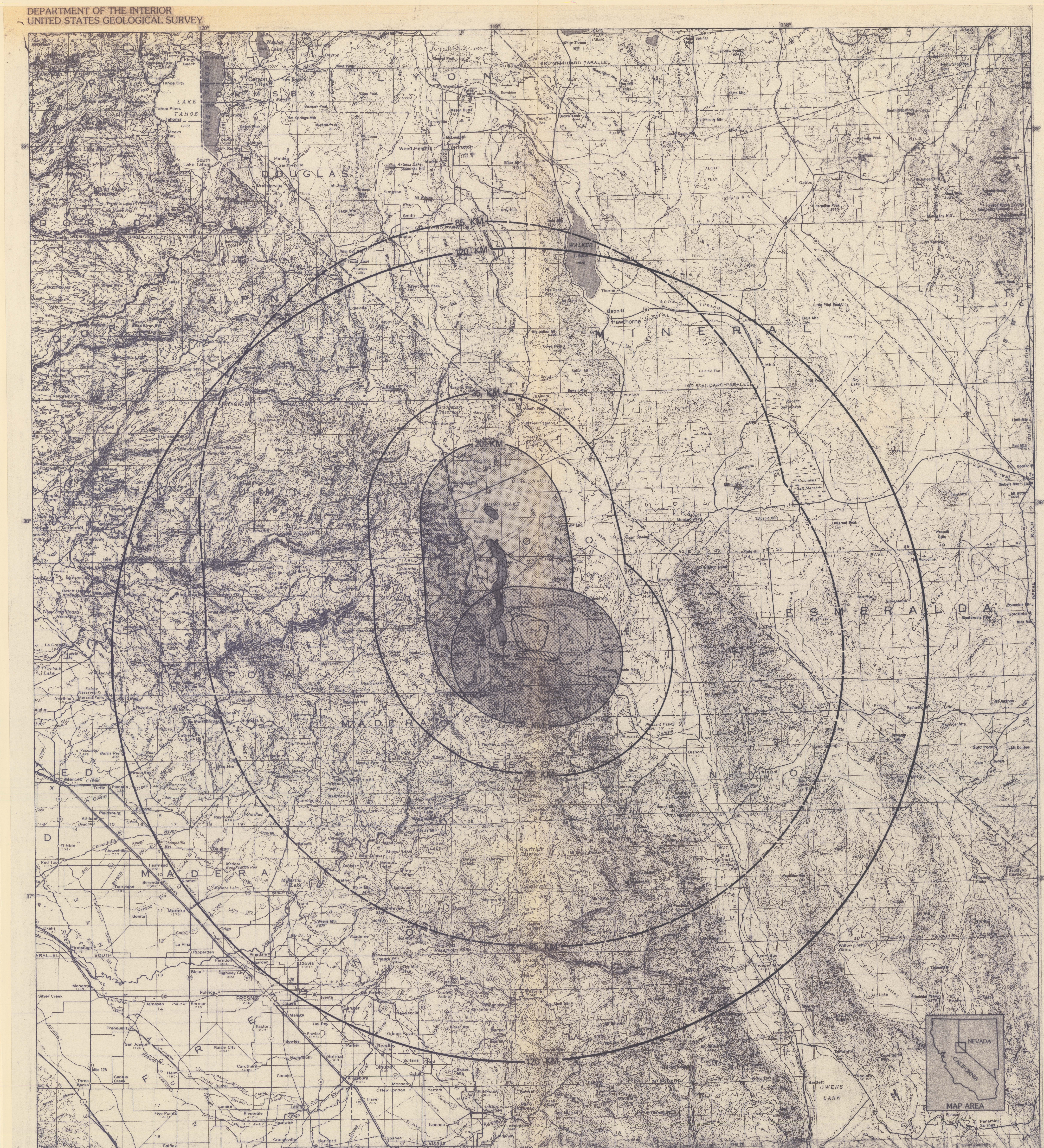
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

OPEN-FILE REPORT
82-583



Base from U.S. Geological Survey
State base maps
North half California, 1967
South half California, 1968
Nevada, 1962

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards.

EXPLANATION

FEATURES OF THE LONG VALLEY CALDERA

·········· Outline of Long Valley caldera floor

– – – – – Outline of resurgent dome within the Long Valley caldera

AREAS INFERRED TO BE POSSIBLE SITES OF FUTURE ERUPTIONS

■ Area of explosive silicic vents active during the last 10,000 years

▨ Potential vent area indicated by seismicity since 1980 and by proximity to the Long Valley ring-fracture system

HAZARD ZONES FROM ERUPTIONS OF THE SIZE AND CHARACTER OF THOSE THAT HAVE OCCURRED WITHIN THE LAST 10,000 YEARS IN THE LONG VALLEY-MONO LAKE AREA

The following hazard zones are drawn around relatively likely sites of future eruptions. During a future eruption, the appropriate hazard zone would be that part of the zone shown on the map that is circumferential to the erupting vent or vents

░ Flowage-hazard zone around existing explosive vents--Areas adjacent to and within 20 km of volcanoes or vents subject to eruption of pyroclastic flows and clouds of hot ash, pyroclastic surges, lava flows, and domes, and, at some vents, mudflows and floods. Some parts of the hazard zone have not been affected by geologically recent events, but could be affected in the future

▒ Flowage-hazard zone around possible future vents inferred from seismicity--Areas adjacent to and within 20 km of possible future vents at or near the epicentral location of earthquake swarms since 1980 and along a part of the caldera ring-fracture system. Areas within this zone are subject to eruption of pyroclastic flows and clouds of hot ash, pyroclastic surges, lava flows, and domes, and, at some locations, mudflows and floods

Ashfall-hazard zones--In general, thickness of ash accumulations gradually decreases with increasing distance from a vent. The ashfall-hazard lines on the accompanying map show where the following thicknesses could accumulate downwind from a vent

—35 KM— Areas within 35 km of erupting vents subject to ash accumulations of 20 cm or more

—85 KM— Areas within 85 km of erupting vents subject to ash accumulations of 5 cm or more

HAZARD ZONE FROM A VERY LARGE ("CATASTROPHIC") ERUPTION LIKE ONE THAT OCCURRED ABOUT 700,000 YEARS AGO IN THE LONG VALLEY AREA

—120 KM— Areas within 120 km of vents subject to accumulation of 1 m or more of airfall ash downwind from catastrophic eruptions--Hot pyroclastic flows can be expected within this area and could extend even farther down valleys that head in this area

INTRODUCTION

Recent earthquake activity, ground deformation, and increased fumarolic activity in the vicinity of Mammoth Lakes in the southern part of the Long Valley-Mono Lake area have increased the concern over the possibility of a volcanic eruption in the near future, although no one can yet reliably predict either that there will be an eruption, or the time, scale, or specific site if an eruption does occur. This report is the result of the increased concern.

In 1978 earthquake activity in the Long Valley region began to increase, and included intense earthquake swarms in mid-May 1980 (Ryall and Ryall, 1980), about 10 days before the Mammoth Lakes area was shaken by a historically unprecedented series of earthquakes including four magnitude-6 earthquakes within a 48-hour period (Cramer and Toppozada, 1980). Since that time, a series of earthquake swarms, accompanied by spasmodic tremor, have occurred underneath an epicentral site about 3 km (2 mi) east of the town of Mammoth Lakes (Ryall and Ryall, 1981, 1982). The depths of origin of earthquakes in these swarms appear to have become shallower since June 1980 (A. Ryall, oral commun., 1982). These seismic events are thought to have been generated by rising magma under the epicentral site near Mammoth Lakes (Ryall, 1982; R. Cockerham, oral commun., 1982).

In October 1980, surveying along U.S. Highway 395 through the Long Valley caldera, a large volcanic depression that formed as a result of colossal eruptions about 700,000 years ago, revealed that the resurgent dome in the western part of the caldera had bulged upward about 25 cm (10 in) possibly within the previous 2 years (Savage and Clark, in press). In addition, other geophysical evidence has indicated that partially molten magma underlies much of the resurgent dome (Hill, 1976; Steeples and Iyer, 1976; Ryall and Ryall, 1981, 1982).

In January 1982, increased fumarolic activity was first noticed in the vicinity of the Casa Diablo Hot Springs about 2.5 km (1.5 mi) east of the epicentral site of the recent unusual seismic activity.

A preliminary interpretation of this evidence is that magma at depth in the Long Valley caldera moved upward at about the time of the May 1980 swarm of earthquakes. This caused bulging of the resurgent dome and opened fractures at depth in the southern part of the caldera (R. A. Bailey and R. Cockerham, written commun., 1982), thereby allowing a tongue of magma to move toward the surface beneath the epicentral site near Mammoth Lakes. It cannot be said whether this magma will reach the surface and cause an eruption, or will result in an intrusive body that remains below the surface.

POTENTIAL HAZARDS

The following preliminary hazard assessment describes potential volcanic hazards for the combined Long Valley, Inyo Craters, and Mono Craters areas in order to provide immediate information for use in consideration of eruptions that might occur. An investigation to provide a comprehensive volcanic hazards assessment for the Long Valley-Mono Lake area is underway, but only partially completed. Thus, this preliminary assessment is based on information that is immediately available, mainly the results of extensive research on the Long Valley volcanic system by Bailey, Dalrymple, and Lanphere (1976), about 9 weeks of fieldwork by Miller, and published reports and unpublished data of other Federal, State, and university scientists.

Future eruptions are most likely to consist of one or more of the types of activity that have occurred before in the Long Valley-Mono Lake region. These include eruption of basaltic lava flows and more silicic (dacitic and rhyolitic) lava domes, and explosive eruptions that produce chiefly dacitic and rhyolitic ash falls and pyroclastic flows and pyroclastic surges of small to large volume. Pyroclastic flows and pyroclastic surges are relatively high and low density mixtures, respectively, of hot volcanic rock debris and gases that move along the ground surface at high speed. Any of these eruptive events could cause floods and mudflows, especially if the area of an active vent is covered with snow.

The location of epicenters of recent earthquakes suggests that if an eruption occurs in the near future, the vent is likely to be in the southern part of the Long Valley-Mono Lake area. Nevertheless, an eruption might occur instead in some other nearby area that has been volcanically active recently, especially along the Mono Crater and Inyo Crater vent systems.

Although future eruptions of lava domes and flows are expectable, explosive eruptions are the chief concern. Explosive eruptions of the last 1,000,000 years in the Long Valley-Mono Lake area have included frequent steam-blast eruptions, frequent eruptions of moderate volumes of dacitic or rhyolitic pumice, and one catastrophic eruption of an immense volume of rhyolitic pumice (Bailey and others, 1976; Wood, 1977). The accompanying map depicts: (1) hazard zones for explosive eruptions of moderate volume from the vicinity of recently active vents and from the vicinity of the epicentral site east of Mammoth Lakes; and (2) a single zone of potential severe to total devastation from a possible catastrophic eruption in the southern part of Long Valley.

Steam-blast (phreatic) eruptions like of those of the Long Valley-Mono Lake area are produced when rising magma (molten rock) heats subsurface water. They may occur without other volcanic activity or may be followed by eruptions of magma. Rock fragments thrown out by such explosions could fall as far as 10 km (6 mi) from the vent, and windborne ash produced by the explosions could fall on areas at distances of many tens of kilometers. Such steam explosions could also produce pyroclastic surges, which may move outward at great speed as far as 10 km (6 mi) from their source vents. A steam-blast eruption up through a lake could also cause large waves, and subsequent floods and mudflows.

Explosive eruptions of moderate magma volume (as much as about 1 km^3, or 1/4 mi^3) at the Mono Craters have produced extensive pyroclastic flows and ashfalls. Pyroclastic flows produced during moderate-volume eruptions of the last 10,000 years, for example, have traveled at least 15 km (9 mi) from their source vents. This distance, plus an additional safety factor of 5 km (3 mi), is the basis for a 20-km-radius flowage-hazard zone shown on the accompanying map. This zone has been drawn around vents that have been explosively active in the last 10,000 years and includes areas that might be affected by pyroclastic flows during future eruptions of moderate volume. A similar flowage-hazard zone extends to a distance of 20 km around a locality of possible future vents near the south margin of the Long Valley caldera. That locality, defined by high seismicity since May 1980, begins at the epicentral location of recent earthquake swarms within the caldera and extends eastward along the inferred caldera ring fracture.

Pyroclastic flows that travel distances of 5-20 km (3-12 mi) typically have speeds of 50-150 km/hr (30-90 mi/hr) and have enough energy to extend up onto or cross over low hills in their paths. Pyroclastic flows tend to move farthest, however, along valleys and other depressions. Clouds of hot ash that commonly precede or accompany pyroclastic flows may, depending on wind conditions, affect areas as much as several kilometers wide adjacent to the margins of the flows.

Downwind deposits of ash produced by an explosive eruption of moderate volume from the Mono Craters probably could reach thicknesses of at least 20 cm (8 in) at a distance of 35 km (22 mi), and 5 cm (2 in) at 85 km (53 mi). These estimates of potential ash thicknesses are based on deposits of ash from past eruptions at other volcanoes that involved volumes of as much as about 1 km^3 (1/4 mi^3). The anticipated outer limit of ash 20 cm or more thick is drawn at 35 km from all relatively likely sites of future vents. Probably, only part of such a zone would be affected by any single ashfall; the part that would be affected would be determined by the wind direction or directions during an eruption. It is, of course, not possible now to predict wind directions that will exist at the time of a future explosive eruption. Records, however, show that on an annual basis the winds at altitudes where most ash is transported, between 3000 m and 16,000 m (about 10,000 and 52,000 ft), blow toward a sector between N. 45° E. and S. 45° E. 65 percent of the time, and about 88 percent of the winds blow toward some easterly direction between due north and due south. Areas in these directions from a vent thus have a greater chance of being affected than do other areas.

An explosive eruption of very large volume (600 km^3 or 140 mi^3) occurred at Long Valley about 700,000 years ago (Bailey and others, 1976). This eruption resulted in immense pyroclastic flows and clouds of airborne ash, and formation of the Long Valley caldera. Pyroclastic flows of hot pumice buried an irregular area of at least 1500 km^2 (580 mi^2) in and adjacent to the Long Valley-Mono Lake area to depths of tens to hundreds of meters. One lobe of these pyroclastic flows extended southward down the Owens Valley to a distance of at least 65 km (40 mi) from its source area, while others traveled down the San Joaquin River and other drainages west of the Sierra Nevada crest and may have reached the Central Valley of California. The pyroclastic flows probably moved at speeds of several hundreds of kilometers per hour, which permitted them to extend across topographic barriers many hundreds of meters high. The eruption also produced voluminous airborne ash that was carried eastward by winds across the United States. A similar eruption in the future could result in ash deposits as much as 100 cm (40 in) thick at a distance of 120 km (75 mi), 40 cm (16 in) at 200 km (125 mi), and 15 cm (6 in) at 500 km (300 mi). Devastation from such an eruption could be severe to total within any part of the circle shown on the map at distances of as much as 120 km (75 mi) from the center of the Long Valley-Mono Lake area. As with smaller eruptions, the directions of thickest ashfall would be determined by wind directions at the time of the eruption. Even upwind, however, hot pumiceous pyroclastic flows could cause complete devastation over much of the area within 120 km of the vent, especially along valleys.

The likelihood of a similarly large eruption in the future cannot be calculated with data now available; such an eruption would be much more damaging but far less likely than a smaller eruption. The probability of an eruption of that volume is tentatively regarded as at least 100 times less probable than an eruption involving a volume of a few cubic kilometers or less.

A catastrophic eruption of a volume like that of 700,000 years ago has occurred nowhere in the world during historic time, so the full range of possible consequences cannot be anticipated. It is believed that volcanic activity on a smaller scale would precede such an eruption, but the nature, sequence, and timing of precursory events cannot be predicted.

EFFECTS OF ERUPTIONS ON LIFE AND PROPERTY

The following section discusses some of the ways in which volcanic eruptions and their products can endanger life and property, and some possible mitigation measures. Additional information about kinds of eruptions and their associated hazards can be found in U.S. Geological Survey Bulletin 1503 (Miller, 1980).

Ashfalls

The chief danger to human health posed by falls of ash is the effect of either hot or cold ash on respiratory systems. A lesser hazard exists from toxic gases which may accompany the ash. Near an erupting vent, impact of large rock fragments which may be thrown from the vent by explosions can endanger people and property; danger from smaller rock fragments can extend as much as 10 km (6 mi) from a vent, and hot rock fragments can start fires. Burial by thick ash can cause roofs to collapse and, especially if wet, ash can also short-circuit and (or) break telephone and electric-power lines. Lightning typically accompanies clouds of ash, and may interrupt telephone, radio, and electrical services and start fires. Ashfall can reduce visibility enough to halt air, rail, and highway traffic, and deposits on the ground can block roadways. Ash affects motor vehicles by clogging air filters and causing rapid wear of moving parts. Ash can cause short circuits in electrical systems and electronic equipment, and clog filters in water- and air-supply systems.

During an ashfall, people generally should stay indoors and avoid ash inhalation by breathing through a commercial dust filter or a moistened cloth. Eyes should also be protected as much as possible. It may be possible but generally is inadvisable to attempt to evacuate an area during an ashfall. Mechanical equipment can be protected chiefly by covering it and allowing it to remain idle; if such equipment is used, filtering intake of air, water, and fuel can reduce adverse effects of the abrasive and corrosive ash.

Pyroclastic flows

Pyroclastic flows are especially dangerous because of their speed, high temperature, and possible long distance of travel. They generally destroy life and structures in areas they cross by impact, incineration, or burial. The paths of some pyroclastic flows that originate on the sides of domes can be anticipated, but other pyroclastic flows can be caused by the collapse of vertical eruption columns and move radially outward in many or all directions. Because of the speed with which pyroclastic flows can be generated and with which they can move, the only mitigative measure likely to be effective is to evacuate people from zones that are likely to be affected.

Pyroclastic surges

Hazards presented by pyroclastic surges include severe abrasion, impact by rock fragments, and deposition of ash and coarser material, and structures can be devastated by a surge moving along the ground surface at high speed. High temperatures of some surges create an added hazard. Pyroclastic surges are especially lethal to all forms of life. The speed of surges is so great that escape is not possible once they have been generated, and only windowless, airtight, and fireproof structures of substantial strength would protect people in the path of a surge. The only mitigative measure likely to be effective is to evacuate people from zones that are likely to be affected.

Lava flows and volcanic domes

Lava flows seldom threaten human life directly because their relatively slow rate of movement usually allows people to move away from the path of the lava. Furthermore, lava flows typically move along paths determined by local topography, and their paths can be anticipated. Basalt lava flows may reach distances of more than 50 km (30 mi) from their sources, but because of their higher viscosity, dacite and rhyolite lava extrusions typically produce short, thick volcanic domes and flows that seldom move as far as 5 km (3 mi).

Lava flows and domes destroy the preexisting ground surface, but the principal hazard associated with their formation results from pyroclastic flows that precede or are derived from a dome, and rock fragments thrown out by explosions. The flanks of domes typically are unstable, and often collapse to form pyroclastic flows that may move downslope beyond the dome. During periods of active dome growth, areas within a distance of at least 15 km could be endangered by such pyroclastic flows.

Floods and mudflows

Eruptions at vents in areas covered with ice or snow may cause floods, and these may become mudflows as they incorporate rock debris. Floods and mudflows can threaten people and structures, and block evacuation routes along valley floors. Reservoirs downvalley from an active vent can trap floods and mudflows, but water displaced from them can become a hazard if the reservoirs are already full. Because of their high density, mudflows can carry large and heavy objects such as vehicles and bridges. Because floods and mudflows follow valleys and other depressions, their paths can be relatively well predicted and people can escape by moving upslope. Floods and mudflows usually move slowly enough that people have time to escape.

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PRELIMINARY ASSESSMENT OF POTENTIAL VOLCANIC HAZARDS IN THE LONG VALLEY-MONO LAKE AREA, EAST-CENTRAL CALIFORNIA AND SOUTHWESTERN NEVADA

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1982