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Proximal Air-Fall Deposits of Eruptions Between
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THE 1980 ERUPTIONS OF MOUNT ST. HELENS, WASHINGTON

PROXIMAL AIR-FALL DEPOSITS OF ERUPTIONS BETWEEN MAY 24 AND AUGUST 7, 1980—STRATIGRAPHY AND FIELD SEDIMENTOLOGY

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ABSTRACT

During each of the magmatic eruptions of Mount St. Helens on May 25, June 12, July 22, and August 7, a vertical eruptive column rose intermittently to altitudes of 12–15 km, from which pumice, lithic fragments, and crystals settled downwind in lobes that generally become thinner and finer away from the volcano. Each ejecta lobe is asymmetric according to several criteria, including (1) the axes of maximum thickness and of maximum pumice size are not midway between the two margins of the lobe, (2) the axis of maximum pumice size does not correspond to the axis of thickness, and (3) the median size of particles grades through several grain-size intervals from one lateral margin to the other. The fining in grain size across the lobe is due to the rotation of wind directions with altitude, so material falling from a high-level airborne plume is winnowed as it falls through transverse low-level winds. Wind directions that rotate clockwise with increasing altitude effect an air-fall lobe whose axis of maximum coarseness is clockwise of the axis of maximum thickness; wind directions that rotate counterclockwise with increasing altitude effect an air-fall lobe whose trend of maximum coarseness is counterclockwise of the axis of maximum thickness.

The thickness of air-fall deposits from eruptions on May 25 through August 7 range variously from one-third to one-fortieth that of the May 18 air-fall deposit at a given distance from the volcano. The post-May 18 deposits are an order of magnitude thinner than Mount St. Helens pumice layer T (A.D. 1800) and two orders of magnitude thinner than Mount St. Helens pumice layer Yn (3400 yr B.P.), which is similar in thickness to the most

voluminous air-fall deposits of other Cascade Range volcanoes. The maximum size of pumice within the May 18 air-fall lobe is 5–10 times that of the post-May 18 lobes. The overlapping air-fall lobes of May 25, June 12, July 22, and August 7 form a stratigraphic layer that in most places is indivisible into deposits of the separate eruptions.

INTRODUCTION

After the May 18, 1980, eruption of Mount St. Helens, smaller magmatic eruptions occurred on May 25, June 12, July 22, August 7, and October 16–18. None of these repeated the devastating events of May 18, but each eruption produced a vertical column over 10 km tall from which ash drifted downwind, and also produced ash flows down the north flank from which a convected cloud drifted downwind. This report analyzes the air-fall deposits in areas within 60 km of the crater. The distal plumes and air-fall deposits are discussed by Sarna-Wojcicki, Shipley, and others (this volume) and the ash-flow deposits by Rowley and others (this volume).

ACKNOWLEDGMENTS

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Meteorological Service, Susan Shipley constructed wind-direction diagrams that accompany the deposit maps.

THICKNESS, GRAIN SIZE, AND COMPOSITION OF AIR-FALL DEPOSITS

DISTRIBUTION OF AIR-FALL DEPOSITS

The limits and field characteristics of air-fall deposits of the first five magmatic eruptions (fig. 366) were determined within a few days of each eruption, but additional data were gathered for weeks afterward. Air-fall materials of eruptions of May 25 and later are generally distinguishable from May 18 material because the upper part of the May 18 air-fall deposit is silt (Waitt and Dzurisin, this volume) that had been wetted and dried and had thus become somewhat coherent before being overlaid by the younger materials.

TOTAL DEPOSIT

The total thickness of air-fall deposits (fig. 367) is dominated by those of the May 18 eruption—the directed-blast (pyroclastic density-flow) deposits impelled to the north (Waitt; Moore and Sisson; Hoblitt and others; this volume), and air-fall deposits from the central column that drifted east-northeast (Waitt and Dzurisin, this volume). The lobe southeast of the volcano apparently resulted mostly from a nonmagmatic eruption on May 24, the lobe to the northwest by the magmatic eruption on May 25, and that to the south by magmatic eruptions on May 25 and June 12. The July 22 air-fall deposit, which accumulated atop

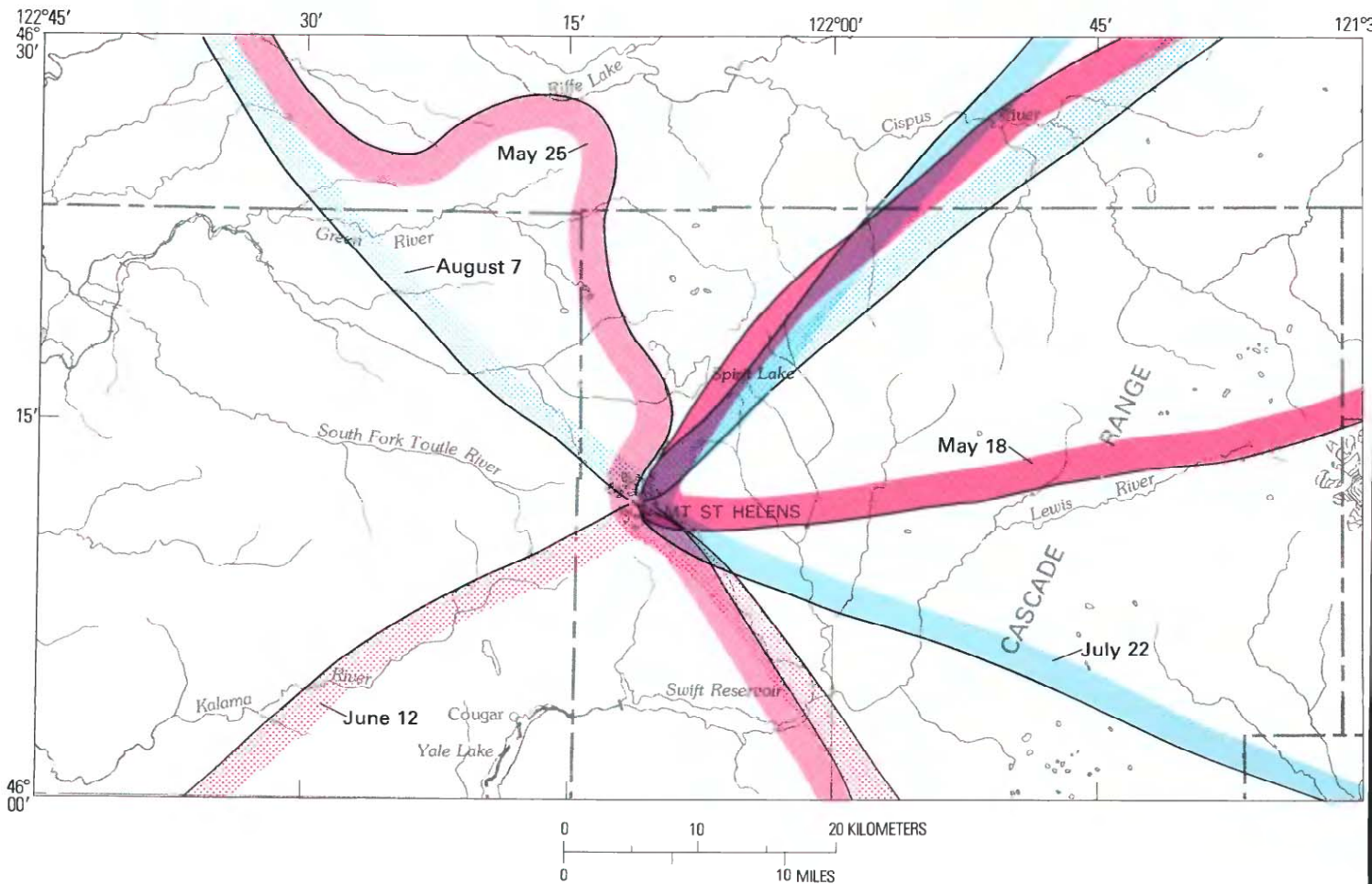


Figure 366.—Index map showing discernible limits of air-fall lobes of eruptions from May 18 through August 7, 1980.

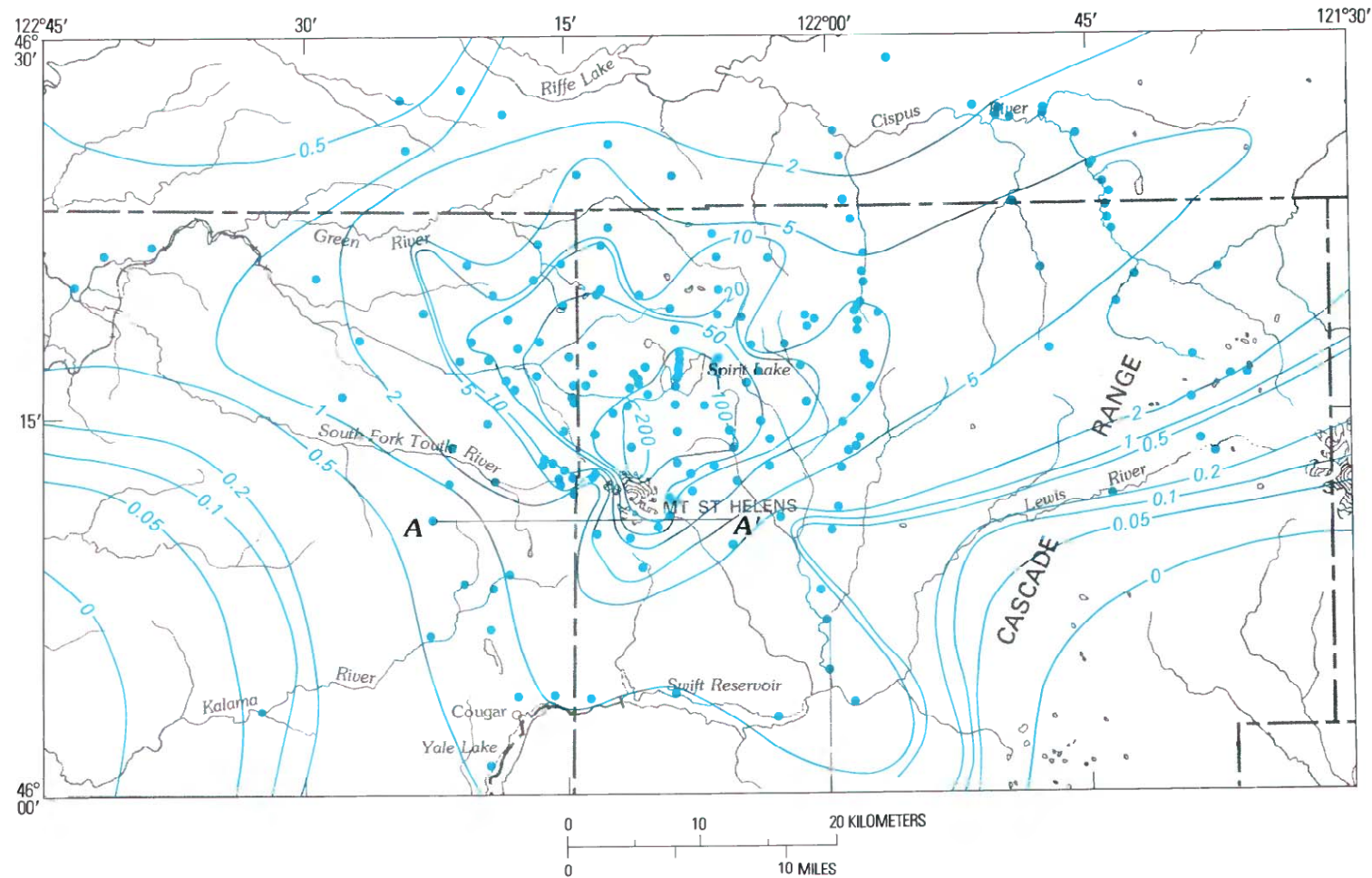


Figure 367.—Isopach maps of air-fall deposits through July 22, 1980. Contour values in centimeters; thickness measured at sites indicated by blue dots. Cross section A-A' is shown in figure 374.

the May 18 air-fall lobe to the east-northeast, scarcely altered the total-thickness isopachs. The August 7 and October 16-18 air-fall deposits are not included on the total-thickness isopach map (fig. 367), but they were even thinner than the deposits of July 22. Of several minor nonmagmatic ash plumes between the magmatic eruptions, only the narrow lobe attributed to May 24 is thick enough to affect the isopach contours.

MAY 24 DEPOSIT

An ash deposit noted on the southeast flank of the volcano on May 30 is dark-gray lithic-crystal fine sand.² This deposit, sharply defined 15 km southeast

of the crater, composes most of the southeastern lobe in the total-thickness isopach map (fig. 367). The lobe is south of the margin of the air-fall lobe of May 18 and is largely east of the margins of May 25 and June 12 air-fall deposits. Although its age is not absolutely certain, it probably resulted from a dense nonmagmatic ash plume on May 24 that for several hours drifted southeast (David A. Gibney, oral commun., 1980).

MAY 25 DEPOSIT

The May 25 air-fall deposit consists of small-pebble gravel to very coarse sand near the volcano on the northwest-through-southwest sector, and grades to medium to very fine sand to the west and northwest away from the volcano (fig. 368). About an arc 30 km from the volcano the median grain size also grades laterally across the deposit from medium sand at the

²Standard Wentworth sediment-size terms are used to provide a distinct designation for each grain-size interval. Unit designations like "granule gravel," taken from Folk (1974), designate only median grain size of deposits, and not rounding, sorting, or genesis of particles. Fuller explanation appears in Waitt (this volume).

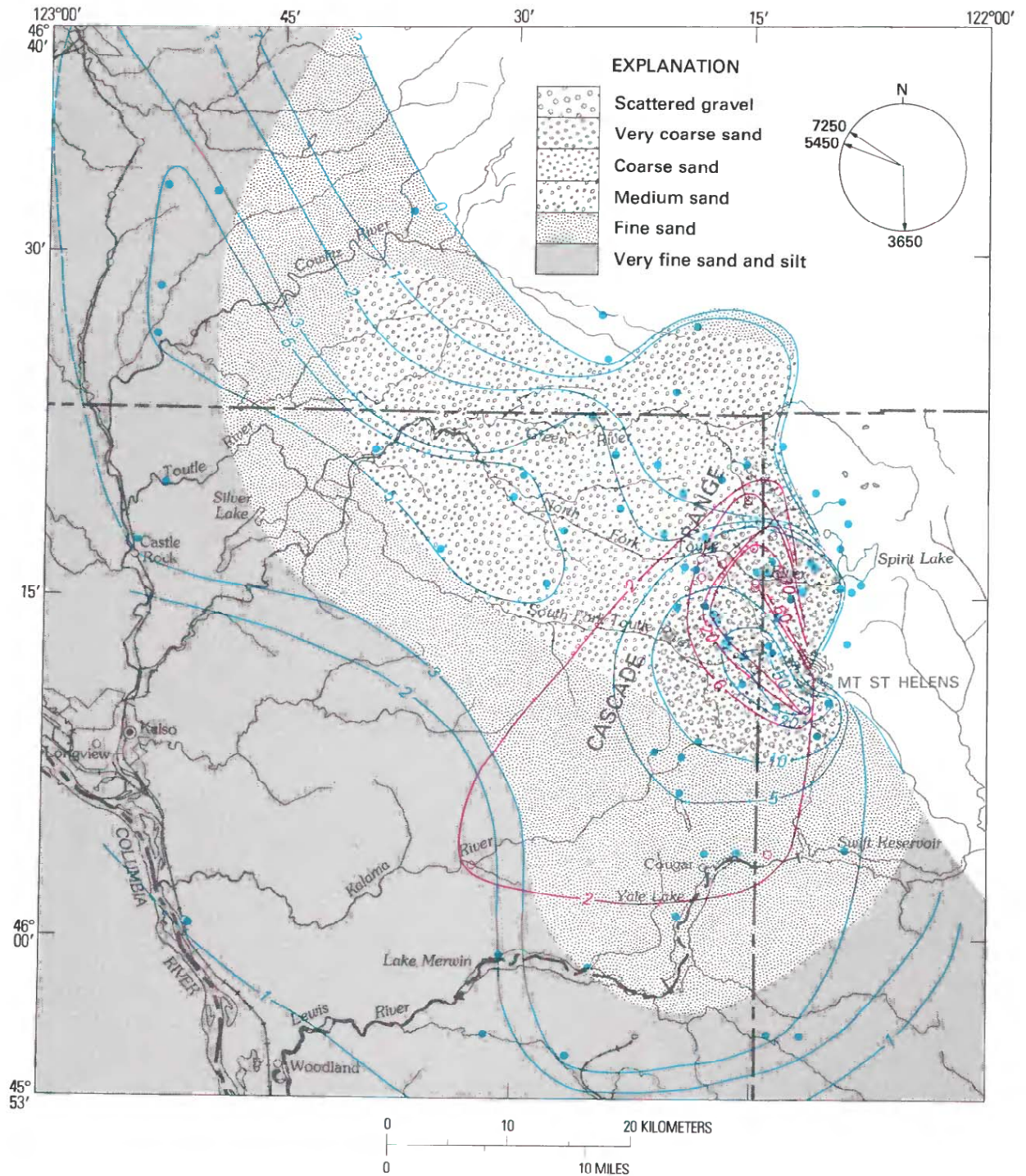


Figure 368.—Map of May 25 air-fall deposit showing isopachs (blue lines), median grain size (pattered areas), and isopleths of intermediate diameter of largest pumice fragment (red lines). All contour values are in millimeters. Wind directions shown for altitudes below 7,500 m. Blue dot, thickness measured at site; red open circle, pumice diameter measured at site. Median grain size determined at about half of the data points.

north margin to silt at the south margin.

Unlike the other air-fall lobes of 1980, each of which is spread through an arc of 90° or less, the May 25 air-fall deposit spread through a 180° arc from south-southeast to north-northwest. The wide arc resulted from a great variance in the wind directions on May 25, which rotated clockwise (in plan view) with altitude: material ejected to altitudes below 4 km drifted south, while that ejected to 5–6 km drifted northwest (fig. 368). The material accumulated thickest to the northwest. The axis of maximum pumice size trends clockwise of the axis of maximum thickness, consistent with the southwardly decrease in median grain size laterally across the lobe. Of the material ejected to high altitude, the finer grained was winnowed to the south by the low-level winds.

The May 25 air-fall deposit contains frothy white pumice like that of the May 18 air-fall deposit (Waitt and Dzurisin, this volume), and also up to 25 percent dense gray pumice similar to a minor component of the May 25 ash-flow deposits (P. W. Lipman, oral commun., 1980). Whereas the May 18 eruption segregated vesicular gray dacite in the directed-blast (pyroclastic density-flow) deposit from the frothy white pumice in the air-fall and ash-flow deposits, the May 25 eruption mixed both rock types into both the air-fall and ash-flow deposits.

JUNE 12 DEPOSIT

The June 12 air-fall lobe is spread broadly southward from the volcano (fig. 369). Although data on maximum pumice size are sparse, gravel-sized pumice fragments fell on the southwest flank of the volcano and other sites near the western margin of the air-fall lobe (fig. 370). The axis of maximum pumice size is clockwise of the axis of maximum thickness. The median grain size grades laterally across the lobe, from scattered pumice gravel and coarse sand at the northwestern margin to fine sand and silt at the eastern margin. Up to an altitude of 12 km, the wind on June 12 rotated clockwise with altitude: material carried west-southwest by high-altitude wind descended through winds toward the southwest, south, and southeast that winnowed the fines from the west side of the plume.

The June 12 air-fall and ash-flow deposits, like those of May 25, contain dense gray pumice sparsely mixed with white frothy pumice. In distal areas like

Vancouver, Wash., the ash near the western margin was a pumice-crystal-lithic sand.

The June 12 air-fall deposit includes a mantle of pale-brown sand and silt that overlay and subdued the microtopography of the May 18 ash-flow deposits just east of the margin of the June 12 ash-flow deposits. The mantle was the same pale-brown color as air-fall unit C of May 18 (Waitt and Dzurisin, this volume). The silt that was convected from the June 12 ash flows accumulated millimeters thick downwind to the east and southeast. Whereas the ash flows were channeled by and ponded in topographic lows, this pale-brown silt to the east accumulated nearly evenly on minor topographic highs and lows alike, including areas higher than the top of the ash flows.

JULY 22 DEPOSIT

The July 22 eruptive plume drifted east-northeast, approximately the same direction as the May 18 plume. The air-fall deposit resulted from an eruption comprising three discrete events.

The air-fall deposit is a pebble gravel near the volcano north of the axis of the lobe and grades outward along the axis to coarse sand (fig. 371). From the east-northeast-trending plume the fallout was blown southeastward by winds below altitude 5 km (R. P. Hoblitt and J. E. Vallance, unpub. aerial-oblique photographs). The low-altitude wind thus winnowed fines from the north toward the south margin of the plume. The effects in the field are conspicuous, for the north margin of the lobe near the volcano is sharp and is characterized by scattered cobble- to granule-sized pumice (fig. 372), while the south half of the lobe is a continuous layer of gray sand and silt that tapers to a diffuse ill-defined margin. The axis of maximum pumice size consequently lies counterclockwise of the axis of maximum thickness (fig. 371)—the opposite of the patterns of May 25 and June 12 (figs. 368, 369).

The material at the north side of the lobe comprises 70 percent white pumice, 20 percent gray pumice, and 10 percent lithics and crystals. The gray pumice is lighter in color and less distinct from the white pumice than in the May 25 and June 12 air-fall deposits.

The July 22 ash flows were small compared to those of June 12, and there is no recognizable downwind deposit of the ash-flow cloud. Much of the plume that

convected from the ash flows was drawn up into the vertical eruptive column (J. E. Vallance, unpub. aerial-oblique photographs), a process that the southward low-level winds of July 22 probably aided.

AUGUST 7 DEPOSIT

The August 7 eruption comprised several plumes; downwind the ash fell during at least two distinct intervals spaced hours apart. Within 25 km of the volcano, sparse pumice granules accumulated in a sector on the north that had not received air-fall material since May 18. The material grades downwind to the north into medium and fine sand, which at Randle and Ellensburg, Wash., fell partly as ac-



Figure 370.—Coarse pumice (from June 12 eruption) that formed impact pits in the finer but much thicker May 25 air fall at Butte Camp, on southwest flank of volcano. Scale is 15 cm long.

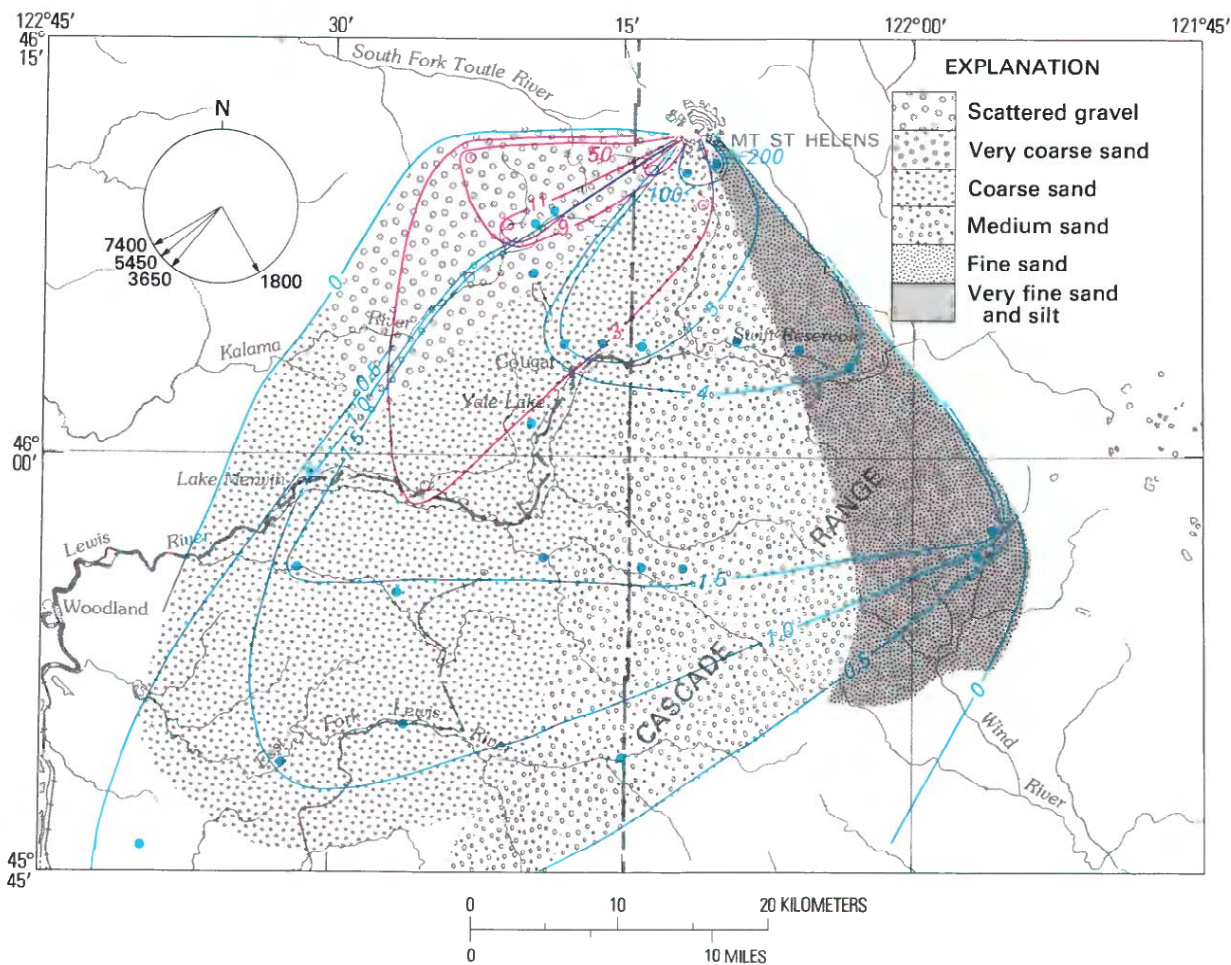


Figure 369.—Map of June 12 air-fall deposits showing isopachs (blue lines), median grain size (patterned areas), and isopleths of intermediate diameter of largest pumice fragment (red lines). All contour values are in millimeters. Wind directions shown for altitudes below 7,500 m. Blue dot, thickness measured at site; red open circle, pumice diameters measured at site. Median grain size determined at about half of the data points.

creted pellets that quickly disintegrated into sand. Almost everywhere this deposit was too thin (less than 0.5 mm) to be measured, but along U.S. Highway 12 in the Cowlitz River valley it was thickest (1 mm) north-northeast of the volcano (fig. 373). The material was thinner and sparser than that of the July 22 eruption, which had been the thinnest magmatic air-fall deposit. The distinction between white and gray pumice had all but disappeared.

The deposit along the eastern margin of the lobe 20 km from the vent consists of scattered small pebbles

to granules of pumice and lithic fragments, whereas along the western margin at a similar distance from the volcano, the deposit was a nearly continuous veneer of medium to fine sand (fig. 373). Although data on maximum pumice diameter are sparse, the axis of maximum pumice size is clockwise of the trend of maximum thickness, as it was on May 25 and June 12. The observed wind below 6 km altitude was counterclockwise of the upper level winds, and consequently the fines tended to be winnowed westward across the plume.

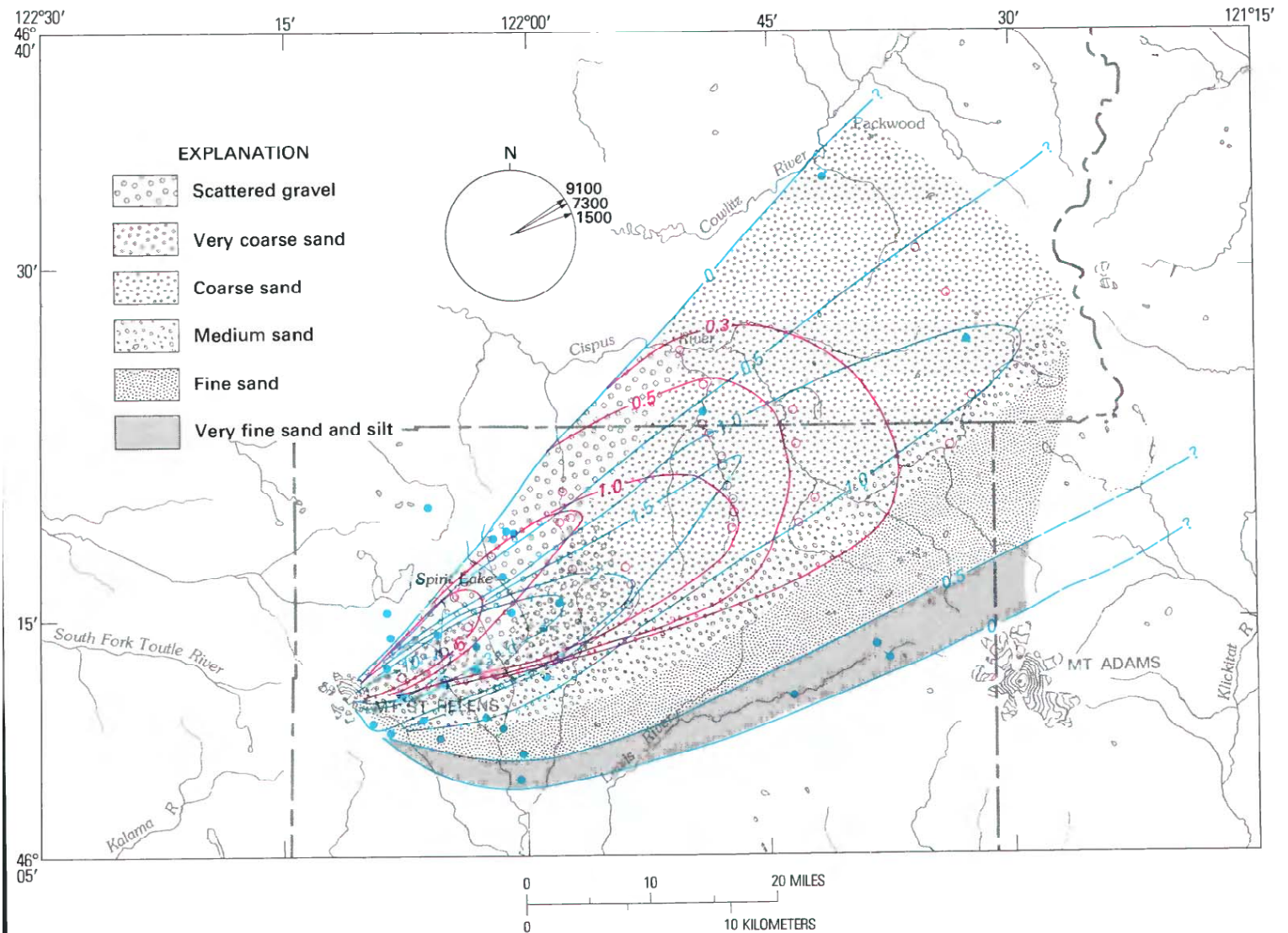


Figure 371.—Map of July 22 air-fall deposit showing isopachs (blue lines), median grain size (patterned areas), and isopleths of intermediate diameter of largest pumice fragment (red lines). All contour values are in millimeters. Wind directions shown for altitudes below 9,500 m. Blue dot, thickness measured at site; red open circle, pumice diameters measured at site. Median grain size determined at about half of the data points.



Figure 372.—Coarse pumice of July 22 eruption overlying coherent surface of silt at top of May 18 air-fall deposit. Shovel handle is about 30 cm long.

MINOR NONMAGMATIC DEPOSITS

Several relatively minor eruptions occurred between the magmatic eruptions. A brief plume on August 15, for example, shot to 4.5 km altitude, from which lithic-crystal sand and silt fell sparsely as far as 50 km to the southeast, where it settled onto the surficial layer of May 24 and June 12 material. The deposits of such nonmagmatic eruptions generally cannot be distinguished from the much thicker and coarser deposits of previous magmatic eruptions.

STRATIGRAPHY OF AIR-FALL LAYERS

Where a thin or scattered coarse air-fall deposit accumulates in an area that previously received thin or scattered coarse air-fall material but subsequently was not overlaid by finer material, the two deposits blend into a single layer. Most of the May 18 air-fall deposit is stratigraphically isolated from various overlying younger air-fall products by the intervening May 18 silt of layer A3 or units C or D (Waite and Dzurisin, this volume). Materials of May 25 and later that overlie this fine-grained May 18 surface have not been similarly mantled.

The coarse July 22 air-fall deposit is readily distinguished from the coarse May 18 air-fall deposit in most of the area of mutual fallout because of the intervening May 18 silt deposits. At the south margin of the May 18 lobe, however, where May 18 units C and

D are absent and layer A3 is less than 1 mm thick, the July 22 air-fall deposit is stratigraphically indistinguishable from May 18 material. The two are rudely distinguishable by the grading across both lobes: scattered pumice and lithic gravel fell on the south side of the May 18 lobe, whereas the south margin of the July 22 lobe tapered to a continuous layer of fine sand to silt. Thus, in the east-to-east-southeast sector, scattered coarse May 18 pumice and lithic fragments mingle with fine sand and silt of July 22 that merely settled among the coarse May 18 fragments. Within the coniferous forest east of the area devastated on May 18, air-fall pumice selectively trapped by the trees on May 18 eventually accumulated on the surface of May 18 layer D (Waite and Dzurisin, this volume), later to mingle with the July 22 air-fall deposit in a single layer.

Northeast of the volcano it was difficult even on August 8 to distinguish the coarse August 7 air-fall deposit from the coarse July 22 air-fall deposit where the two overlapped. But on vehicles, swept roads, and the May 18 silt surface specifically cleared between July 24 and August 6, the scattered pumice and lithic fragments of August 7 could be distinguished from the similar but much coarser and more abundant July 22 material. On unprepared natural surfaces, the two air-fall deposits constitute an indivisible stratigraphic layer. Similarly on the northwest, the August 7 air-fall deposit is indistinguishable from the May 25 air-fall deposit.

The southwest flank of the volcano received coarse pumice and lithic fragments on May 25 and again on June 12. The pebble-size scattered fragments of the June 12 deposit are distinguishable from the continuous layer of much finer May 25 material because observations just before, during, and just after the June 12 eruption recorded the changes. For the stratigraphic record, however, the two deposits now constitute a layer barely distinguishable into two deposits (figs. 370, 374). From Butte Camp on the lower southwest flank of the volcano, the coarse scattered pumice of June 12 thickens into a continuous but finer layer on the south flank, where the underlying layer of May 25 thins and becomes even finer (fig. 374); from Butte Camp the coarse surficial June 12 pumice becomes progressively sparser and finer on the west flank, where the underlying May 25 layer becomes much thicker, and the two layers are thus partly distinguishable (fig. 374).

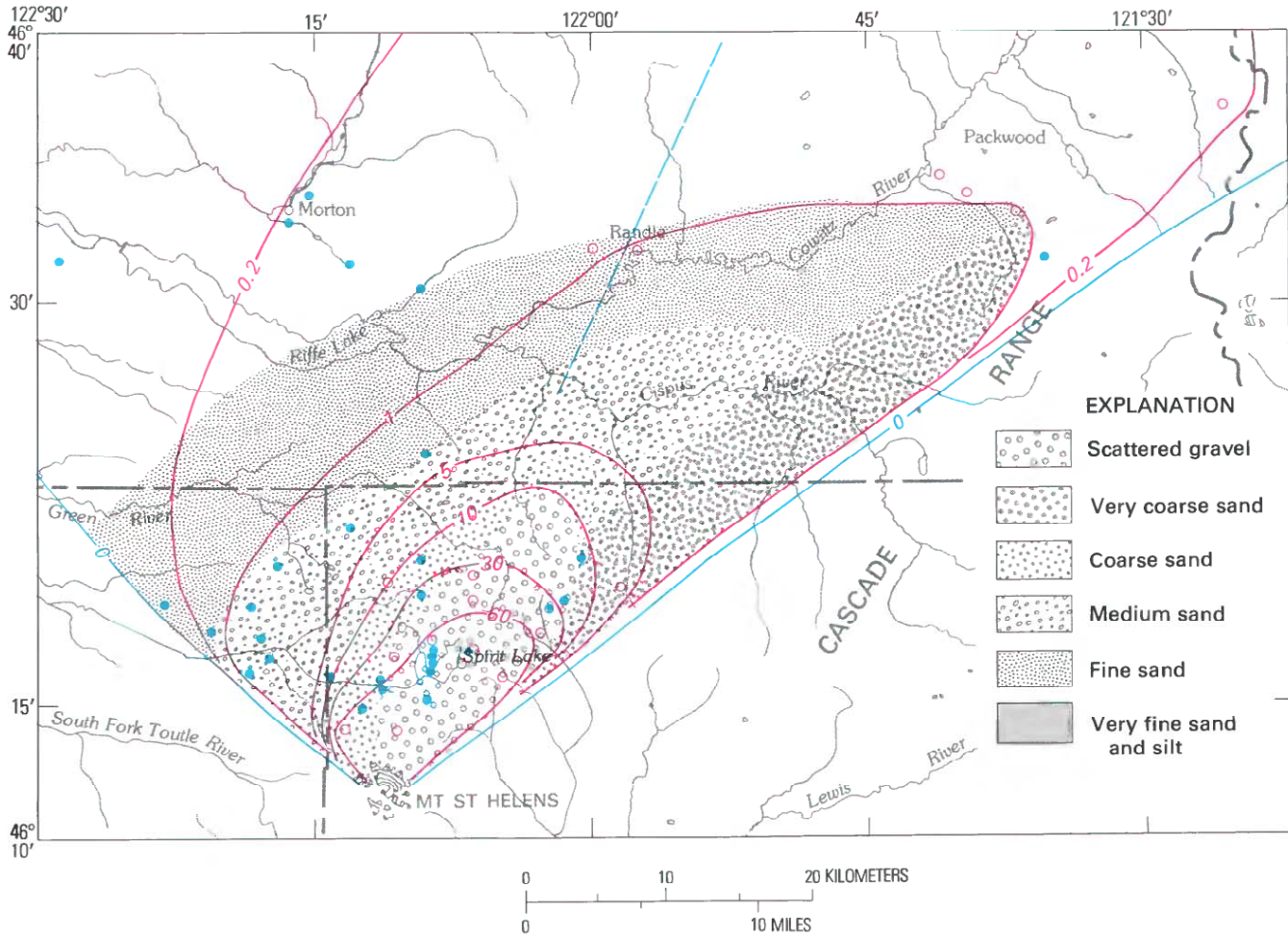


Figure 373.—Map of August 7 air-fall deposit showing median grain size (patterned areas), isopleths of intermediate diameter of largest pumice fragment (red lines), and axis of maximum thickness (blue dashed line). High-level wind was toward northeast; low-level wind toward northwest. All contour values are in millimeters. Blue dot, thickness measured at site; red open circle, pumice diameter measured at site. Median grain size was determined at about half of the data points.

Most of the air-fall material overlying the coherent silt surface of the May 18 deposits is thus a single stratigraphic layer consisting of five overlapping air-fall lobes. From the southwest clockwise to the east they are June 12, May 25, August 7, May 18 (late fall from trees), and July 22.

Except for the relatively thick lobe of May 24, air-fall deposits from relatively minor nonmagmatic eruptions cannot be distinguished from the deposits of the major magmatic eruptions. These minor additions do not affect the field thicknesses or the isopach or isopleth maps, but they do constitute a contaminant to the finer fractions of the magmatic deposits with which they mix.

RELATIVE MAGNITUDE OF ERUPTIONS

Magmatic eruptions of May 25 through August 7 may be compared to each other and to the May 18 eruption by the relative thicknesses of lobes. The maximum thickness of each lobe decreases roughly exponentially with distance from the vent, although the rate of decrease is somewhat irregular, especially in the May 25 deposit (fig. 375). The eruptions became generally less voluminous with time, the August 7 lobe being thinner by an order of magnitude than the May 25 lobe. At distances of 20–60 km from the volcano, the May 18 lobe is 3–10 times thicker

than the May 25 and June 12 lobes, 20 times thicker than the July 22 lobe, and 40 times thicker than the August 7 lobe. The individual thicknesses of the post-May 18 lobes are of the same order of magnitude as that of unit D of May 18, which resulted from only the final wane of the eruptive column (fig. 375; Waitt and Dzurisin, this volume). The thicknesses of the May 25 through August 7 lobes may also be compared to pre-20th century air-fall lobes from Mount St. Helens (Crandell and Mullineaux, 1978, table 2; Hoblitt and others, 1980). The May 25 and June 12 lobes are similar in thickness to the thickest lobe (A.D. 1842-43) of the mid-19th-century eruptive episode (fig. 375).

The largest pumice fragments at a given distance from the volcano are a measure of the transportational competence of the central eruptive column and of the wind velocity. The maximum pumice diameter decreases roughly exponentially with distance from the volcano, although the rate is variable (fig. 376). At distances of 25 km from the vent, the largest pumice fragments of the post-May 18 lobes, taken as a group, show that these eruptive columns were 3-10 times less competent than the May 18 eruptive column, if the wind velocities were roughly the same. The post-May 18 columns were roughly 50 times less competent than two ancient plumes from highly explosive eruptions of Cascade Range volcanoes Glacier Peak (11,250-13,000 yr B.P.) and Mount Mazama (6,700 yr B.P.) (fig. 376).

DISCUSSION OF ASYMMETRY OF LOBES

Each of the air-fall lobes of magmatic eruptions from Mount St. Helens on May 25 through August 7 is asymmetric in five ways: (1) the axis of maximum thickness is not midway between the two margins of the lobe; (2) the axis of maximum pumice diameter is not centered between the lateral boundaries; (3) the axis of maximum pumice size does not correspond to the axis of maximum thickness; (4) the median size of particles grades through several grain-size intervals from one lateral margin to the other, and (5) the boundary defining the coarse side of the lobe is sharp but the opposite boundary is diffuse. This asymmetry is caused by rotation in wind direction with altitude, so the material falling from a high-level plume is winnowed by transverse low-level winds.

Because coarse fragments are less affected by transverse winds than are fine particles, they fall more nearly vertically, causing the sharp outer boundary of coarse material on the windward side of the lobe. The axis of maximum pumice size therefore more closely approximates the path of the high-level plume than does any other single depositional characteristic. Winnowing by transverse low-level winds shifts the zone of maximum thickness downwind from the path of the high-level plume. The arc defined by the entire lobe, the arc between the axes of maximum pumice size and of maximum thickness,

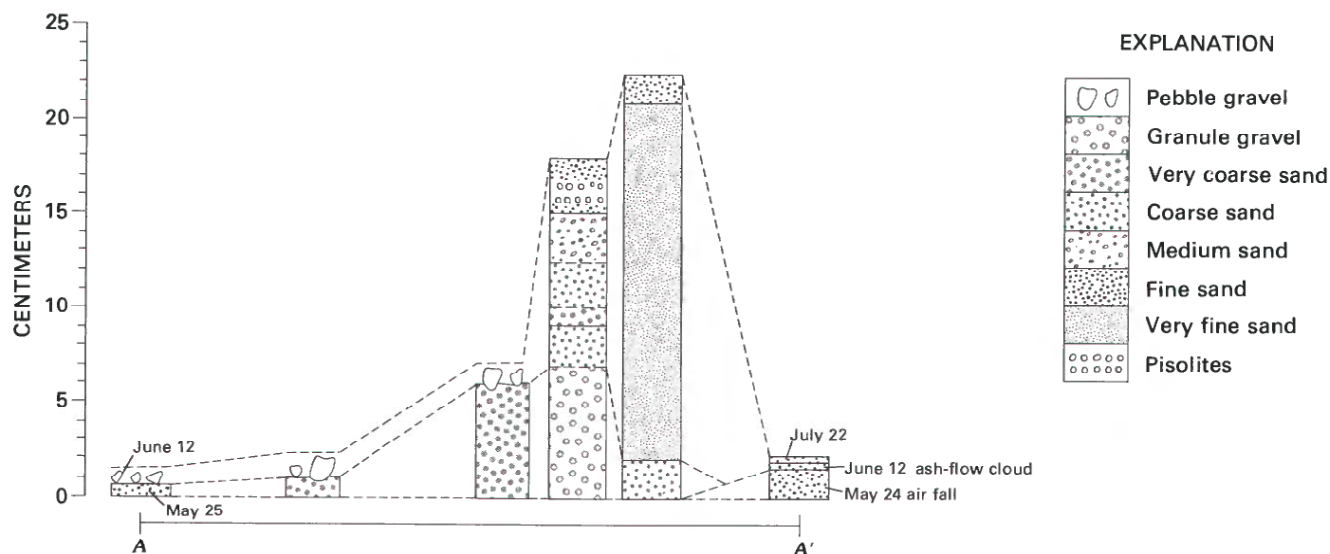


Figure 374.—Stratigraphic cross section A-A' (see figure 367 for location) of air-fall deposits on west and south flanks of Mount St. Helens; data through July 20, 1980. Dashed lines show correlation of air-fall deposits.

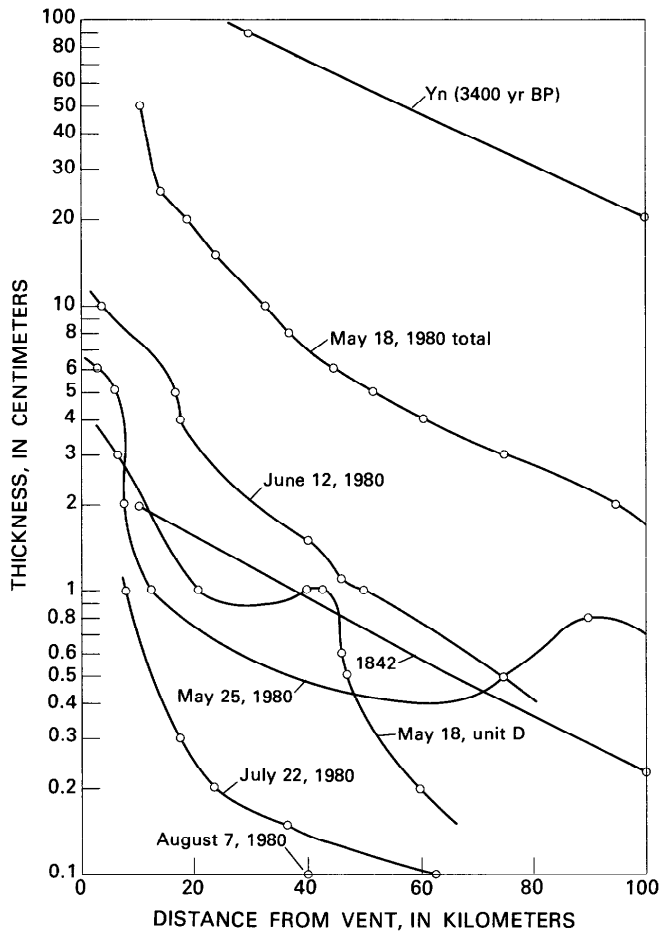


Figure 375.—Maximal thickness of air-fall lobes from Mount St. Helens plotted as function of distance downwind from volcano. Data for pre-1980 Mount St. Helens eruptions from Crandell and Mullineaux (1978, fig. 9). Open circles, data points.

and the lateral spread between the fallout zones of coarse and fine particles must vary directly with the magnitude of shear between the high-level and low-level wind vectors.

Most of the important variables that affected air-fall distribution—rotation in wind direction with altitude, and duration, height, and qualitative density of eruption column—are known for the May 25 through August 7 eruptions. All of these variables and the measured parameters of the consequent air-fall distribution can be written as a mathematical equation by which a computerized “model” could relate these variables to each other. The materials of each air-fall lobe reflect the rotation in wind direction with altitude. The maps presented herein may be used

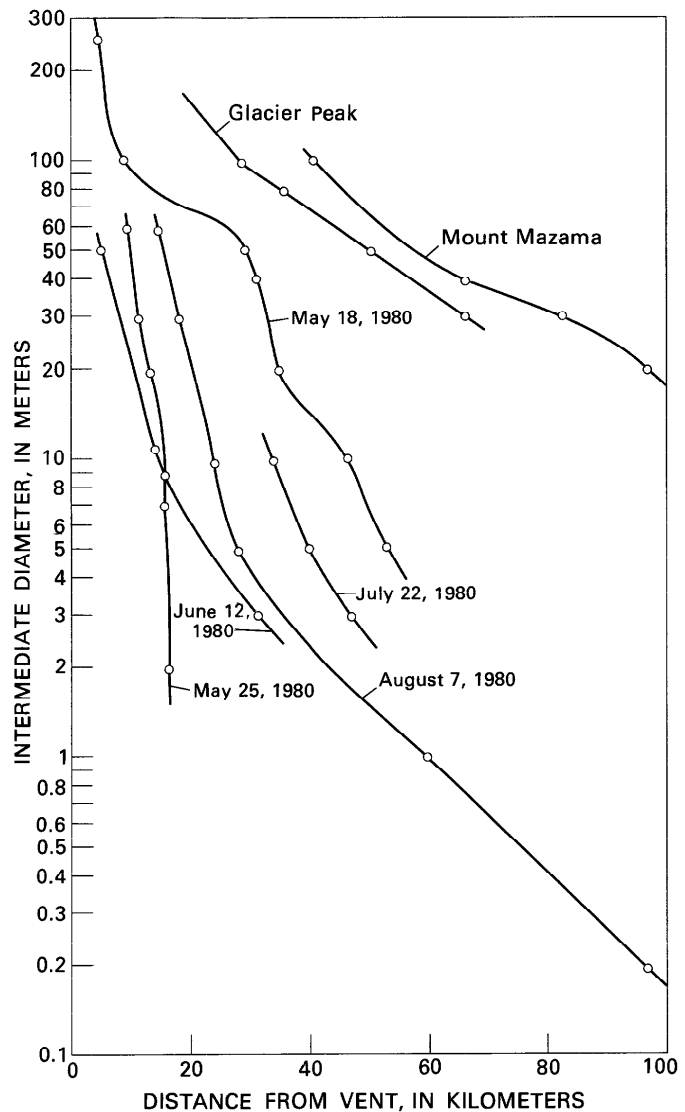


Figure 376.—Intermediate diameter of largest pumice fragment plotted as a function of distance downwind from Mount St. Helens volcano. Data from Glacier Peak and Mount Mazama volcanoes are from Porter (1978, fig. 8). Open circles, data points.

to calibrate such a model, one that will predict air-fall distribution and grain size for future eruptions of similar magnitude. For a hypothetical eruption column of a certain density ejected to a certain height for a certain duration, it should be possible to predict with some accuracy the distribution, thickness, and grain-size pattern of fallout influenced by each future-day’s projected wind vectors.

Some studies of ancient air-fall lobes suggest that the axis of maximum thickness coincides with the axis

of maximum pumice size (for example, Porter, 1978, figs. 3, 4). The small post-May 18 lobes from Mount St. Helens suggest that these axes do not necessarily coincide. Nor does median size necessarily decrease toward both margins of the lobe from an axis of maximum coarseness along the middle. Because a rotation of wind direction with altitude displaces the axis of maximum thickness from the axis of maximum pumice size and causes a grading of median size across the lobe, the general structure of the wind column at the time of an ancient eruption may be deduced from these parameters in ancient volcanic air-fall lobes.

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