.9	34.5	46.2	10.7	5.0
Wn-2d	Colfax Sec. 14 (16-43E)	0.4	5.3	45.4	37.6	8.6	2.6
Wn-2e	Uniontown Sec. 7 (12-46E)	23.5	1.1	8.0	11.3	7.4	48.7
Wn-2c	Pullman (14-45E)	0	8.4	37.8	40.6	10.5	2.7

APPENDIX C

Chemical Analyses of Major Elements

Since the onset of the 1980 eruptive activity at Mount St. Helens, Washington Division of Geology and Earth Resources has received over 50 chemical analyses of St. Helens ash, pumice, and glass from a variety of federal, state, and private agencies. The average of 25 of these analyses appears in table 3. The following appendix contains 46 ash analyses of the April 8, May 18, May 25, and June 12 eruptions. Also included are four analyses of volcanic glass of the May 18 eruption, as well as seven analyses of pumice from the May 18 and May 25 eruptions.

Appendix C-1

WEIGHT PERCENTAGES OF MAJOR OXIDES IN MOUNT ST. HELENS ASH, MAY 18, 1980, ERUPTION

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	LOI	Total
1.	64.21	17.20	0.70	4.74	0.07	1.85	5.07	1.52	4.47	0.19	---	100.02
2.	66.98	16.41	0.59	3.95	0.06	1.41	4.12	1.75	4.59	0.17	---	100.03
3.	68.20	16.15	0.53	3.56	0.05	1.22	3.70	1.85	4.57	0.15	---	100.13
4.	61.90	19.43	0.73	6.84	0.11	3.63	6.05	1.06	4.36	---	0.28	104.39
5.	66.05	18.46	0.52	4.49	0.07	1.78	4.19	1.65	4.59	---	0.80	102.60
6.	60.81	19.69	0.73	6.97	0.10	3.82	6.27	0.97	4.33	---	0.50	104.69
7.	63.46	16.62	0.63	5.57	0.08	2.40	5.39	1.43	4.41	---	0.96	100.95
8.	65.78	16.62	0.49	4.44	0.06	1.69	4.35	1.63	4.62	---	0.76	100.44
9.	63.92	16.31	0.49	4.59	0.06	1.71	4.13	1.94	4.16	---	2.04	103.94
10.	64.60	17.80	0.70	3.70	---	2.0	4.80	1.60	4.70	---	---	99.90
11.	67.70	17.10	0.55	3.20	---	0.50	4.0	1.85	5.0	---	---	99.90
12.	61.53	17.18	0.74	5.46	0.07	2.44	5.41	1.39	4.67	0.20	---	99.09
13.	59.69	19.54	0.64	4.60	0.06	2.33	6.60	1.02	4.83	0.13	---	99.44
14.	64.17	17.07	0.64	4.68	0.06	2.21	5.12	1.06	4.33	0.18	---	99.52
15.	62.11	17.54	0.73	5.05	0.07	2.14	5.40	1.35	4.74	0.18	---	99.31
16.	61.45	17.18	0.75	5.39	0.07	2.42	5.38	1.37	4.64	0.18	---	98.83
17.	65.83	16.43	0.56	4.02	0.06	1.35	4.07	1.68	5.13	0.15	---	99.28
18.	63.37	17.27	0.71	5.33	---	2.27	4.93	1.37	4.78	0.23	---	100.26
19.	61.70	20.50	---	3.70	---	1.70	3.90	2.20	5.30	0.09	---	99.09
20.	65.60	17.0	---	4.0	---	1.30	4.60	1.63	4.35	---	0.70	99.18
21.	61.10	16.50	---	5.30	---	2.24	8.10	1.28	4.31	---	0.53	99.36
22.	60.50	16.0	0.90	6.0	0.12	2.59	5.36	1.20	4.18	0.35	---	97.20
23.	64.50	16.41	0.70	4.15	---	1.52	4.20	1.59	4.67	---	2.20	99.94
24.	58.50	18.30	1.00	6.50	---	3.30	6.20	0.97	4.30	---	0.38	99.45
25.	66.50	17.40	---	4.40	---	1.40	2.90	4.80	2.02	---	0.36	99.78
26.	65.10	17.60	---	4.50	---	1.40	2.70	4.44	1.98	---	0.65	98.37
27.	62.90	20.0	---	7.0	---	3.40	4.30	0.21	1.89	---	0.27	99.97
28.	67.80	17.60	---	4.30	---	1.60	3.50	3.90	1.99	---	0.32	101.01
29.	64.60	18.1	0.70	5.24	0.09	2.70	5.14	1.31	4.57	0.23	0.51	103.49
30.	59.40	17.40	0.88	6.64	0.12	4.10	6.57	0.88	4.35	0.37	0.56	101.27
31.	63.30	17.40	0.83	5.59	0.09	2.80	5.74	1.25	4.49	0.33	0.62	102.44
32.	60.30	16.40	0.85	5.61	0.09	2.77	5.55	1.56	4.83	0.46	0.56	98.98
33.	66.90	17.10	0.68	4.99	0.08	1.84	4.74	1.55	4.56	0.32	0.35	103.11
34.	68.20	17.20	0.63	4.22	0.07	1.61	4.77	1.60	4.42	0.37	0.56	103.65
35.	66.90	16.10	0.53	3.69	0.06	1.28	3.71	1.75	4.85	0.39	0.55	99.81
36.	68.20	16.20	0.55	3.56	0.06	1.33	4.00	1.69	4.52	0.48	0.56	101.15
37.	67.20	16.30	0.58	3.76	0.06	1.48	4.20	1.66	4.52	0.37	0.78	100.91
38.	59.5	18.5	0.73	5.14	0.09	6.47	3.13	0.95	4.32	0.16	---	98.99
39.	59.9	18.0	0.79	5.48	0.09	6.22	3.22	1.01	4.29	0.16	---	99.16
40.	66.8	16.0	0.59	3.23	0.05	3.93	1.30	1.69	4.62	0.14	---	98.35
41.	67.4	16.0	0.53	3.20	0.05	3.84	1.24	1.72	4.68	0.14	---	98.80
42.	63.2	16.4	0.58	3.55	0.05	4.48	1.59	1.60	4.46	0.16	---	96.07

Appendix C-1—Continued

1. P. Hooper and others, 1980, Washington State University unpublished report, p. 4, table 1; X-ray fluorescence analysis, average of 3 analyses of dark ash from early afternoon fallout in Pullman, sample A.
2. Same as above, average of 2 analyses of mixed dark and pale ash, sample B.
3. Same as above, average of 4 analyses of pale ash from late afternoon fallout, sample C.
4. G. Mustoe, written communication; atomic absorption analysis, Yakima ash, sample DLG-2Y.
5. Same as above, Spokane ash, sample SH-SK-1.
6. Same as above, Yakima ash, sample DLG-1Y.
7. Same as above, Randle ash, sample RBW-80-42.
8. Same as above, Missoula, Montana ash, sample SH-MS-2.
9. Same as above, Denver, Colorado ash, sample SH-D-1.
10. K. Wozniak and others, 1980, Oregon Geology, v. 42, p. 130; X-ray fluorescence analysis, Pullman ash, sample 3.
11. Same as above, collected 12:30 to 8:00 a.m., Pullman, sample 4.
12. J. Carr, written communication; base surge deposit, unit A, collected Mount St. Helens, sample RBW-80-77A.
13. Same as above, air-fall ash, unit B, sample RBW-80-77B.
14. Same as above, air-fall ash, unit C, sample RBW-80-77C.
15. J. Carr, written communication; air fall ash, unit D, sample RBW-80-77D.
16. Same as above, air-fall ash, collected at Mount Adams, sample 5-18.
17. Same as above, air-fall ash, collected at Moscow, Idaho, sample WOOD-1.
18. R. Berman, written communication; X-ray fluorescence, collected near Mount St. Helens.
19. M. K. Weiss, written communication; Kellogg, Idaho ash.
20. W. G. Miller, written communication; Yakima ash.
21. Same as above, Richland ash.
22. Same as above, collection site uncertain.
23. W. Mivelaz, written communication; X-ray fluorescence, Spokane ash.
24. Same as above, Yakima ash.
25. O. Manz, written communication; Ritzville ash, sample 80-163.
26. Same as above, Spokane ash, sample 80-154
27. Same as above, Yakima ash, sample 80-155.
28. Same as above, Moses Lake ash, sample 80-162.
29. J. Fruchter and others, 1980, Science, v. 209, p. 19; plasma emission spectroscopy, Tieton ash.
30. Same as above, Ahtanum ash.
31. Same as above, Yakima ash.
32. Same as above, Richland ash.
33. Same as above, Moses Lake ash.
34. Same as above, Spokane ash.
35. Same as above, Rosalia ash.
36. Same as above, Pullman ash.
37. Same as above, Missoula, Montana ash.
38. J. Taggart, S. Wahlberg, written communication; X-ray fluorescence spectroscopy, Ahtanum ash.
39. Same as above, Tieton ash.
40. Same as above, Moscow, Idaho ash.
41. Same as above, Palouse, Idaho ash.
42. Same as above, Helena, Montana ash.

Appendix C-2

WEIGHT PERCENTAGES OF MAJOR OXIDES IN MOUNT ST. HELENS ASH, APRIL AND JUNE, 1980, ERUPTIONS

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	LOI	Total
1.	64.54	18.69	0.60	5.46	0.08	2.62	5.56	1.29	4.49	---	0.20	103.53
2.	62.99	17.34	0.63	5.91	0.09	2.74	5.53	1.23	4.21	---	---	100.67
3.	64.20	17.23	0.60	4.94	0.07	1.94	5.12	1.46	4.60	---	0.58	100.74
4.	60.40	16.80	---	5.90	---	2.0	6.10	1.16	4.14	---	0.40	96.9

1. G. Mustoe, written communication; atomic absorption analysis, Mount St. Helens sheet, sec. 34, T. 9 N., R. 5 E., April 8, 1980, eruption, sample SH-1E.
2. Same as above, sample SH-1E1.
3. Same as above, Castle Rock ash, April 25, 1980, eruption, sample CR4/25.
4. W. G. Miller, written communication; Hillsboro, Oregon ash, June 12, 1980, eruption.

Appendix C-3

WEIGHT PERCENTAGES OF MAJOR OXIDES IN MOUNT ST. HELENS VOLCANIC GLASS, MAY 18, 1980, ERUPTION

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	MnO	MgO	CaO	K_2O	Na_2O	Total
1.	71.47	14.99	0.37	2.48	0.05	0.52	2.32	2.03	4.68	98.91
2.	71.37	15.09	0.44	2.57	0.06	0.49	2.76	1.94	4.30	98.99
3.	76.15	13.50	---	1.43	---	---	1.22	3.02	4.05	99.37
4.	72.92	15.60	0.46	1.40	0.04	1.00	2.50	2.00	3.90	99.82

1. C. Meyer, written communication; electron microprobe analysis, airfall ash, glass only, Moscow, Idaho.
2. Same as above, pumice clast from unit B, glass only, collected near Mount St. Helens.
3. P. Hooper and others, 1980, Washington State University unpublished report, p. 4, table 1; X-ray fluorescence analysis, glass particles in dark Pullman ash.
4. Same as above, colorless glass in pale Pullman ash.

Appendix C-4

WEIGHT PERCENTAGES OF MAJOR OXIDES IN MOUNT ST. HELENS PUMICE, MAY 18, 1980, ERUPTION

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	Total
1.	64.30	18.20	0.06	4.20	---	2.0	4.80	1.45	4.80	---	99.81
2.	64.10	18.0	0.65	4.20	---	2.0	4.80	1.45	4.70	---	99.9
3.	64.10	17.50	0.60	4.10	---	1.90	4.60	1.45	4.80	---	99.05
4.	64.20	18.0	0.65	4.30	---	1.90	4.90	1.45	4.80	---	100.2
5.	64.30	18.0	0.60	4.0	---	1.80	4.70	1.50	4.70	---	99.6
6.	64.35	17.17	0.61	4.67	---	2.09	4.63	1.34	4.78	0.17	99.81
7.	62.56	18.12	0.62	4.57	0.06	2.02	5.41	1.23	4.68	0.13	99.40

1. K. Wozniak and others, Oregon Geology, v. 42, p. 130; X-ray fluorescence, pumice lapilli, west fork Pine Creek, May 18, 1980.
2. Same as above, light tan pumice lapilli, 1 mile south of Spirit Lake, May 18, 1980.
3. Same as above, gray pumice lapilli, Castle Creek, May 18, 1980.
4. Same as above, light tan pumice lapilli, 2 miles south of Spirit Lake, May 25, 1980.
5. Same as above, banded pumice lapilli, May 25, 1980.
6. R. Berman, written communication; X-ray fluorescence, ash collected near Mount St. Helens, May 18, 1980.
7. J. Carr, written communication; X-ray fluorescence, pumice clast from Unit B near Mount St. Helens, May 18, 1980.

APPENDIX D

Minor and Trace Element Analyses of Mount St. Helens Ash, May 18, 1980, Eruption

(ppm of sample, by weight)

Appendix D

MINOR AND TRACE ELEMENT ANALYSES OF MOUNT ST. HELENS ASH, MAY 18, 1980, ERUPTION

(ppm of sample, by weight)

	1	2	3	4	5	6	7	8	9	10
Ag	---	---	---	---	---	<1	<0.2	---	10	---
As	---	---	---	---	---	<200	3	---	---	1
Au	---	---	---	---	---	<10	0.2	---	---	---
B	---	---	---	---	---	<10	15	---	---	---
Ba	191	218	344	390	344	440	300	---	---	---
Be	0.4	0.5	0.6	0.8	0.7	2.4	2	---	---	---
Bi	---	---	---	---	---	<10	0.2	---	---	---
Cd	---	---	---	---	---	<10	0.2	8	---	---
Ce	29	26	33	40	43	<100	70	---	---	---
Co	14	15	8	9	9	6	10	8	30	---
Cr	9	11	3	4	15	11	10	---	40	7
Cu	25	33	37	40	42	37	30	44	40	40
Eu	---	---	---	---	---	---	<1	---	---	---
Ga	---	---	---	---	---	21	20	---	---	---
Ge	---	---	---	---	---	---	7	---	---	---
Hf	---	---	---	---	---	---	<50	---	---	---
Hg	---	---	---	---	---	---	1	---	---	---
In	---	---	---	---	---	---	<2	---	---	---
La	---	---	---	---	---	<20	30	---	---	---
Li	16	23	29	33	28	<50	200	---	10	---
Mn	641	733	453	498	501	500	500	560	250	---
Mo	<1	<1	2	2	2	<10	2	---	---	4
Nb	4	3	3	3	3	<25	10	---	---	---
Ni	13	13	8	6	14	11	10	10	50	---
Pb	10	13	11	10	19	<10	20	65	50	4
Pd	---	---	---	---	---	<1	1	---	---	---
Pt	---	---	---	---	---	<5	10	---	---	---
Re	---	---	---	---	---	---	15	---	---	---
Sb	---	---	---	---	---	<100	1	---	30	0.1
Sc	10	11	7	8	9	<10	15	---	---	---
Se	---	---	---	---	---	---	5	---	---	---
Sn	---	---	---	---	---	<10	2	---	---	---
Sr	498	488	345	379	391	360	500	---	---	---
Ta	---	---	---	---	---	---	<50	---	---	---
Te	---	---	---	---	---	<300	1	---	---	---
Th	---	---	---	---	---	---	<150	---	---	---
Tl	---	---	---	---	---	---	<1	---	---	---
U	---	---	---	---	---	<150	150	---	---	---
V	82	100	52	57	61	53	70	---	---	---
W	---	---	---	---	---	<100	10	---	---	---
Y	10	11	13	15	15	16	20	---	---	---
Yb	1.1	1.0	1.3	1.0	1.2		2	---	---	---
Zn	63	71	53	59	56	290	300	150	70	62
Zr	64	83	131	150	116	---	---	---	---	---

Appendix D—Continued

1. C. Gent; R. Riddle; F. Lichte, written communication; analysis by induction coupled plasma atomic emission spectroscopy, Ahtanum ash.
2. Same as above, Tieton ash.
3. Same as above, Moscow, Idaho ash.
4. Same as above, Palouse, Idaho ash.
5. Same as above, Helena, Montana ash.
6. T. Fries; P. Lamothe, written communication; direct-reading quantitative emission spectrometric analysis, Moscow, Idaho ash.
7. Same as above, six-step semiquantitative emission spectrometric analysis, Moscow, Idaho ash.
8. W. K. Weiss, written communication; Kellogg, Idaho ash.
9. R. L. Strachila, written communication; Randle ash.
10. Washington Division of Geology and Earth Resources; atomic absorption analysis by Chemex Ltd., Vancouver, British Columbia.

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