U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Preliminary Volcano-Hazard Assessment for Mount Spurr Volcano, Alaska

Open-File Report 01–482

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The Alaska Volcano Observatory (AVO) was established in 1988 to monitor dangerous volcanoes, issue eruption alerts, assess volcano hazards, and conduct volcano research in Alaska. The cooperating agencies of AVO are the U.S. Geological Survey (USGS), the University of Alaska Fairbanks Geophysical Institute (UAFGI), and the Alaska Division of Geological and Geophysical Surveys (ADGGS). AVO also plays a key role in notification and tracking eruptions on the Kamchatka Peninsula of the Russian Far East as part of a formal working relationship with the Kamchatkan Volcanic Eruptions Response Team.

Cover photograph: Steam plume rising from Crater Peak vent on south flank of Mount Spurr volcano. Summit of Mount Spurr in background and partially obscured by steam plume. Aerial photograph taken September 4, 1992, by C.A. Neal (U.S. Geological Survey—Alaska Volcano Observatory, Anchorage, Alaska).

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By Christopher F. Waythomas and Christopher J. Nye

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Anchorage, Alaska
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U.S. DEPARTMENT OF THE INTERIOR
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CONVERSION FACTORS and VERTICAL DATUM

Multiply	by	To obtain
millimeter (mm)	0.03937	inch
centimeter (cm)	0.3937	inch
meter (m)	3.281	foot
kilometer (km)	0.6214	mile
square meter (m^2)	10.76	square foot
cubic meter (m^3)	35.31	cubic foot
cubic kilometer (km^3)	0.2399	cubic mile
meter per second (m/s)	3.281	foot per second
meter per hour (m/h)	3.281	feet per hour
cubic meter per second (m^3/s)	35.31	cubic foot per second
meter per square second (m/s^2)	3.281	foot per square second

In this report, temperature is reported in degrees Celsius (°C), which can be converted to degrees Fahrenheit (°F) by the equation

$$°F = (1.8 \times °C) + 32)$$

Sea level: In this report, “sea level” refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929, formerly called “Sea-Level Datum of 1929”), which is derived from a general adjustment of the first-order leveling networks of the United States and Canada. In the area of this report, datum is mean lower low water.

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SUMMARY OF HAZARDS AT MOUNT SPURR VOLCANO

Mount Spurr volcano is an ice- and snow-covered *stratovolcano* complex located in the north-central Cook Inlet region about 100 kilometers west of Anchorage, Alaska. Mount Spurr volcano consists of a breached stratovolcano, a *lava dome* at the summit of Mount Spurr, and Crater Peak *vent*, a small stratocone on the south flank of Mount Spurr volcano. Historical eruptions of Crater Peak occurred in 1953 and 1992. These eruptions were relatively small but explosive, and they dispersed volcanic *ash* over areas of interior, south-central, and southeastern Alaska. Individual ash clouds produced by the 1992 eruption drifted east, north, and south. Within a few days of the eruption, the south-moving ash cloud was detected over the North Atlantic. *Pyroclastic flows* that descended the south flank of Crater Peak during both historical eruptions initiated volcanic-debris flows or *lahars* that formed temporary debris dams across the Chakachatna River, the principal drainage south of Crater Peak. Prehistoric eruptions of Crater Peak and Mount Spurr generated clouds of volcanic ash, pyroclastic flows, and lahars that extended to the volcano flanks and beyond. A flank collapse on the southeast side of Mount Spurr generated a large *debris avalanche* that flowed about 20 kilometers beyond the volcano into the Chakachatna River valley. The debris-avalanche deposit probably formed a large, temporary debris dam across the Chakachatna River.

The distribution and thickness of volcanic-ash deposits from Mount Spurr volcano in the Cook Inlet region indicate that volcanic-ash clouds from most prehistoric eruptions were as voluminous as those produced by the 1953 and 1992 eruptions. Clouds of volcanic ash emitted from the active vent, Crater Peak, would be a major hazard to all aircraft using Ted Stevens Anchorage International Airport and other local airports and, depending on wind direction, could drift a considerable distance beyond the volcano. Ash fall from future eruptions could disrupt many types of economic and social activities, including oil and gas operations and shipping activities in the Cook Inlet area. Eruptions of Crater Peak could involve significant amounts of ice and snow that would lead to the formation of large lahars, formation of volcanic-debris dams, and downstream flooding. The greatest hazards in order of importance are described below and shown on plate 1.

• Volcanic-ash clouds

Clouds of fine volcanic ash would drift away from the volcano with the wind. These ash clouds are a hazard to all aircraft downwind. Airborne volcanic ash can drift thousands of kilometers from its source volcano. Ash from future eruptions could interfere with air travel, especially during a large sustained eruption.

THE ALASKA VOLCANO-HAZARD ASSESSMENT SERIES

This report is part of a series of volcano-hazard assessment reports being prepared by the Alaska Volcano Observatory. The reports are intended to describe the nature of volcanic hazards at Alaska volcanoes and show the extent of hazardous areas with maps, photographs, and other appropriate illustrations. Considered preliminary, these reports are subject to revision as new data become available.

- **Volcanic-ash fallout**

  Ash fallout *from historical and prehistoric eruptions of the Mount Spurr volcano reached parts of south-central Alaska where known accumulations of fine ash are several millimeters or more in thickness. Fine ash is a nuisance and may cause respiratory problems in some humans and animals. Heavy ash fall can disrupt many human activities, interfere with power generation, affect visibility, and damage electrical components and equipment. Resuspension of ash by wind could extend the unpleasant effects of ash fallout.*

- **Lahar and flood**

  Hot volcanic debris interacts with snow and ice to form fast-moving slurries of water, mud, rocks, and sand. These flows, called lahars, are expected to form during most future eruptions of Crater Peak. Lahars would follow streams and drainages and could flow to the coastline down the Chakachatna River valley. Lahars could be hazardous to people and facilities in the Chakachatna River valley during an eruption of Crater Peak.

- **Pyroclastic flow and surge**

  Hot material expelled from the volcano may travel rapidly down the volcano flanks as flows of volcanic debris called pyroclastic flows and surges. These flows would travel primarily along valleys and low-lying topography and are not expected to reach the Cook Inlet coastline. They pose little hazard except to people on or near the volcano during an eruption.

Other hazardous phenomena that may occur but are uncommon during typical eruptions of the Mount Spurr volcano include the following:

- **Debris avalanche**

  A debris avalanche is a rapidly moving mass of solid or incoherent blocks, boulders, and gravel initiated by a large-scale failure of the volcano flank. A large prehistoric debris avalanche occurred at Mount Spurr volcano and extended about 20 kilometers beyond the base of the volcano and blocked the Chakachatna River. Debris avalanches could form during future eruptions of Crater Peak but are not likely to be voluminous.

- **Directed blasts**

  A directed blast *is a lateral explosion of the volcano caused by rapid release of internal pressure commonly caused by a slope failure or landslide. Directed blasts are rare volcanic events. Evidence for a directed blast has not been identified at the Mount Spurr volcano.*

- **Volcanic gases**

  Some volcanoes emit gases in concentrations that are harmful to humans. The vent area on Crater Peak is a partially closed rock basin that could collect harmful gases. However, the frequently windy conditions around Crater Peak likely would prevent the buildup of volcanic gases. Thus, the hazard from volcanic gases is minimal unless one is in the crater for prolonged periods of time.

- **Lava flow**

  *Streams of molten rock (*lava*) may extend a few kilometers from the Crater Peak vent. Lava flows move slowly, only a few tens of meters per hour, and pose little hazard to humans. Some lava flows may develop steep, blocky fronts and avalanching of blocks could be hazardous to someone close to the flow front.*

SUGGESTIONS FOR READING THIS REPORT

Readers who want a brief overview of volcano hazards at the Mount Spurr volcano are encouraged to read the summary section and consult plate 1 and the illustrations. Individual sections of this report provide a slightly more comprehensive overview of the various hazards at the Mount Spurr volcano. A glossary of relevant geologic terms is included. Additional information about the Mount Spurr volcano can be obtained by consulting the references cited at the end of this report or by visiting the Alaska Volcano Observatory web site (URL: <http://www.avo.alaska.edu>).

INTRODUCTION

The Spurr volcanic complex is an assemblage of volcanic landforms that includes the ancestral stratovolcano known as Mount Spurr volcano, an *andesite* lava dome at the summit of Mount Spurr, and Crater Peak, a small stratocone on the south flank of Mount Spurr volcano (fig. 1). Crater Peak was the site of the most recent eruptive activity (Miller and others, 1998), during 1953 and 1992, and has been the active vent throughout most of the past 6,000 years (Riehle, 1985; Nye and Turner, 1990). The Spurr volcanic complex is located about 100 kilometers west of Anchorage, Alaska, within the Tordrillo Mountains on the northwest side of Cook Inlet (fig. 1) and is within a few hundred kilometers of the major population, commerce, and industrial centers of south-central Alaska. Future eruptions of Crater Peak are likely and, if explosive, could impact significantly the citizens and economy of the region.

The Spurr volcanic complex is situated on the north side of the Chakachatna River valley, a typical U-shaped glacial valley developed in hard crystalline rocks (figs. 1 and 2). The summit altitude of Mount Spurr is 3,374 meters. Mount Spurr volcano is dissected by several valley glaciers that head on Mount Spurr. Crater Peak is 2,309 meters high and, as its name implies, is a cone-shaped flank volcano with a circular summit crater. Crater Peak presently supports no glaciers. The vent area above about 1,700 meters altitude is typically snow covered for about 10 months of the year. Mount Spurr volcano has an extensive cover of perennial snow and glacier ice that is a source of water for volcanic-debris flows or lahars. The volume of snow and ice on the volcano is about 67 cubic kilometers (March and others, 1997). About one-third of the perennial snow and ice on Mount Spurr volcano is distributed around presently inactive volcanic vents and would not be affected by most eruptions of Crater Peak.

The Chakachatna River is the principal drainage on the south side of the Spurr volcanic complex, and it flows eastward to Cook Inlet from Chakachamna Lake, a 72-square-kilometer lake (estimated volume, 5.5 cubic kilometers) that occupies an elongate glacial trough in the Tordrillo Mountains (fig. 1). The east end of Chakachamna Lake is partially blocked by Barrier Glacier, an ice dam about 100 meters thick. The Chakachatna River exits Chakachamna Lake through a narrow channel, about 50 meters wide, between the terminus of Barrier Glacier and a steep bedrock valley wall to the south. The glacial ice dam of Barrier Glacier is unstable and at least one large outburst flood occurred in 1968 when excessive outflow from the lake enlarged the ice outlet, allowing significantly more water to exit the lake (Lamke, 1972).

Most of the area around the Mount Spurr volcano is uninhabited wilderness. Recreational use of the area is minimal because of the remote location, although the area is visited by small groups of people in summer and winter. An oil pipeline crosses the Chakachatna River valley along the Cook Inlet coastline, and two villages, Tyonek and Shirleyville, are located near the valley (fig. 1). Life and property are not at risk in the immediate vicinity of the volcano.

Purpose and Scope

This report summarizes the principal volcano hazards associated with eruptions of Mount Spurr volcano. Hazardous volcanic phenomena likely to occur on or near the volcano as well as distal effects of eruptions are described. The present status of monitoring efforts to detect volcanic unrest and the procedures for eruption notification and dissemination of information also are presented. A series of maps and illustrations that show potentially hazardous areas are included. A glossary of geologic terms is at the end of the report.

Physical Setting of Spurr Volcanic Complex

The Spurr volcanic complex is an assemblage of volcanic landforms that includes ancestral Mount Spurr volcano, an andesitic stratovolcano that has a summit caldera which is breached toward the south; Mount Spurr, a lava dome in the center of the caldera; and the active vent, Crater Peak, a small cone-shaped stratovolcano that formed in the breach on the south flank of Mount Spurr volcano (fig. 2). Mount Spurr is 3,374 meters high and sits within a nearly circular, 5-kilometer-diameter caldera. The caldera at Mount Spurr volcano was formed by collapse of the volcano summit during an eruption 10,000 to 4,000 years ago.

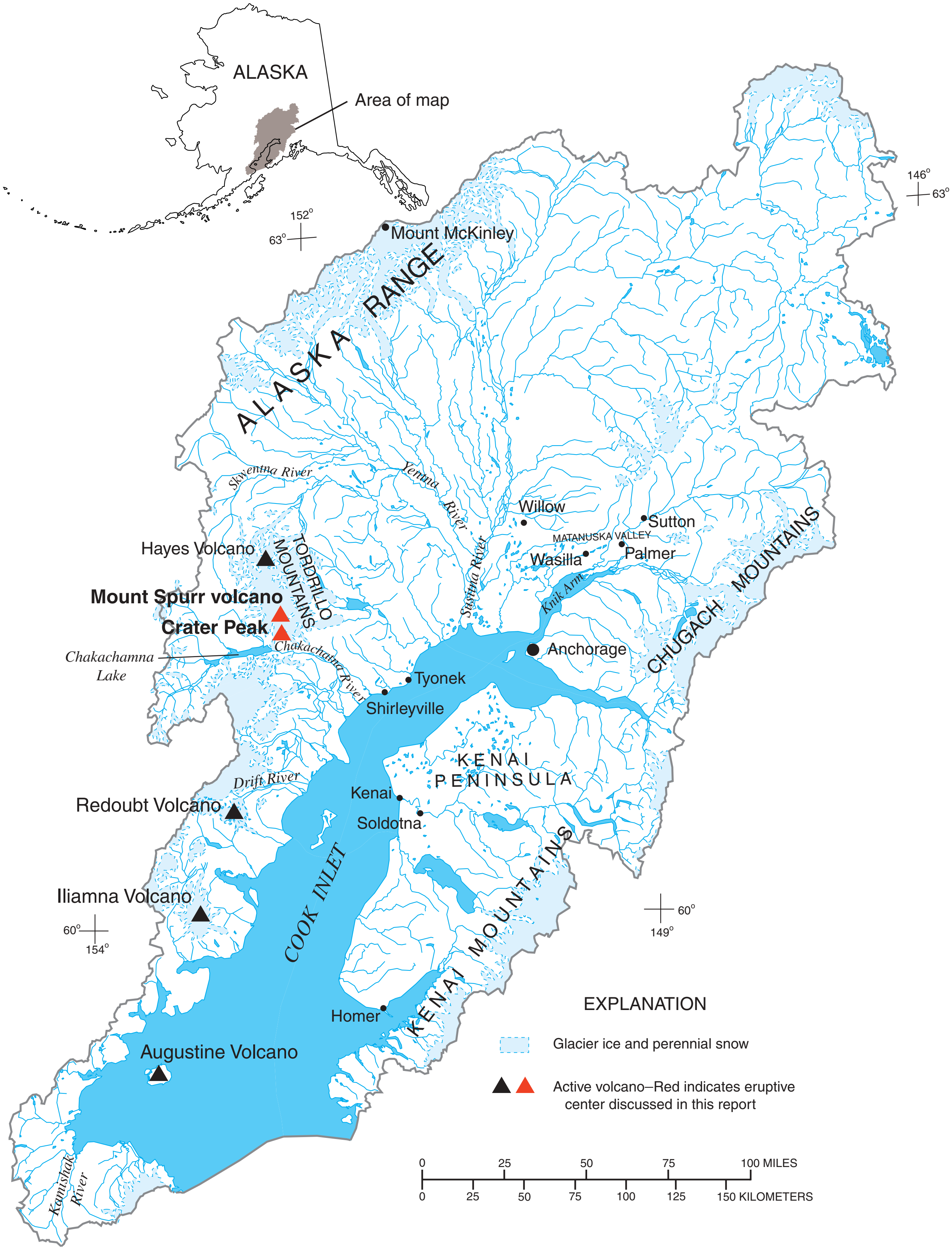

Figure 1. Location of Mount Spurr and other volcanoes in Cook Inlet Basin, Alaska.

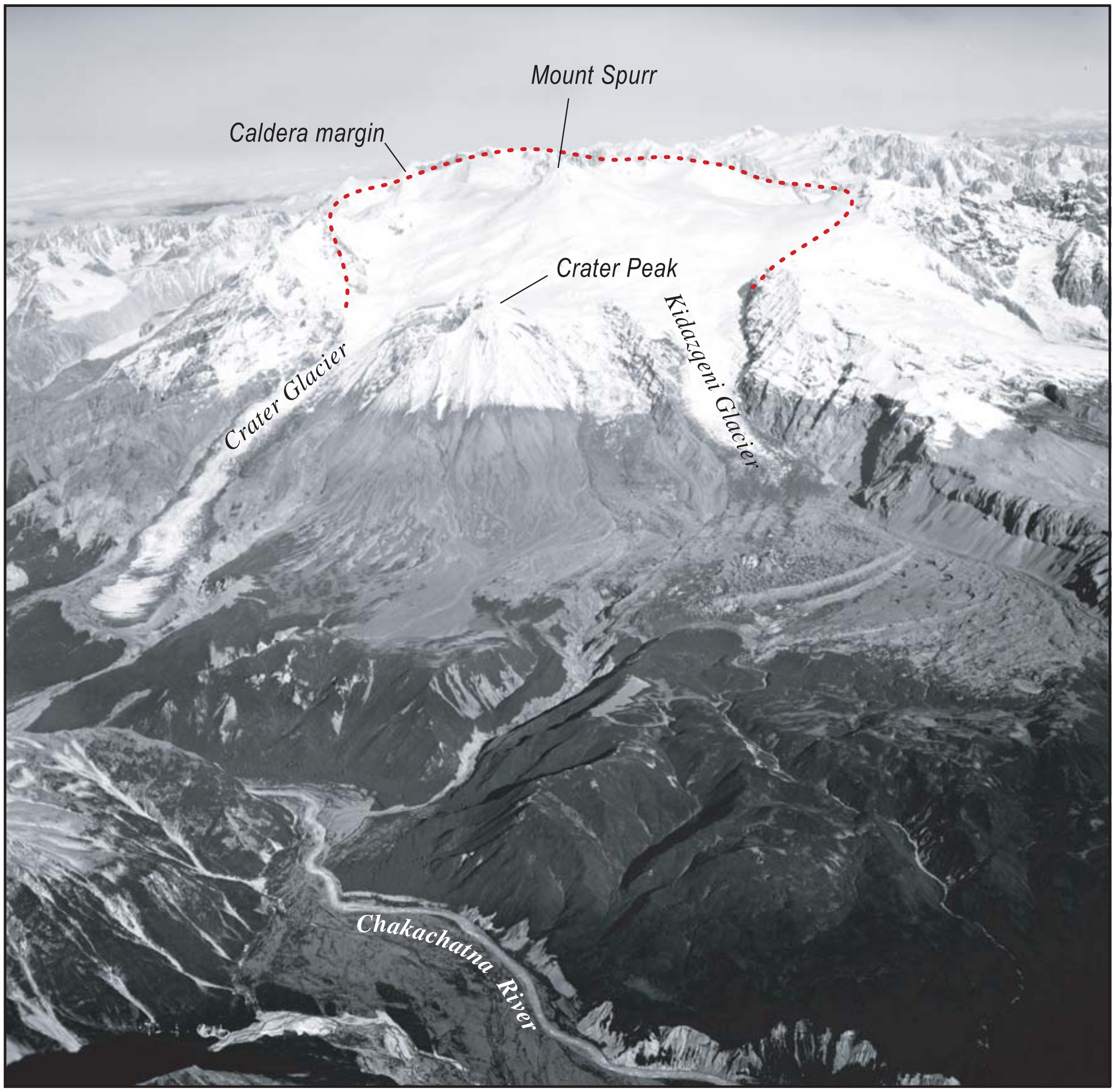

Figure 2. Mount Spurr volcano, showing Crater Peak and lateral margins of Mount Spurr caldera structure. Also shown are Crater and Kidazqeni Glaciers, two prominent glaciers exiting breached caldera. View is toward north. Aerial photograph by Austin Post, September 1966.

Much of the caldera is filled with glacier ice, and several valley glaciers extend from the caldera onto the lower flanks of the volcano. The volume of perennial snow and glacier ice on Mount Spurr volcano is about 67 cubic kilometers, about 15 times more snow and ice than present on Mount Rainier, the most extensively glacierized volcano in the Cascade Range (March and others, 1997).

Mount Spurr volcano consists of a stratified assemblage of andesite lava flows and minor lahar, pyroclastic-flow, and debris-avalanche deposits. These rock units are truncated by the summit caldera and are incised by glaciers that extend from the summit. The lava dome at the summit of Mount Spurr is composed mainly of high-silica andesite. The Crater Peak cone, which has a distinctive circular crater at its summit, is also a stratified assemblage of basaltic andesite lava flows and *pyroclastic* deposits (fig. 3). Steam issuing from the crater is common and is often visible on calm cloudless days.

Mount Spurr volcano is in a remote wilderness area and is only occasionally visited by people. The Chakachatna River is an important sport fishery, and recreational use of bottomland areas in the Chakachatna River valley is common in summer and winter.

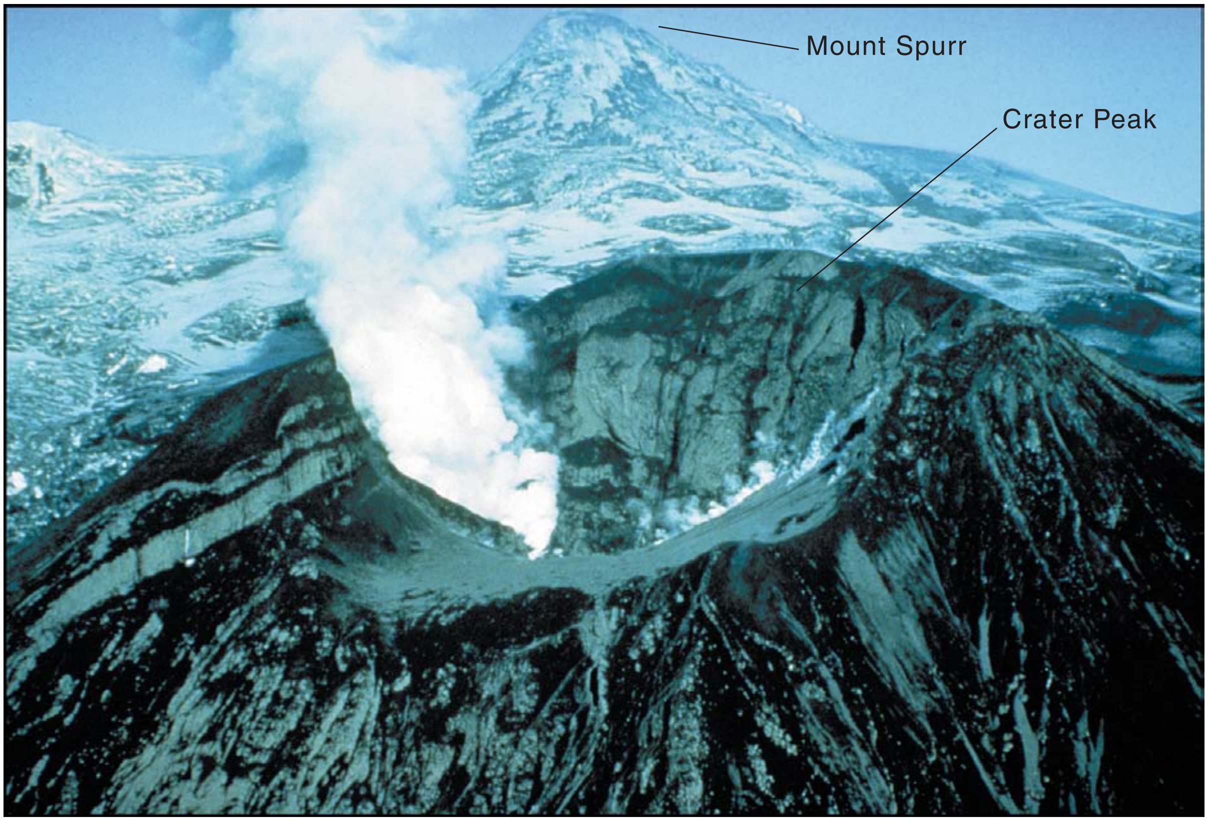

Figure 3. Crater Peak vent area just after 1992 eruption. View is toward north. Aerial photograph by Alaska Volcano Observatory staff, 1992.

Residential areas and developments along the Cook Inlet coastline are more than 50 kilometers from the volcano but could be at risk from ash fall should an explosive eruption occur.

PREHISTORIC ERUPTIVE ACTIVITY

Mount Spurr volcano began forming about 255,000 years ago (Nye and Turner, 1990), and eruptive activity has continued intermittently to the present. Rock units preserved on the lower flanks of the volcano indicate that during its early history, eruptions were primarily explosive pyroclastic eruptions (Nye and Turner, 1990). The upper part of volcano is composed mainly of andesitic lava flows indicating a change to a more *effusive* style of volcanism. The present caldera formed during a major flank collapse of Mount Spurr volcano that either caused or resulted from a major eruption in late Pleistocene or early Holocene time. A discontinuous mantle of pyroclastic debris composed of high-silica andesite rests directly on the debris-avalanche deposits on the proximal south flank of the volcano. The debris-avalanche and pyroclastic-flow deposits and the caldera structure itself are the primary evidence that the eruption and flank collapse were initiated by magmatic activity (fig. 4). At present, the age of the debris-avalanche and associated pyroclastic-flow deposits is not known. Debris-avalanche deposits exposed along the Chakachatna River are overlain by the 3,800-to-3,500-year-old Hayes *tephra* (Riehle and others, 1990) and overlie ice-erosional topography formed during late Pleistocene glaciation of the Chakachatna River valley. Tephra deposits should have been generated during this eruption, but, thus far, none have been recognized. This may indicate that there was extensive ice cover at the time of the caldera-forming eruption. These relations indicate that the debris-avalanche and pyroclastic-flow deposits and associated eruption occurred between 10,000 and 4,000 years ago.

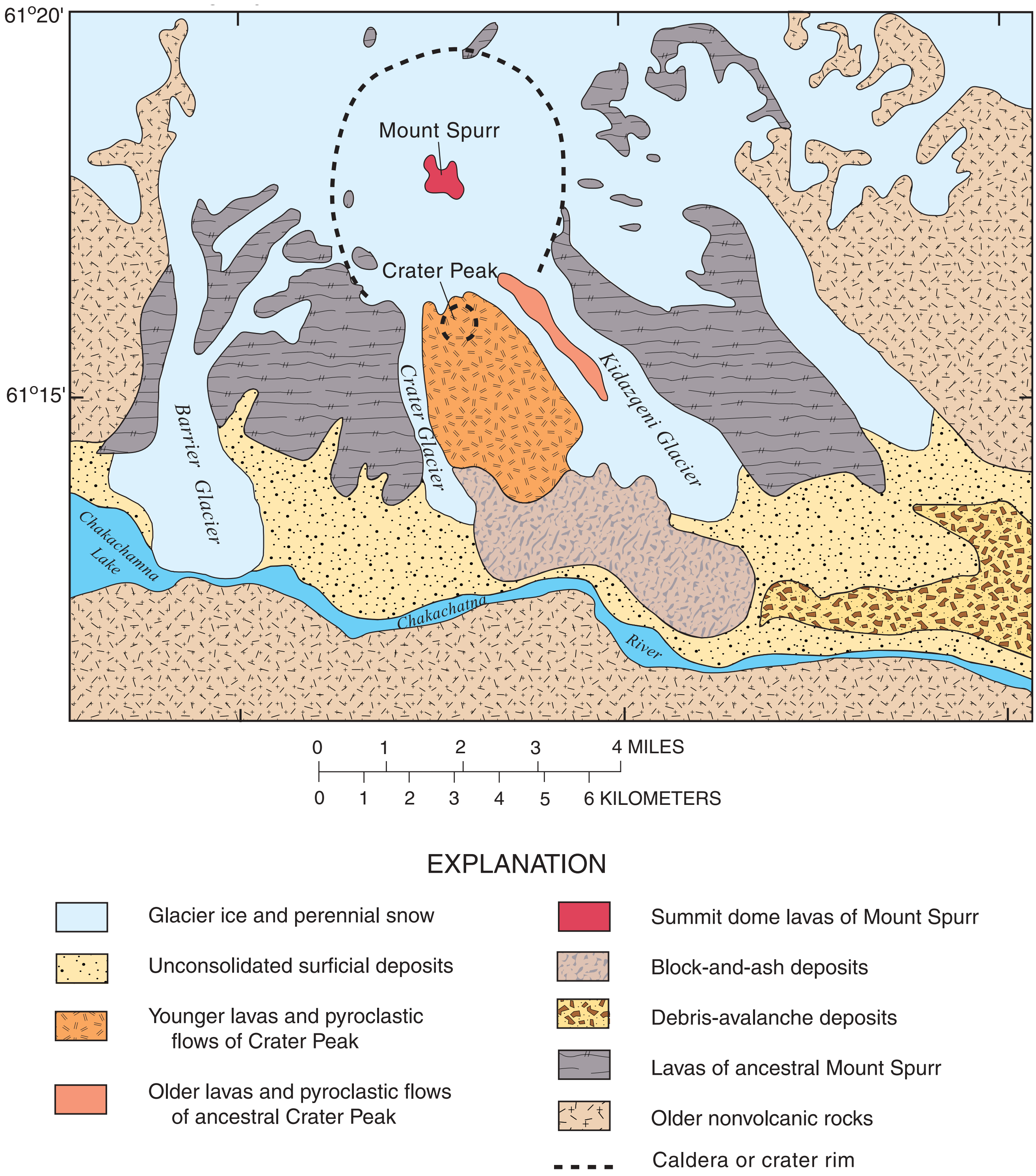

Figure 4. Simplified geology of Spurr volcanic complex (modified from Nye and Turner, 1990).

The history of Holocene eruptive activity is determined by studying the stratigraphic relations of volcanic rocks and deposits exposed in riverbanks and gullies on the flanks of the volcano and by analyzing volcanic-ash deposits preserved in areas beyond the volcano. In general, volcanic activity is episodic, and long periods of inactivity are punctuated by periods of rapid deposition of volcanic sediment during eruptions. During periods between eruptions, vegetation growth and soil development may occur, and during subsequent eruptions, vegetation and soil may be buried by volcanic deposits. Over time, a vertical sequence of buried soils and vegetation, volcanic deposits, and volcanic ash develops. A stratigraphic sequence of volcanic deposits evolves in this manner over many thousands of years, and it is possible to determine the eruptive history of the volcano by dating buried soils and plant remains associated with the volcanic deposits. Volcanic rocks can be dated directly using *radiometric-dating* techniques such as potassium–argon dating. This method has been applied at the Mount Spurr volcano and is the basis for deciphering the eruptive history of the volcano.

According to Nye and Turner (1990), two eruptive centers developed after the destruction of the ancestral Mount Spurr volcano. A lava dome was extruded and forms the present summit of Mount Spurr, and another vent grew in the breach of ancestral Mount Spurr volcano and forms Crater Peak (fig. 4). Eroded remnants of an older cone lie east and west of Crater Peak indicating that Crater Peak must have been larger than it is now. The Mount Spurr vent was intermittently active until about 5,200 years ago, as determined from studying distal tephra deposits (Riehle, 1985). Lava flows of andesitic composition were extruded from the proto-Crater Peak vent, but the cone was destroyed or buried by eruptive products from the Crater Peak vent since about 6,000 years ago (Riehle, 1985). Apparently, eruptions from both the Mount Spurr vent and the proto-Crater Peak/Crater Peak vent were contemporaneous for a short interval from about 6,000 to 5,000 years ago (Riehle, 1985; Nye and Turner, 1990).

Recent studies of volcaniclastic deposits on the south flank of Crater Peak exhumed by erosion during the 1992 eruption provide additional information about the late Holocene eruptive history of Crater Peak. Pyroclastic-flow and lahar deposits that overlie the debris-avalanche–*block-and-ash-flow* sequence record a probable middle Holocene pyroclastic eruption of Crater Peak. Large lahars formed during this eruption that flowed down the south flank of the volcano and across the Chakachatna River and formed temporary lahar dams. These deposits are overlain by a several-meters-thick soils–tephra sequence. The buried soils are rich in organic materials, and the tephra consists of thin (less than 1-centimeter-thick), fine-grained volcanic-ash deposits that probably record small explosive eruptions of Crater Peak about 1,000 years ago (fig. 5). Lahar deposits that overlie the soil–tephra sequence were probably generated by pyroclastic flows during one or two eruptions about 840 years ago. A soil developed on the lahar deposits indicates a quiescent period when ash or other volcaniclastic deposits did not accumulate and surfaces on the flanks of the volcano remained stable enough that, at least locally, vegetation grew and soil developed. A relatively large explosive eruption of Crater Peak is recorded by a 40-centimeter-thick pumiceous *lapilli* ash that is younger than about 840 years but older than A.D. 1953.

Fine-grained volcanic-ash deposits of Holocene age from Mount Spurr volcano have been identified on the Kenai Peninsula and in areas east of Mount Spurr (Riehle, 1985). These ash layers are within a vertical sequence of unconsolidated sediment and volcanic-ash deposits from other Cook Inlet volcanoes and have been correlated by radiocarbon dating and geochemistry with volcanic deposits on the proximal flanks of Mount Spurr and Crater Peak. Distal tephra deposits are evidence for relatively large eruptions of Mount Spurr volcano and Crater Peak during the past 7,000 years.

During Holocene eruptions of Crater Peak, volcanic mudflows or lahars were formed and many of the valleys and gullies on the volcano were inundated by lahars. The lahars were generated by the dynamic interaction of pyroclastic flows with ice and snow, and they are the direct products of eruptive activity. Many of the lahars flowed into and across the Chakachatna River and formed debris dams that temporarily blocked the river. When the lahar dams failed, the lakes that formed upstream from the dams were released rapidly and initiated flood surges that swept down the Chakachatna River probably as debris flows or highly sediment-laden water flows extending as far as the Cook Inlet coastline.

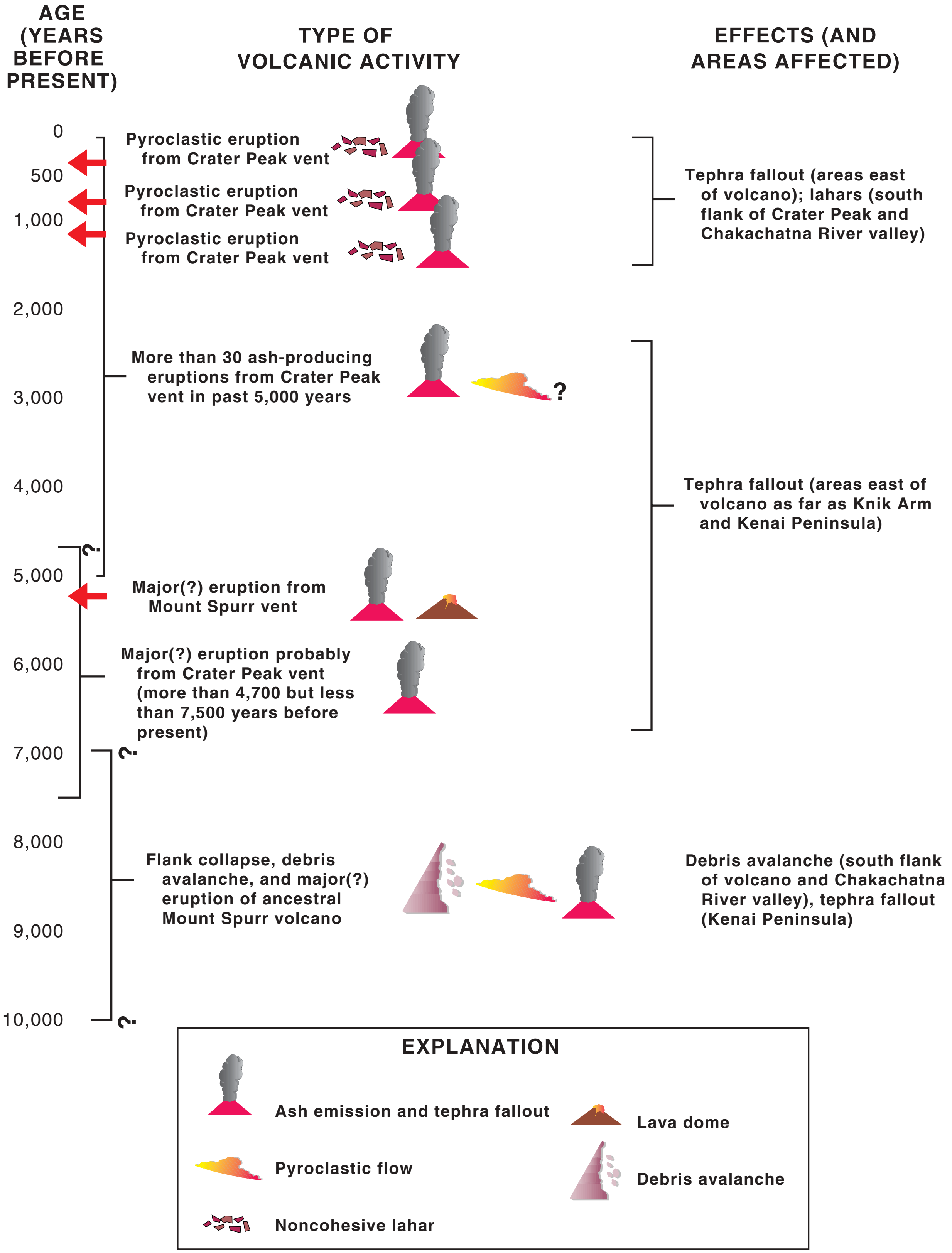

Figure 5. Outline of prehistoric eruptive history of Mount Spurr volcano. Timing of ash-producing eruptions based on on radiocarbon-dated tephra deposits (Riehle, 1985).

HISTORICAL ERUPTIONS

Historical eruptions of Crater Peak occurred in 1953 and 1992 (table 1). Both eruptions were *volcanian* to sub-*Plinian* pyroclastic eruptions that generated relatively large volumes of volcanic ash that fell over parts of south-central Alaska. Ash clouds produced during the 1992 eruptions drifted over southwestern Canada August 19–20 and over southwestern Canada, the north-central United States, and southeastern Canada September 17–20. The ash cloud from the September 16–17 eruption eventually reached the Atlantic Ocean on September 20 (Schneider and others, 1995).

The first known historical eruption of Crater Peak occurred at about 5 a.m. on July 9, 1953 (Juhle and Coulter, 1955; Miller and others, 1998). For at least 30 years prior to the 1953 eruption, plumes of whitish steam commonly were observed rising from the summit of Crater Peak; pilots reported an increase in the vigor of steaming in late spring 1953 (Juhle and Coulter, 1955). At the time of the 1953 eruption, instruments to monitor the seismic activity of the volcano were not available. The 1953 eruption was a single explosive burst lasting about one hour, and it generated an ash cloud that rose more than 10,000 meters above sea level (Juhle and Coulter, 1955). Ash fall occurred east of the volcano (fig. 6) and approximately 6 millimeters of ash accumulated in Anchorage. A light dusting of ash was reported as far away as Valdez and as close as 48 kilometers to Cordova (Juhle and Coulter, 1955). Pyroclastic flows mixed with snow and ice high on the crater rim and combined with heavy rainfall to produce lahars that inundated tributaries to the Chakachatna River on the south flank of Crater Peak. The lahars flowed into the Chakachatna River and formed a substantial debris dam across the river (Juhle and Coulter, 1955; Meyer and Trabant, 1995). After the 1953 eruption ended, Crater Peak remained quiet until it erupted again in 1992.

Seismic monitoring of Mount Spurr volcano began in 1971, and six or more seismic instruments have been operated on the volcano since 1989 by the Alaska Volcano Observatory (AVO). Beginning in August 1991, an increase in the frequency of small earthquakes beneath Crater Peak heralded the onset of a renewed period of volcanic unrest. Elevated levels of seismicity continued into 1992, and before June, AVO scientists issued written memoranda urging government agencies and the aviation industry to prepare for

Table 1. Outline of historical eruptive activity at Crater Peak

[ADT, Alaska Daylight Time. —, no specific time (continuous or intermittent)]

Date	Time (ADT)	Eruptive activity or observation
1992 eruption		
June 27	7:04 a.m.	Explosive eruptions, pyroclastic flows, and lahars on south flank of Crater Peak. Lahars formed temporary debris dams.
	7:16 a.m.	Ash column rose above Crater Peak (reported by pilot).
	10:25 a.m.	Ash plume reached maximum altitude of 14,500 meters.
	10:30 a.m.	Ash fallout 1 to 3 millimeters thick, Denali National Park.
	—	Ash cloud drifted northeastward over Beaufort Sea, turned south, and eventually reached conterminous United States.
August 18	3:48 a.m.	Ash cloud over crater (reported by pilot).
	4:42 a.m.	Explosive eruption. Ash cloud rose to altitude of 14,000 meters. Pyroclastic flows, lahars, and ballistic fallout on south flank of Crater Peak. Ash fallout (sand-size particles) 3 millimeters thick in Anchorage; Ted Stevens Anchorage International Airport closed for 20 hours.
September 16–17	10:36 p.m.	Brief, explosive eruption.
	12:03 a.m.	Explosive eruption. Pyroclastic flows and lahars on south flank of Crater Peak. Debris dams formed across Chakachatna River. Ash fallout 1 to 2 millimeters thick in Matanuska–Susitna valley region.
1953 eruption		
July 9	—	Pyroclastic flows and lahars swept down south flank of Crater Peak. Lahars formed temporary debris dams across Chakachatna River.
	5:05 a.m.	Ash column rose to height of 21,000 meters (reported by pilot).
	6:00 a.m.	Ash began falling on distal flanks of volcano.
	12:00 noon	Ash began falling on Anchorage; fine ash fallout accumulated to thickness of 6 millimeters.

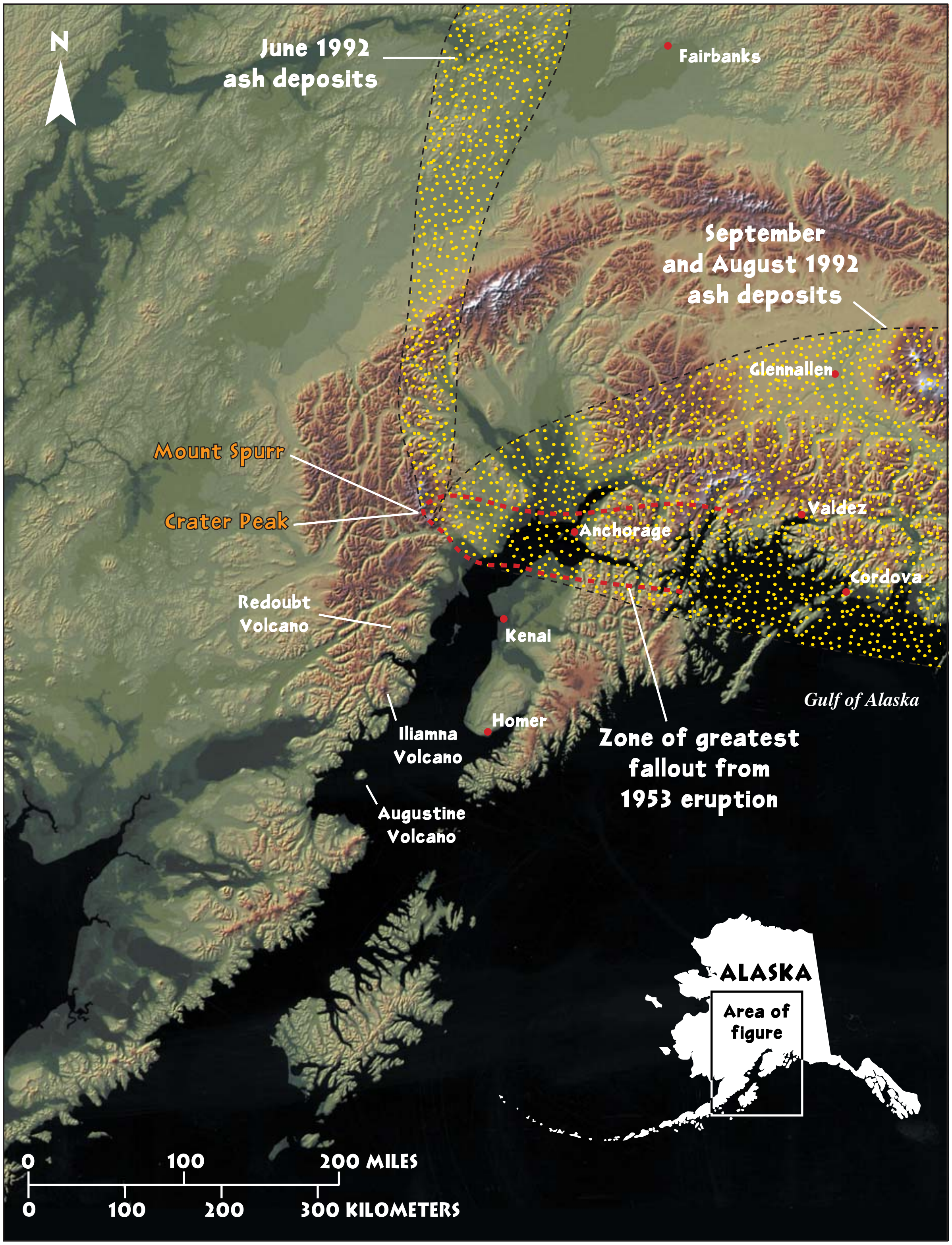

Figure 6. Areas in south-central and interior Alaska that received ash fallout during 1953 and 1992 eruptions of Crater Peak. Ash-fallout limits, modified from Wilcox (1959) and Neal and others (1995), are overlaid on composite false-color infrared satellite image.

a possible eruption of Crater Peak. A few days prior to the June 27, 1992, eruption, observers noticed that the normally blue-green lake, which had developed in the crater after the 1953 eruption, had turned grey in color, and its ordinarily ambient temperature had risen to about 50°C (Doukas and Gerlach, 1995). A strong hydrogen sulfide odor and boiling and upwelling of the lake water also were noticed.

The following narrative is a summary of the eruptive activity during the 1992 eruption modified from Eichelberger and others (1995), who provided a detailed account of the 1992 eruption and its effects.

On June 24, 1992, the level of seismic activity beneath Crater Peak increased dramatically; long episodes of volcanic tremor began and continued intermittently for several days. In the early morning hours of June 27, 1992, the level of seismic activity again increased and was greater than at any time during the previous three days. An abrupt increase in volcanic tremor at about 7:04 a.m. ADT[1] later was confirmed as the start of the 1992 eruption. At 7:16 a.m., AVO received confirmation of an ash cloud above Crater Peak from an Alaska Airlines pilot who reported that an eruption plume had risen above the cloud cover to an altitude of about 5,000 meters. By about 10 a.m., reports from pilots in the vicinity of the volcano estimated that the ash plume had risen to about 9,000 meters, and radar data collected by the National Weather Service[2] indicated that the plume had reached a maximum height of 14,500 meters (Rose and others, 1995). The ash cloud drifted northward, and at about 10:30 a.m., ash began falling on areas north of the volcano (fig. 6), including Denali National Park, where about 1 to 2 millimeters of ash accumulated. At about 11:30 a.m., the level of seismic activity decreased sharply. The eruption had ended, but the ash cloud continued drifting northward, eventually reaching the Beaufort Sea, then turning southward and drifting over Canada into the conterminous United States (Schneider and others, 1995). After July 2, 1992, the ash cloud could not be differentiated from weather clouds, and AVO received no reports of volcanic-ash encounters by jet aircraft.

Pyroclastic flows generated by the eruption initiated lahars on the south flank of Crater Peak. The lahars flowed down small tributaries to the Chakachatna River and built temporary debris dams across the river as they did during the 1953 eruption.

After June 27, Crater Peak remained quiescent until August 12–17, when a few small earthquakes were detected. On August 18 at 3:37 p.m. ADT, low-level seismic activity began, and at 3:48 p.m., AVO received a pilot report of an ash plume rising 300–600 meters above Crater Peak. Within an hour, seismic activity beneath the volcano increased abruptly, and by 4:58 p.m., an ash cloud observed over the volcano had risen to about 11,000 meters and eventually reached an altitude of 14,000 meters. The *eruption column* was a dense roiling cloud of fine volcanic ash that was intermittently jolted by shock waves generated by volcanic explosions in the vent. Large fragments of volcanic rock (volcanic bombs) as much as 1 meter in diameter were observed being forcibly hurled from the vent, some landing as far as 10 kilometers away (Waitt and others, 1995). Pyroclastic flows extended a short distance down the south flank of Crater Peak, and small volume lahars flowed into the Chakachatna River but apparently did not form debris dams (Meyer and Trabant, 1995).

The ash cloud generated by the August 18, 1992, eruption drifted east-southeastward directly over Anchorage, and about 3 millimeters of sand-size ash accumulated in and near the city (fig. 6; Neal and others, 1995). Ted Stevens Anchorage International Airport was closed for 20 hours as a result of the August 18 eruption, and numerous air-quality alerts were issued for several days after the eruption. The ash cloud drifted south over the west coast of Canada and the conterminous United States and could be detected by satellite for about 85 hours. Air fouled by resuspended ash dust remained a problem in the Anchorage area until the first snow of autumn 1992 and then again during the summer of 1993.

By mid-September 1992, seismic activity again increased dramatically and reached levels similar to those detected in mid-June. Crater Peak erupted a third time at about 10:36 p.m. ADT on September 16 and continued erupting incandescent blocks and bombs that could be seen as far away as Anchorage. The main phase of the eruption occurred at 12:03 a.m. on September 17 and generated pyroclastic flows on the southeast flank of Crater Peak, lahars that formed temporary debris dams across the Chakachatna River, and

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[1] Alaska Daylight Time.

[2] National Oceanic and Atmospheric Administration.

an ash cloud that drifted northeastward and dropped about 1 to 2 millimeters of fine ash on Palmer, Wasilla, and nearby parts of Matanuska Valley and the Susitna River valley (Neal and others, 1995). Small amounts of ash also fell on Glennallen, 350 kilometers northeast of Crater Peak (fig. 6).

HAZARDOUS PHENOMENA ASSOCIATED WITH ERUPTIONS

A volcano hazard (fig. 7) is any volcanic phenomenon that is potentially threatening to life or property. In general, hazards associated with volcanic eruptions are grouped as proximal or distal relative to the areas most likely to be affected by specific volcanic phenomena as a function of distance from the vent. The classification of hazardous phenomena at the Mount Spurr volcano as proximal or distal is an approximate classification because the extent of a particular hazard is in part related to the scale of the eruption. Thus, a large eruption may cause some phenomena to affect areas well beyond the volcano, whereas during a smaller eruption, the same phenomena may affect areas only in the immediate vicinity of the volcano.

Proximal hazards are those phenomena that occur in the immediate vicinity of the volcano, typically within a few tens of kilometers of the active vent. The proximal hazard zone is delineated by the ratio of the volcano summit height (H) to the runout length (L) of on-ground hazardous phenomena such as pyroclastic flows, debris avalanches, and lahars. Typical H/L values range from 0.1 to 0.3. Life and property within the proximal hazard zone may be at risk during eruptions depending on the eruptive style and duration of activity. Anyone in this zone would have little or no time to escape from the area in the event of an eruption. Because most of the area around the Mount Spurr volcano is uninhabited, only the occasional visitor is at risk from the various proximal hazards (fig. 8).

Distal hazards pose less risk to people because time for warning and evacuation is usually adequate. This group of hazards affects people and structures that are more than about 10 to 30 kilometers from the active vent. Volcanic ash, either in explosive eruption columns or ash clouds that drift far away from the volcano can be both a proximal and a distal hazard, especially to aircraft. Fallout of volcanic ash also can be a proximal and a distal hazard.

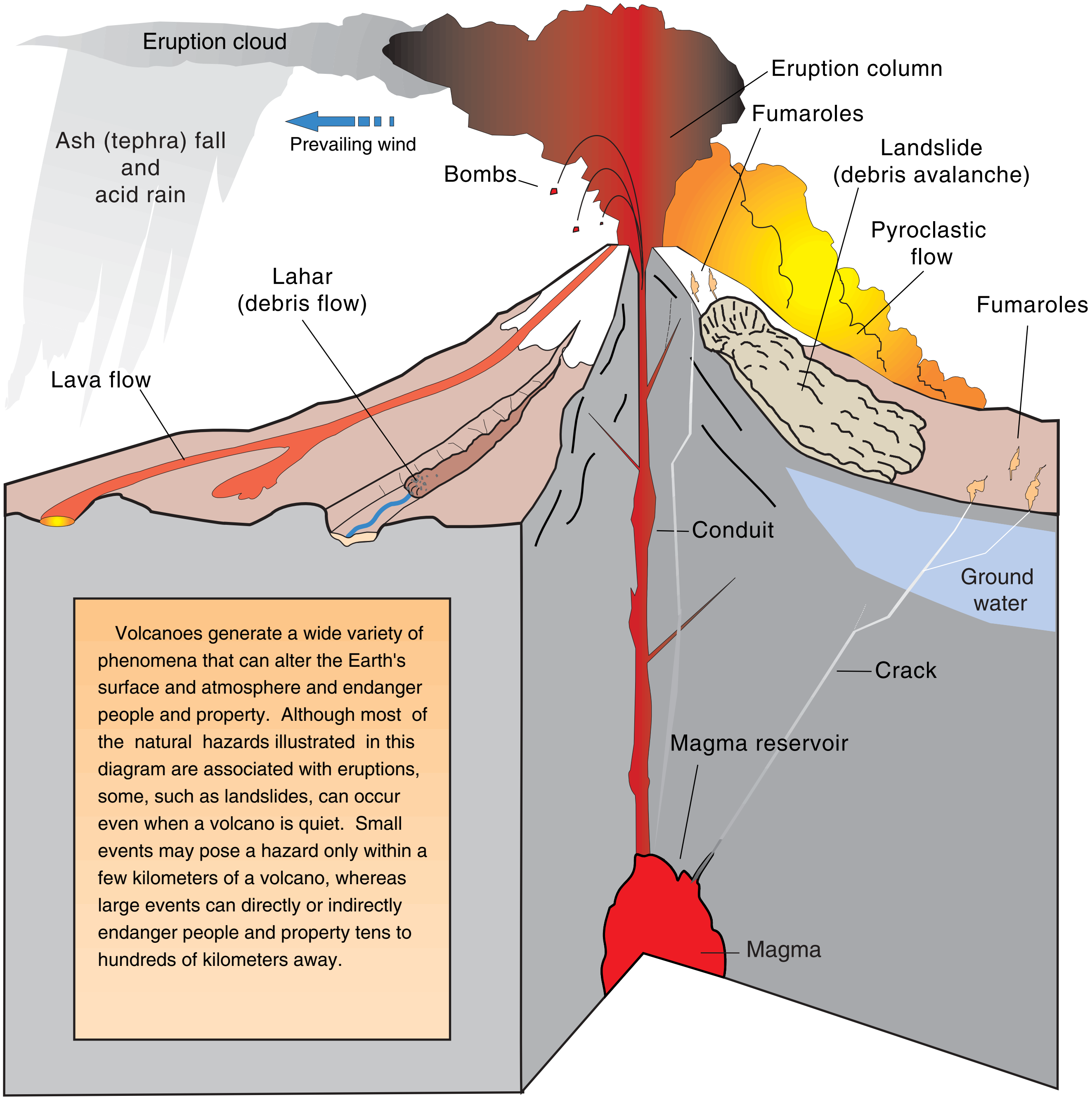
Deposits and features formed by various volcanic phenomena are shown on the geologic map of the Mount Spurr volcano (fig. 4). The processes that produced these deposits and features are generally confined to the flanks of the volcano and the major drainages that extend from the summit. Only volcanic-ash clouds, ash fallout, pyroclastic flows and surges, and unusually large volume lahars are likely to affect areas more than a few kilometers from the active vent on Mount Spurr volcano.

VOLCANIC HAZARDS

Volcanic-Ash Clouds

More than 10 times in the past 10,000 years, explosive eruptions of Mount Spurr and Crater Peak propelled significant quantities of fine ash particles or tephra into the atmosphere forming an *eruption cloud* (fig. 7) that drifted away from the volcano with the wind (figs. 9 and 10). The fine ash particles may remain in the atmosphere for days to weeks depending on the size of the eruption. Volcanic-ash clouds are a potential hazard to all aircraft downwind from the volcano (Casadevall, 1994).

Eruptions from Crater Peak on June 27, August 18, and September 16–17, 1992, produced ash clouds (fig. 11) that reached altitudes of 13 to 15 kilometers above sea level. These ash clouds drifted in a variety of directions and were tracked in satellite images for thousands of kilometers beyond the volcano (Schneider and others, 1995). One ash cloud that drifted southeastward over western Canada and over parts of the conterminous United States and eventually out across the Atlantic Ocean (fig. 12) significantly disrupted air travel over these regions but caused no direct damage to flying aircraft (Casadevall and Krohn, 1995). The ash clouds produced by the 1992 eruptions of Crater Peak were about as large as those produced by the December 1989 eruption of Redoubt Volcano (Miller and Chouet, 1994) but did not result in ash–aircraft encounters as they had during the Redoubt eruption. This may have been because of a greater awareness of the hazard and improved methods of communication during the eruption.



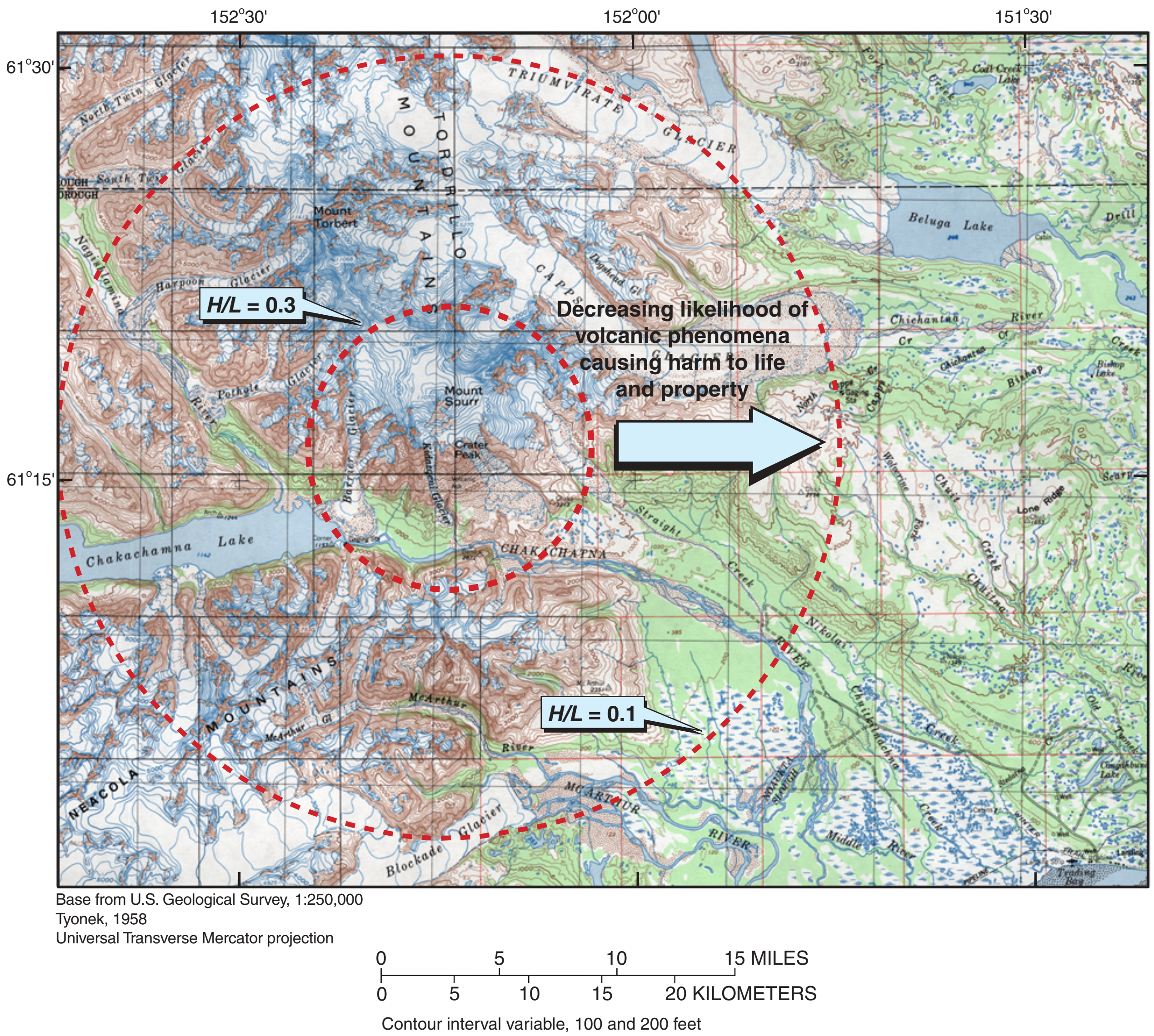
Volcanoes generate a wide variety of phenomena that can alter the Earth's surface and atmosphere and endanger people and property. Although most of the natural hazards illustrated in this diagram are associated with eruptions, some, such as landslides, can occur even when a volcano is quiet. Small events may pose a hazard only within a few kilometers of a volcano, whereas large events can directly or indirectly endanger people and property tens to hundreds of kilometers away.

Figure 7. Volcanic processes and hazards at stratovolcanoes (modified from Myers and others, 1997).

During future eruptions of Crater Peak, it is likely that ash would be dispersed over interior and south-central Alaska and beyond, and fallout could occur over this area and parts of western Canada. Variable winds over the zone of fallout could temporarily detain a drifting ash cloud causing dusty ash-laden air to linger in the region.

Volcanic-Ash Fallout and Volcanic Bombs

Volcanic ash is one of the most troublesome and hazardous products of explosive volcanism. Clouds of volcanic ash produced during explosive eruptions are carried by the wind away from the volcano, and a steady rain or fallout of ash usually occurs. Volcanic



Base from U.S. Geological Survey, 1:250,000
Tyonek, 1958
Universal Transverse Mercator projection

Figure 8. Extent of proximal hazard zones around Mount Spurr volcano. Red circles define hazard zones for $H/L = 0.1$ and $H/L = 0.3$, where H and L are fall height and runout length, respectively; they are centered on Crater Peak (presently active vent).

ash in the atmosphere may be transported long distances and has the potential to affect areas many hundreds of kilometers from the volcano (fig. 12). Few people have ever been killed directly by falling ash, but the weight of a thick ash fall could cause structures to collapse, and inhaling fine ash particles is a health hazard that can be life threatening to some people with respiratory problems. Sometimes a “mud rain” results if airborne volcanic ash mixes with falling rain or snow.

The 1992 eruption of Crater Peak spread ash over areas north and east of the volcano (fig. 6). Although only small amounts of fine ash (less than 5 millimeters thick) were deposited by the drifting ash cloud on populated areas downwind, even this amount of ash was sufficient to severely curtail the daily activities of residents in the affected areas. Ash fall from the August 18 eruption disrupted air traffic over south-central Alaska and forced a temporary closure of airports in the Anchorage area. The Municipality of Anchorage incurred significant economic losses from ash fallout on August 18. Businesses, schools, and industrial facilities were closed, and vehicles, computers, air-conditioning systems, and other types of electronic equipment were damaged or rendered inoperable.

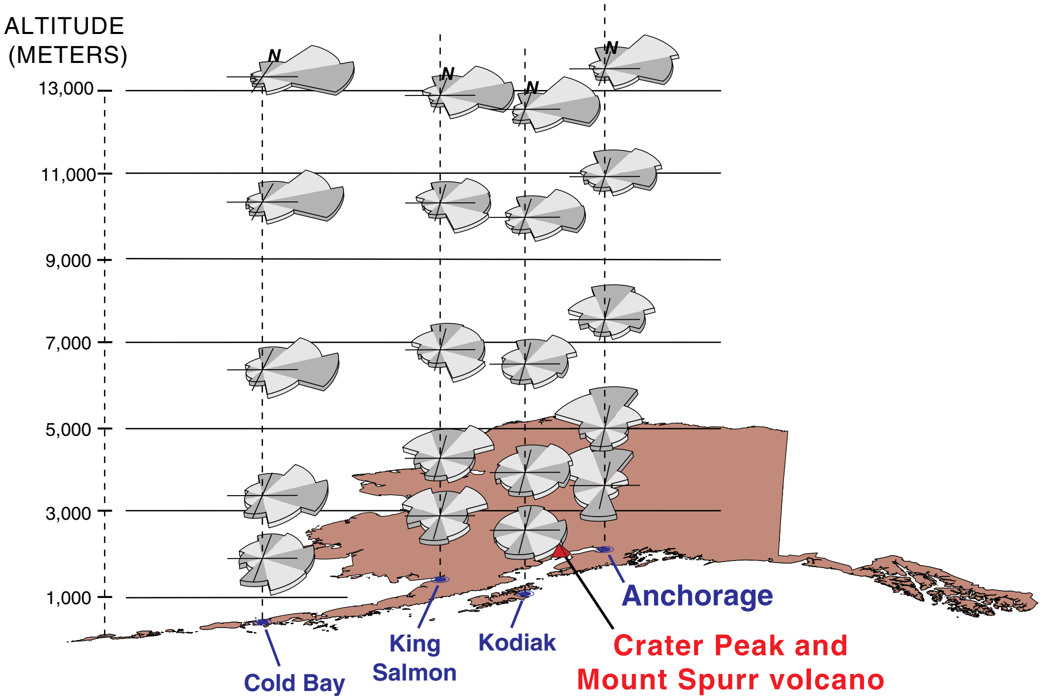


Figure 9. Prevailing-wind directions for south-central and southwestern Alaska. Vector lengths in each rose diagram are proportional to amount of time wind blows in particular direction. Wind data from National Oceanic and Atmospheric Administration, National Climatic Data Center, Asheville, N.C.

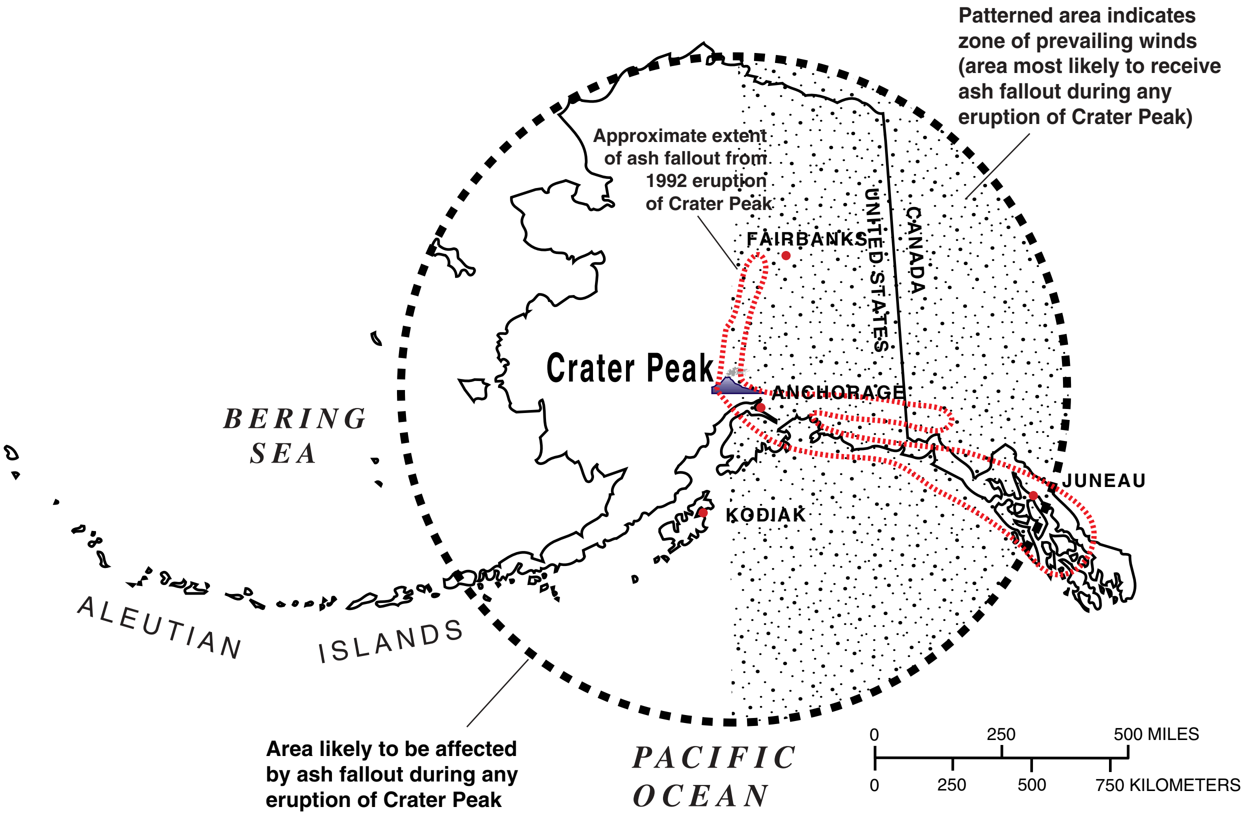


Figure 10. Areas most likely to receive ash fallout from future eruption of Crater Peak, given prevailing winds (fig. 9).

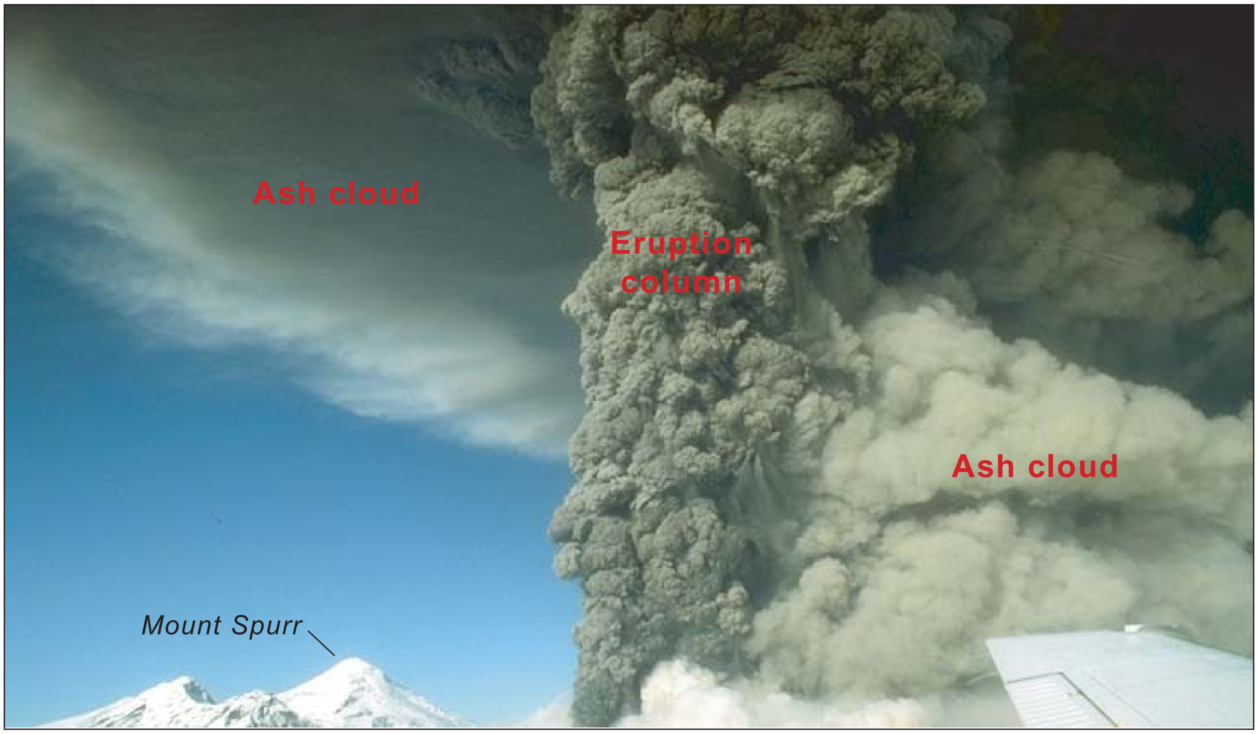


Figure 11. Eruption column and ash cloud produced during August 18, 1992, eruption of Crater Peak. View is toward north. Oblique aerial photograph by Robert G. McGimsey, U.S. Geological Survey, September 1992.

No people were killed by the direct effects of the falling ash, but two individuals suffered heart attacks while shoveling ash. Ash fall from future eruptions of Crater Peak could be a serious public health concern for parts of south-central and southeastern Alaska or wherever fallout occurs. If an eruption occurs during a prolonged period of dry weather, ash particles may persist in the atmosphere or be periodically resuspended by wind. This condition could significantly diminish air quality for days to weeks after the eruption.

Wind direction and speed control the movement of an ash plume, and the areas most likely to receive ash fall are those in the zone of prevailing winds (figs. 9 and 10). The strongest and most consistent winds in the vicinity of Mount Spurr volcano are from the west, southwest, and northwest. The thickness of ash fallout decreases in a downwind direction, but how much ash would be produced during an individual future eruption is impossible to predict. Any amount of ash fall could be disruptive. Industrial equipment and facilities in the upper Cook Inlet region, such as oil-drilling rigs, oil refineries, manufacturing plants, and power plants, could be affected by ash fall.

Blocks and bombs of volcanic-rock debris may be ejected as ballistic projectiles during explosive eruptions, especially those involving water. Usually, ballistic fallout occurs in areas near the vent, but in extreme cases, bombs may be ejected distances of 10 to more than 30 kilometers from the vent. Typically, the zone of ballistic fallout is within a few kilometers of the vent and people or low-flying aircraft would be at risk only within this zone.

Ballistic particles were ejected from the Crater Peak vent during each of the three eruptions in 1992 (Waitt and others, 1995). Most of the blocks and bombs ranged in size from 2 meters to about 8 centimeters (intermediate-axis diameter) and generally fell between 2 and 4 kilometers from the vent, although some were found as much as 8 kilometers from the vent (fig. 13; Waitt and others, 1995). Once the ballistic particles leave the vent, they generally follow a parabolic trajectory and may reach heights of roughly 1,500 meters above the vent at the apex of the trajectory. At the vent, the ballistic particles have velocities in the range of 150 to 840 meters per second (Waitt and others, 1995). For comparison, the velocity of a bullet leaving the muzzle of a typical firearm is in the range of 300-400 meters per second.

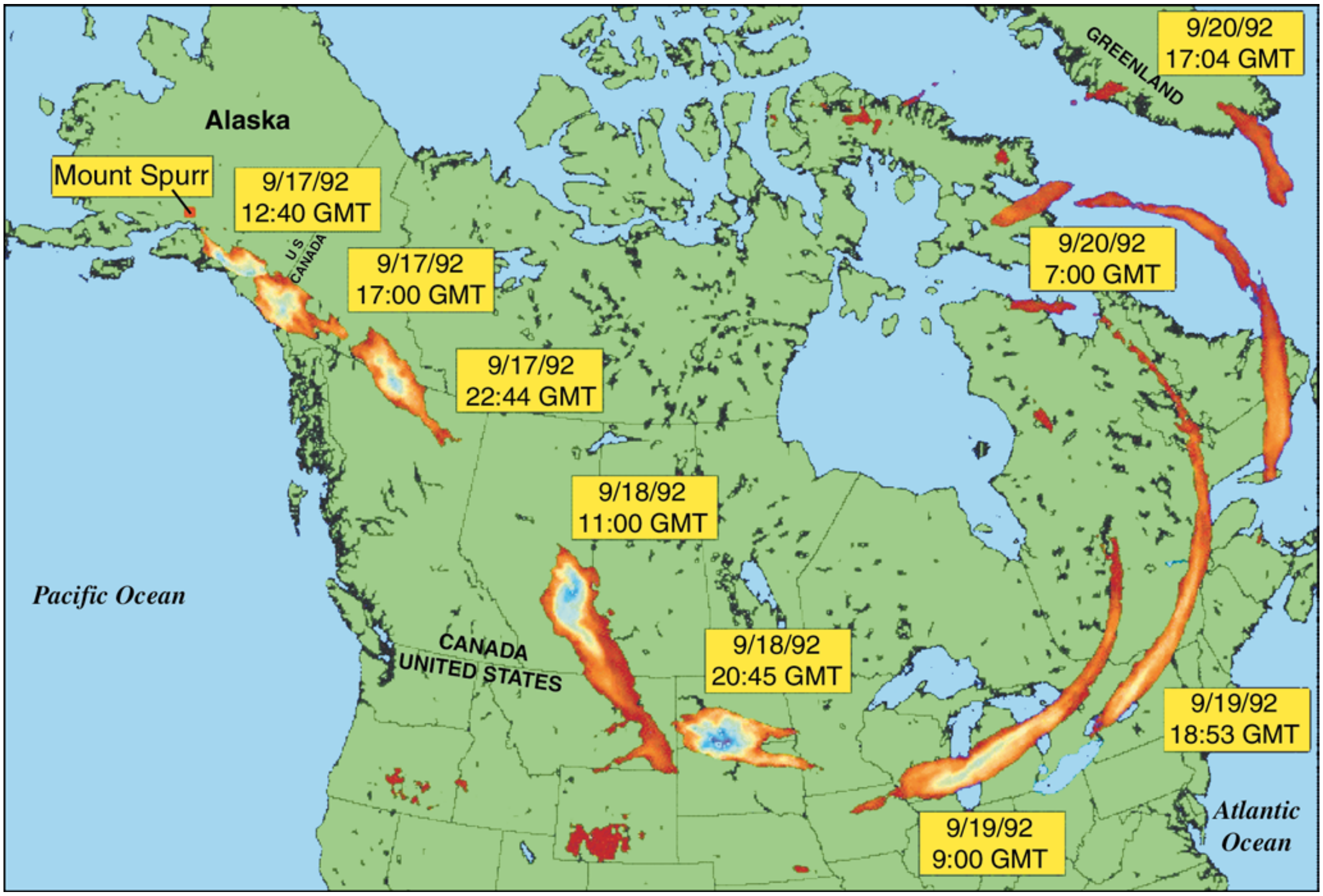


Figure 12. Satellite-derived positions of ash cloud produced during September 16–17, 1992, eruption of Crater Peak. Map is a composite of nine AVHRR (band 4 minus band 5) satellite images (modified from Schneider and others, 1995). Air traffic was disrupted in Canada and upper midwestern United States as plume drifted eastward. Stippled pattern indicates areas where pilots reported sightings of ash cloud (modified from Casadevall and Krohn, 1995). GMT, Greenwich Mean Time.

Lahars, Lahar-Runout Flows, and Floods

Most of the volcanoes in Alaska support glaciers or are snow covered most of the year. During typical eruptions, hot pyroclastic debris expelled from the volcano interacts dynamically with the snowpack or glacier cover causing rapid, extensive melting and water production. As meltwater mixes with available unconsolidated volcanic debris, various types of flowage phenomena may occur on the volcano flanks and in stream channels and drainages downstream from the volcano. Most of these phenomena are categorized as debris flows (fig. 7) or more specifically as noncohesive (clay-poor) lahars. Lahars consist of a poorly sorted mixture of boulders, sand, silt, and water that has the consistency of wet concrete. As these lahars flow downstream, they typically transform into finer grained, watery flows, called hyperconcentrated flows or lahar-runout flows. If enough sediment is lost from a lahar during flowage, the lahar may transform into a normal streamflow or flood and consist mostly of water.

Lahars also may form directly from water-saturated, clay-rich volcanic-rock avalanches (Hoblitt and others, 1995; Vallance and Scott, 1997; Vallance, 1999). Such lahars are called *cohesive* (clay-rich) lahars because the matrix sediment of typical deposits contains more than about 3 percent clay. Lahars of this type have not been found at Mount Spurr volcano.

Noncohesive lahar deposits of Holocene and Pleistocene age have been identified in the Chakachatna River valley and immediately south of Capps

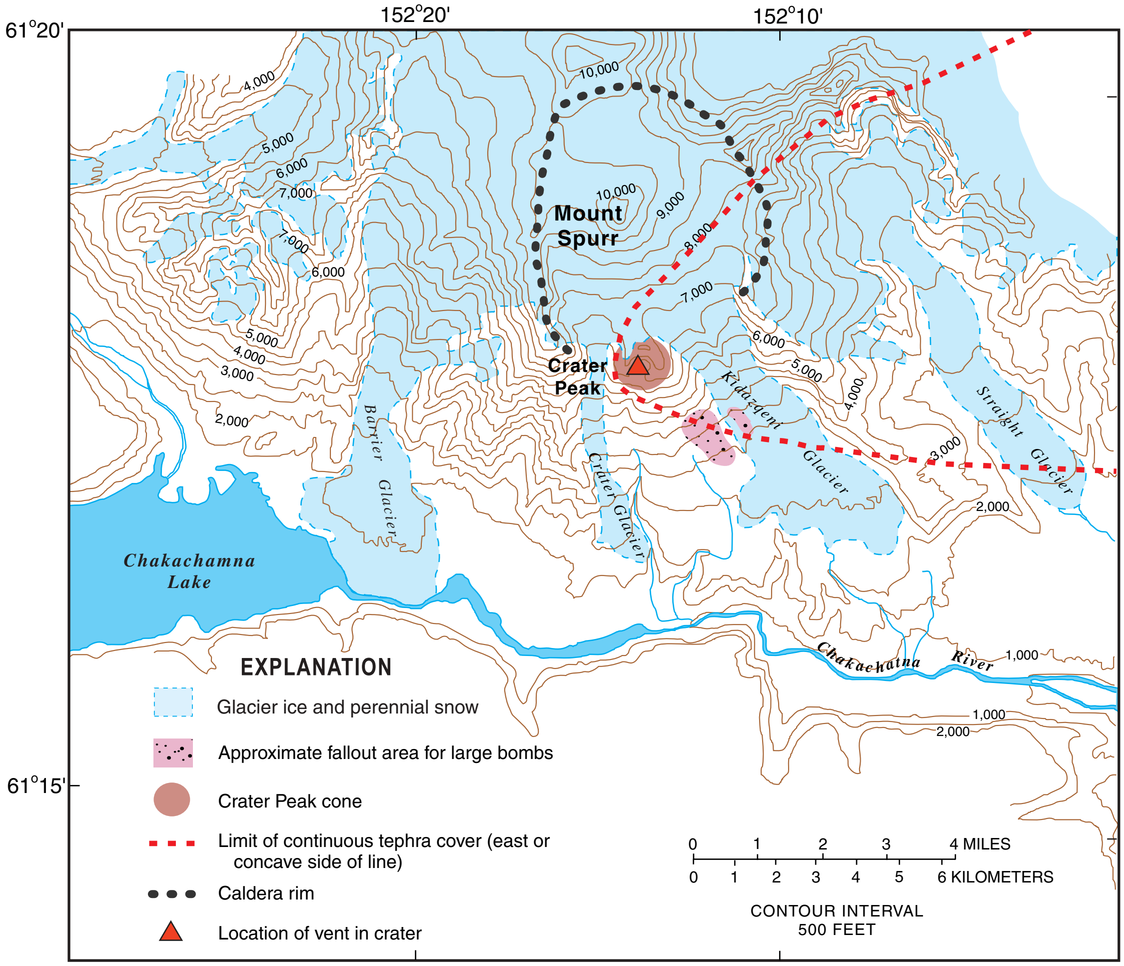
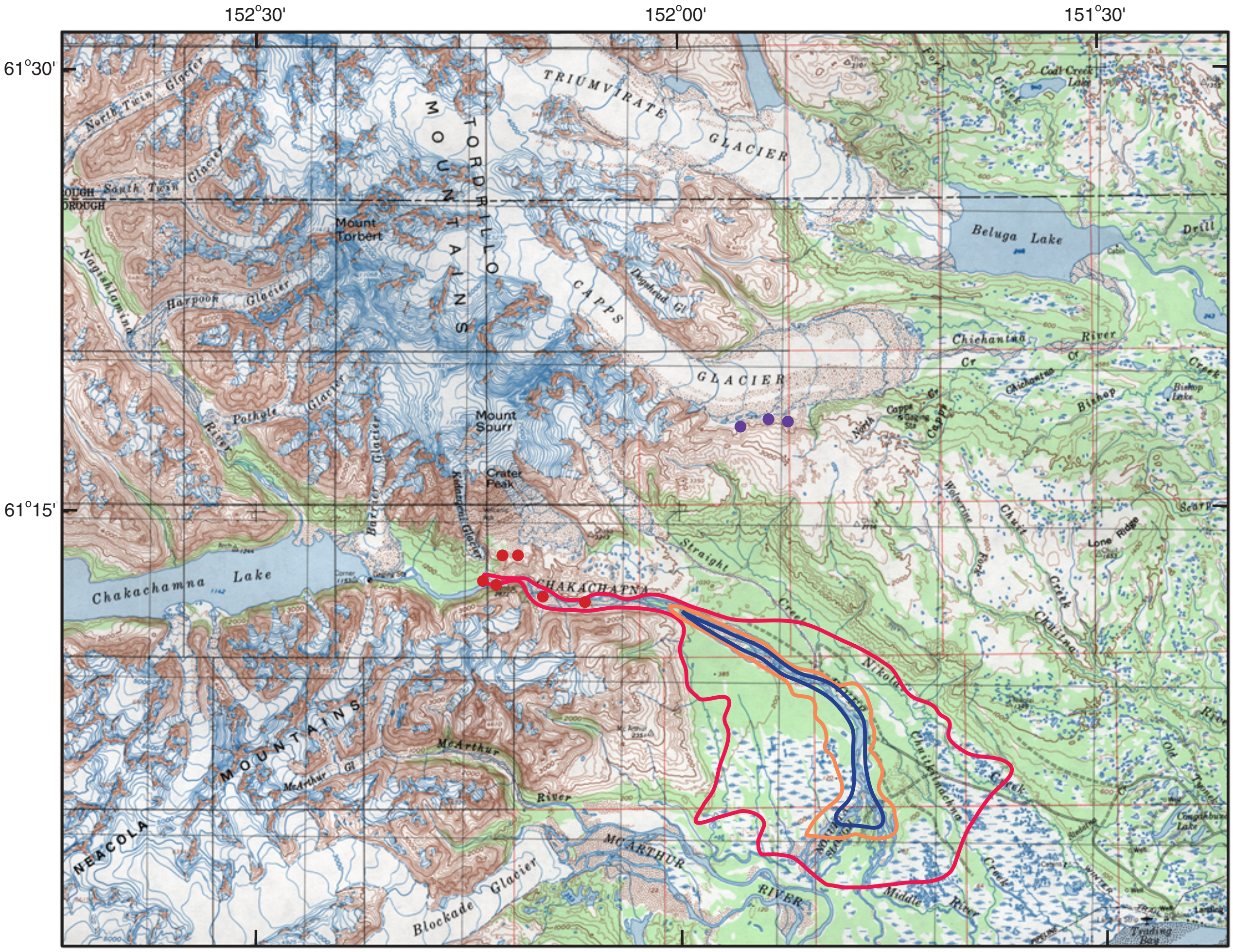


Figure 13. Areas of ballistic fallout and continuous tephra cover from August 18, 1992, eruption of Crater Peak (modified from Waitt and others, 1995).

Glacier (fig. 14), and several lahars entered and blocked the Chakachatna River during the 1953 and 1992 eruptions of Crater Peak (Juhle and Coulter, 1955; Meyer and Trabant, 1995). Previously unrecognized lahar deposits on the south flank of Crater Peak indicate that three or four noncohesive lahars have formed in the 2,000 years prior to the 1953 eruption and most likely were initiated by eruptions similar to those in 1953 and 1992.

Holocene eruptions of Crater Peak produced lahars that flowed into the Chakachatna River valley and formed temporary debris dams across the Chakachatna River (fig. 15). Lakes formed upstream from the lahar dams and eventually the lahar dams failed causing flooding of the Chakachatna River valley farther downstream. The formation and failure of volcanic debris dams on the Chakachatna River probably has happened during most if not all eruptions of Crater Peak. None of the lahars that blocked the Chakachatna River were particularly voluminous and they did not form large lakes. However, the topography of the Chakachatna River valley in the area south of Crater Peak is steep and narrow, and if more voluminous lahars are generated during future eruptions, they could easily block the river and substantially larger lakes could form upstream. Larger lakes would extend upstream to Barrier Glacier, a small valley glacier that terminates at the Chakachatna River and forms the eastern end of Chakachamna Lake (fig. 4). If the water depth of a lahar-dammed lake in contact with Barrier Glacier approaches or exceeds the ice thickness of the glacier terminus, the ice dam may become unstable and fail leading to a large and possibly catastrophic flood of lake water down the Chakachatna Valley.



Base from U.S. Geological Survey, 1:250,000
Tyonek, 1958
Universal Transverse Mercator projection

Contour interval variable, 100 and 200 feet

EXPLANATION

Boundaries of lahar-hazard zones:

—	L1—Area that would be inundated by lahars exiting proximal hazard zone and having initial volumes of about 100,000 cubic meters. These flows are equivalent to those generated by 1992 eruption of Crater Peak
—	L2—Area that would be inundated by lahars exiting proximal hazard zone and having initial volumes of about 1,000,000 cubic meters
—	L3—Area that would be inundated by lahars exiting proximal hazard zone and having initial volumes of about 10,000,000 cubic meters

Lahar deposits:

● Known to be associated with Crater Peak vent

● Known to be associated with Mount Spurr volcano

Figure 14. Distribution of lahar deposits known to be associated with Crater Peak vent and Mount Spurr volcano and extent of lahar-hazard zones.

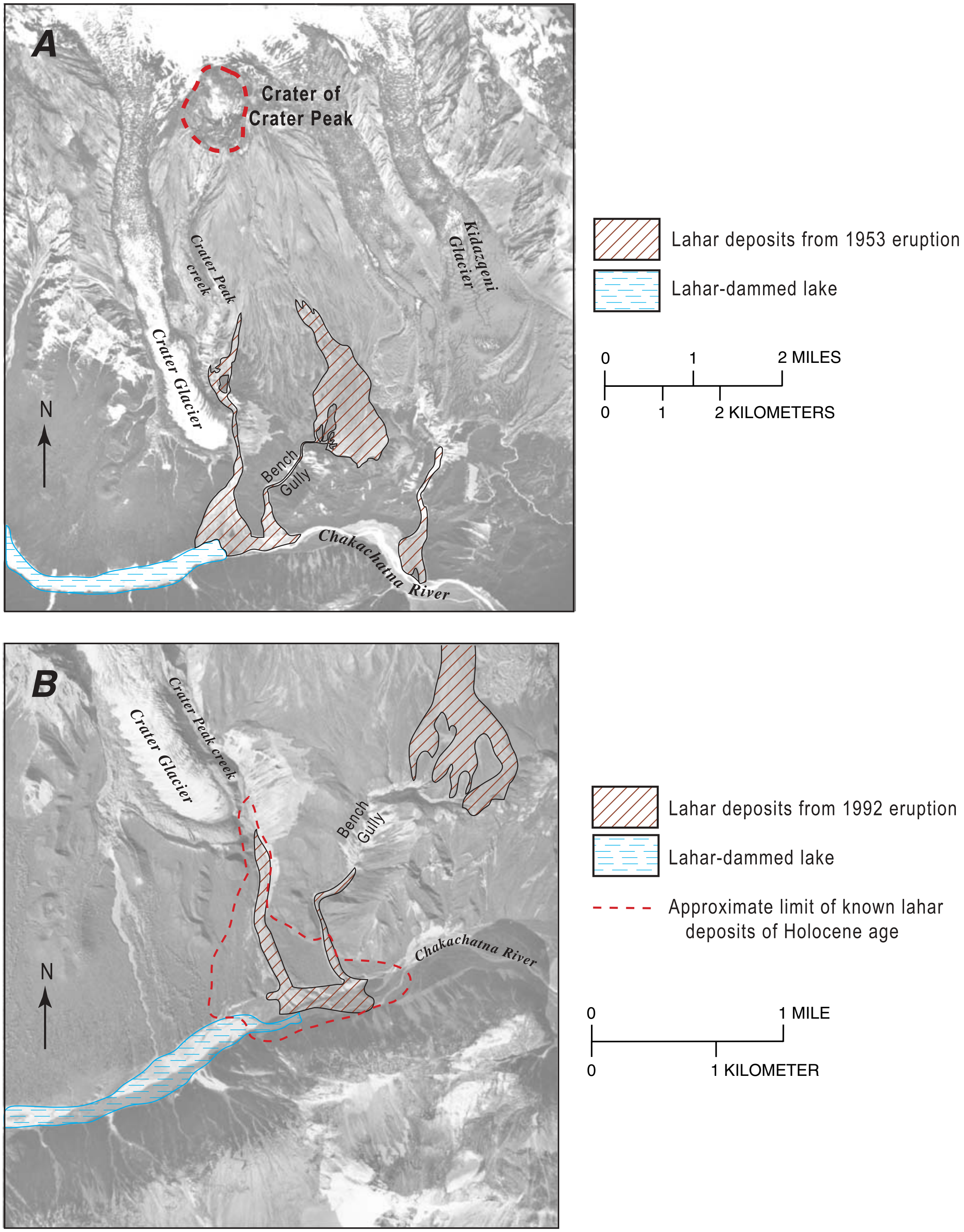


Figure 15. Lahar deposits on south flank of Crater Peak, lahar dams along Chakachatna River, and parts of lahar-dammed lakes (near Crater Peak and Mount Spurr volcano) associated with 1953 (*A*) and 1992 (*B*) Crater Peak eruptions. Vertical aerial photographs taken in August 1954 (source unknown) and in September 1992 (by Aeromap, Inc.), respectively.

The combined volume of Chakachamna Lake and a lahar-dammed lake big enough to overtop Barrier Glacier is about 1 billion cubic meters and a flood with this volume would inundate significant parts of the Chakachatna River valley (fig. 16) and probably reach Cook Inlet about 60 kilometers downstream.

Typical lake volumes for lahar-dammed lakes in the upper Chakachatna Valley are about 10 million to 100 million cubic meters. Lakes of this size could produce maximum flood discharges in the range of 9,000 to 135,000 cubic meters per second where they exit the lahar dam. Floods of this size would be hazardous to areas of the Chakachatna River valley for at least 5 to 10 kilometers downstream of the lahar dam (fig.16).

The lahars generated by historical eruptions of Crater Peak were several meters deep and carried rock, sediment debris, and boulders (some of which were 5 to 10 meters in diameter) several kilometers downstream (fig. 17). The lahars transformed to sediment-laden water floods by the time they reached the middle part of the Chakachatna River valley about 20 kilometers downstream from the lahar dam (fig. 17). It would take about 30 minutes for the lahars (greater than 10 million cubic meters in volume) to travel this far.

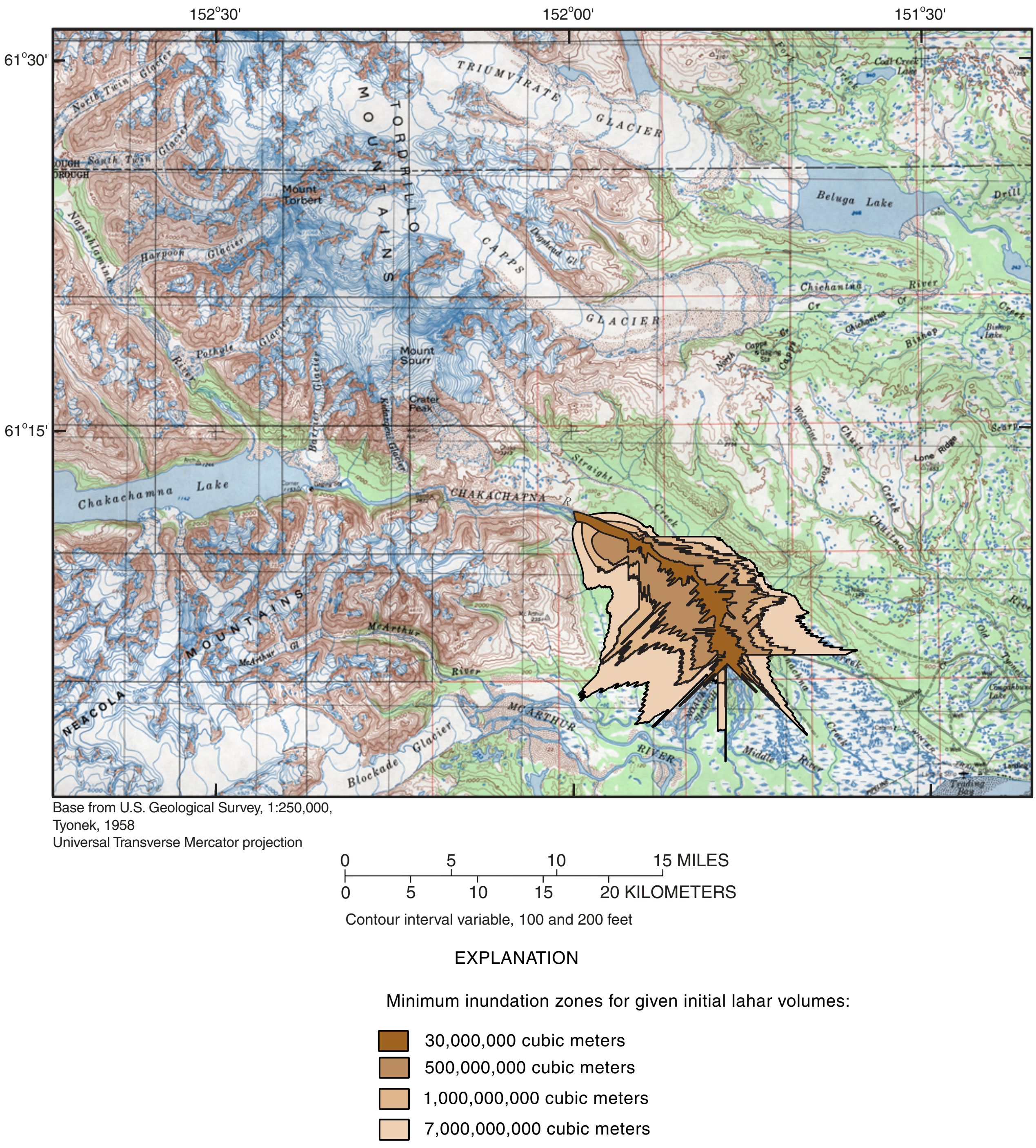
Other lahar deposits that originated on the east flank of Mount Spurr volcano are preserved east of the volcano along the south side of Capps Glacier (fig. 14). These deposits consist of poorly sorted gravelly deposits with cobble- and boulder-size clasts of grey andesite and probably record several pyroclastic lahar-forming eruptions of Mount Spurr volcano. The age of these deposits is not known, but they are overlain by glacial deposits formed during the last major ice age of the *Pleistocene Epoch* that began about 20,000 years ago and therefore must be at least this old.

Hazard zones for lahars, lahar-runout flows, and floods generated by eruptions from the Crater Peak vent are shown on figure 14 and on plate 1. Three hazard zones (L1, L2, and L3) that depict differing degrees of hazard are indicated. Hazard zone L1 indicates areas that are likely to be inundated by lahars, lahar-runout flows, and floods that exit the proximal hazard zone with volumes as large as the lahars generated by the 1992 eruption of Crater Peak (about 100,000 cubic meters). Lahars of this size probably occur during most eruptions. Hazard zone L2 includes areas that are susceptible to inundation by lahars, lahar-runout flows, and floods but is less likely to be affected than hazard zone L1 during most eruptions from the Crater Peak vent. Lahar volumes would exceed those of the 1992 lahars and could be as large as 1 million cubic meters where they exit the proximal hazard zone (fig. 14). Hazard zone L3 includes areas that could be affected by lahars, lahar-runout flows, and floods only during large, sustained eruptions, and lahar volumes greater than 10 million cubic meters could be generated (fig. 14).

Because lahars, lahar-runout flows, and floods can move rapidly, can be several meters deep, and can transport boulder- and block-size particles, they would be hazardous to life and property in the flow path. The distribution and age of lahar deposits indicate that future developments in the most of the Chakachatna River valley could be at risk from lahars, lahar-runout flows, and floods. At present however, lahars pose only a limited hazard in this area because the Chakachatna River valley is only seasonally occupied by few people and no permanent structures or facilities are present.

Debris Avalanches

Volcanic rock or debris avalanches (fig. 7) typically form by structural collapse of the upper part of the volcano. The ensuing avalanche moves rapidly down the volcano flank and forms a bouldery unsorted gravel deposit many kilometers from the source that may exhibit a characteristic hummocky surface and broad areal extent. Most debris-avalanche deposits are traceable up the slopes of the volcano to an arcuate- or horseshoe-shaped scar at or near the volcano summit that marks the zone of collapse and origin of the avalanche (figs. 2 and 4). Most large debris avalanches (greater than 1 cubic kilometer) occur during eruptions (Siebert, 1996). However, it is possible for large-scale collapse of a volcanic cone to occur during a distinctly noneruptive period, sometimes as a result of long-term chemical alteration of volcanic rock in the *edifice* by hot, acidic ground water.



Base from U.S. Geological Survey, 1:250,000,
Tyonek, 1958
Universal Transverse Mercator projection

0 5 10 15 MILES
0 5 10 15 20 KILOMETERS

Contour interval variable, 100 and 200 feet

EXPLANATION

Minimum inundation zones for given initial lahar volumes:

- ▇ 30,000,000 cubic meters
- ▇ 500,000,000 cubic meters
- ▇ 1,000,000,000 cubic meters
- ▇ 7,000,000,000 cubic meters

Figure 16. Extent of flooding associated with failure of lahar dams in Chakachatna River valley. Inundated areas were estimated by method of Iverson and others' (1998). Floods were assumed to transform to debris flows as they moved downstream. Areas indicated are minimum inundation zones for given initial lahar volumes, which equal maximum estimated lake volumes impounded by volcanic-debris dams.

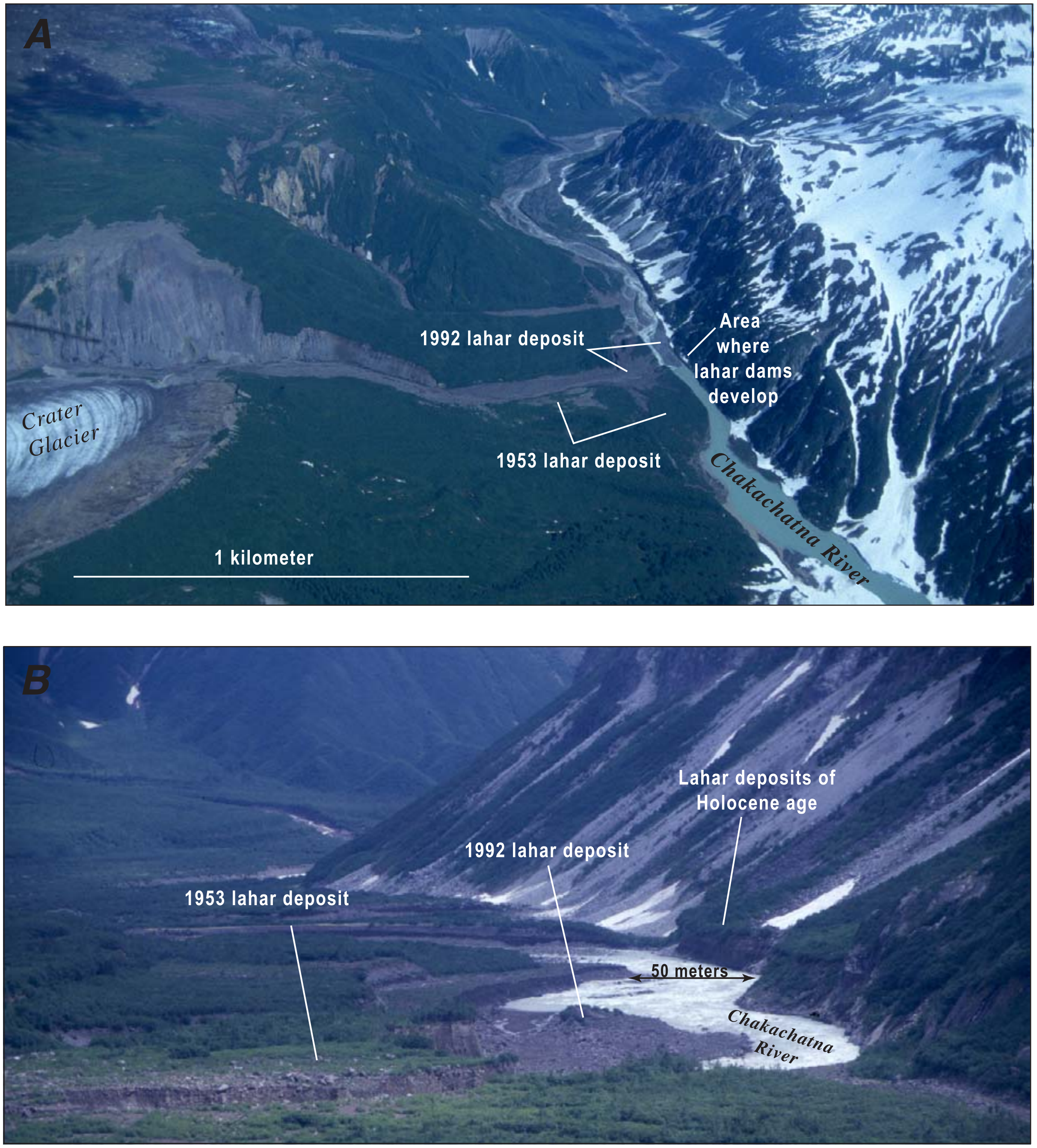


Figure 17. Chakachatna River valley showing lahar deposits from 1953 and 1992 Crater Peak eruptions. Views are toward east. Oblique aerial photographs by author C.F. Waythomas, August 1994. *A*, Mouth of Crater Peak creek, where lahars from 1953 and 1992 eruptions have built lahar fans that have displaced Chakachatna River southward. *B*, Lahar deposits along Chakachatna River.

Only one debris-avalanche deposit is known at Mount Spurr volcano, and it apparently represents a major collapse of the volcanic edifice during the caldera-forming eruption of the volcano. The debris-avalanche deposit consists of angular unsorted gravel, boulders, and blocks of altered volcanic rock (fig. 18). The surface of the deposit is uneven and irregular and is characterized by an assemblage of closely spaced mounds and low hills called hummocks (figs. 18*A* and 19). As the south flank of Mount Spurr volcano became destabilized, probably because *magma* was rising upward into the edifice, it slumped away from

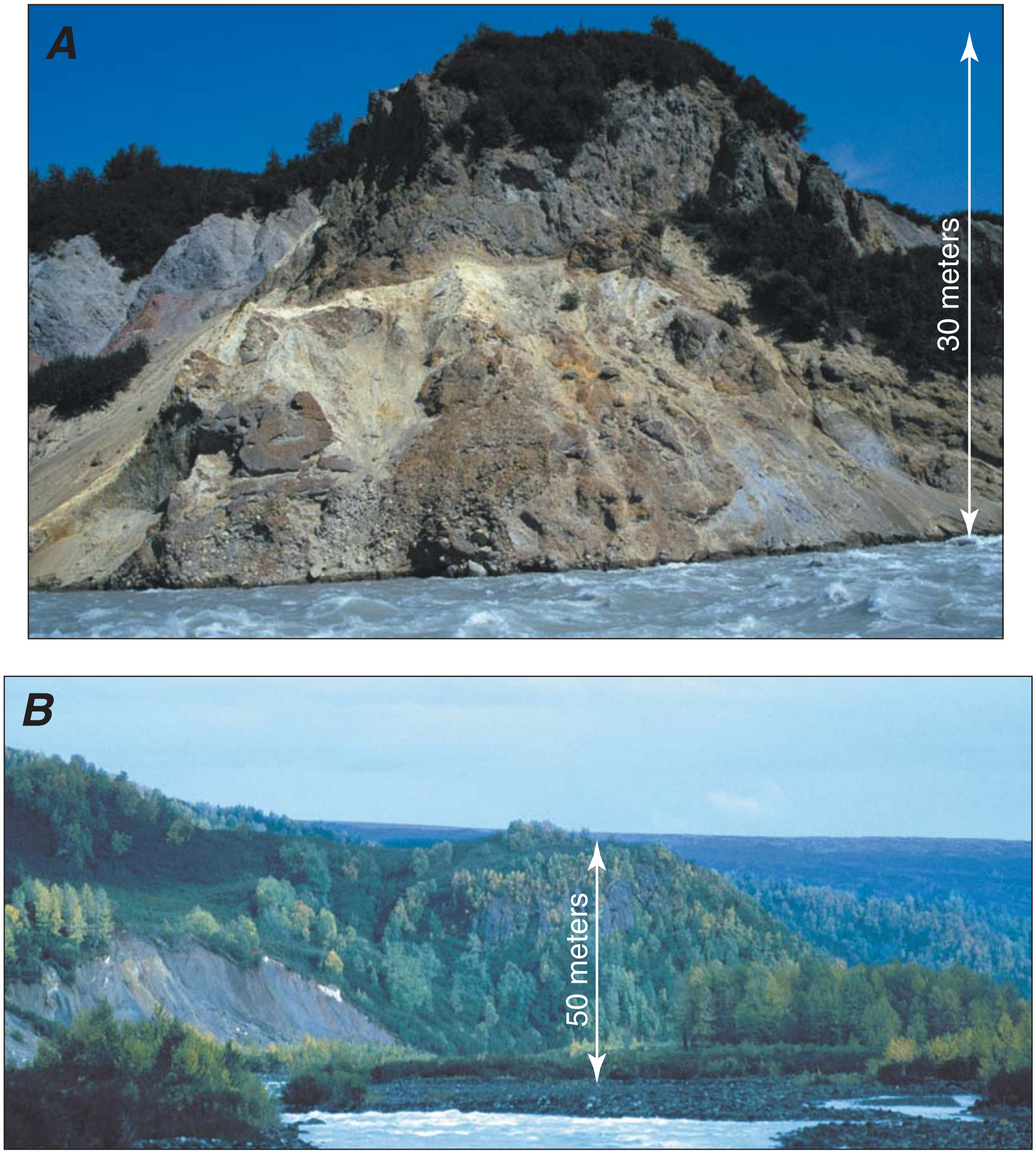


Figure 18. Debris-avalanche deposits exposed along Chakachatna River. *A*, Block-cored hummock, about 30 meters high. View is toward north. Photograph by author C.F. Waythomas, July 1998. *B*, Large block of altered andesite, about 50 meters high, along Chakachatna River. View is toward east. Photograph by author C.F. Waythomas, August 1999.

the volcano summit and flowed into the Chakachatna River valley as a large volcanic landslide (fig. 20). The debris-avalanche deposit travelled about 20 kilometers and blocked the Chakachatna River. Although not well documented, an extensive lake probably formed upstream from the avalanche deposit, and failure of the debris dam may have initiated a large flood on the Chakachatna River similar to those shown in figure 16.

Hazard zonation for debris avalanche at Mount Spurr volcano (fig. 21) and the maximum likely runout distance of a future debris avalanche was estimated by using the ratio of the fall height (*H*) to runout distance (*L*) of known avalanche deposits (fig. 22). The *H*/*L* ratio for the only known debris-avalanche deposit at Mount Spurr volcano is 0.17 (obtained using the summit altitude of Mount Spurr as *H*, and the distance from Mount Spurr to the distal end of the debris-

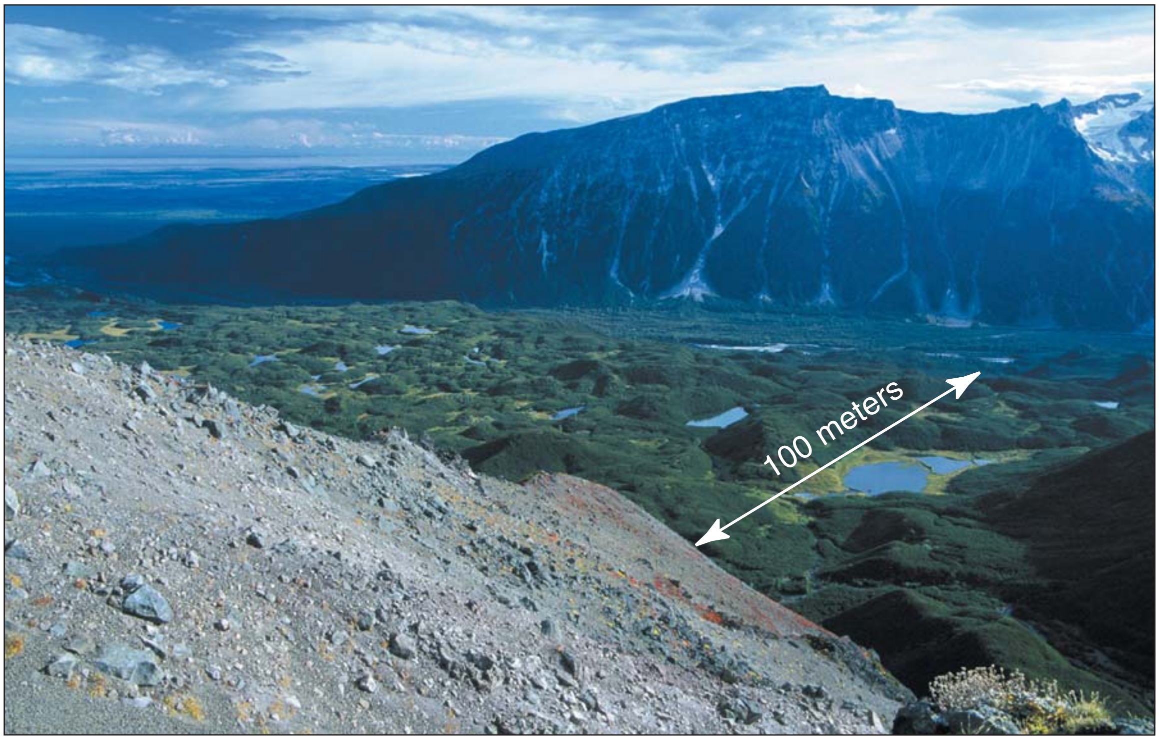


Figure 19. Hummocky surface of debris-avalanche deposit along north side of Chakachatna River. View is toward south. Photograph by author C.F. Waythomas, July 1998.

avalanche deposit as *L*) and the estimated volume of this deposit is 4,600,000,000 cubic meters. Hazard boundaries were estimated by using *H*/*L* values of 0.1 and 0.2, which give the approximate runout of moderate to large debris avalanches. Future debris avalanches this size are unlikely given the present location of the active vent at Crater Peak, which is a relatively small volume eruptive center. The cone-shaped edifice of Crater Peak is not obviously unstable, and alteration of the rocks exposed in the crater is not extensive. A major collapse of the cone is unlikely unless a very large amount of magma began rising through the crust toward the surface beneath the cone or beneath Mount Spurr. Thus, the hazard from debris avalanche is minor unless conditions at the volcano change significantly, and that is not expected.

Pyroclastic Flows and Surges

A pyroclastic flow is a hot, dry mixture of volcanic-rock debris and gas that flows rapidly downslope (fig. 7). A *pyroclastic surge* is similar to and often occurs with a pyroclastic flow but has a higher gas content. Because it is mostly gas, a pyroclastic surge moves more rapidly than a pyroclastic flow and may not be confined by topography, and therefore may climb up and over ridges. Pyroclastic flows are relatively dense and generally follow topographically low areas such as stream valleys. Any of the major drainages that head on Crater Peak could be engulfed by pyroclastic flows even during modest eruptions. Because they are hot (several hundred degrees Celsius) and fast moving, both pyroclastic flows and surges could be lethal to anyone on the flanks of Crater Peak during an eruption.

Pyroclastic flows generated by the 1992 eruptions of Crater Peak flowed only a few kilometers down the southeast flank of the volcano (fig. 23). These flows were produced in part by collapse of the dense, near-vent part of the inclined eruption column and in part by flows of still-hot pumiceous ejecta avalanching from the crater rim (fig. 24; Miller and others, 1995). Unlike most pyroclastic flows from more explosive eruptions, the 1992 Crater Peak flows were slow moving, incandescent, clast-rich flows of mostly dense, bread-crusted *pumice* (fig. 25) that were emplaced high on the crater rim and flanks instead of through the area of lowest topography (Miller and

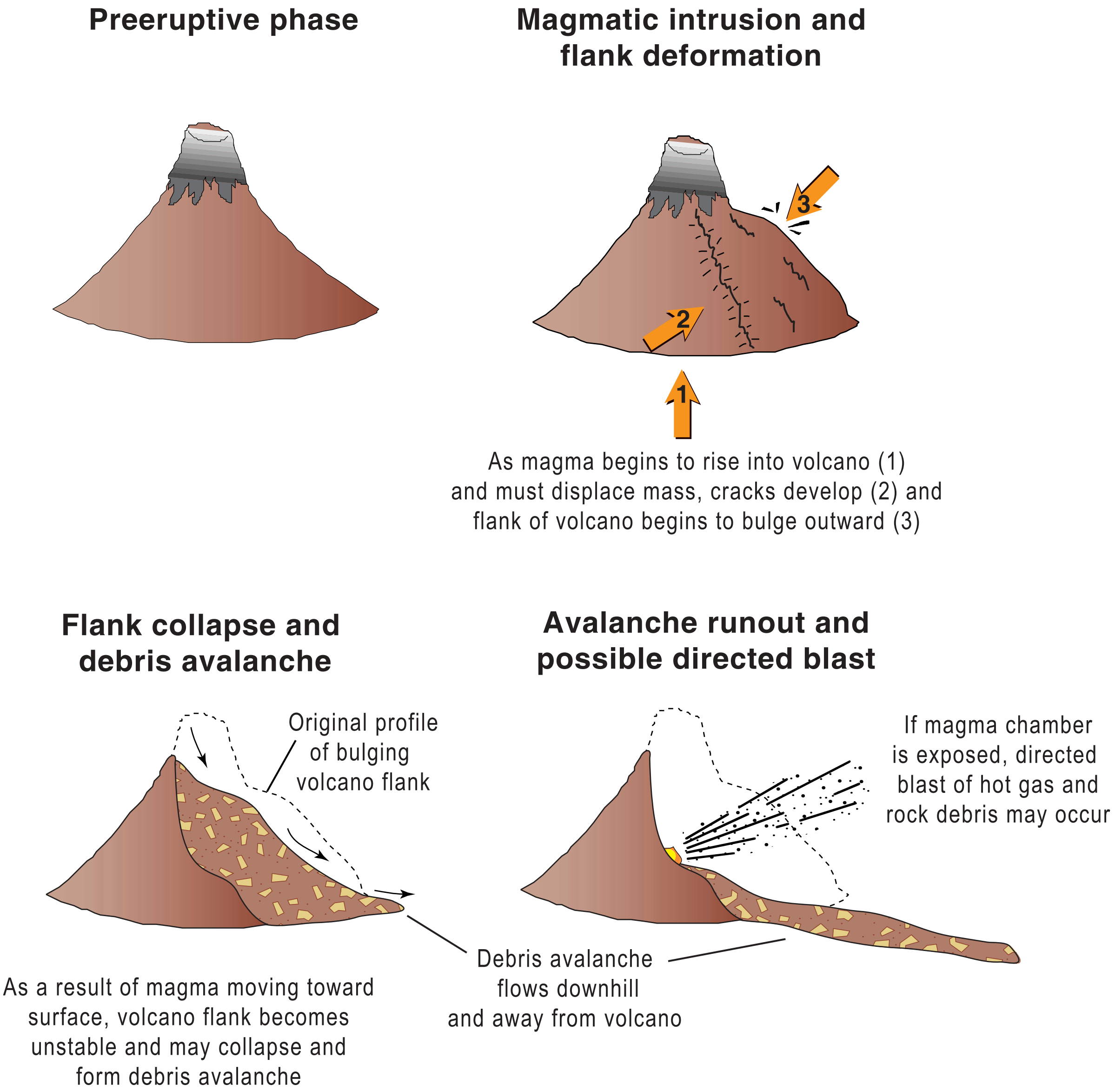
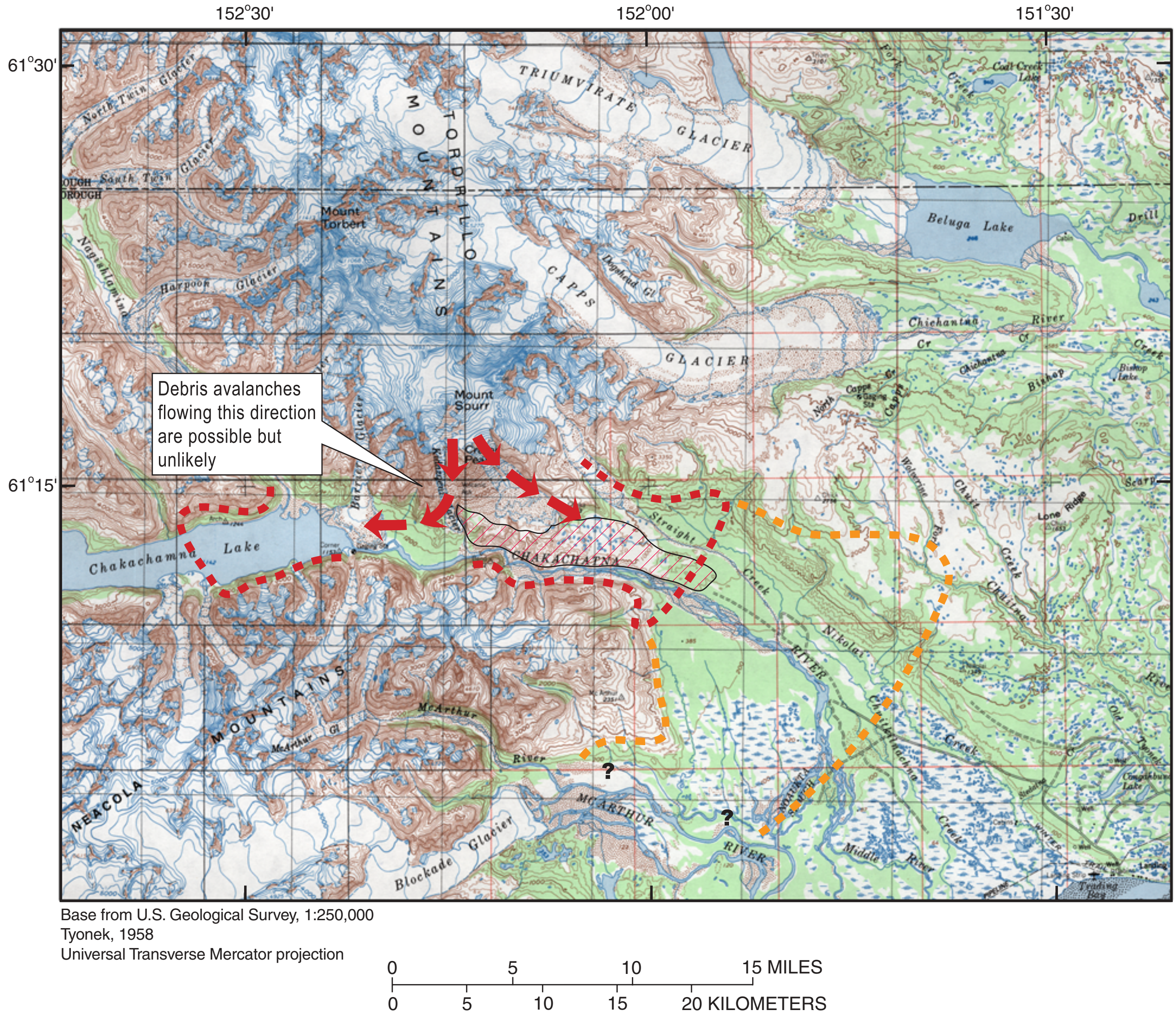


Figure 20. Simplified evolution of debris avalanche at Mount Spurr volcano.

others, 1995). This indicates that the orientation of the vent, which can change from eruption to eruption, is significant in controlling the emplacement direction of pyroclastic flows of this type and that all sides of the cone could be at risk from pyroclastic flows despite the presence or absence of controlling topography.

During explosive Plinian-style eruptions, characterized by high vertical eruption columns, the eruption column would collapse and fall back toward the volcano forming a fast-moving pyroclastic flow. Pyroclastic-flow deposits of this type have a greater areal extent. They can sweep all sides of the volcano and are more likely to be directed by topographically low areas like river valleys. Pyroclastic-flow deposits of Holocene age found along the Chakachatna River (fig. 23) may have been formed by this process.

Pyroclastic flows and surges from most eruptions would be expected to reach at least several kilometers beyond the vent and could travel in almost any direction but are most likely to flow southeastward from the vent (fig. 23). The runout distance of pyroclastic flows is estimated to have typical *H*/*L* values of 0.2 and 0.3, and these values yield runout distances of 11 to 17 kilometers. These values are most relevant to pyroclastic flows generated by a lava-dome collapse or column collapse of low-angle eruption columns similar to



Debris avalanches flowing this direction are possible but unlikely

Base from U.S. Geological Survey, 1:250,000
Tyonek, 1958
Universal Transverse Mercator projection

Contour interval variable, 100 and 200 feet

EXPLANATION

▨ Extent of debris-avalanche deposit from Mount Spurr volcano. This deposit has estimated volume of about 4,600,000,000 cubic meters

■ ■ ■ ■ Boundary of debris-avalanche hazard zone for *H*/*L* = 0.2. Possible runout extent of debris avalanche from major flank collapse. Initial volumes of debris avalanche could range from about 100,000,000 to about 12,000,000,000 cubic meters

■ ■ ■ ■ Boundary of debris-avalanche hazard zone for *H*/*L* = 0.1. Possible runout extent of debris avalanche from major flank collapse. Initial volumes of debris avalanche could range from about 1,000,000 to about 12,000,000,000 cubic meters

➘ ➘ ➞ Likely flow path of debris avalanche from Mount Spurr for present location of active vent

Figure 21. Debris-avalanche hazard zones. Likely flow paths for future debris avalanches are for eruptions and activity at Crater Peak. Although unlikely, if magma is intruded beneath other sectors of volcano, flank collapse and debris avalanche could occur on other flanks of volcano. *H*, debris-avalanche fall height; *L*, debris-avalanche runout length.

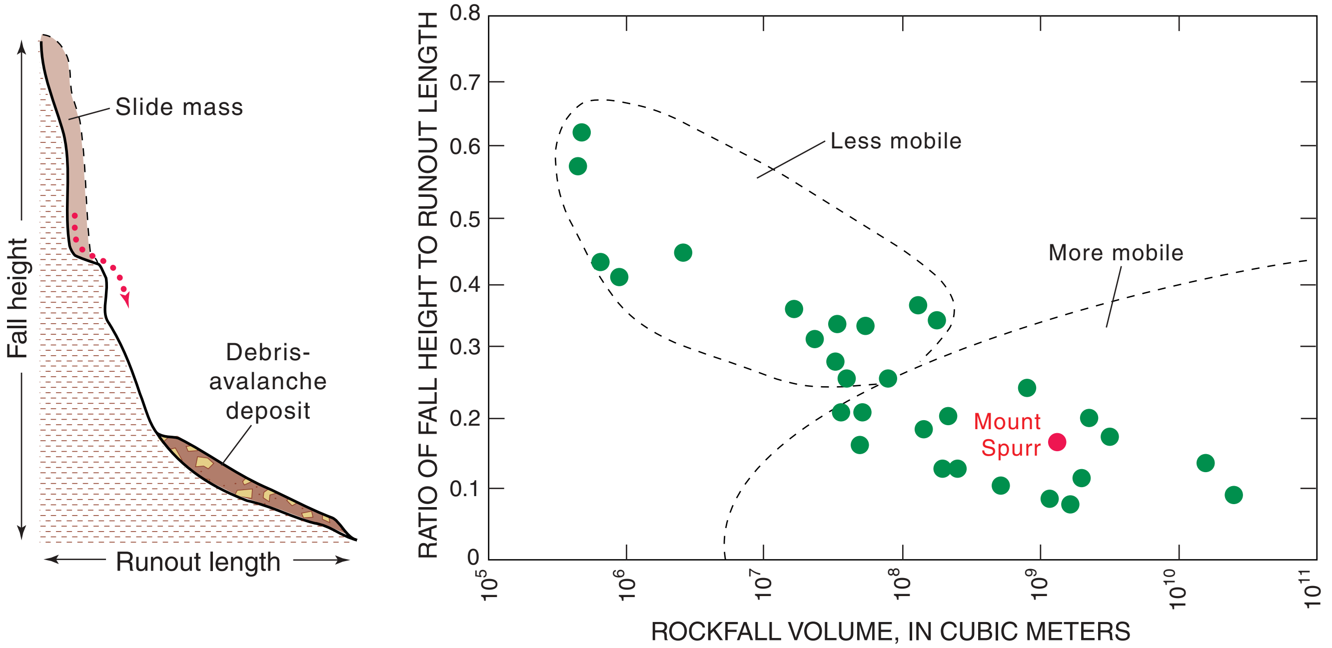


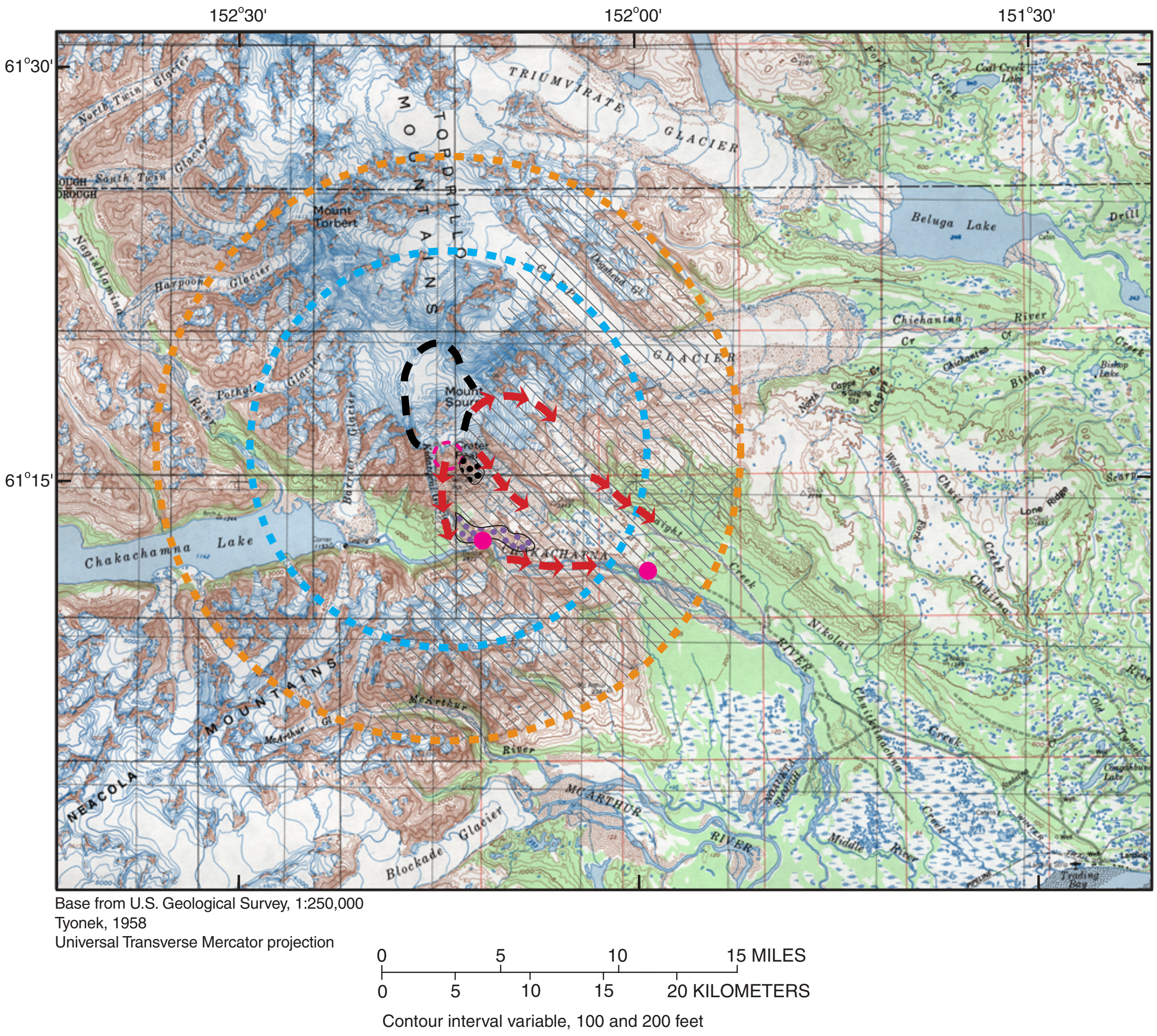
Figure 22. Relations among debris-avalanche fall height, runout length, and rockfall volume.

those associated with the 1992 Crater Peak eruption. During a very large (and therefore rare) eruption, pyroclastic flows could reach as far as 75 to 100 kilometers from the volcano, but this is unlikely, and evidence for far-traveled pyroclastic flows from Mount Spurr volcano has not been found.

To predict accurately the extent of a pyroclastic surge is difficult. However, because of their genetic relation to pyroclastic flows, they have a greater lateral extent. The location of the hazard boundary is uncertain and is not shown in figure 23 or on plate 1. The boundary is approximated conservatively by the hazard boundary for pyroclastic flow, although we expect a pyroclastic surge to extend beyond this boundary, perhaps by at least several kilometers. Pyroclastic surges are hot (300 to 800°C) and gaseous, and death or injury from asphyxiation and burning is likely. Because the surge cloud may travel very fast (at least tens of meters per second), detach itself from the pyroclastic flow, and surmount topographic barriers, evacuation of the area near the volcano prior to the eruption is the only way to eliminate risk from pyroclastic surges.

Directed Blasts

A directed blast is a large-scale lateral volcanic explosion caused by a major landslide or slope failure that uncaps the internal vent system of the volcano. Such an event is rare in the history of a volcano. Although geologic evidence indicates that at least one major slope failure did occur at Mount Spurr volcano, evidence for a directed blast has not been discovered. The hazard-zone boundary showing the area most likely to be affected by a directed blast (fig. 26) is based on data from the 1980 eruption of Mount St. Helens. The directed blast associated with that eruption is one of the largest known historical events and thus is assumed to be a “worst case” example. If a directed blast were to occur from Crater Peak, it could affect a broad area, possibly a 180° sector from the vent. A directed blast usually happens in the first few minutes of an eruption and thus there is no time for warning or evacuation once the eruption is imminent. Living things in the path of a directed blast would be killed or destroyed by impact, burning, abrasion, burial, and heat.



Base from U.S. Geological Survey, 1:250,000
Tyonek, 1958
Universal Transverse Mercator projection

Contour interval variable, 100 and 200 feet

EXPLANATION

- ⁘ Approximate extent of pyroclastic-flow deposits from 1992 eruption of Crater Peak
- ⁘ Approximate extent of block-and-ash-flow deposits from ancestral Mount Spurr
- ▨ Area most likely to be affected by pyroclastic flows for present vent geometry
- ■ ■ ■ ■ Pyroclastic-flow-hazard zone for *H/L* = 0.2. Possible runout extent of pyroclastic flows for moderate to large eruptions of Crater Peak, where pyroclastic fows are generated by dome collapse
- ■ ■ ■ ■ Pyroclastic-flow-hazard zone for *H/L* = 0.3. Possible runout extent of pyroclastic flows for small to moderate eruptions of Crater Peak, where pyroclastic fows are generated by dome collapse
- ➜➜➜ Likely flow path of pyroclastic flows from Mount Spurr
- ‒ ‒ Mount Spurr caldera rim
- ◌ Crater Peak cone
- ● Pyroclastic-flow deposits of Holocene(?) age

Volcanic Gases

Gases are emitted by most active volcanoes, because magma contains dissolved gases and boils off shallow ground water that is typically present within volcanoes. The most common volcanic gases are water vapor, carbon dioxide, carbon monoxide, sulfur dioxide, and hydrogen sulfide. Volcanic sulfur and halide gases that encounter water can form large amounts of sulfuric acid and minor amounts of hydrochloric acid and hydrofluoric acid as aerosols or droplets. Both carbon monoxide and carbon dioxide are colorless and odorless and thus impossible to detect without a measuring device. Carbon dioxide is heavier than air and may displace the available oxygen in confined spaces or low-lying areas and thus cause suffocation. In high concentrations, carbon dioxide, hydrogen sulfide, and sulfur dioxide may be harmful or toxic to humans and may damage vegetation downwind from the volcano. Acid precipitation may develop from the mixing of snow or rain with acidic volcanic aerosols, which may cause various types of skin and respiratory irritations and cause corrosive damage to materials. Because wind tends to disperse volcanic gas, it is typically not found near the ground in concentrations hazardous to humans or animals more than about 10 kilometers from the volcano. During large eruptions, significant volumes of gas can travel high in the atmosphere downwind from the volcano for days and thousands of kilometers.

The 1992 eruptions of Crater Peak generated measurable amounts of sulfur dioxide (200,000 to 400,000 tons for each of the three eruptions) and carbon dioxide (400 to 12,000 tons per day on days that measurements were made; Doukas and Gerlach, 1995). Sulfur dioxide gas was detected, measured, and tracked by satellite (Bluth and others, 1995), whereas carbon dioxide gas was measured by using an airborne measurement device (Doukas and Gerlach, 1995).

Figure 23. Pyroclastic-flow hazard zones and locations of known pyroclastic-flow deposits. *H*, pyroclastic-flow fall height; *L*, pyroclastic-flow runout length.

The hazard from volcanic gases at Mount Spurr volcano is unlikely to be greater than that posed by other volcanic phenomena. Emission of gases from the Crater Peak vent occurs occasionally and could be continuous. Because of the geometry of the crater, gases may become trapped if the air is calm. A plume, composed of water with small amounts of carbon dioxide and sulfur dioxide gas, is sometimes apparent (fig. 3). At times, the steam plume may be vigorous and has been mistaken for an eruption cloud. Volcanic gas may pose a health concern to someone near or in the crater on Crater Peak; however, frequent windy conditions usually inhibit localized buildup of volcanic gas. Therefore, the hazard from volcanic gases is minor.

Prior to the 1992 eruption, a lake was present in the crater on Crater Peak. The lake water was acidic (pH, about 2.5) and hot (about 50°C) when sampled in 1970 and just prior to the June, 1992, eruption (Keith and others, 1995). At present the crater does not contain a lake, and for a lake to develop in the future would not be unusual. Because Crater Peak is an active volcano, the temperature and pH of the lake water could reach hazardous levels in a short amount of time (days to weeks). Entering any size lake in the crater could be hazardous.

Lava Flows

Narrow streams of molten rock or lava may form during a future eruption of Crater Peak. Commonly, lava flows (fig. 7) develop after explosive activity at the volcano declines. Much of the Crater Peak cone is composed of bedded lava flows (fig. 4). Typical lava flows are andesitic in composition and are relatively viscous when molten. Future eruptions probably would generate lava flows similar to those preserved on the volcano. The lava flows are expected to move slowly downslope, probably not more than a few tens of meters per hour. Lava flows of this type pose little hazard to people who could walk away from them easily; however, lava flows from Crater Peak may develop steep fronts and could shed hot blocks and debris downslope. Lava flows that reach snow and ice could generate localized flooding and may initiate minor steam explosions.

Pyroclastic flows formed by near-vent column collapse

Pyroclastic flows formed by near-vent avalanching of pyroclastic debris

Pyroclastic flows formed by avalanching of lava dome

Figure 24. Development of pyroclastic flows at Crater Peak.

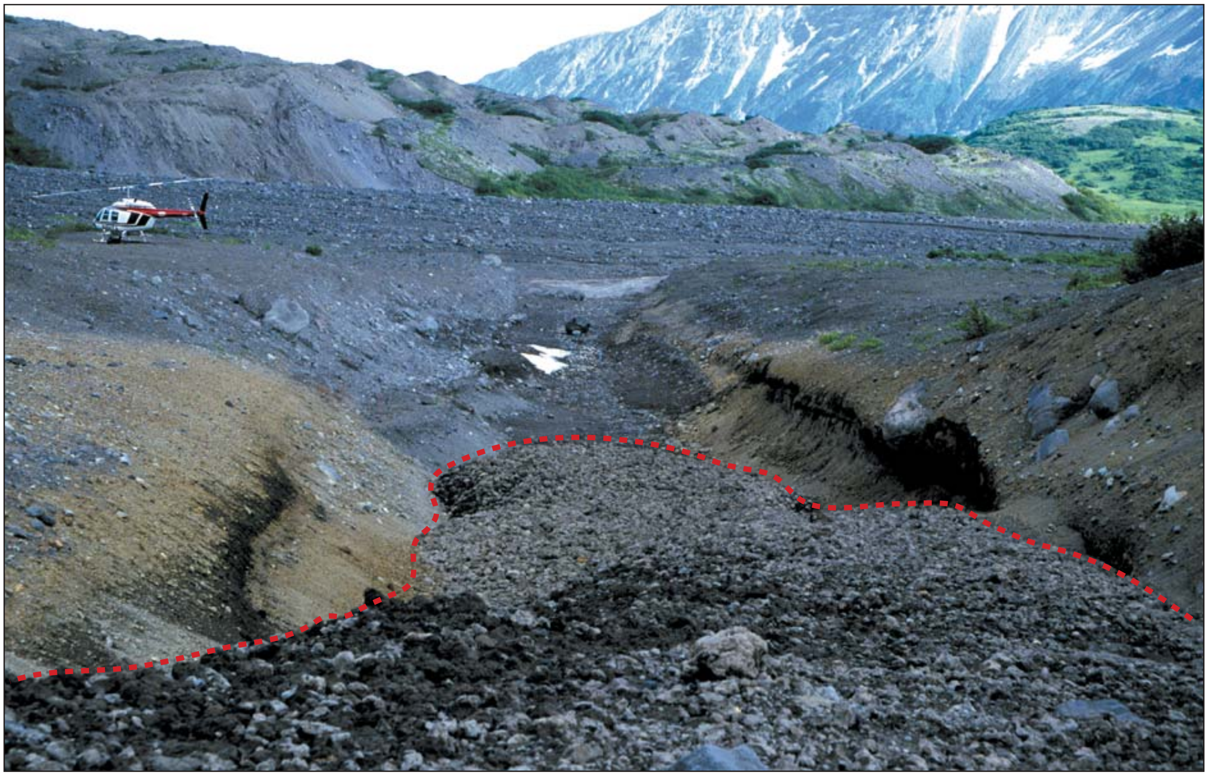
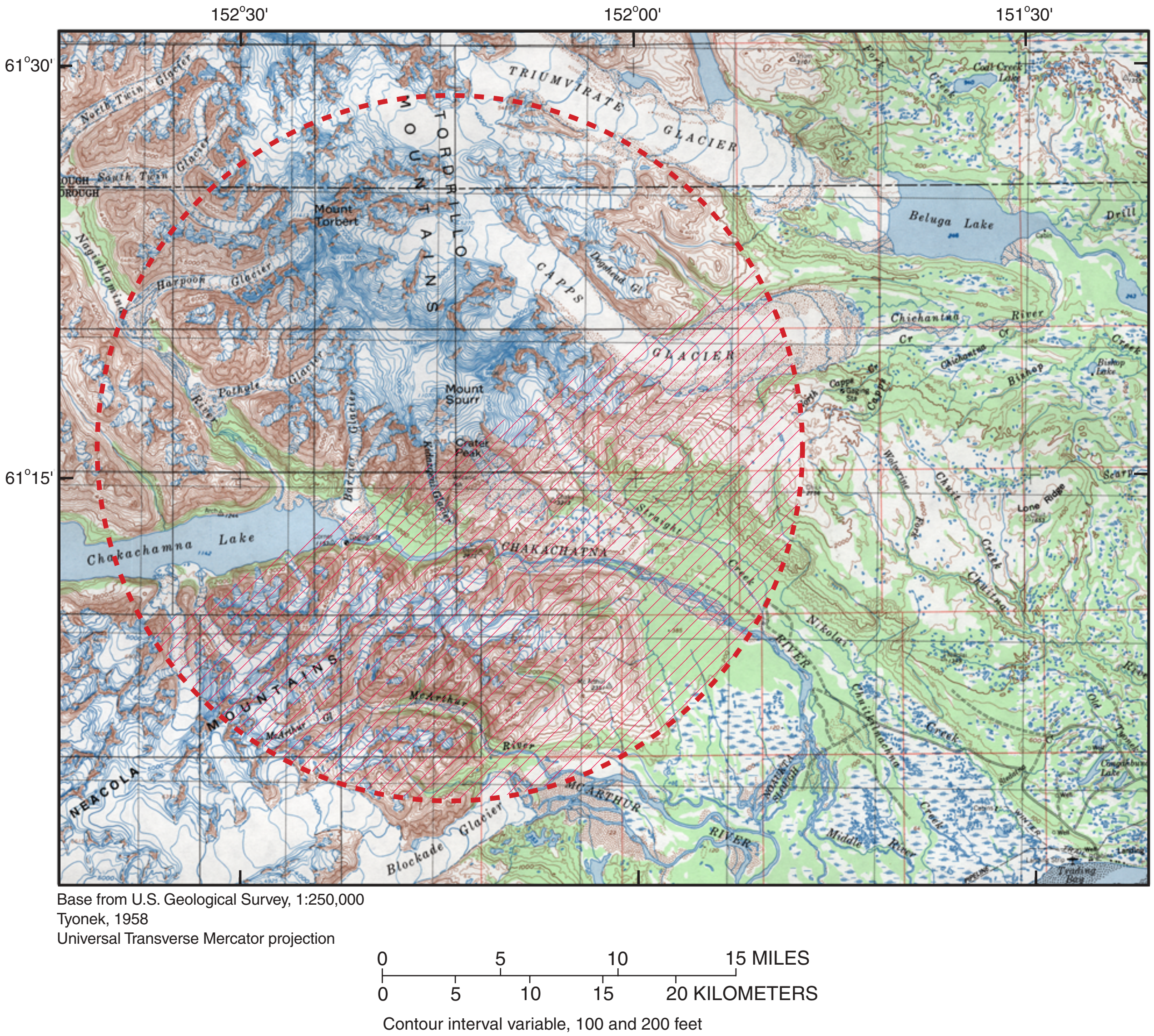


Figure 25. Pyroclastic-flow deposit from 1992 Crater Peak eruption. (Red dashed line marks terminus.) Pyroclastic flow that generated deposit traveled about 3 kilometers beyond rim of Crater Peak vent. View is toward south. Photograph by author C.F. Waythomas, August 1999.



Base from U.S. Geological Survey, 1:250,000
Tyonek, 1958
Universal Transverse Mercator projection

Contour interval variable, 100 and 200 feet

EXPLANATION

▨ Area most likely to be affected by directed blast similar to blast generated during 1980 eruption of Mount St. Helens, Wash.

▪ ▪ ▪ ▪ Boundary of area that could be affected by directed blast similar to blast generated during 1980 eruption of Mount St. Helens, Wash. This hazard-zone boundary is worst-case condition for Mount Spurr volcano assuming future eruptions occur from Crater Peak vent

Figure 26. Directed-blast hazard zones.

EVENT FREQUENCY AND RISK AT MOUNT SPURR VOLCANO

A future eruption of Mount Spurr volcano from the Crater Peak vent can be expected, but the timing of the next eruption is uncertain. The primary proximal hazards would be lahars, lahar-runout flows, and floods, ash fall, ballistic fallout, and pyroclastic flows. Lahars likely would inundate major drainages on Crater Peak and could produce lahar dams across the Chakachatna River. Failure of the lahar dams could lead to flooding of the Chakachatna River valley if large volumes of water become impounded above the dam. Watery lahar-runout flows could reach the Cook Inlet coastline, but are unlikely to be deep or swift enough to cause damage to pipelines or structures in this area. Thick accumulations of volcaniclastic sediment in affected valleys and drainages would occur and sediment-laden runoff could persist for months to years after the eruption.

Because the immediate area around Mount Spurr volcano is uninhabited and no permanent structures or facilities are present, nothing within about 40 kilometers of the volcano is at risk from future eruptions. During any future eruption, ash could fall on residential areas along the Cook Inlet coastline, such as Shirleyville and Tyonek (fig. 1), and several millimeters of ash could accumulate downwind from the volcano on the Kenai Peninsula, Anchorage, Matanuska Valley and the Susitna River valley, and other areas in south-central Alaska. In the event of a large, explosive eruption, pyroclastic flows could engulf tributary valleys on the volcano as well as the upper Chakachatna River valley.

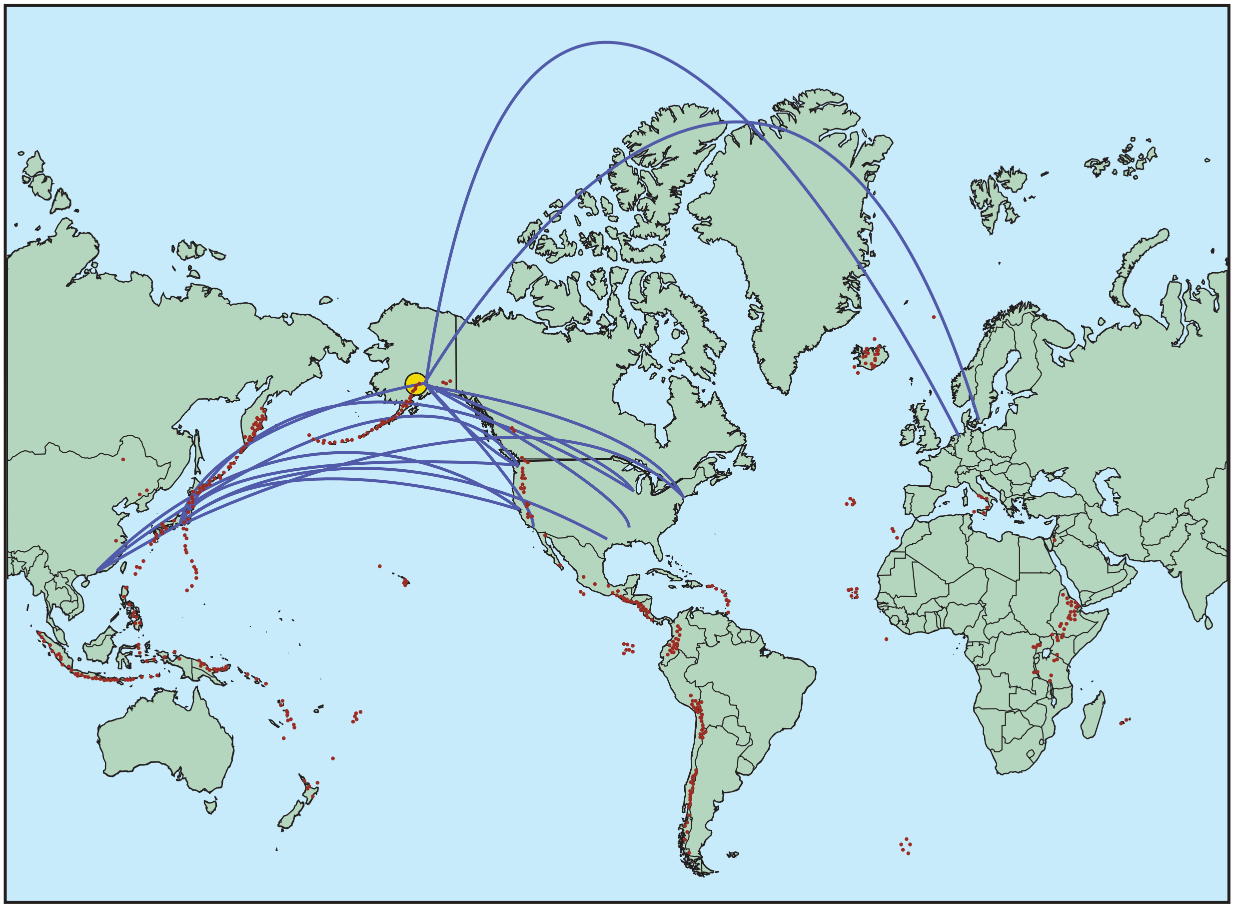
Should a sustained explosive eruption occur, clouds of volcanic ash would be generated that could drift thousands of kilometers downwind (fig. 12). All aircraft, some facilities, and living things—including humans—downwind from the volcano are at risk from effects of volcanic-ash clouds and ash fallout. Ash clouds from Crater Peak could rise to altitudes of 15,000 meters or more and move into the flight paths of aircraft using Ted Stevens Anchorage International and other airports in south-central and interior Alaska. Local air routes in the vicinity of Mount Spurr volcano could be blocked by drifting clouds of volcanic ash making access to or from interior Alaska impossible. Aircraft using air routes over the North Pacific and other areas downwind from Mount Spurr volcano (fig. 27), especially the Gulf of Alaska and Pacific Northwest, could encounter clouds of volcanic ash. The frequency at which dangerous clouds of volcanic ash are produced and the amount of ash fall cannot be estimated with certainty. Signs of volcanic unrest, such as elevated levels of earthquake activity, a change in emission rate and volume of volcanic gas, or an increase in ground temperature at or near the vent, usually precede an eruption. These signs of unrest permit reasonable estimates of the likelihood of volcanic-ash emission once an eruptive phase is detected. However, the characteristics of an ash cloud cannot be predicted before an eruption occurs, except that it is likely to be similar to those generated by historical eruptions of Crater Peak and other Cook Inlet volcanoes.

HAZARD WARNING AND MITIGATION

Typically, eruptions at Cook Inlet volcanoes are preceded by weeks to months of precursory earthquake activity; such seismicity gives some degree of warning of an impending eruption. Many eruptions also are preceded by at least several weeks of increased gas emission from the summit area. When volcanic unrest is detected, other monitoring techniques—such as measurement of volcanic-gas flux, remote observation using satellite imagery as well as real-time video or time-lapse cameras, and geodetic surveying—are used to develop a comprehensive assessment of the likelihood of an eruption and its potential effects.

AVO monitors Mount Spurr volcano by using a real-time seismic network equipped with an alarm system that is triggered by elevated levels of seismic (earthquake) activity indicating volcanic unrest. A network of six radio-telemetered seismometers sends real-time radio signals to the AVO offices in Anchorage and Fairbanks. In addition, AVO maintains a field-based data-collection program that includes geodetic, temperature, and gas measurements. Satellite images of the volcano are analyzed twice daily.

One of the primary roles of AVO is to communicate timely warnings of volcanic unrest and potential eruptions (Eichelberger and others, 1995, p. 4). AVO distributes by fax and electronic mail a weekly update



EXPLANATION

Figure 27. Major air-travel routes in relation to location of Mount Spurr volcano.

of volcanic activity that summarizes the status of the currently monitored volcanoes and some historically active but unmonitored volcanoes along the Aleutian volcanic arc. During periods of unrest or volcanic crises, updates are issued more frequently to advise the public of significant changes in activity. Recipients of these updates include the Federal Aviation Administration, air carriers, the National Weather Service, the Alaska Division of Emergency Services, local military bases, the Governor's office, various other State offices, television and radio stations, news wire services, and others. Updates also are distributed by electronic mail to various volcano information networks and are posted on the AVO web site (URL: <http://www.avo.alaska.edu>).

During the 1989–90 eruptions of Redoubt Volcano, AVO developed a "level of concern color code" (Brantley, 1990; table 2). This code provides efficient and simple information about the status of volcanic activity or unrest and conveys the AVO interpretation of that activity or unrest in terms of the potential for an eruption and its likely effects. In the event of a volcanic crisis, various Federal, State, and local officials are contacted by telephone, advised of the situation, and the level-of-concern color code is established while an update is being prepared. This approach has been used successfully during recent eruptions at monitored volcanoes such as Redoubt Volcano (during 1989–90), Crater Peak (in 1992), Pavlof Volcano (in 1996), and Shishaldin Volcano (in 1999).

Table 2. Alaska Volcano Observatory Level-of-Concern color code

Color	Intensity of unrest at volcano	Forecast
GREEN	Volcano is in quiet, "dormant" state.	No eruption anticipated.
YELLOW	Small earthquakes detected locally and (or) increased levels of volcanic-gas emissions.	Eruption is possible in next few weeks and may occur with little or no additional warning.
ORANGE	Increased numbers of local earthquakes. Extrusion of lava dome or lava flows (nonexplosive eruption) may be occurring.	Explosive eruption is possible within a few days and may occur with little or no warning. Ash plume(s) not expected to reach 7,600 meters (25,000 feet) above sea level.
RED	Strong earthquake activity detected even at distant monitoring stations. Explosive eruption may be in progress.	Major explosive eruption expected within 24 hours. Large ash plume(s) expected to reach at least 7,600 meters (25,000 feet) above sea level.

Minimizing the risks posed by eruptions of Mount Spurr volcano is possible through understanding potential hazards, adequate warning of eruptive activity, and preparing for an eruption. Areas within about 10 to 20 kilometers of Crater Peak are at risk from all hazardous volcanic phenomena. If for some reason, development is unavoidable in hazardous areas, engineering measures may be employed to minimize or prevent undesirable consequences.

Knowledge of potential hazards is required to assess the risk associated with a specific location on or near the volcano and to assess whether or not movement to another location would be safer. Recreational users of the area around Mount Spurr volcano should recognize that all areas within about 20 kilometers of Crater Peak, as well as all areas downwind from the vent, are subject to tephra and ballistic fallout. Low-lying terrain along streams and gullies that extend toward the summit of Crater Peak is subject to pyroclastic flows and surges, lahars, lahar-runout flows, floods, and avalanches. Given the present configuration of the Crater Peak vent, pyroclastic flows and tephra fallout are most likely on the south and southeast flanks of the cone. During an eruption, access closer than about 10 kilometers from the volcano could be impossible and the risks to human life great. Small planes and helicopters seeking a view of an eruption could be at risk from intermittent and unpredictable discharge of ballistic projectiles (volcanic bombs) or sudden changes in the travel direction of the eruption plume.

People and facilities located farther away from the volcano may have additional time to prepare for the adverse effects of an eruption; however, an emergency plan developed and ready prior to the onset of an eruption is useful. The planning for volcanic emergencies is similar to that for other emergencies, such as flooding or extreme weather. The sources of emergency information are often the same and the usual interruption of essential services may result. Thus, planning for interruptions in electrical service, transportation (especially air travel), and outdoor activities is appropriate for volcanic emergencies.

REFERENCES CITED

Blong, R.J., 1984, Volcanic hazards—A sourcebook on the effects of eruptions: Academic Press, Sydney, 424 p.

Bluth, G.J.S., Scott, C.J., Sprod, I.E., Schnetzler, C.C., Krueger, A.J., and Walter, L.S., 1995, Explosive emissions of sulfur dioxide from the 1992 Crater Peak eruptions, Mount Spurr volcano, Alaska, *in* Keith, T.E.C., ed., The 1992 eruptions of Crater Peak vent, Mount Spurr volcano, Alaska: U.S. Geological Survey Bulletin 2139, p. 37–46.

Brantley, S.R., ed., 1990, The eruption of Redoubt Volcano, Alaska, December 14, 1989–August 31, 1990: U.S. Geological Survey Circular 1061, 33 p.

Casadevall, T.J., ed., 1994, Volcanic ash and aviation safety—Proceedings of the First International Symposium on Volcanic Ash and Aviation Safety, Seattle, Washington, July 1991: U.S. Geological Survey Bulletin 2047, 450 p.

Casadevall, T.J., and Krohn, D.M., 1995, Effects of the 1992 Crater Peak eruptions on airports and aviation operations in the United States and Canada, *in* Keith, T.E.C., ed., The 1992 eruptions of Crater Peak vent, Mount Spurr volcano, Alaska: U.S. Geological Survey Bulletin 2139, p. 205–220.

Doukas, M.P., and Gerlach, T.M., 1995, Sulfur dioxide scrubbing during the 1992 eruptions of Crater Peak, Mount Spurr volcano, Alaska, *in* Keith, T.E.C., ed., The 1992 eruptions of Crater Peak vent, Mount Spurr volcano, Alaska: U.S. Geological Survey Bulletin 2139, p. 47–57.

Eichelberger, J.C., Keith, T.E.C., Miller, T.P., and Nye, C.J., 1995, The 1992 eruption of Crater Peak vent, Mount Spurr volcano, Alaska: chronology, and summary, *in* Keith, T.E.C., ed., The 1992 eruptions of Crater Peak vent, Mount Spurr volcano, Alaska: U.S. Geological Survey Bulletin 2139, p. 1–18.

Hoblitt, R.P., Walder, J.S., Dreidger, C.L., Scott, K.M., Pringle, P.T., and Vallance, J.W., 1995, Volcano hazards from Mount Rainier, Washington: U.S. Geological Survey Open-File Report 98–273, 12 p.

Iverson, R.M., Schilling, S.P., and Vallance, J.W., 1998, Objective delineation of lahar-inundation hazard zones: Geological Society of America Bulletin, v. 110, p. 972–984.

Juhle, W., and Coulter, H., 1955, The Mount Spurr eruption, July 9, 1953: Transactions of the American Geophysical Union, v. 36, p. 199.

Keith, T.E.C., Thompson, J.M., and McGimsey, R.G., 1995, Chemistry of lake waters prior to the 1992 eruptions of Crater Peak, Mount Spurr volcano, Alaska, *in* Keith, T.E.C., ed., The 1992 eruptions of Crater Peak vent, Mount Spurr volcano, Alaska: U.S. Geological Survey Bulletin 2139, p. 59–64.

Lamke, R.D., 1972, Floods of summer 1971 in south-central Alaska: U.S. Geological Survey Open-File Report 78–498, 102 p.

March, R.S., Mayo, L.R., and Trabant, D.C., 1997. Snow and ice volume on Mount Spurr volcano, Alaska, 1981: U.S. Geological Survey Water-Resources Investigations Report 97–4142, 36 p.

Meyer, D.F., and Trabant, D.C., 1995, Lahars from the 1992 eruptions of Crater Peak, Mount Spurr volcano, Alaska, *in* Keith, T.E.C., ed., The 1992 eruptions of Crater Peak vent, Mount Spurr volcano, Alaska: U.S. Geological Survey Bulletin 2139, p. 183–198.

Miller, T.P., and Chouet, B.A, 1994, The 1989–1990 eruptions of Redoubt Volcano—An introduction: Journal of Volcanology and Geothermal Research, v. 62, p. 1–10.

Miller, T.P., McGimsey, R.G., Richter, D.H., Riehle, J.R., Nye, C.J., Yount, M.E., and Dumoulin, J.A., 1998, Catalog of the historically active volcanoes of Alaska: U.S. Geological Survey Open-File Report 98–582, 104 p.

Miller, T.P., Neal, C.A., and Waitt, R.B., 1995, Pyroclastic flows of the 1992 Crater Peak eruptions: Distribution and origin, *in* Keith, T.E.C., ed., The 1992 eruptions of Crater Peak vent, Mount Spurr volcano, Alaska: U.S. Geological Survey Bulletin 2139, p. 81–88.

Myers, Barbara, Brantley, S.R., Stauffer, Peter, and Hendley, J.W., II, 1997, What are volcano hazards?: U.S. Geological Survey Fact Sheet 002–97, 2 p. (Revised 1998.)

Neal, C.A., McGimsey, R.G., Gardner, C.A., Harbin, M., and Nye, C.J., 1995, Tephra-fall deposits from the 1992 eruptions of Crater Peak, Mount Spurr volcano, Alaska—A preliminary report on distribution, stratigraphy, and composition, *in* Keith, T.E.C., ed., The 1992 eruptions of Crater Peak vent, Mount Spurr volcano, Alaska: U.S. Geological Survey Bulletin 2139, p. 65–80.

Nye, C.J., and Turner, D.L., 1990, Petrology, geochemistry, and age of the Spurr volcanic complex, eastern Aleutian arc: Bulletin of Volcanology, v. 52, p. 205–226.

Riehle, J.R., 1985, A reconnaissance of the major Holocene tephra deposits in the upper Cook Inlet region, Alaska. Journal of Volcanology and Geothermal Research, v. 26, p. 37–74.

Riehle, J.R., Bowers, P.M., and Ager, T.A., 1990, The Hayes tephra deposits, an upper Holocene marker horizon in south-central Alaska: Quaternary Research, v. 33, p. 276–290.

Rose, W.I., Kostinski, A.B., and Kelley, L., 1995, Real-time C-band radar observations of the 1992 eruption clouds from Crater Peak, Mount Spurr volcano, Alaska, *in* Keith, T.E.C., ed., The 1992 eruptions of Crater Peak vent, Mount Spurr volcano, Alaska: U.S. Geological Survey Bulletin 2139, p. 19–26.

Schneider, D.J., Rose, W.I., and Kelley, L., 1995, Tracking of 1992 eruption clouds from Crater Peak vent of Mount Spurr volcano, Alaska, using AVHRR, *in* Keith, T.E.C., ed., The 1992 eruptions of Crater Peak vent, Mount Spurr volcano, Alaska: U.S. Geological Survey Bulletin 2139, p. 27–36.

Siebert, L., 1996, Hazards of large volcanic debris avalanches and associated eruptive phenomena, *in* Scarpa, R., and Tilling, R.I., eds., Monitoring and mitigation of volcano hazards: Berlin, Springer–Verlag, p. 541–572.

Vallance, J.W., 1999, Postglacial lahars and potential hazards in the White Salmon River system on the southwest flank of Mount Adams, Washington: U.S. Geological Survey Bulletin 2161, 49 p.

Vallance, J.W., and Scott, K.M., 1997, The Osceola mudflow from Mount Rainier—Sedimentology and hazard implications of a huge clay-rich debris flow: Geological Society of America Bulletin, v. 109, p. 143–163.

Waitt, R.B., Mastin, L.G., and Miller, T.P., 1995, Ballistic showers during Crater Peak eruptions of Mount Spurr volcano, *in* Keith, T.E.C., ed., The 1992 eruptions of Crater Peak vent, Mount Spurr volcano, Alaska: U.S. Geological Survey Bulletin 2139, p. 89–106.

Wilcox, R.E., 1959, Some effects of recent volcanic ash falls with especial reference to Alaska. U.S. Geological Survey Bulletin 1028–N, 476 p.

GLOSSARY

Andesite. Fine-grained volcanic rock made up of feldspars and ferromagnesian minerals and having silica content of 54 to about 62 percent.

Ash. Fine fragments (less than 2 millimeters in diameter) of lava or rock formed in explosive volcanic eruption. Ash particles are typically sharp, angular, and abrasive and are composed of volcanic glass, mineral, and rock fragments.

Block-and-ash flow. Pyroclastic flow that contains blocks of primary volcanic rock in coarse ashy matrix. Block-and-ash flows commonly form from collapsing lava dome.

Cohesive. Said of lahars that contain more than about 3 percent clay in deposit matrix.

Debris avalanche. Rapidly moving, dry flows of disaggregated rock debris, sand, and silt. Volcanic-debris avalanches commonly form by some type of structural collapse of volcano, typically steep front of cooled lava dome or other parts of upper edifice. Large part of volcano may become unstable, break away from volcanic massif, and avalanche. Debris avalanche may be triggered by eruption or earthquake. Debris avalanches move at velocities ranging from a few tens of meters per second to more than 100 meters per second and behave like complex granular flows or slide flows. Typically they are quite voluminous (greater than 10 cubic kilometers) and may run out considerable distances (as much as 85 kilometers) from their source. Resulting debris-avalanche deposit commonly exhibits hummocky surface morphology.

Directed blast. Large-scale volcanic explosions caused by a major landslide or slope failure that results in rapid drop in pressure of intruding magma near surface of volcanic edifice. Eruption of Mount St. Helens in 1980 was triggered by massive slope failure and subsequent laterally directed blast affected 180° sector north of volcano and extended for several tens of kilometers outward. Directed blast typically travels away from volcano at low angle and may not be deflected by ridges or other topographic barriers. Rock debris propelled by directed blast moves much faster than typical landslides and rockfalls. For example, at Mount St. Helens, initial velocity of directed blast cloud was about 600 kilometers per hour; velocity decreased to about 100 kilometers per hour at distance of 25 kilometers from volcano.

Edifice. Upper part of volcanic cone, including vent and summit areas.

Effusive. Said of nonexplosive eruption characterized by production of lava flows.

Eruption cloud. Cloud of gas and ash and other fragments that forms during explosive volcanic eruption and travels long distances with prevailing winds.

Eruption column. Vertical part of eruption cloud that rises above volcanic vent.

Fallout. General term for debris that falls to Earth's surface from eruption cloud.

Lahar. Indonesian term for wet debris flow containing angular clasts of volcanic material. For purposes of this report, lahar is any type of sediment–water mixture originating on or from volcano. Most lahars move rapidly down slopes of volcano as channelized flows and deliver large amounts of sediment to rivers and streams that drain volcano. Flow velocity of some lahars may be as high as 20 to 40 meters per second (Blong, 1984), and sediment concentrations of greater than 750,000 parts per million are not uncommon. Large-volume lahars can travel great distances if they have appreciable clay content (greater than 3 to as much as 5 percent), remain confined to stream channel, and do not significantly gain sediment while losing water. Thus, they may affect areas many tens to hundreds of kilometers downstream from volcano.

Lapilli. Ejected rock or pumice fragments 2 to 64 millimeters in diameter.

Lava. Molten rock that reaches Earth's surface.

Lava dome. Steep-sided mass of viscous and often blocky lava extruded from vent; typically has rounded top and roughly circular outline.

Magma. Molten rock beneath Earth's surface.

Pleistocene Epoch. Span of time in Earth history from about 1.8 million to 10,000 years before present.

Plinian. Said of volcanic eruptions characterized by highly explosive ejection of tephra and large-volume emissions of ash. Ash plumes from Plinian eruptions commonly reach 10,000 to 45,000 meters in height above vent. Sub-Plinian eruption is similar but total volume of material erupted and maximum height of eruption column are less.

Pumice. Highly vesicular, silica-rich volcanic ejecta; owing to its extremely low density, it commonly floats on water.

Pyroclastic. General term applied to volcanic products or processes that involve explosive ejection and fragmentation of erupting material.

Pyroclastic flow. Dense, hot, chaotic avalanche of rock fragments, gas, and ash that travels rapidly away from explosive eruption column, typically down flanks of volcano. Pyroclastic flows move at speeds ranging from 10 to several hundred meters per second and are typically at temperatures of 300 to 800°C (Blong, 1984). Pyroclastic flows form either by collapse of eruption column or by failure of front of cooling lava dome. Once these flows are initiated, they may travel distances of several kilometers or more and easily override topographic obstacles in flow path. Person could not outrun advancing pyroclastic flow.

Pyroclastic surge. Low-density, turbulent flow of fine-grained volcanic rock debris and hot gas. Pyroclastic surges differ from pyroclastic flows in that they are less dense and tend to travel as low, ground-hugging, but highly mobile cloud that can surmount topographic barriers. Surges often affect areas beyond limits of pyroclastic flows.

Radiometric dating. Technique for determining age of formation of volcanic rocks based on measuring amounts of radiogenic isotopes that decay at known rates.

Stratovolcano. Steep-sided volcano, typically conical in shape, built of lava flows and fragmental deposits from explosive eruptions. Also called stratocone or composite cone.

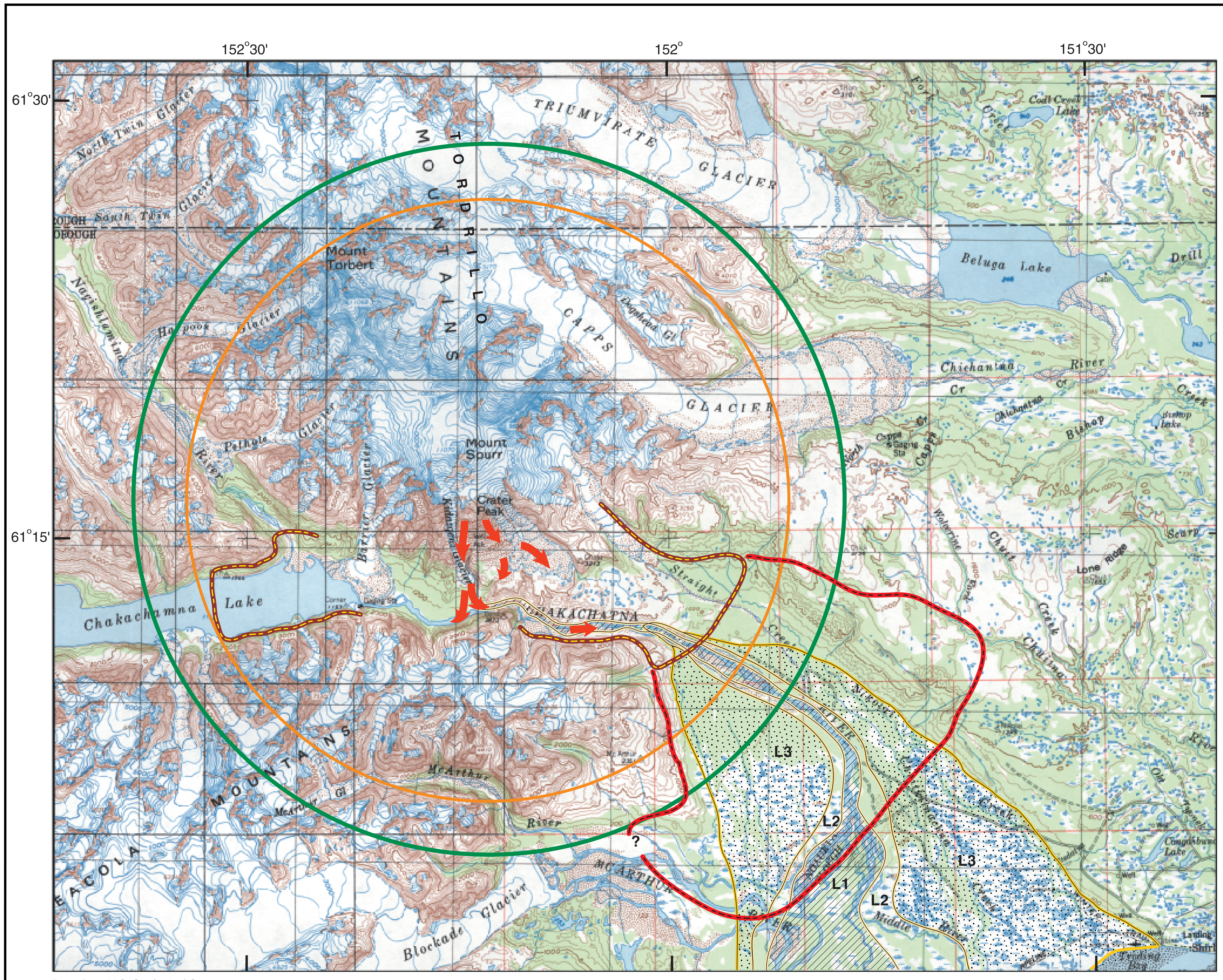
Tephra. Any type of rock fragment that is ejected forcibly from volcano during eruption. Tephra may be fine-grained particles or dust, also called volcanic ash (0.0625 to 2 millimeters in diameter, or silt to sand sized); coarser grained particles, also called lapilli (2 to 64 millimeters in diameter, or sand to pebble sized); or large blocks or bombs (greater than 64 millimeters, or cobble to boulder sized). When tephra is airborne, coarsest fraction is deposited close to volcano, but fine fraction may be transported long distances and can stay suspended in atmosphere for many months.

Vent. Opening in Earth's surface through which magma erupts or volcanic gases are emitted.

Volcanian. Applies to explosive eruption of relatively small volume (less than 1 cubic kilometer) and having eruption columns that reach heights of 10,000 to 20,000 meters.

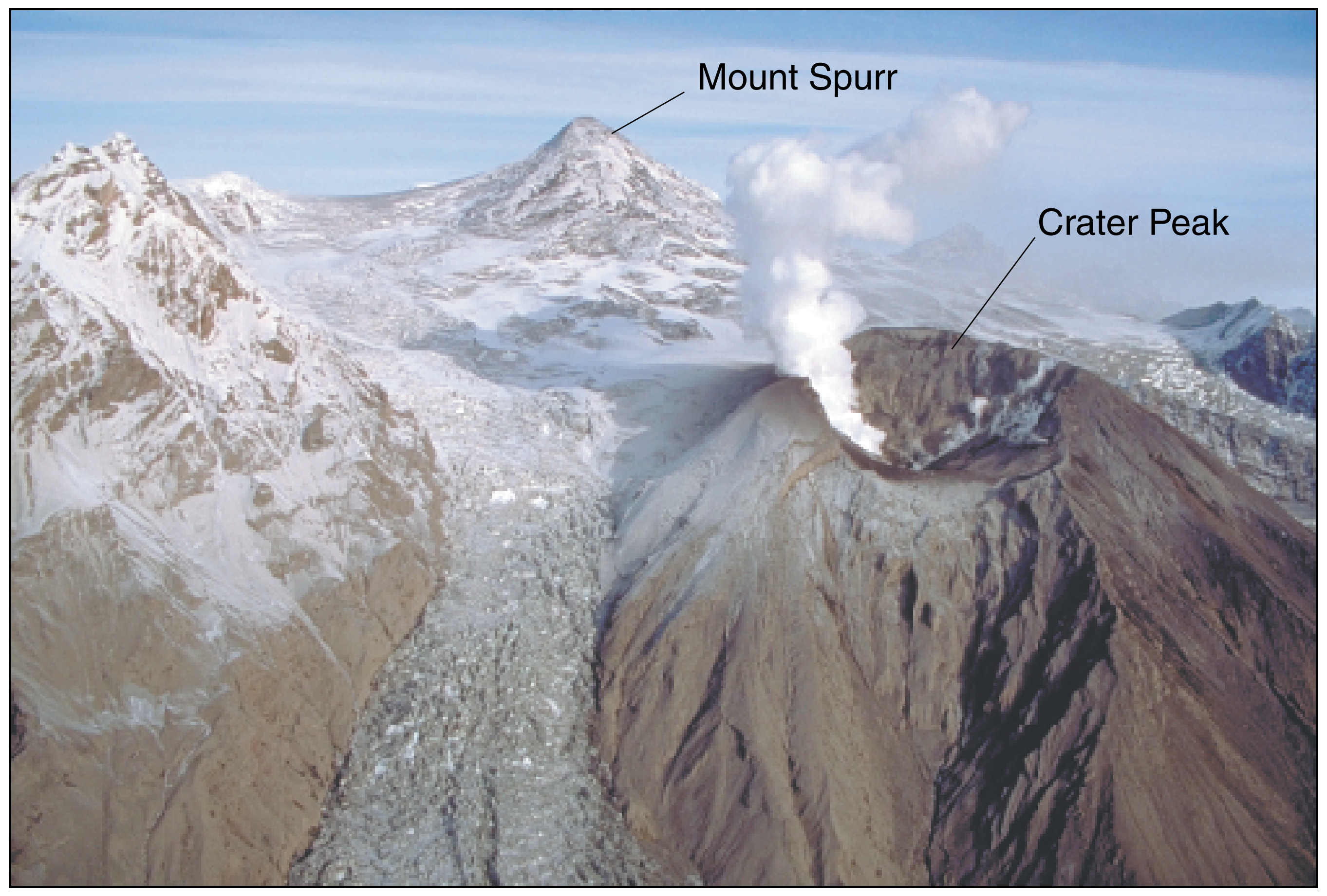
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

OPEN-FILE REPORT 01–482
PLATE 1



Base from U.S. Geological Survey, 1:250,000
Tyonek, 1958
Universal Transverse Mercator projection

Contour interval variable, 100 and 200 feet



Mount Spurr and Crater Peak, showing steam plume. Crater Peak was vent for 1953 and 1992 eruptions. View is toward northeast.

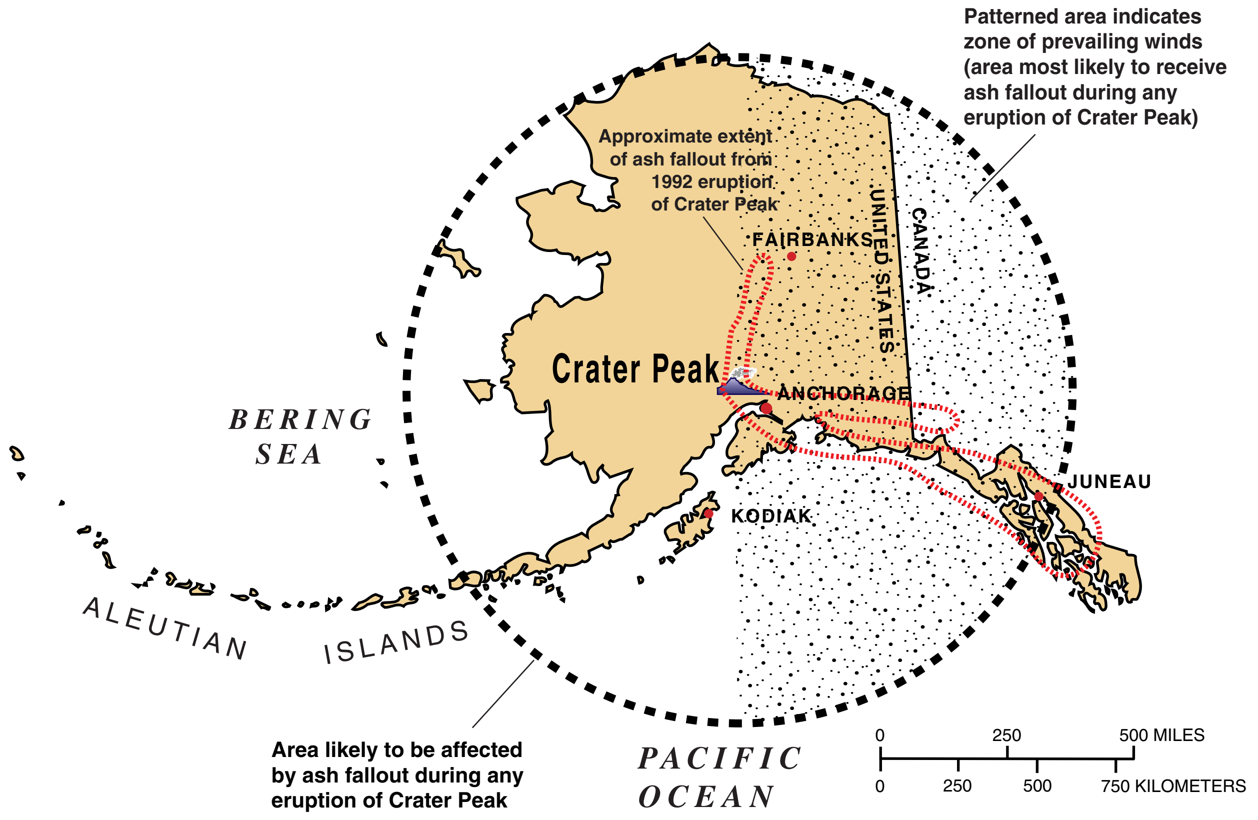
NOTE ABOUT VOLCANO HAZARD-ZONE BOUNDARIES

The preliminary hazard-zonation map indicates generalized hazardous areas associated with future eruptions of Mount Spurr volcano from Crater Peak vent. Also indicated are areas at risk from various volcano-related events such as debris avalanches and lahars that may not be related to an actual eruption. Pyroclastic eruptions are likely to initiate lahars and floods and probably would result in variable amounts of ash fall. Debris avalanches are uncommon at this volcano and are unlikely to be significant hazards. A large flank collapse could evolve to a lahar that would inundate some parts of Chakachatna River valley.

The hazard-zone boundaries do not indicate a major change in the degree of hazard but are generalized approximations based on known deposits and eruptive characteristics of similar volcanoes. The degree of hazard generally decreases in a downvalley direction and as height above the valley floor increases.

VOLCANIC-ASH HAZARDS

The hazard zone for volcanic ash is likely to be similar to the extent of ash fallout of recent eruptions of Crater Peak and other Cook Inlet volcanoes. The specific area of ash fallout depends on the prevailing winds, which are generally from the west. Ash plumes could rise to a height of 15,000 meters or more and would drift down-wind as ash clouds for days to weeks after an eruption. Drifting clouds of volcanic ash would be hazardous to all aircraft in areas downwind from the volcano.



EXPLANATION

LAHAR HAZARDS

[See discussion in section “Lahars, Lahar-Runout Flows, and Floods,” under “Volcanic Hazards,” in main text of report]

▨ L1	Areas likely to be inundated by lahars (volcanic-debris flows), lahar-runout flows, and floods having initial volumes of about 100,000 cubic meters. These flows are about as large as those generated by 1992 eruption of Crater Peak
L2	Areas likely to be inundated by lahars (volcanic-debris flows), lahar-runout flows, and floods having initial volumes of about 1,000,000 cubic meters. These areas are less likely to be affected than zone L1
L3	Areas likely to be inundated by lahars (volcanic-debris flows), lahar-runout flows, and floods having initial volumes of about 10,000,000 cubic meters. These areas are less likely to be affected than zones L1 or L2

DEBRIS-AVALANCHE HAZARDS

[See discussion in section “Debris Avalanches,” under “Volcanic Hazards,” in main text of report]

‐ ‐ ‐	Probable extent of debris avalanche from Crater Peak for *H*/*L* = 0.2
‐ ‐ ‐	Probable extent of debris avalanche from Crater Peak for *H*/*L* = 0.1

PYROCLASTIC-FLOW AND PYROCLASTIC-SURGE HAZARDS

[See discussion in section “Pyroclastic Flows and Surges,” under “Volcanic Hazards,” in main text of report]

—	Possible extent of pyroclastic flows for *H*/*L* = 0.2. Pyroclastic flows associated with lava-dome collapse could extend to about this (approximate) boundary during moderate to large eruptions. Pyroclastic flows associated with collapsing lava domes would be directed over discrete sectors of volcano and along major valleys—most likely in upper Chakachatna River Valley
➘	Most likely flow paths for pyroclastic flows and surges. During moderate to large eruptions, pyroclastic flows and surges could be directed along topographically low areas such as valleys and drainages and could extend beyond hazard-zone boundary defined by *H*/*L* = 0.2

LATERAL-BLAST HAZARDS

[See discussion in section “Directed Blasts,” under “Volcanic Hazards,” in main text of report]

—	Extent of area that could be affected by directed blast similar to blast generated during 1980 eruption of Mount St. Helens in Washington. This hazard boundary is worst-case condition for Mount Spurr volcano. If directed blast were to occur, it could engulf as much as 180-degree sector of indicated hazard zone

Alaska Volcano Observatory
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by

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2002

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