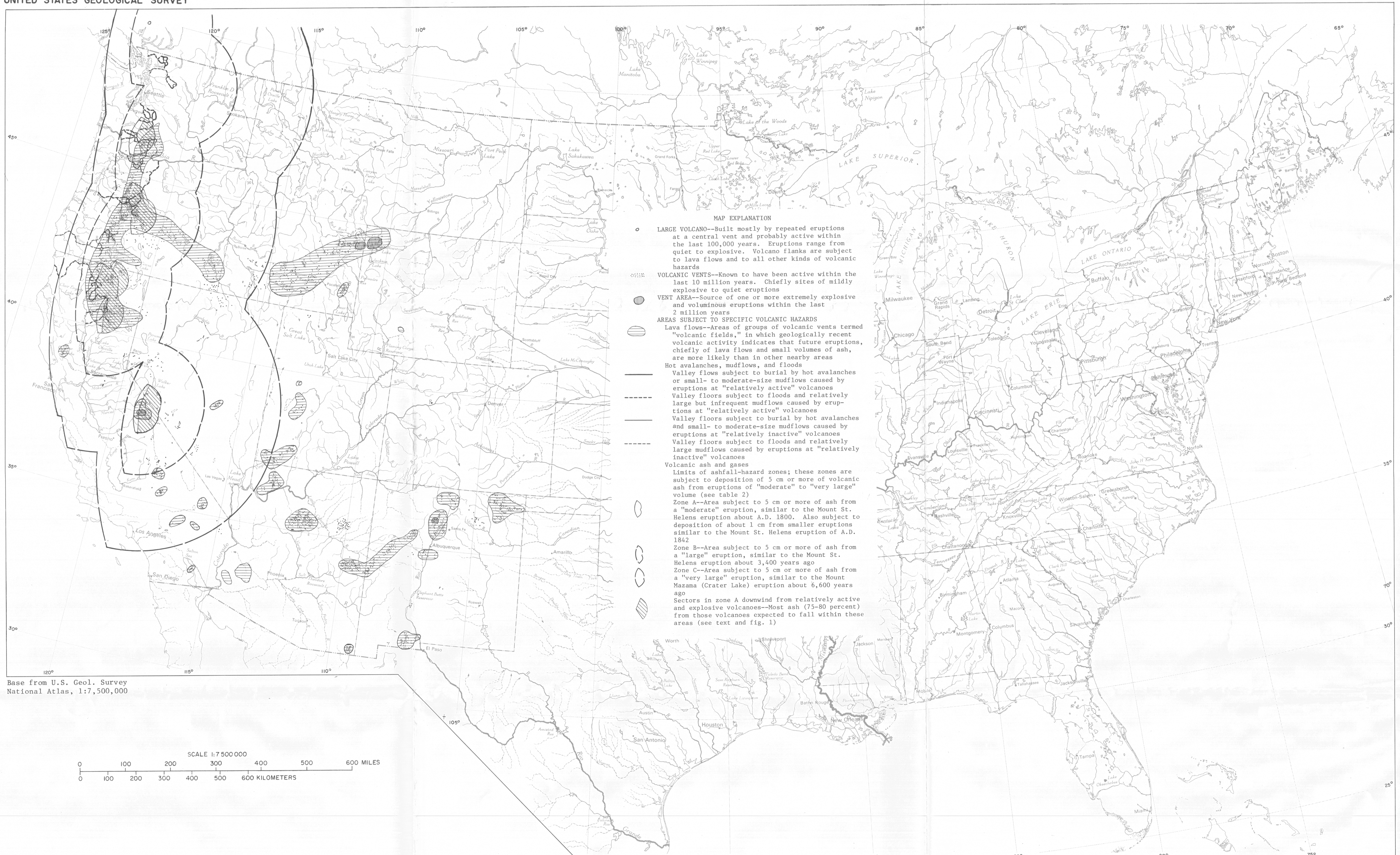
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

MISCELLANEOUS FIELD STUDIES MAP MF-786 VOLCANIC HAZARDS, U.S.



Base from U.S. Geol. Survey National Atlas, 1:7,500,000

SCALE 1:7 500 000
0 100 200 300 400 500 600 MILES
0 100 200 300 400 500 600 KILOMETERS

Sources of information and acknowledgments

Information for the accompanying map has come from published and unpublished sources too numerous to list in a brief text. One chief source has been a set of maps with accompanying data showing locations of volcanoes in the United States, prepared in 1966 by R. L. Smith and C. E. Soule for the International Association of Volcanology. Most vents plotted are from that compilation. Other data have been taken from published works on individual volcanoes and volcanic centers. Unpublished information has been provided by J. W. Babcock, R. A. Bailey, R. L. Christiansen, D. R. Crandell, W. A. Duffield, B. C. Hearn, K. D. Hopkins, M. A. Kuntz, W. P. Leeman, P. W. Lipman, R. G. Luedke, N. S. MacLeod, C. D. Miller, S. C. Porter, H. J. Prostka, W. E. Scott, H. W. Smith, R. L. Smith, E. M. Taylor, G. W. Walker, R. E. Wilcox, and E. W. Wolfe.

Wind data used to outline potential ashfall-hazard zones were taken from "Winds Aloft Summaries," obtained from the U.S. National Climate Center at Asheville, North Carolina.

SELECTED REFERENCES

Crandell, D. R., 1973, Map showing potential hazards from future eruptions of Mount Rainier, Washington: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-836 (1974) (extents of mudflow and ashfall hazard zones around Mount Rainier).

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Crandell, D. R., and Mullineaux, D. R., 1975, Technique and rationale of volcanic-hazards appraisals in the Cascade Range, northwestern United States: Environmental Geology, v. 1, no. 1, p. 23-32 (general evaluation of volcanic hazards).

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Mullineaux, D. R., 1974, Pumice and other pyroclastic deposits in Mount Rainier National Park, Washington: U.S. Geological Survey Bull. 1326, 83 p. (describes volcanic ash deposits, including thicknesses of some ash beds from Mount St. Helens, Washington, and Crater Lake, Oregon).

Mullineaux, D. R., Hyde, J. H., and Rubin, Meyer, 1975, Widespread late glacial and postglacial tephra deposits from Mount St. Helens volcano, Washington: U.S. Geological Survey Journal of Research, v. 3, no. 3, p. 329-335 (describes volcanic ash deposits from Mount St. Helens).

Williams, Howel, 1942, The geology of Crater Lake National Park, Oregon, with a reconnaissance of the Cascade Range southward to Mount Shasta: Carnegie Institute of Washington Publication 540, 162 p. (the great eruptions from Mount Mazama at Crater Lake).

Williams, Howel, and Goles, Gordon, 1968, Volume of the Mazama ashfall and the origin of Crater Lake caldera, in Andesite Conference Guidebook--International Upper Mantle Project, Scientific Report 16-S: Oregon Dept. Geology and Mineral Industries Bulletin 62, p. 37-41 (volume and thickness of some ashfall deposits from the Mount Mazama eruption).

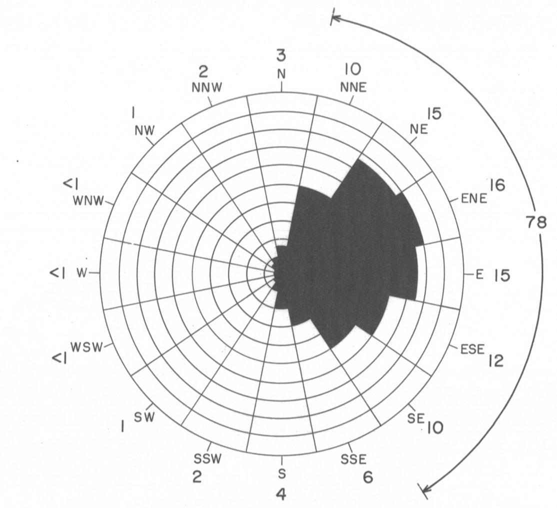

Figure 1.--Percentage of winds at six altitudes from about 3,000 to 16,000 m (10,000-53,000 ft) that blow into pie-shaped sectors along 16 principal compass directions. Percentages are rounded overall averages from 20-year records at Salem, Oregon, and Quillayute, Washington.

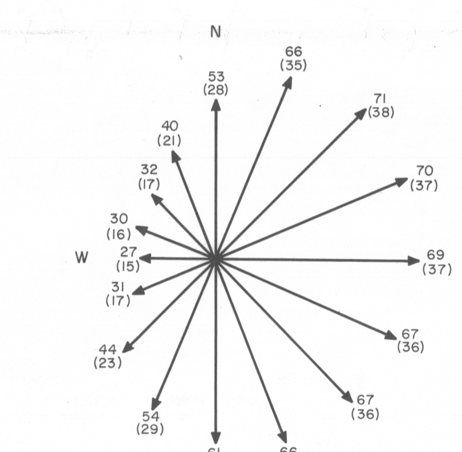

Figure 2.--Average speeds of winds in km/hr and nautical mph (in parentheses) at six altitudes from about 3,000 to 16,000 m (10,000-53,000 ft) that blow into pie-shaped sectors along 16 principal compass directions. Numbers are rounded overall average speeds from 20-year records at Salem, Oregon.

Table 2.--Approximate range of thicknesses (in centimetres) of airfall ash that could be expected along the thickest part of a deposit downwind from an erupting volcano

[Thicknesses shown are probable ranges from the inner to outer boundaries of zones A, B, and C that could result from eruptions termed "moderate," "large," and "very large." Based on data from Mount St. Helens eruptions of about A.D. 1800 and 3,400 years ago ("moderate" and "large" eruptions), and that of Mount Mazama about 6,600 years ago ("very large" eruption)]

	Zone A		Zone B		Zone C	
	Inner	Outer	Inner	Outer	Inner	Outer
Moderate eruption (Mount St. Helens A.D. 1800).	100	5	5	1	1	No data.
Large eruption (Mount St. Helens, 3,400 years ago).	>150	30	30	5	5	1
Very large eruption (Mount Mazama).	>200	50	50	30	30	5

DISCUSSION

Volcanic eruptions and related phenomena can be expected to occur in the Western United States, and in some places are potentially hazardous enough to be considered in longer-range land-use planning. But the immediate risk from volcanic hazards is low because eruptions are so infrequent in the conterminous United States that few, if any, occur during any one person's lifetime. Furthermore, severely destructive effects of eruptions, other than extremely rare ones of catastrophic scale, probably would be limited to areas within a few tens of kilometres downvalley or downwind from a volcano. Thus, the area seriously endangered by any one eruption would be only a very small part of the Western United States.

The accompanying map identifies areas in which volcanic hazards pose some degree of risk, and shows that the problem is virtually limited to the far-western States. The map also shows the possible areal distribution of several kinds of dangerous eruptive events and indicates the relative likelihood of their occurrence at various volcanoes. The kinds of events described here as hazards are those that can occur suddenly and with little or no warning; they do not include long-term geologic processes. Table 1 summarizes the origin and some characteristics of potentially hazardous volcanic phenomena.

The map is diagrammatic. It does not show the specific location of the next expected eruption, because such an event cannot be reliably predicted. Instead, the map shows general areas or zones that, over a long period of time, are relatively likely to be affected in one or more places by various kinds of hazardous volcanic events. However, only a small part of one of these areas would be affected by any single eruption.

The most likely sites of future eruptions can be predicted fairly accurately because most volcanic activity occurs at large, central-vent volcanoes. However, some eruptions do occur at other widely scattered vents; they commonly erupt only once or a few times. The specific sites of future eruptions from such scattered vents are virtually unpredictable. Geologic history suggests that such eruptions are more likely in certain areas than in others, but the limits of those areas can only be approximately defined.

Prediction of the timing of future eruptions is not reliable. The best we can do is estimate probable frequencies of eruptive activity at each volcano or volcanic area. These estimates are based on historical records and geologic studies, both of which vary widely in detail and reliability from one volcanic area to the next. The best information available for estimating the frequencies and locations of future eruptions is sketchy, and the accompanying map could be changed markedly by the addition of new information.

Small-volume eruptions occur most frequently; generally the larger the volume of the eruption the less frequent its occurrence. For example, the ashfall-hazard zones shown on the map are based on eruptions termed "moderate" to "very large" (table 2). Eruptions of "moderate" volume may occur somewhere in the Cascade Range as often as once every 1,000-2,000 years, but "very large" eruptions may occur no more than once every 10,000 years. A few larger, cataclysmic eruptions have occurred in the Western United States during the last 2 million years, in and near Yellowstone National Park, at Long Valley, California, and in the Jemez Mountains of New Mexico. These eruptions affected very large regions, and deposited ash over much of the Western United States. The sites of these eruptions are shown on the map, but such cataclysmic eruptions were not considered in outlining potential hazard zones. Although those sites may be likely locations of future cataclysmic eruptions, such eruptions are so infrequent that it is not possible to judge whether one might occur during the time for which planning is feasible.

HAZARD ZONES

Risk from volcanic hazards decreases as distance from an erupting volcano increases; areas are affected less frequently and generally less severely with increasing distance. Lava flows are nearly uniformly destructive to their outer limits; the risk from them decreases with distance from their source because fewer flows reach the more distant sites. Some other volcanic hazards, especially ashfalls, become less destructive as well as less frequent with increasing distance. The risk from such hazards gradually diminishes to an insignificant level; thus, the boundary of such a hazard is indefinite and often dependent upon land use. For example, an ashfall a centimetre or so thick might cause little damage to structures, yet destroy crops.

The hazard zones outlined on the map are estimates of areas likely to be significantly affected by volcanic hazards from future eruptions. The zone boundaries are determined chiefly by the expected severity of those hazards at various distances from volcanoes. Probable frequencies of various hazards are indicated on the map by designation of certain volcanoes as "relatively active" or "relatively inactive," and by shading areas of relatively high frequency of ashfall. Volcanoes termed "relatively active" are known to have erupted many times during the last 10,000 years. "Relatively inactive" volcanoes are those which probably have not erupted more than a few times during that time.

Hazard zones of lava flows, pyroclastic flows, mudflows, and floods

Lava flows and hot avalanches, as well as mudflows and floods of volcanic origin, are virtually confined to areas that are downslope from an erupting vent. Thus, beyond the flanks of the volcanoes, the most hazardous areas are the floors of valleys that head on volcanoes. Hazard zones are not shown for lava flows that originate on and extend beyond the flanks of large, central-vent volcanoes. Most future flows from those volcanoes will cover too small an area to be shown at this map scale. A slight risk from lava flows that originate at other, scattered vents exists over much of the Western United States. Such scattered eruptions are relatively likely within volcanic fields outlined on the map, but specific sites where eruptions will occur in the future cannot be identified.

Hazard zones are also not shown for steam-blast (phreatic) eruptions, because the effects of such eruptions generally are restricted to areas within a few kilometres of an erupting vent.

Hazard zones for hot avalanches and mudflows of small to moderate size are shown to extend about 30 km (20 mi) down major valleys from large volcanoes. The risk also exists in small valleys that head on the volcanoes but it is not portrayed on the map. The downvalley limit of risk is based on the distance such mudflows have extended beyond Mount Rainier in the recent geologic past.

Hazard zones for floods and large, relatively infrequent mudflows are shown to extend downvalley to the nearest reservoir or junction with a river whose normal range in volume is probably large enough to accommodate an increased flow without transmitting a significant hazard farther downvalley. Some valleys do not contain a reservoir and do not join a larger river valley; in them, the hazard is shown as extending to the ocean.

Ashfall-hazard zones

Volcanic airfall ash and gases move downwind rather than downslope from an erupting volcano. The resulting hazard zones are determined by the directions and speeds of winds that blow past the volcano at all altitudes reached by the erupted material. The frequency with which winds blow in a certain direction determines the likelihood that a site in that direction from the volcano will be affected. The wind speeds in a given direction control the distance to which ash will be carried and thus determine the severity of the hazard.

Probable wind directions and speeds can be estimated from past ashfalls and from modern wind records. More than 90 percent of the geologically recent ash beds resulting from eruptions of Mounts Rainier and St. Helens in Washington, for example, lie east of those volcanoes. The ash beds also extend much farther to the east of the volcanoes than to the west. Thus, the distribution of past ashfalls indicates that winds toward the east have been prevalent and also stronger than winds toward the west for many thousands of years.

Modern records show such wind conditions in detail. Twenty-year records from 1950 to 1970 for the two stations closest to Mounts Rainier and St. Helens indicate that nearly 90 percent of the winds at altitudes from about 3,000 to 16,000 m (about 10,000 to 53,000 ft) blow toward directions that are east of a north-south line (fig. 1). The records also show that wind speeds toward the east are more than twice those toward the west (fig. 2). These measured wind directions and speeds correspond closely with the distribution of ash beds erupted during the past several thousand years. That correspondence confirms that wind patterns have been generally similar for a long time, and that recent wind records can be used to estimate future ash distributions.

Figure 2 shows average wind speeds in various directions for six altitudes from about 3,000 to 16,000 m. These altitudes range from about the height of Cascade Range volcanoes to just above the altitudes of high-speed winds that most strongly influence ash distribution. These and similar wind-speed data from other stations are used to define the limits of ashfall-hazard zones, because wind speed strongly affects ash thicknesses and thus severity of effects. The records suggest that winds blow at relatively high speeds toward all sectors from north clockwise around to the south (fig. 2). Winds toward the northeast are slightly stronger than winds toward the southeast. The difference is small, however, and the easterly boundaries of hazard zones are drawn on the assumption that ash of any specific thickness could be carried an equal distance in all easterly directions. The potential thicknesses for various distances are based on measured thicknesses of ash beds from past eruptions (table 2).

The wind records show that speeds are lower toward all westerly compass points (fig. 2). They are least toward the west and northwest; in those directions, average and maximum wind speeds are about 40 percent of the average and maximum speeds toward the east. The few ash beds known to extend west of their source vents, however, reach less than 10 percent of the distance that similar beds extend to the east. Apparently, the occurrence of strong winds toward the west at all altitudes at which a single ash is carried is so uncommon that the occurrence is not recorded by known ash beds. A review of the 1950-1970 wind records from stations near Mount St. Helens suggests that the likelihood of such a combination of winds is less than one percent; that likelihood is regarded as too low to incorporate into the limits of the ashfall-hazard zones. The western limits shown are 25 percent of the distance that the same zones extend toward the east. Winds toward the southwest near the Salem station are somewhat stronger than those toward the northwest (fig. 2). This difference is not well defined for the Western United States, and would make little change in the hazard zone patterns. Consequently, the hazard-zone limits are not extended farther to the southwest than to the northwest to incorporate that apparent difference.

Only a small part of any hazard zone would be affected by a single eruption. The 1800 A.D. "moderate" ashfall from Mount St. Helens (table 2), for example, covers a narrow, elongate band that is only about 5 km wide at distances of 10-20 km. Thus, we can usefully subdivide hazard zones into radial sectors around certain volcanoes in which the wind frequencies and therefore likelihood of ashfall differ. Figure 1 shows average wind frequencies for the six altitudes from about 3,000 to 16,000 m for two stations in the Pacific Northwest. The figure shows that 75-80 percent of winds at those altitudes in Pacific Northwest States blow toward a broad, pie-shaped sector that includes compass directions from north-northeast clockwise around to southeast. In southwestern States, 75-80 percent of winds at those altitudes blow toward the sector from north-northeast to south-southeast. These sectors are shown downwind from certain volcanoes on the map as areas in which the probability of ashfalls is relatively high. Wind directions are fairly similar over much of the Western United States; thus, figure 1 can also be used to judge approximately the likelihood that ash will fall into various radial sectors around any specific volcano.

Hazard zone A is drawn around volcanoes or clusters of volcanic vents that are known to have erupted both repeatedly and explosively during the last 15,000 years. The zone extends 70 km (about 45 mi) east of those volcanoes, and 17.5 km (11 mi) to the west. Zones B and C are drawn around volcanoes or clusters of volcanoes that have had at least one highly explosive eruption within the last 15,000 years or that are regarded as potentially explosive. The easterly boundaries of zones B and C are at distances of 220 and 500 km (about 140 and 300 mi), respectively, from the pertinent volcanoes, and the western limits are at 55 and 125 km (about 35 and 75 mi), respectively. Table 2 gives thicknesses that would be expected in the three ashfall-hazard zones from eruptions of three different magnitudes. This ash from "large" and "very large" eruptions could be expected to fall beyond the limits shown on the map, but both the severity of effects and the frequency of such ashfalls should be low.

Table 1.--Description of volcanic hazards

	LAVA FLOWS	HOT AVALANCHES, MUDFLOWS, AND FLOODS	VOLCANIC ASH AND GASES
ORIGIN	Result from quiet eruptions of molten lava.	Hot avalanches can be caused directly by eruption of fragments of molten or hot solid rock; mudflows and floods commonly result from eruption of hot material onto snow and ice, and eruptive displacement of crater lakes. Mudflows also commonly caused by avalanches of unstable rock from volcano.	Produced by explosion or high-velocity expulsion of vertical to low-angle columns of fragments and gas into the air; materials can then be carried great distances by wind. Gases alone may issue quietly from vents.
EFFECTS	Land and objects in affected areas subject to burial and destruction.	Land and objects subject to burning, burial, dislodgment, impact damage and inundation by water.	Land and objects near an erupting vent are subject to blast effects, burial, and infiltration by abrasive rock particles accompanied by corrosive gases. Blanketing and infiltration effects can reach hundreds of km downwind.
FREQUENCY, in conterminous U.S. as a whole.	Probably one to several small flows per century that cover less than 10 km^2. Flows that cover tens to hundreds of km^2 probably occur at an average rate of about once every 1,000 years.	Probably one to several events per century caused directly by eruptions at "relatively active" volcanoes. Probably no more than one event per 1,000 years caused directly by eruption at "relatively inactive" volcanoes.	"Moderate" and smaller but significant eruption expected about once every 100 years. "Large" eruption expected about once every 1,000-5,000 years. "Very large" eruption probably only about once every 10,000 years.
SEVERITY of risk in affected area.	To people, low. To property, high.	Moderate to high for both people and property near erupting volcano. Risk can be high to people because avalanches and mudflows can originate suddenly and travel at speeds of many tens of km/hr. Risk decreases gradually downvalley.	Moderate risk to both people and property near erupting volcano; decreases gradually downwind to very low.
LOCATION	Flows are restricted to areas downslope from vents, and most reach distances of less than 10 km. At central-vent volcanoes, flows occur repeatedly at the same general sites, but successive eruptions may affect different flanks. Elsewhere, flows commonly erupted only during single episodes of a few years or less duration.	Beyond volcano flanks, effects of these events are confined mostly to floors of valleys and basins that head on volcanoes. Large, snowcovered volcanoes and those that erupt explosively are principal sources of these hazards.	All areas toward which wind blows from potentially active volcanoes are susceptible. Zone A surrounds volcanoes that have been repeatedly and explosively active in the last 15,000 years. Zones B and C surround volcanoes or clusters of vents that have erupted explosively at least once in the last 15,000 years.
PREDICTABILITY of location of future endangered areas.	Relatively reliable at large, central-vent volcanoes because flows are erupted repeatedly at the same site. Unreliable elsewhere.	Relatively reliable, because most originate at central-vent volcanoes and are restricted to valleys leading from them.	Moderately reliable. Ash originates mostly at central-vent volcanoes; its distribution depends mainly on winds.
SIZE OF AREA affected by single event.	Relatively small to moderate; most cover no more than a few km^2. Relatively large flows probably would cover only hundreds rather than thousands of km^2.	Relatively small to moderate, covering a few km^2 to a few hundreds of km^2. Mudflows and floods may extend downvalley from volcano many tens of km.	Large. Even a "moderate" eruption could significantly affect thousands of km^2.
OVERALL RISK compared to other volcanic hazards.	Low.	High.	Moderate.

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PRELIMINARY OVERVIEW MAP OF VOLCANIC HAZARDS IN THE 48 CONTERMINOUS UNITED STATES

By
D. R. Mullineaux

1976

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