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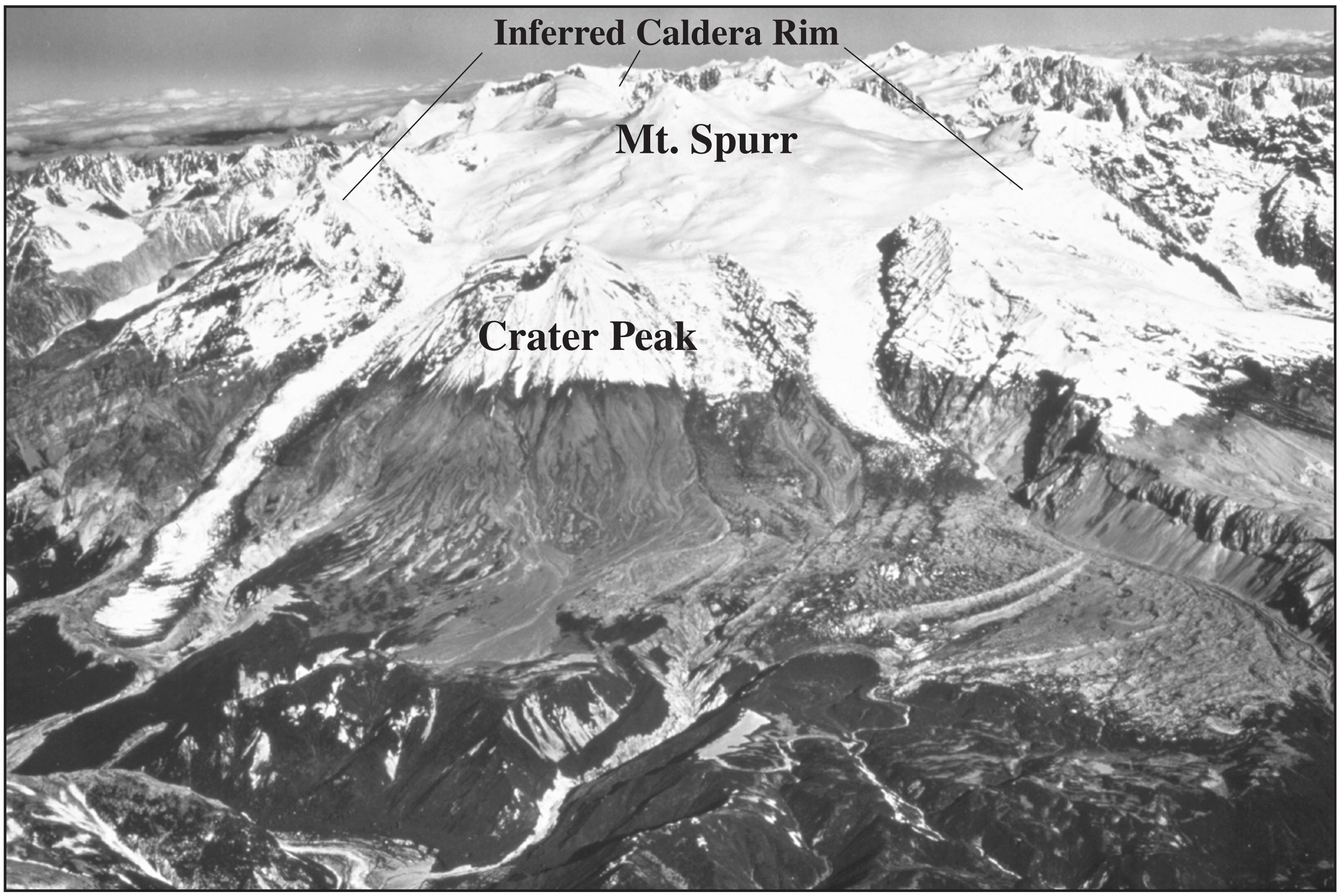
Areal Distribution, Thickness, Mass, Volume, and Grain Size of Tephra-Fall Deposits from the 1992 Eruptions of Crater Peak Vent, Mt. Spurr Volcano, Alaska

Open-File Report 01–370



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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: Oblique aerial view from the southeast of Mount Spurr volcano and Crater Peak flank vent, which is the site of all late Holocene and historical eruptive activity at this volcanic center. Photograph by Austin Post, September 4, 1996.

Areal Distribution, Thickness, Mass, Volume, and Grain Size of Tephra-Fall Deposits from the 1992 Eruptions of Crater Peak Vent, Mt. Spurr Volcano, Alaska

By Robert G. McGimsey[1], Christina A. Neal[1], and Colleen M. Riley[2]

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Alaska Volcano Observatory
Anchorage, Alaska
2001

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U.S. DEPARTMENT OF THE INTERIOR
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CHARLES G. GROAT, Director

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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 kilometer (km^2)	0.3861	square mile
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 second (m/s)	2.237	mile per hour
kilometer per hour (km/h)	0.6214	mile 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.

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ABSTRACT

The Crater Peak flank vent of Mount Spurr volcano erupted June 27, August 18, and September 16-17, 1992. The three eruptions were similar in intensity (vulcanian to subplinian eruption columns reaching up to 14 km Above Sea Level) and duration (3.5 to 4.0 hours) and produced tephra-fall deposits (12, 14, 15 x 10^6 m^3 Dense Rock Equivalent [DRE]) discernible up to 1,000 km downwind. The June 27 ash cloud traveled north over the rugged, ice- and snow-covered Alaska Range. The August 18 ash cloud was carried southeastward over Anchorage, across Prince William Sound, and down the southeastern shoreline of the Gulf of Alaska. The September 16-17 ash plume was directed eastward over the Talkeetna and Wrangell mountains and into the Yukon Territory of Canada. Over 50 mass-per-unit-area (MPUA) samples were collected for each of the latter two fall deposits at distances ranging from about 2 km to 370 km downwind from the volcano. Only 10 (mostly proximal) samples were collected for the June fall deposit due to inaccessible terrain and funding constraints. MPUA data were plotted and contoured (isomass lines) to graphically display the distribution of each fall deposit. For the August and September eruptions, fallout was concentrated along a narrow (30 to 50 km wide) belt. The fallout was most concentrated (100,000 to greater than 250,000 g/m^2) within about 80 km of the volcano. Secondary maxima occur at 200 km (2,620 g/m^2) and 300 km (4,659 g/m^2), respectively, down axis for the August and September deposits. The maxima contain bimodal grain size distributions (with peaks at 88.4 and 22.1 microns) indicating aggregation within the ash cloud. Combined tephra-volume for the 1992 Mount Spurr eruptions (41 x 10^6 m^3 DRE) is comparable to that (tephra-fall only) of the 1989-90 eruptions of nearby Redoubt volcano (31-49 x 10^6 m^3 DRE).

ACKNOWLEDGEMENTS

We wish to thank Kristi Wallace, Linda Harris, and Gail Davidson for their diligent help in preparing the tephra-fall distribution maps and some of the figures. Willie Scott and Dick Moore provided swift, pragmatic reviews of the report. Thanks to all the tephra collectors who responded to our requests to provide samples and information from distant locations that we were unable to visit.

INTRODUCTION

Mount Spurr volcano is located 130 km west of Anchorage near the southern tip of the Alaska Range (fig. 1). The andesitic stratovolcano is the easternmost of the 41 historically active volcanoes of the Aleutian arc (fig. 2; Miller and others, 1998). The 3,374-m-high ice-covered summit is a dome or cone situated in the middle of a 6-km-wide explosion caldera created in an early Holocene Bezymianny-type eruption (cover photo; Riehle, 1985; Nye and Turner, 1990). A satellite flank vent—Crater Peak, 2,309 m high, located 3.5 km south of the Spurr summit along the south rim of the caldera (fig. 3)—is the source of all late Holocene and historical eruptive activity at Mt. Spurr (Riehle, 1985; Miller and others, 1998). Written historical records began in Alaska in the mid-18th century, Cook Inlet was first visited by Europeans in 1778, and Anchorage was founded about 1900. With this in mind, prior to 1992, only one historical eruption had been documented for Mt. Spurr. This eruption, on July 9-10, 1953, consisted of two eruptive pulses that placed an ash cloud to an altitude up to 20 km (Juehle and Coulter, 1955; Wilcox, 1959). Ash fell as far as 350 km downwind to the east, and up to 4 mm of ash fell on Anchorage. In the decades following this eruption, the Crater Peak vent hosted a warm turquoise-colored lake and several fumaroles issued from the inner walls. In August, 1991, the 6 to 10-station seismic network maintained around Mt. Spurr by the Alaska Volcano Observatory (AVO) began to record anomalous seismic activity that gradually increased during the subsequent 10 months, culminating in three explosive eruptions, June 27, August 18, and September 16-17, 1992 (Eichelberger and others, 1995; Power and others, 1995). Tephra produced by these eruptions covered large swaths through south-central Alaska (fig. 1).

This report contains primary data and analysis of distribution, thickness, mass, volume and grain size of tephra collected in the days and weeks following each eruption. A preliminary report of tephra studies, including data on stratigraphy and composition, which is not covered in this report, can be found in Neal and others (1995). Other reports on 1992 Spurr tephra include Gardner and others (1998), Harbin and others (1995), McGimsey and Dorava (1994), Nye and others (1995), Rose and others (1995), Rose and others (in press), Schneider and others (1995), and Shannon (1996).

METHODS

Over 50 measured-area tephra samples were collected from proximal and distal deposits produced from each of the August and September eruptions; only 10 samples were collected from the June deposit. Most tephra was collected from carefully measured areas ranging from 1.0 m^2 to 0.01 m^2 during the first several days to a week following each eruption. Several samples were collected at some sites to verify consistency of the local deposits and collection techniques. The character of the surface on which tephra accumulated—snow, or hard and dry surfaces such as decks, car hoods, roofs, etc.—determined the collection technique. Tephra from the August and September eruptions of Mount Spurr fell on perennial snow in high proximal terrain and on snow-free surfaces at distal areas of lower elevation; northerly directed winds during the June eruption deposited tephra primarily on the rugged, ice- and snow-covered terrain of the Alaska Range. From on or within snow, samples were collected largely following the techniques described in Scott and McGimsey (1994), where by a template is used to mark the measured area and the tephra and over- and underlying snow is collected by trowel (fig. 4). The samples were placed in plastic bags and thawed and dried in the lab. In snow-free areas, hard, flat surfaces were located and collection areas were carefully measured with a tape. Adjacent tephra was removed and then tephra within the measured area was collected by trowel and fine-bristle brush (fig. 5). Because some of these samples had been wetted, all samples were dried in an oven before weighing. Mass of each sample was determined in the lab using a Mettler PC 400 digital scale. Water-saturated samples were poured through weighed filter paper and then dried overnight in a warm oven prior to weighing. The MPUA measurements were plotted on a base map and isomass contours were drawn by hand.

Thickness measurements were made when possible; however, primary thickness of air-fall tephra deposits can be severely affected by (1) deposition on snow, which exaggerates thickness; (2) wetting, which causes compaction; and (3) wind and water, which can cause redistribution of the deposit. Moreover, deposit thickness reported by the general public and other untrained observers (e.g. in distal villages and communities) tended to be greatly overstated, often by as much as 3 times the actual value. Therefore, we used mass-per-unit-area (MPUA) measurements, instead of deposit-thickness measurements, for determining distribution trends and minimum tephra volumes.

Grain size analyses were conducted at Cascade Volcano Observatory in Vancouver, WA, (using sedigraph, M. Couchman, analyst) and at Michigan Technological University in Houghton, MI, (sedigraph and laser diffraction, C. Riley, analyst). Large volume- and coarse samples were hand sieved at AVO.

JUNE 27 TEPHRA-FALL DEPOSIT

After 10 months of gradually increasing unrest, seismicity beneath Mt. Spurr changed dramatically on June 24, culminating in a subplinian eruption that lasted for approximately four hours and sent an ash cloud to an altitude of 14.5 km above sea level (ASL) (Rose and others, 1995). Southerly winds carried ash northward over the rugged, snow- and ice-covered Alaska Range (figs. 6-8).

Of the three eruptions, we have the least amount of tephra data on the June deposit (fig. 8) owing in part to the remoteness and rugged nature of the terrain over which much of the deposit accumulated, and in part to budget constrains. AVO geologists Jim Beget and Tom Miller collected six measured-area tephra samples and measured deposit thickness between 17 and 64 km from the vent along the deposit axis, mapped the deposit boundaries to 200 km north, and calculated a bulk tephra volume based on thickness measurements (fig. 9, tables 1,2). Two of the authors (McGimsey and Neal) collected several more samples (#9 and #10, fig. 8) during the summer of 1993 from within the snowpack on high peaks of the Alaska Range from near Mt. Foraker south to Mt. Spurr. Grain size analyses were not acquired for any of the June samples, however, “Bombs and blocks more than a meter in diameter were found in the crater, but the modal diameter of tephra [clasts] rapidly decreased to 3 mm at 15 km from the vent, and to 1 mm at 40 km from the vent.” (J. Beget and T. Miller, written communication, 1992).

The thickness of air-fall tephra deposits ideally decreases exponentially with increasing distance from the source vent, and such appears to be the case with the June deposit (Fisher and Schmincke, 1984; fig. 9a, this report). “Traces of ash…were reported from as far north as the village of Tanana on the Yukon River, some 450 km from the vent…[the] tephra thinned from more than a meter near the vent, to about 5 cm at 15 km, 1 cm at 50 km, and to a few millimeters at 250 km” (J. Beget and T. Miller, written communication, 1992). Although secondary MPUA maxima were present in later deposits, the lack of evidence for one in the June 27 deposit may be related to the relatively few samples collected and their proximity to the vent.

Beget and Miller integrated the thickness of June 27 tephra over its fallout area using the method of Fierstein and Nathenson (1992) to determine a bulk tephra volume of 44 x 10^6 m^3 (fig. 9b). Using a deposit density of 0.7 g/cm^3 and a rock density of 2,600 kg/m^3, the dense rock equivalent (DRE) is estimated to be 12 x 10^6 m^3.

AUGUST 18 TEPHRA-FALL DEPOSIT

Seismic activity beneath Mt. Spurr volcano dropped dramatically following the June eruption and remained low through the first half of August (Power and others, 1995). With virtually no seismic precursor—other than a 12-minute stretch of weak tremor including 3 long-period events—the Crater Peak vent burst forth with a second eruption late on the afternoon of August 18, 1992 (McNutt and others, 1995). The eruption lasted 3 hours and 40 minutes and sent an ash cloud to an altitude of 13.7 km ASL (44,950 ft.) (Rose and others, 1995). Westerly winds carried the ash over south-central Alaska including the Anchorage bowl, Prince William Sound, and the southeastern shoreline of the Gulf of Alaska (fig. 1). Traces of ash were reported up to 1,200 km downwind of the vent (#51, table 3). Video footage of the eruption taken by AVO staff shows an anvil-shaped cloud composed of a nearly vertical, roiling, eruption column topped with an easterly directed, expanding ash plume (fig. 10; McGimsey and Dorava, 1994).

Over 50 field stations were established and 40 MPUA samples were collected (tables 3, 4) to delineate the areal distribution of the August tephra-fall deposit (fig. 11). Grain-size data for selected samples are presented in Figure 12. The fall-out deposit is weighted asymmetrically south of the deposit axis, a probable reflection of lower altitude wind shear that existed at the time of the eruption (fig. 13); lower altitude winds were more northerly than upper level winds, thus directing some falling tephra further north of the main fall axis compared to what fell south of the axis. Anchorage received about 3 mm of fine sand-size tephra over a 3-hour period (fig. 14).

Although tephra-fall deposits ideally thin with increasing distance from the source vent—and by inference, the mass of tephra per unit-area likewise decreases—the August Mt. Spurr deposit has a well-defined secondary MPUA maximum that begins about 132 km from the vent and extends to about 305 km down the deposit axis. The maximum resulted from fallout of aggregates of fine ash of bimodal grain size distribution with peaks at 88.4 and 22.1 microns (plot 43, fig. 12). Aggregation-induced secondary maxima and anomalously thick distal tephra deposits may be a more common phenomenon than once believed and may be related to fine particle shape (Riley and others, 1997).

The dense-rock volume of tephra released from the August 18 eruption, 14 x 10^6 m^3 (d=2,600 kg/m^3), was estimated by plotting the logarithm of MPUA versus the square root of the corresponding isomass area following the method of Fierstein and Nathenson (1992). Assuming a mean deposit density of 0.7 g/cm^3, the bulk volume is 52 x 10^6 m^3.

SEPTEMBER 16-17 TEPHRA-FALL DEPOSIT

The third and final eruption of Mt. Spurr in 1992 began late on the evening of September 16 following a month-long gradual increase in deep seismicity (Eichelberger and others, 1995; Power and others, 1995). The eruption lasted for approximated 3.6 hours with the main phase beginning just after midnight. C-band radar records indicate that the eruption cloud reached a maximum height of 13.9 km ASL (45,600 ft.) (Rose and others, 1995). Westerly winds carried ash eastward (fig. 15), dusting the north edge of the Knik Arm of Cook Inlet and depositing about 1.5 to 2.5 mm of ash on communities in the Matanuska Valley (fig. 16; tables 5, 6).

As with the August 18 tephra-fall deposit, the September deposit has a diffuse northern edge, presumably owing to lower altitude wind shear (fig. 15); lower altitude winds were more northerly than upper level winds, thus directing some falling tephra further north of the main fall axis compared to what fell south of the axis. The deposit is 65 km wide at the 50 g/m^2 isomass about 350 km from the vent. A secondary MPUA maximum begins 182 km from the vent and extends to 365 km downwind. Bimodal grain size also characterizes the secondary maximum (fig. 17). Our farthest east sample along the deposit axis is from near Glennallen, Alaska (#48, fig. 16). Beyond there, the tephra fell on remote, rugged, uninhabited terrain with difficult access. The finest fraction was carried many thousands of kilometers before departing the skies over North America near Greenland on September 20 (Schneider and others, 1995). The dense-rock volume of tephra released from the September 16-17 eruption, 15 x 10^6 m^3 (d=2,600 kg/m^3), was estimated by plotting the logarithm of MPUA versus the square root of the corresponding isomass area following the method of Fierstein and Nathenson (1992). Assuming a mean deposit density of 0.7 g/cm^3, the bulk volume is 56 x 10^6 m^3.

The mass, dense-rock volume, and bulk volume of tephra-fall deposits from the 1992 eruptions of Mt. Spurr are summarized in Table 7. Combined tephra volume for the 1992 Mt. Spurr eruptions (41 x 10^6 m^3 DRE) is comparable to that of the 1989-90 eruptions of Redoubt Volcano (31-49 x 10^6 m^3 DRE, Scott and McGimsey, 1994), located about 95 km to the south (fig. 1).

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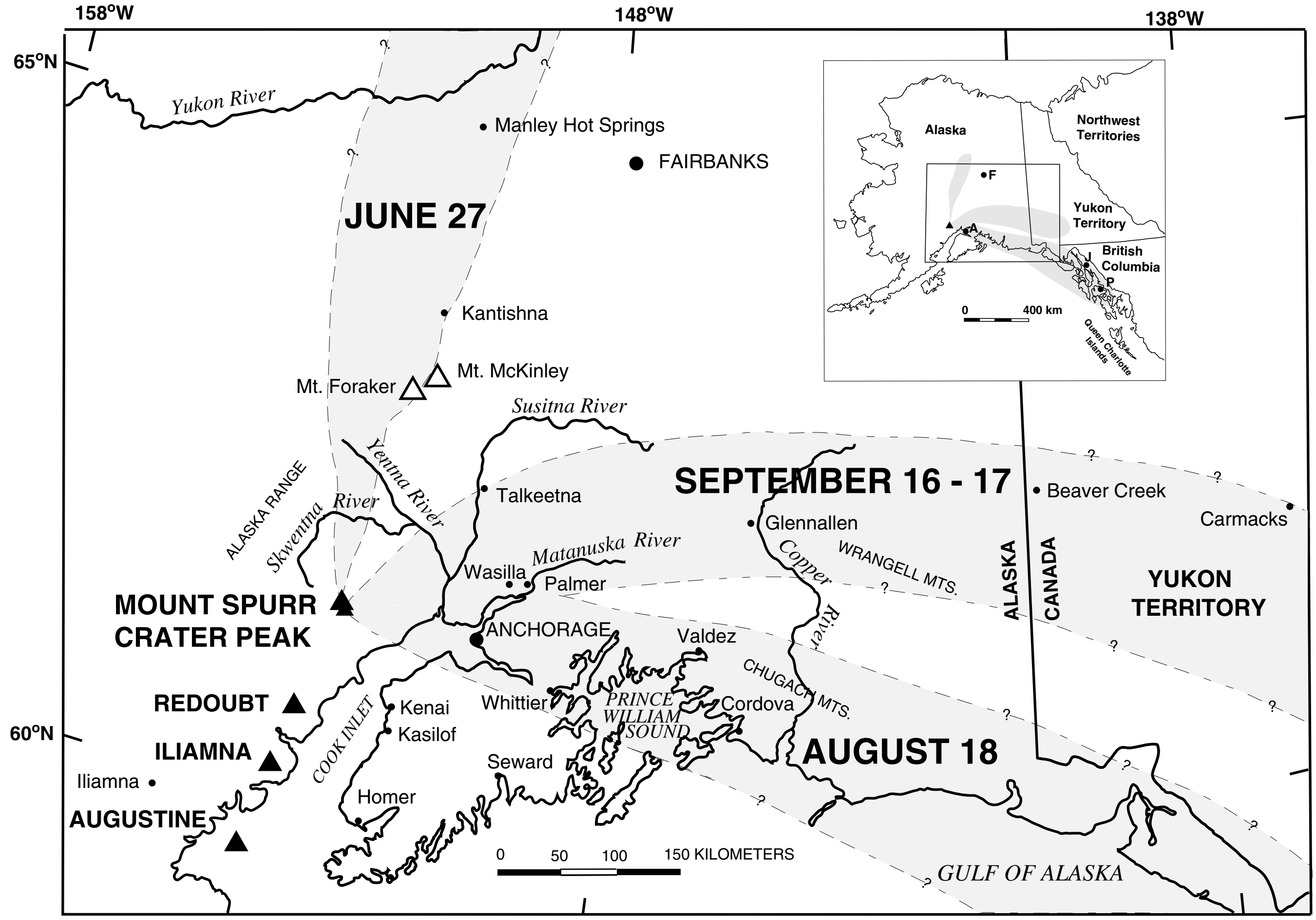


Figure 1. Map of south-central Alaska showing approximate areas of tephra deposition from ash plumes generated from each of the three 1992 eruptions of Mt. Spurr volcano. Tephra distributions sketched from Figures 8, 11, and 16.

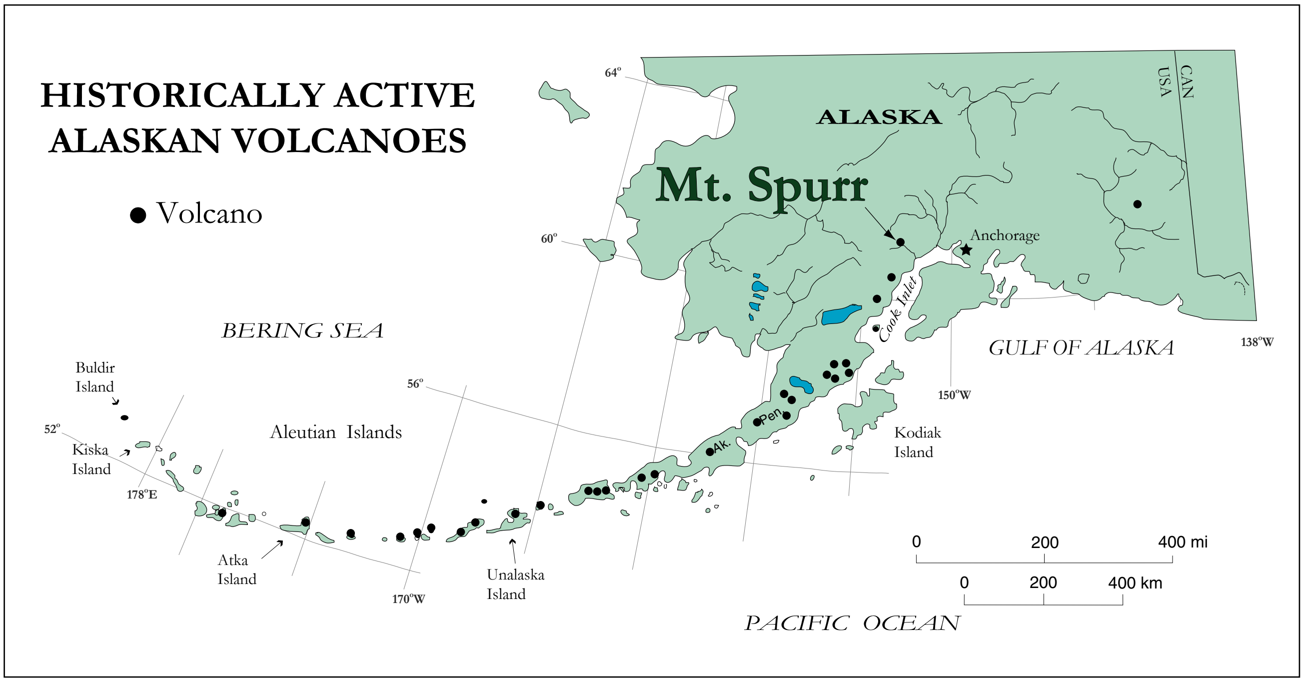


Figure 2. Index map showing the location of Mt. Spurr and the other historically active volcanoes of the Aleutian Arc.

Figure 3. Crater Peak vent and summit of Mt. Spurr (photograph by T.P. Miller, October 23, 1992).

Figure 4. Collection of measured-area tephra samples from snowpack (September 24, 1992).

Figure 5. Collection of measured-area tephra samples from hard surfaces in areas below snowline (September 21, 1992).

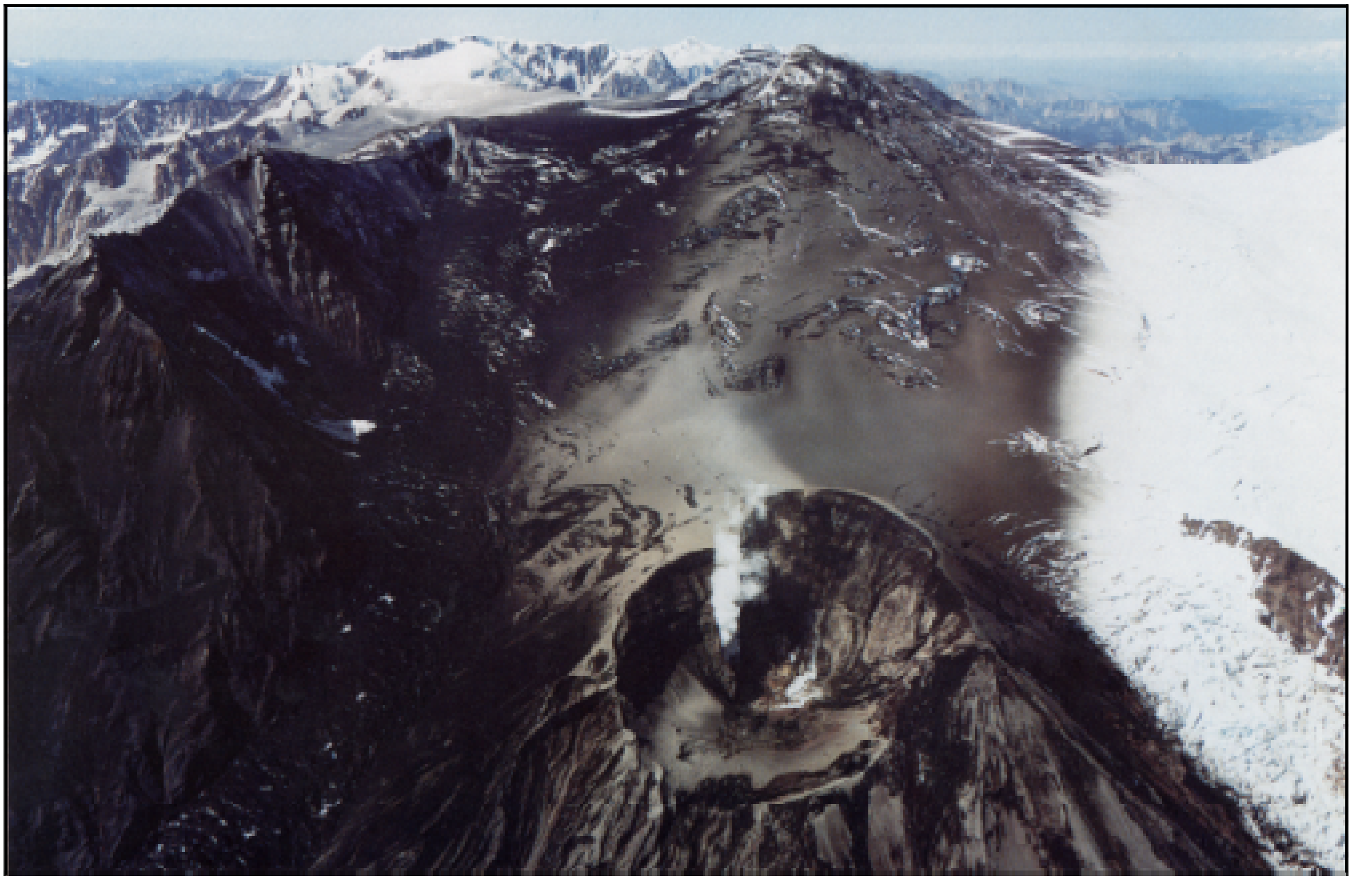


Figure 6. Oblique northward aerial veiw of Mt. Spurr, showing dark, June 27, 1992, tephra on snow; the steaming source vent, Crater Peak; Mt. Spurr's summit dome; and part of the caldera rim (photograph courtesy of Aeromap U.S.).

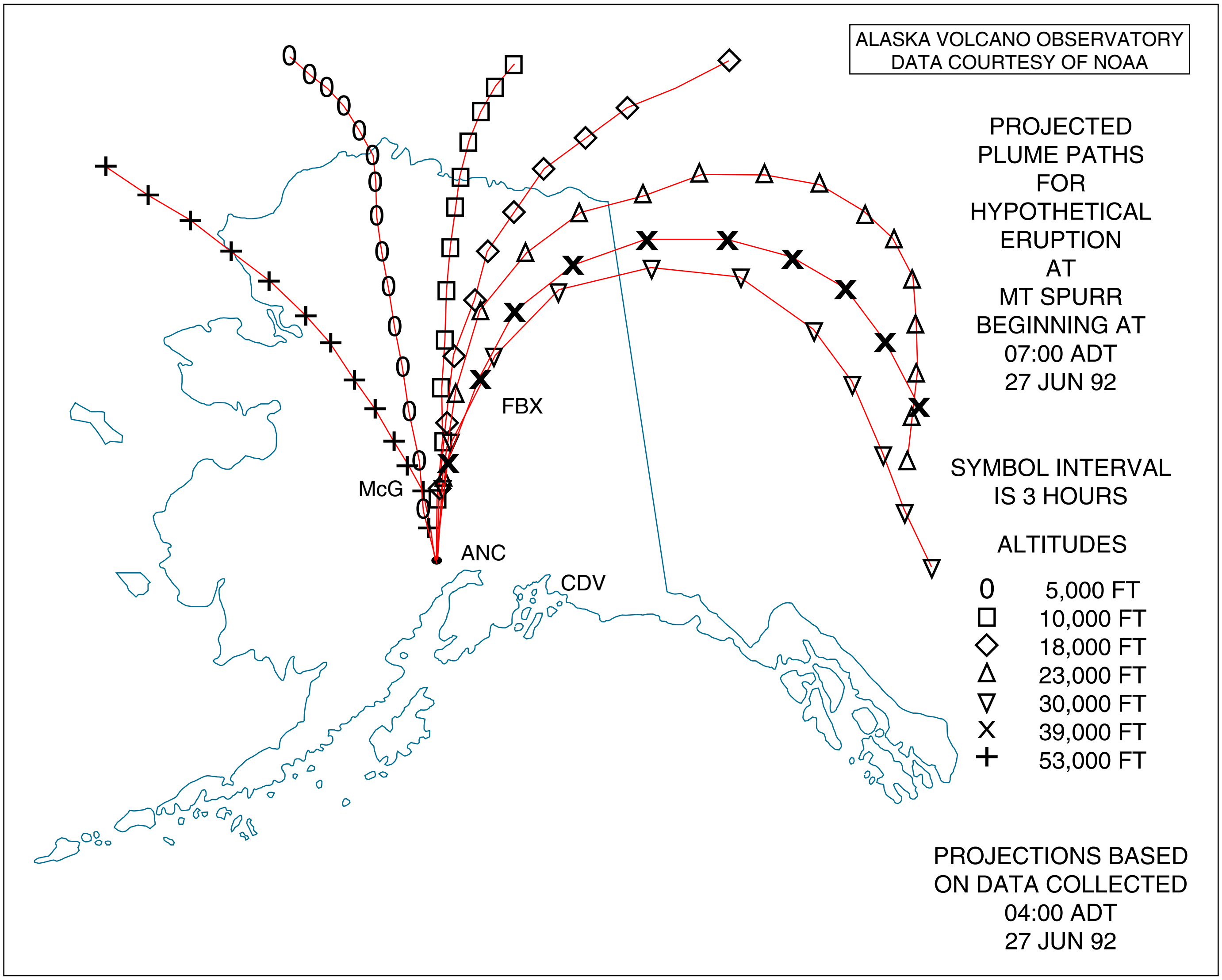


Figure 7. Plume trajectory forecast for 7:00 am Alaska Daylight Time (ADT) on June 27, 1992. Symbols represent the location of parcels of air originating above Mt. Spurr volcano at successive 3-hour intervals for specific altitudes (Murray and others, 1994). The explosive eruption that began at about 7 am generated a tephra plume to an estimated altitude of 14.5 km ASL (47,575 ft.). The plume was carried from Mt. Spurr to the north- northeast, as predicted by this forecast. FBX =Fairbanks, McG = McGrath, ANC = Anchorage, and CDV = Cordova.

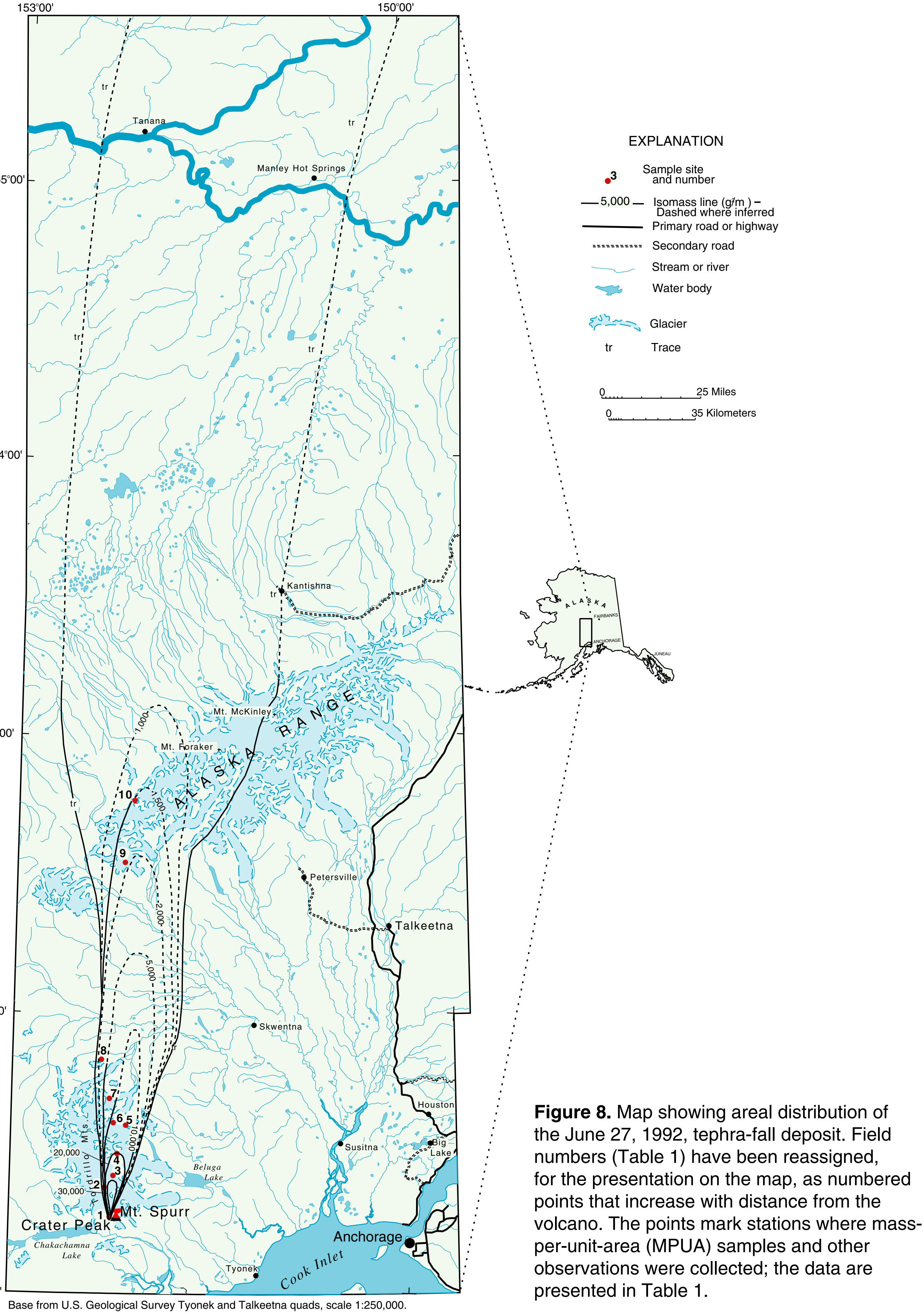


Figure 8. Map showing areal distribution of the June 27, 1992, tephra-fall deposit. Field numbers (Table 1) have been reassigned, for the presentation on the map, as numbered points that increase with distance from the volcano. The points mark stations where mass-per-unit-area (MPUA) samples and other observations were collected; the data are presented in Table 1.

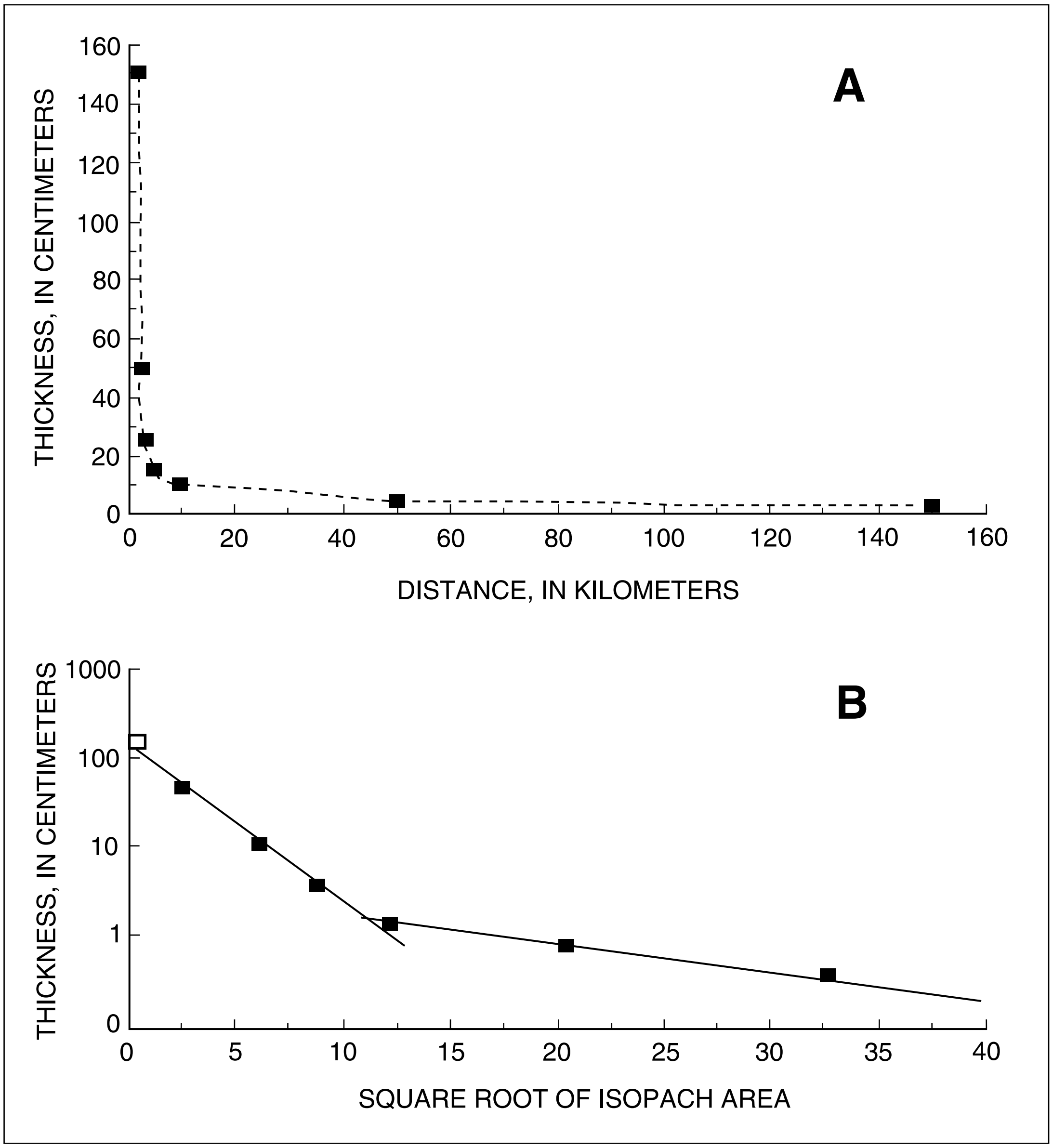


Figure 9. A. Decrease in thickness of June 27 tephra-fall deposit with distance to the north from Mt. Spurr as measured along the plume axis. B. Semi-logarithmic plot of tephra thickness versus the square root of isopach area, after Fierstein and Nathenson (1992). Graphs provided by J. Beget and T. Miller (written communication, 1992).

Figure 10. August 18, 1992, eruption column from Crater Peak vent on Mt. Spurr volcano taken from about 2.5 km to the southwest.

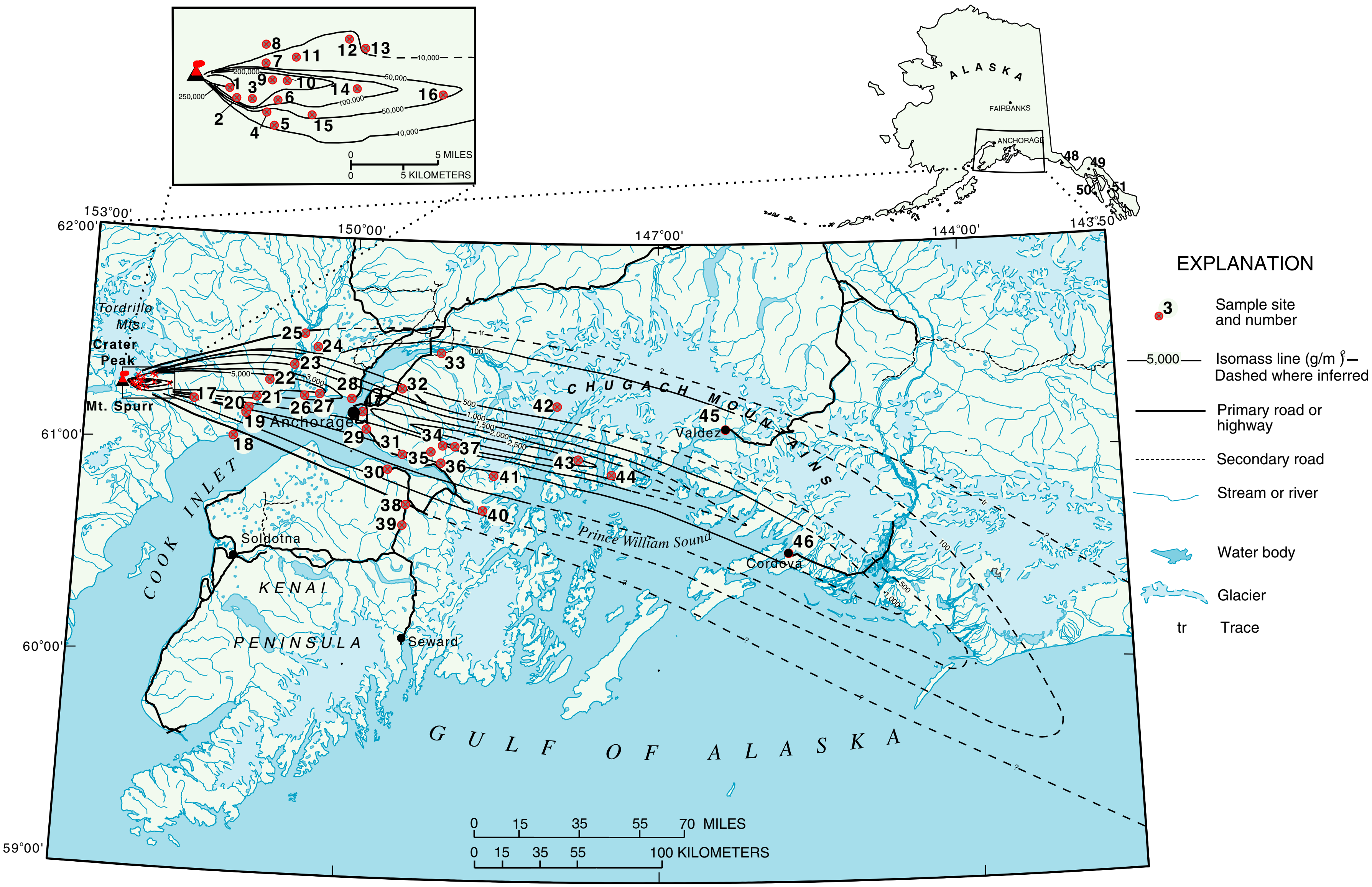
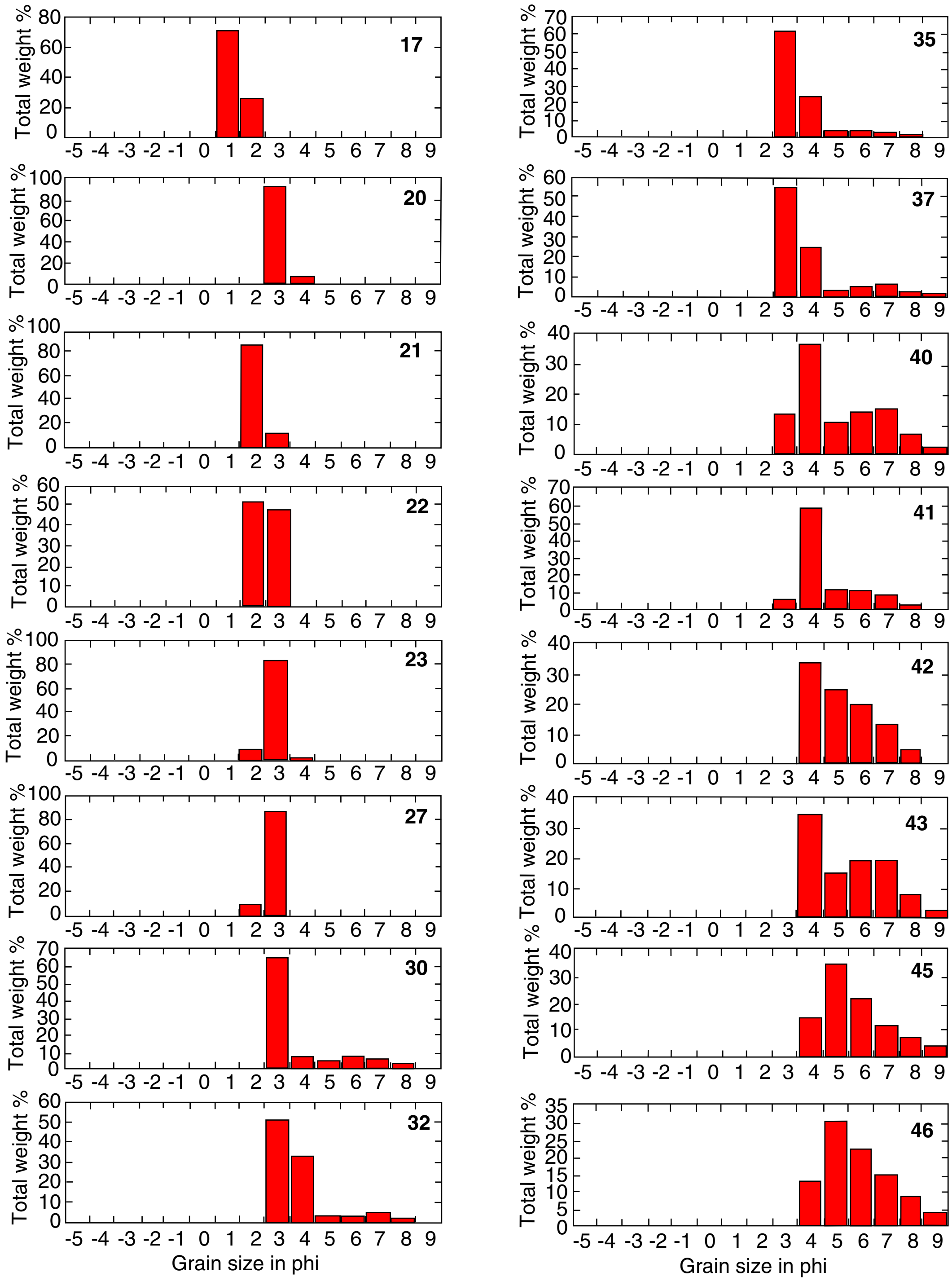


Figure 11. Map showing areal and mass distributions of August 18 tephra-fall deposit. Field numbers (Table 3) have been reassigned, for presentation on the map, as numbered points that increase with distance from the volcano. The points mark stations where mass-per-unit-area (MPUA) samples and other observations were collected; the data are presented in Table 3. Note the secondary MPUA maximum beginning 132 km from the vent and extending to 305 km downwind.



46 Map number

Conversion table

mm	phi
32	-5
16	-4
8	-3
4	-2
2	-1
1	0
0.5	1
0.25	2
0.125	3
0.063	4
0.03	5
0.015	6
0.0075	7
0.00375	8
0.001875	9

Figure 12. Grain-size plots for selected samples from the August, 1992, Mt. Spurr tephra-fall deposit. Plot numbers correspond to numbered points on Figure 11.

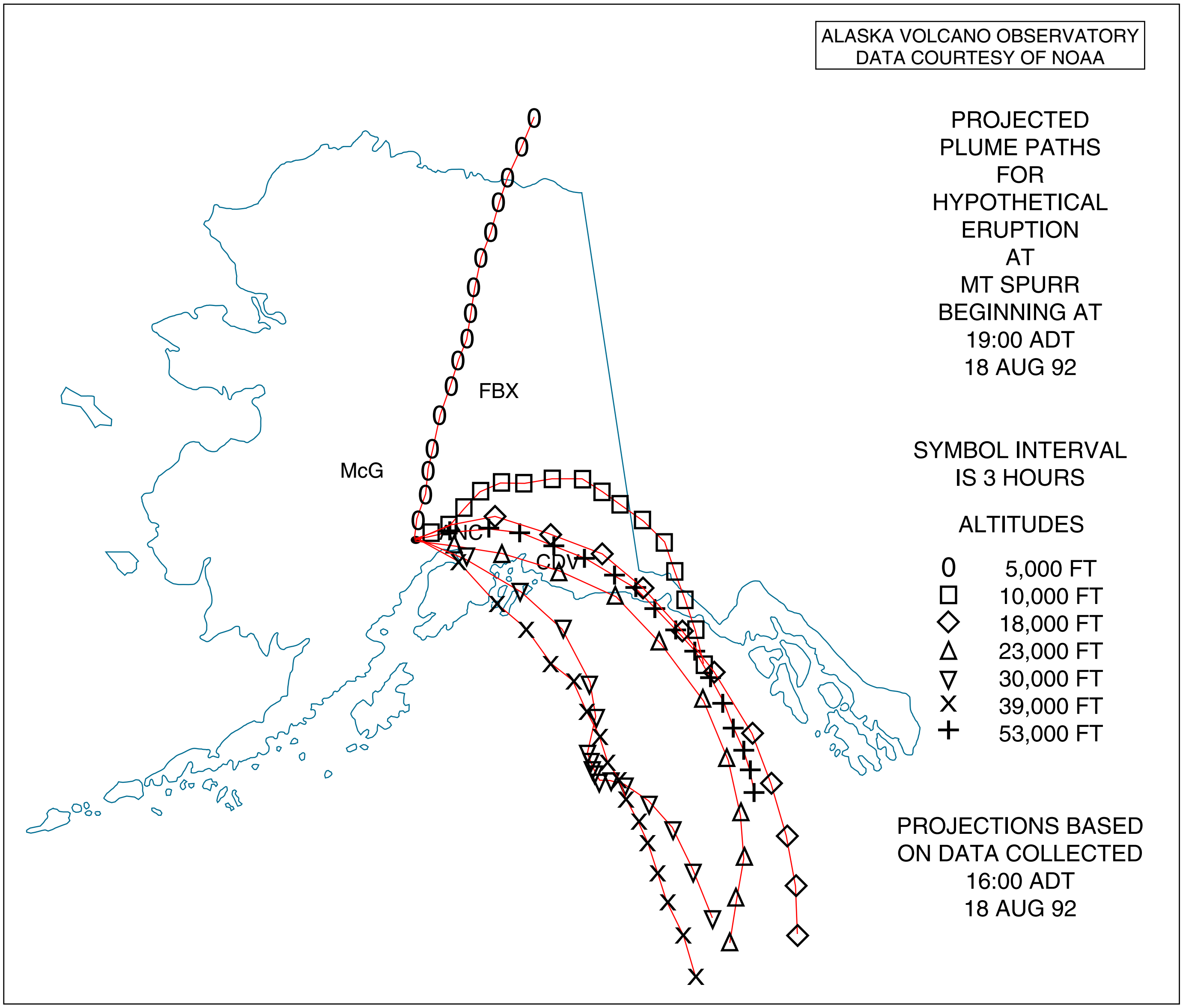


Figure 13. Plume trajectory forecast for 7:00 pm Alaska Daylight Time (ADT) on August 18, 1992. Symbols represent the location of parcels of air originating above Mt. Spurr volcano at successive 3-hour intervals for specific altitudes. The explosive eruption that began at about 4 pm generated a tephra plume to an estimated altitude of 13.7 km ASL (44,950 ft.). The plume was carried from Mt. Spurr to the southeast, as predicted by this forecast. FBX =Fairbanks, McG = McGrath, ANC = Anchorage, and CDV = Cordova.

Figure 14. Car in Anchorage covered with 3 mm of fine sand-sized ash from the August 18, 1992, eruption of Mt. Spurr.

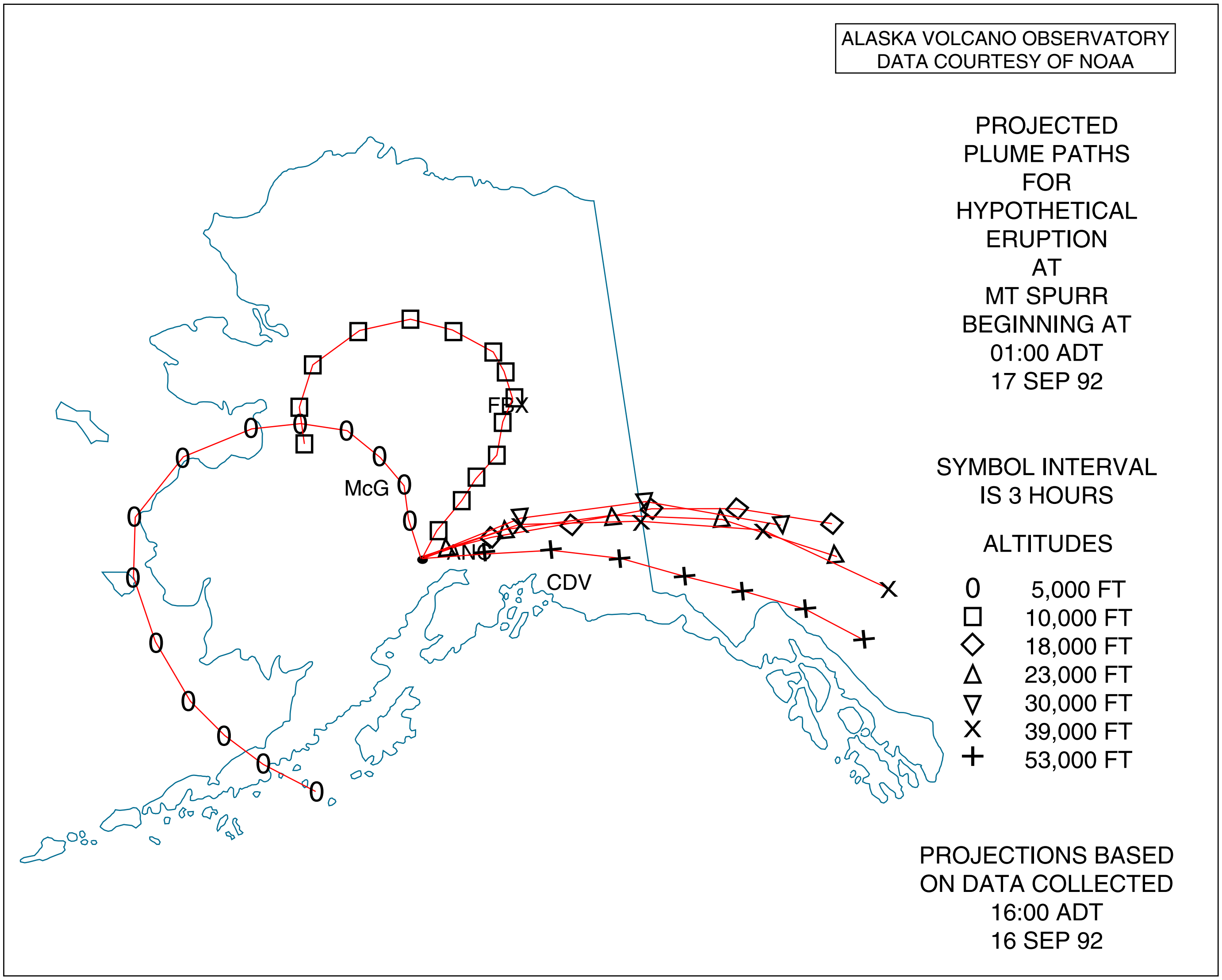


Figure 15. Plume trajectory forecast for 1:00 am Alaska Daylight Time (ADT) on September 17, 1992. Symbols represent the location of parcels of air originating above Mt. Spurr volcano at successive 3-hour intervals for specific altitudes. The explosive eruption that began at about midnight generated a tephra plume to an estimated altitude of 13.9 km ASL (45,600 ft.). The plume was carried from Mt. Spurr to the east, as predicted by this forecast. FBX =Fairbanks, McG = McGrath, ANC = Anchorage, and CDV = Cordova.

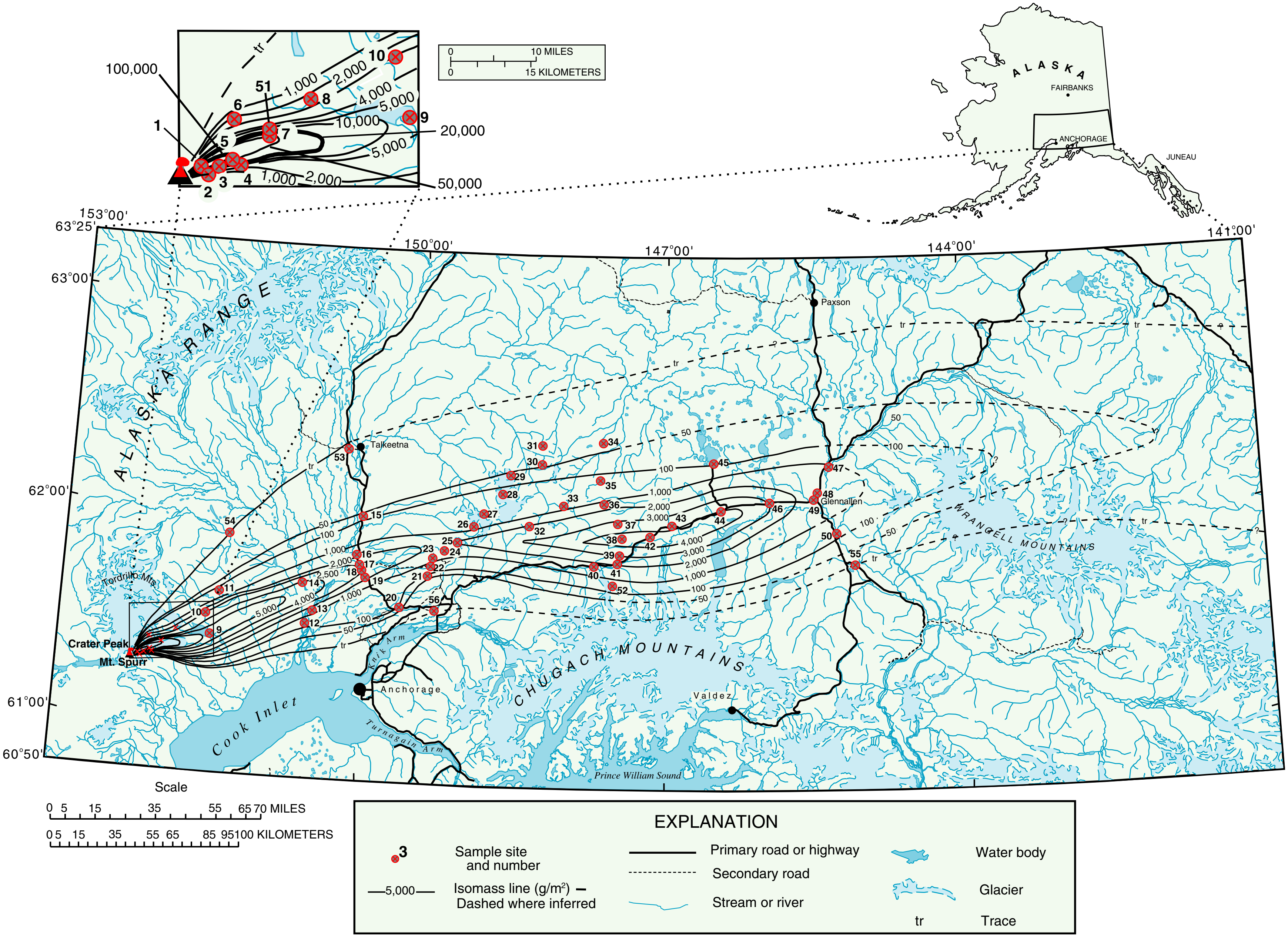
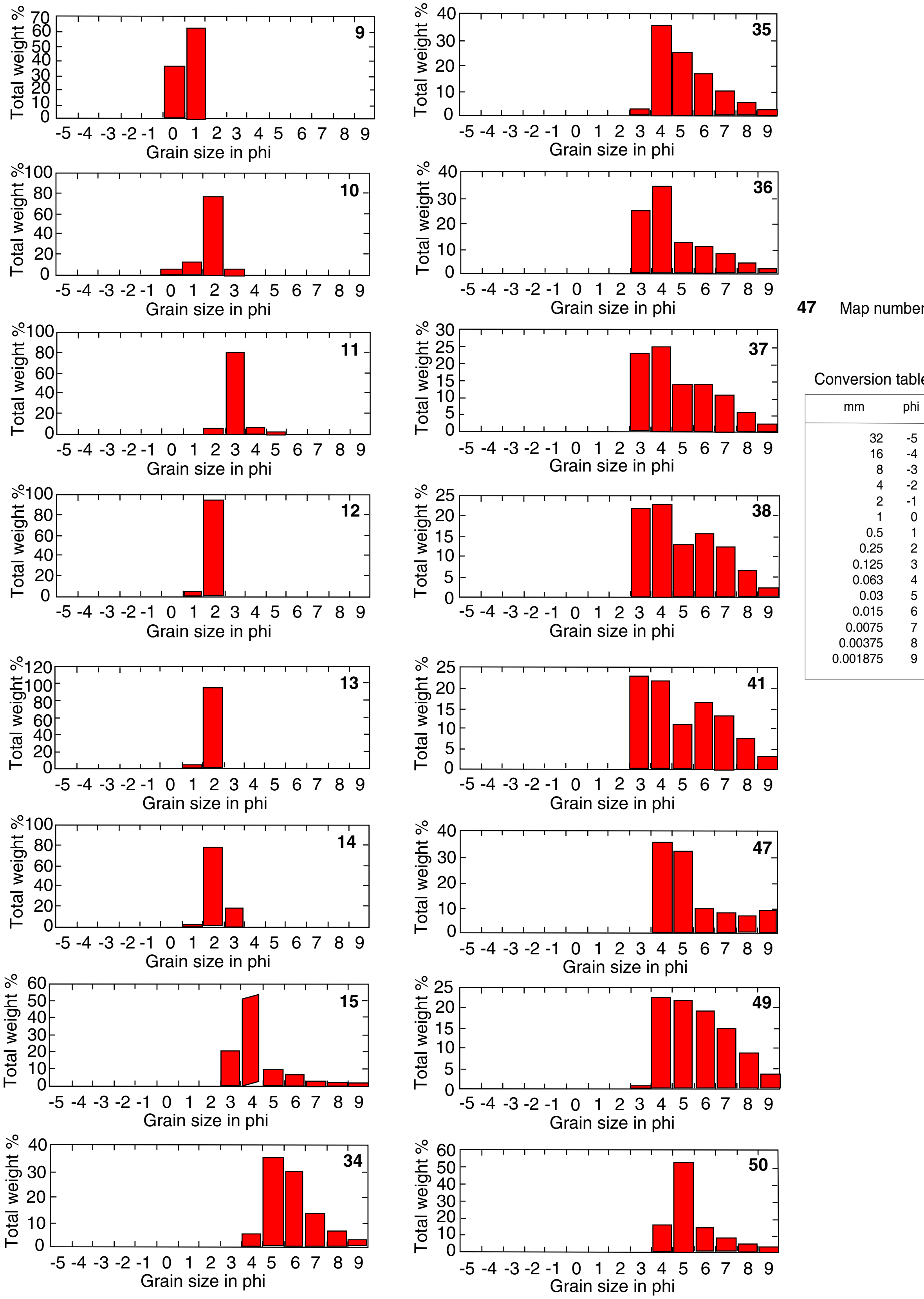


Figure 16. Map showing areal and mass distributions of September 16-17 tephra-fall deposit. Field numbers (Table 5) have been reassigned, for presentation on the map, as numbered points that increase with distance from the volcano. The points mark stations where mass-per-unit-area (MPUA) samples and other observations were collected; the data are presented in Table 5. Note the secondary MPUA maximum beginning 182 km from the vent and extending to 365 km down the deposit axis.



Conversion table

mm	phi
32	-5
16	-4
8	-3
4	-2
2	-1
1	0
0.5	1
0.25	2
0.125	3
0.063	4
0.03	5
0.015	6
0.0075	7
0.00375	8
0.001875	9

Figure 17. Grain-size plots for selected samples from the September Mt. Spurr tephra-fall deposit. Plot numbers correspond to numbered points on Figure 16.

Table 1. Mass-per-unit-area (MPUA) measurements of June 27, 1992, Mt. Spurr tephra. Numbered points correspond with tephra stations on Figure 8. *Area (m^2)* refers to the actual area of tephra collected in the field. Entries in the *g/m^2* column occur when multiple samples were collected at a particular station; the average is reported in the *g/m^2 ave.* column. Stations 1-8 were collected July 3, 1992, by T.P. Miller (U.S. Geological Survey) and J.E. Beget (University of Alaska—Fairbanks); tephra was on top of snowpack. Stations 9-10 were collected by McGimsey and Neal on September 22, 1993, from within old (1992) snow. Lack of data points between stations 8 and 9 and beyond stations 10 preclude determining whether or not a MPUA secondary maximum occurred.

Station#	Field#	Sample	Thickness (mm)	Area (m^2)	Mass (g)	g/m^2	g/m^2 ave.	Comments
1	J1	none	600					
2	J3	none	80					
3	J2	1	35-40	0.25	6930		27720	on snow
4	J4	1	20	0.25	4979		19916	on snow
5	J5	1	10	0.25	4246		16984	on snow
6	J6	1	15	1.0	13240		13240	on snow
7	J7	1	10	1.0	6968		6968	on snow
8	J8	1	5-7.5	1.0	4076		4076	on snow
9	Stop 1	1	5-7	0.0625	122.6	1962	1926	in corn snow, 1.9 m deep
		2	5-7	0.0625	118.1	1890		in corn snow, 1.9 m deep
10	Stop 3	3	3-4	0.0625	92.0	1472	1549	in corn snow, 85 cm deep
		5	3-4	0.0625	101.6	1626		in corn snow, 85 cm deep

Table 2. Latitude and longitude locations for measured-area samples of June 27, 1992 Mt. Spurr tephra, shown in Table 1 and on Figure 8. All sample points were digitized from 1:250,000-scale U.S. Geological Survey maps, UTM zone 6, using Arc/Info and a CalComp DrawingBoard III digitizing tablet. Map Latitude/Longitude corner points were used as tick marks. The maps were digitized in UTM NAD27 projection using the appropriate Zone number as indicated on the individual maps with an RMS error less than or equal to 0.005. Arc/Info point identities were recorded and assigned to the Sample identifier. Locations were assigned appropriate Northings and Eastings. To assign locations in decimal-degrees and degrees/minutes/seconds, the point coverage was projected to Geographic Coordinate System NAD27.

Station	Latitude (N)	Longitude (W)
1	61°16'22"	152°14'34"
2	61°25'26"	152°12'36"
3	61°22'45"	152°17'08"
4	61°30'03"	152°11'08"
5	61°36'10"	152°07'30"
6	61°36'44"	152°13'37"
7	61°42'02"	152°15'33"
8	61°50'15"	152°19'06"
9	62°32'32"	152°10'40"
10	62°46'03"	152°05'26"

Table 3. Measured-area samples of August 18, 1992, Mt. Spurr tephra. Numbered points correspond to tephra stations shown on Figure 11. Most samples collected by McGimsey and Neal between August 21 and September 9, 1992. *Area (m^2)* refers to the actual area of tephra collected in the field. Entries in the *g/m^2* column occur when multiple samples were collected at a particular station; the average, or best, is reported in the *g/m^2 ave.* column. Station #45-51 were collected by onsite observers and citizens at the request of AVO. Station #48-51 are distant data points and locations are shown on index map on Figure 11. NM indicates thickness was not measured or not measurable. Trace indicates ash present but not in sufficient quantity for collection as a measured-area sample.

Station#	Field#	Sample	Thickness (mm)	Area (m^2)	Mass (g)	g/m^2	g/m^2 ave.	Comments
1	35	1		0.0225	5792		257422	2300' level Kid Gl, btw cracks
2	34	none	100-200					uneven tephra distribution
3	26	1	110	0.01	2143		214300	5000' level on CRP ridge
4	27	1	40-50	0.04	1676		41900	3700' level on CRP ridge
5	28	none	30					lapilli
6	29	1	130	0.04	5820		145500	
7	21	1	30-40	0.0625	1946	31136	31024	
		2	30-40	0.0625	1932	30912		
8	31	1	10	0.0625	24		384	diffused in granular snow
9	30	1	160	0.04	8768		219200	
10	32	1	160	0.04	8569		214225	2600' level Straight Glacier
11	22	1	38	0.0625	1110		17760	
12	11	1	20	0.04	642	16050	15525	Capps Gl, opposite bend
		2	20	0.04	600	15000		Capps Gl, opposite bend
13	10	1	2-4	0.0225	89.5	3978		excluded from average
		2	4-5	0.0225	166	7377	7888	top of rock, Capps Gl
		3	6-8	0.0225	189	8400		top of rock, Capps Gl
14	36	1	90	0.04	4913	122825	122462	2300', east of CRP ridge
		2	90	0.04	4884	122100		
15	33	1	70-80	0.04	2882		72050	1600' level Straight Gl
16	37	1	45	0.04	2215	55375	54662	south of Capps Gl
		2	45	0.04	2158	53950		
17	9	none	2					Chuit Cr; no surface to sample
18	8	none	no ash					foreland equipment yard
19	7	none	light					discontinuous, redistributed
20	6	1	<1	0.0625	66.3	1061	1104	Beluga salvage yard
		2	<1	0.0625	71.7	1147		
21	5	1	1.5-2	0.0625	192	3072	3311	cabin, Beluga River
		2	1.5-2	0.04	142	3550		
22	4	1	1.5-2	0.0625	350	5600	5528	wellhead construction site
		2	1.5-2	0.0625	341	5456		
23	3	1	1-2	0.04	58.9		1473	boat deck, Alexander Cr.
24	1	none	trace					near Flathorn Lk
25	2	none	trace					Hanson's on the Susitna R.
26	12	1	2-4	0.0225	75.6		3360	from wooden dock at duck shed
27	13	1	3	0.0625	312		4992	porch of cabin, possibly reworked
28	14	1	2	0.0625	168		2688	Pt. MacKenzie; wood surface

Table 3. Continued.

Station#	Field#	Sample	Thickness (mm)	Area (m^2)	Mass (g)	g/m^2	g/m^2 ave.	Comments
29	52	1	NM	0.0532	64.7		1216	South Anch., D. Meyer's house
30	47	1	NM	0.04	13.2	330	352	Hope, B.J.W. Giftshop
		2	NM	0.04	3.5	88		Hope School (bad sample?)
		3	1	0.04	14.9	373		Hope, car hood
31	51	1	NM	0.0625	60.6		970	Indian Road, 1/3 mi up
32	38	1	NM	0.0543	31.6		582	Eagle River, McGimsey's house
33	39	1	NM	0.01	2.02		202	Eklutna Fish Hatchery
34	50	1	1.5	0.04	26.5	662	1423	Crow Creek Mine, picnic table
		2	1.5	0.04	56.9	1423		picnic table; best of the two
35	15	1	NM	0.0625	77.6		1242	redistributed?
36	48	1	1	0.0625	65		1040	Alyeska, metal surface
37	16	1	NM	0.0625	125		2000	in snow, good sample
38	54	none	trace				0	7.5 mi N of Lower Summit Lake
39	53	none	0				0	Lower Summit Lake
40	20	1	NM	1.0	473	473	455	Whittier Gl., south of Whittier
		2	NM	0.0625	26.8	429		
		3	NM	0.25	116	464		
41	17	1	NM	0.0625	28.3	453	556	fell on irregular surface
		2	NM	0.0625	41.1	658		fell on irregular surface
42	18	1	NM	0.0625	23.2		372	Barry Gl., under 23 cm snow
43	19	1	NM	0.0625	164		2620	Amherst/Crescent Glaciers
44	57	1	NM	0.3045	670		2200	B. Ashton, Wells Bay
45	46	1	NM	0.1055	22.2		211	Valdez
46	42	1	NM	0.3716	496		1336	Cordova
47	49	1	2-3	0.04	77.5		1938	picnic table
	WRD	2	NM	0.032	55.8		1740	WRD office rain gauge
48		1	NM	0.07611	0.02	0.263	0.592	Yakutat, 720 km from Spurr
		2	NM	0.07611	0.02	0.920		
49		1	trace					Haines, 960 km from Spurr
50		1	NM	0.28106	0.02		0.071	Sitka, 1075 km from Spurr
51		1	trace					Petersburg, 1210 km from Spurr

Table 4. Latitude and longitude locations for measured-area samples of August 18, 1992 Mt. Spurr tephra shown in Table 3 and on Figure 11. All sample points were digitized from 1:250,000-scale U.S. Geological Survey maps, UTM zone 6, using Arc/Info and a CalComp DrawingBoard III digitizing tablet. Map Latitude/Longitude corner points were used as tick marks. The maps were digitized in UTM NAD27 projection using the appropriate Zone number as indicated on the individual maps with an RMS error less than or equal to 0.005. Arc/Info point identities were recorded and assigned to the Sample identifier. Locations were assigned appropriate Northings and Eastings. To assign locations in decimal-degrees and degrees/minutes/seconds, the point coverage was projected to Geographic Coordinate System NAD27.

Station	Latitude (N)	Longitude (W)	Station	Latitude (N)	Longitude (W)
1	61°15'55"	152°11'03"	30	60°55'21"	149°38'32"
2	61°15'25"	152°10'15"	31	60°59'45"	149°30'05"
3	61°15'21"	152°08'38"	32	61°18'15"	149°31'20"
4	61°14'50"	152°07'02"	33	61°28'21"	149°09'39"
5	61°14'14"	152°06'16"	34	61°02'37"	149°06'46"
6	61°15'26"	152°06'03"	35	61°00'44"	149°13'33"
7	61°17'08"	152°07'29"	36	60°57'35"	149°07'16"
8	61°18'02"	152°07'46"	37	61°02'22"	148°59'34"
9	61°16'23"	152°06'41"	38	60°45'42"	149°27'11"
10	61°16'24"	152°05'07"	39	60°39'50"	149°28'46"
11	61°17'33"	152°04'26"	40	60°44'37"	148°42'10"
12	61°18'34"	151°59'09"	41	60°54'19"	148°36'09"
13	61°18'14"	151°57'20"	42	61°14'11"	147°59'35"
14	61°16'15"	151°57'56"	43	60°59'14"	147°47'50"
15	61°14'46"	152°02'24"	44	60°54'57"	147°27'42"
16	61°16'18"	151°49'09"	45	61°07'43"	146°20'37"
17	61°13'15"	151°34'43"	46	60°32'45"	145°44'52"
18	61°02'58"	151°09'39"	47	61°11'50"	149°50'41"
19	61°10'03"	151°02'21"	48	59°33'	139°44'
20	61°10'46"	151°01'46"	49	59°14'	135°27'
21	61°14'20"	150°56'51"	50	57°03'	135°20'
22	61°19'19"	150°49'49"	51	56°49'	132°57'
23	61°23'52"	150°35'60"			
24	61°29'13"	150°22'34"			
25	61°32'39"	150°30'18"			
26	61°15'22"	150°28'57"			
27	61°16'06"	150°20'14"			
28	61°14'59"	150°01'03"			
29	61°06'35"	149°51'54"			

Table 5. Mass-per-unit-area measurements of September 16-17, 1992, Mt. Spurr tephra. Numbered points correspond to tephra stations shown in Figure16. Most samples collected by authors McGimsey and Neal as well as C.A. Gardner and T.E.C. Keith (U.S. Geological Survey), from September 17 to October 5, 1992. *Area (m^2)* refers to the actual area of tephra collected in the field. Entries in the *g/m²* column occur when multiple samples were collected at a particular station; the average, or best, is reported in the *g/m² ave.* column. NM indicates thickness was not measured or not measurable.

Station#	Field#	Sample	Thickness (mm)	Area (m^2)	Mass (g)	g/m^2	g/m^2 ave.	Comments
1	53N	1	100-200	0.04	5366		134150	7750' btw Straight and Kid Gl.
2	54N	1	NM	0.0625	12.31	197	162	at seis. sta. CRP, 5540'
		2	NM	0.0625	7.94	127		diffuse ash and snow for both
3	56N	1	50-110	0.04	2569		64225	4100' E side Straight Ck. Gl.
4	25	1	NM	0.25	3368		13472	lap. to sm. bombs in 4-6" snow
5	55N	1	70-130	0.04	3271		81775	5800' btw Capps and Strai. Gl.
6	26	1	0.5	0.0625	150.3		2405	in snow
7	52N	1	40-60	0.0625	2809	44944	44944	
		2	40-60	0.04	1553	38825	[excluded]	incomplete sample collection
8	50N	1	1-2	0.0625	135.1	2162	2128	740' level of Triumvirate Gl.
		2	1-2	0.0625	130.8	2093		
9	22	1	10	0.01	77.01		7701	on tree stump; cg, well sorted
10	23	1	1-1.5	0.0625	152.9	2446	2570	flat wooden surface
		2	1-1.5	0.0625	168.4	2694		wooden dock
11	24	1	<1	0.01	3.05		305	metal surface
12	21	1	NM	0.0625	11.51		184	poor distribution on surface
13	20	1	1	0.04	55.72	1393	1620	plywood surface
		2	1	0.04	73.84	1846		outdoor shower stall floor board
14	19	1	3	0.04	169.8	4245	4246	wooden porch step
		2	3	0.04	169.9	4248		outhouse roof
15	5	1	NM	0.03375	2.05		61	picnic table; raining
16	6	1	1.5	0.0625	119.6		1914	from racecar hood
17	4	1	2.5	0.03375	82.28		2438	picnic table
18	3	1	2.5	0.06	150.1		2502	lumber pile
19	2	1	2.5	0.0625	131.1		2098	wooden step
20	1	1	NM	0.028	2.39	85	90	picnic table
		2	NM	0.028	2.62	94		picnic table
21	29	1	NM	0.0625	3.86		62	near base of snow
22	30	1	NM	0.0625	10.95		175	near base of snow
23	31	1	NM	0.0625	85.93	1375	1340	in snow
		2	NM	0.0625	81.58	1305		in snow
24	32	1	NM	0.0625	78.22	1252	1280	in snow
		2	NM	0.25	326.8	1307		in snow
25	33	1	2.5	0.25	505.2		2021	frozen at base of snowpack
26	34	1	<1	0.25	212.3		849	in snow
27	35	1	NM	0.25	158.9	636	636	
		2	NM	0.25	43.79	175	[excluded]	probable redistribution

Table 5. Continued.

Station#	Field#	Sample	Thickness (mm)	Area (m^2)	Mass (g)	g/m^2	g/m^2 ave.	Comments
28	36	1	NM	0.25	44.29		177	in snow
29	39	none						obvious redistribution
30	37	1	NM	0.25	11.79		47	in snow
31	38	1	NM	0.25	5.45		22	in snow
32	49	1	2	0.25	542.2		2169	in snow
33	48	1	2	0.25	196.0	784	802	in snow
		2	2	0.25	204.9	820		
34	47	1	<0.5	0.25	8.95		36	in snow
35	46	1	0.5-1	0.25	33.15		133	in snow
36	45	1	1	0.25	314.1		1257	in snow
37	44	1	4-5	0.25	795.2		3181	in snow
38	43	1	6-7	0.0625	274.2	4387	4387	in snow
39	42	1	NM	0.25	750.5		3002	frozen in snow
40	7	1	1	0.04	69.08		1727	on plywood cover
41	8	1	1.5	0.04	101.8	2545	2484	in snow
		2	1.5	0.04	96.94	2424		in snow
42	9	1	3-4	0.04	147.8	3695	4660	from flatbed truck
		2	3-4	0.04	225.0	5625		in old snow
43	10	1	3	0.0225	51.87	2305	[excluded]	concrete bridge curb
		2	3	0.0225	78.99	3511	3486	picnic table
		3	3	0.0225	77.89	3462		picnic table
44	11	1	3	0.0225	91.98		4088	wooden trailer bed
45	12	1	<1	0.04	3.58	90	89	picnic table
		2	<1	0.04	3.5	88		picnic table
46	13	1	2	0.0225	65.15		2896	picnic table
47	16	1	NM	0.04	51.06	1277	1288	lumber
		2	NM	0.01	13.0	1300		lumber
48	15	1	NM	0.0225	28.2		1253	picnic table
49	14	1	0.5	0.0225	36.12	1605	1533	metal surface
		2	NM	0.0645	94.25	1461		collected on paper during fall
50	17	1	NM	0.01	1.8	180	[excluded]	wooden step
		2	NM	0.0225	5.04	224	224	dumpster lid (better sample)
51	51N	1	1-3	0.0081	29.02	3583	[excluded]	base frozen, not collected
		2	1-3	0.01	56.47	5647	5647	better sample
52	41	1	NM	0.25	102.2		409	from snow on ridge
53	53T	1	NM	0.076	0.97		13	collected on paper during fall
54	54S	none	<0.5					observed but not collected
55	55S	none						no ashfall observed
56	56	none	NM					light dusting

Table 6. Latitude and longitude locations for measured-area samples of September 16-17, 1992 Mt. Spurr tephra shown in Table 5 and on Figure 16. All sample points were digitized from 1:250,000-scale U.S. Geological Survey maps, UTM zone 6, using Arc/Info and a CalComp DrawingBoard III digitizing tablet. Map Latitude/Longitude corner points were used as tick marks. The maps were digitized in UTM NAD27 projection using the appropriate Zone number as indicated on the individual maps with an RMS error less than or equal to 0.005. Arc/Info point identities were recorded and assigned to the Sample identifier. Locations were assigned appropriate Northings and Eastings. To assign locations in decimal-degrees and degrees/minutes/seconds, the point coverage was projected to Geographic Coordinate System NAD27.

Station	Latitude (N)	Longitude (W)	Station	Latitude (N)	Longitude (W)
1	61°17'05"	152°11'28"	30	62°16'12"	148°16'12"
2	61°16'22"	152°10'04"	31	62°21'31"	148°15'48"
3	61°17'32"	152°04'23"	32	61°58'44"	148°22'38"
4	61°17'42"	152°03'15"	33	62°04'52"	148°02'24"
5	61°18'23"	152°04'32"	34	62°22'52"	147°39'08"
6	61°22'05"	152°05'33"	35	62°12'22"	147°40'27"
7	61°20'46"	151°58'05"	36	62°05'17"	147°37'28"
8	61°24'34"	151°50'12"	37	62°00'01"	147°29'25"
9	61°23'39"	151°29'33"	38	61°55'24"	147°26'54"
10	61°29'41"	151°32'53"	39	61°50'57"	147°27'52"
11	61°35'58"	151°26'21"	40	61°47'50"	147°43'18"
12	61°28'40"	150°34'21"	41	61°48'51"	147°29'37"
13	61°32'29"	150°30'23"	42	61°56'21"	147°10'17"
14	61°40'03"	150°37'04"	43	61°59'32"	146°56'41"
15	61°59'44"	150°02'38"	44	62°03'38"	146°27'11"
16	61°48'40"	150°05'29"	45	62°17'05"	146°32'11"
17	61°46'06"	150°03'57"	46	62°06'03"	145°57'36"
18	61°44'27"	150°02'29"	47	62°16'07"	145°22'02"
19	61°42'22"	149°59'45"	48	62°08'46"	145°28'46"
20	61°34'32"	149°39'20"	49	62°06'32"	145°31'28"
21	61°43'40"	149°22'30"	50	61°57'14"	145°17'31"
22	61°46'30"	149°20'53"	51	61°22'45"	151°58'36"
23	61°48'54"	149°19'45"	52	61°42'50"	147°30'24"
24	61°50'42"	149°12'38"	53	62°21'02"	150°38'34"
25	61°53'25"	149°05'23"	54	61°57'37"	151°09'58"
26	61°58'01"	148°56'41"	55	61°48'19"	145°05'19"
27	62°01'50"	148°50'04"	56	61°34'04"	149°17'56"
28	62°07'30"	148°39'15"			
29	62°13'09"	148°34'47"			

Table 7. Summary of mass, dense-rock volume, and bulk volume of tephra-fall deposits of the June 27, August 18, and September 16-17, 1992, eruptions of Mt. Spurr volcano.

	June	August	September	Total
Mass (kg)	[1]31 x 10^9	36 x 10^9	39 x 10^9	106 x 10^9
[2]Dense-rock volume (km^3)	0.012	0.014	0.015	0.041
[3]Bulk volume (km^3)	0.044	0.052	0.056	0.152

[1]June mass calculated from bulk volume using d=0.7 g/cm^3
[2]Calculated using d=2.6 g/cm^3
[3]Calculated using d=0.7 g/cm^3