Use of Volcanic Glass from Ash as a Monitoring Tool: An Example from the 1992 Eruptions of Crater Peak, Mount Spurr Volcano, Alaska

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ABSTRACT

Compositions of volcanic glass from ash ejected during the 1992 eruptions of the Crater Peak vent of Mount Spurr are dominantly andesitic (SiO_2 of 61–62 weight percent), but they include much smaller amounts of dacitic (SiO_2 of 63–69 weight percent) and rhyolitic (SiO_2 of 74–77 weight percent) glass. In each eruption (June, August, and September), glass in the ash and matrix glass in rocks from proximal deposits show similar chemical trends.

The rhyolitic glass component was first recognized in the ash from the June 27, 1992, eruption of Crater Peak. Subsequent work on proximal samples resulted in the identification of rhyolitic glasses in the matrices of juvenile volcanic blocks and in partially melted metamorphic xenoliths (buchites). Reexamination of prehistoric tephra materials from Crater Peak reveals a similar rhyolitic component; this discovery suggests that generation of minor amounts of silica-rich melt is common at Crater Peak. Rapid analysis of volcanic glass in ash from the 1992 Crater Peak eruptions proved a useful monitor of the chemistry of the erupting magma.

INTRODUCTION

Volcanic ash is a common component of eruptions of andesitic magmas. The ash can be hazardous, especially to aircraft and other air-filtering cultural activities (Swanson and Kienle, 1988; Casadevall, 1992). Volcanic ash is fine-grained material that enters the air during an eruption. Ash may be injected into the atmosphere directly as part of the explosive phase of the eruption or as an elutriating cloud from advancing pyroclastic flows or avalanches. Materials in the ash are typically glass (quenched melt) as well as mineral and rock fragments. The mineral and rock fragments may be juvenile magmatic material or part of the vent fill, crater, or conduit walls that were entrained during eruption.

Petrologists have been reluctant to monitor the petrologic evolution of volcanic systems using ash because of the potential for mechanical sorting during ash transportation and deposition (Steen-McIntyre, 1977). Another problem is the heterogeneity of ash; it may contain various proportions of rock fragments, mineral grains, and volcanic glass, any of which can be accidental or comagmatic. Even so, ash can be easily sampled and can provide samples of erupted material before proximal materials can be sampled. Volcanic ash can also reveal something about the nature of the ongoing eruption (that is, whether or not new magma is involved, Swanson and others, 1991). Bulk compositions of volcanic ash are subject to sorting or contamination, however, compositions of individual phases within the ash may provide important clues about an erupting magmatic system, especially if one can demonstrate that the phase is clearly a juvenile magmatic product.

The glass phase (quenched melt) in the ash is a sensitive monitor of the magmatic conditions during an eruption (Swanson and others, 1991). Most, if not all, the glass in andesitic ash represents the fractionated melt after crystallization of some mineral phases. Accordingly, the composition of the melt is controlled by the mineralogy and proportion of the crystallizing phases, which, in turn, are controlled by magmatic conditions (for example, temperature, pressure, water content, and oxygen fugacity). Using the morphology of glass particles (delicate, vesicular, often shard-like), it is relatively easy to identify juvenile material in the ash. Small differences in glass compositions produced by different fractionating mineral assemblages can quickly and routinely be measured using an electron microprobe. Glass compositions from different eruptions will be different depending on the fractionation process, and there may even be changes in glass compositions during an eruption. This lesson was learned from numerous tephra studies of individual eruptions (Mount St. Helens, Scheidegger and Federman, 1982; Pinatubo, Pallister and others, 1992; 1912 Novarupta, Federman and Scheidegger, 1984, Avery, 1992; Redoubt Volcano 1989–90 eruption, Swanson and others, 1994).

Volcanic glass is generally enriched in incompatible components with respect to the bulk-rock composition (see Swanson and others, 1994). Thus it is common for andesite to have a matrix glass with a rhyolitic composition produced by crystallization of plagioclase, pyroxenes, FeTi oxides, and perhaps hornblende from the bulk magma.

If glass in volcanic ash is used to monitor magmatic systems during volcanic eruptions, then it must be established that changes in the magmatic system are clearly reflected in the glass chemistry in a timely fashion. During the 1989–90 eruptions of Redoubt Volcano, there was a change from bimodal dacite-rhyolite matrix glass early in the eruption to solely rhyolite matrix glass (Swanson and others, 1994). This change in matrix glass compositions (determined from blocks and pumice bombs) was perfectly mimicked by the glass in the volcanic ash (Swanson and others, 1991).

Questions about the nature of the erupting material and what that means in terms of eruption phenomena are some of the first questions asked during the early stages of a volcanic eruption (Sarna-Wojcicki and others, 1981). Recognition of juvenile magmatic material (typically represented by glass) in an eruption can result in an upgrading of the hazard assessment for that event (Fiske, 1984). Some workers (Sparks and others, 1977; Gourgaud and others, 1989; Pallister and others, 1992) think that magma mixing is an important triggering process in some eruptions.

Thus, the timely recognition of mixed magma during an eruption may indicate a higher hazard level than for single-magma eruptions.

Volcanic ash provides an ideal material for monitoring magmatic changes during an eruption. Glass compositions in the Redoubt ashes (measured after the eruption) reflected changes in the magmatic system. This observation prompted us to consider using volcanic ash glass compositions as a way of monitoring magmatic changes during a protracted volcanic eruption (Swanson and others, 1991). We developed techniques for rapid sample preparation and analysis of glass from volcanic ash. The eruption of Crater Peak in 1992 provided the opportunity to test our technique of monitoring an ongoing volcanic eruption using glass from volcanic ash.

1992 ERUPTIONS OF CRATER PEAK

Crater Peak, a vent on the flank of Mount Spurr volcano, erupted three times during the summer and fall of 1992 (Eichelberger and others, this volume). The eruptions were from the same vent that last erupted in 1953 (Juhle and Coulter, 1955). Each of the eruptions was similar to the 1953 event: a moderate subplinian eruption that lasted for several hours and then stopped. Each of the eruptions was accompanied by a large ash cloud that was carried upward from 6 to 15 km and was then dispersed to the north and east by prevailing winds (Neal and others, this volume). Pyroclastic flows accompanied the eruptions in August and September, and ash was produced from these flows (Miller and others, this volume).

ERUPTION OF JUNE 27,1992

Ash from the June 27 eruption came from an erupting column with a maximum height estimated by radar to be 14.5 km (Rose and others, this volume). Prevailing winds carried the ash north over Mount McKinley, just west of Fairbanks, and over the Yukon River just downstream from Fort Yukon on June 27 (Neal and others, this volume).

The ash provided the first material from the June 27 eruption for analysis. Samples of the ash were obtained from near the volcano and from distal sites (200 to 450 km north of Mount Spurr) in the Mount McKinley area, Lake Minchumina, and Manley Hot Springs. All of the ash samples are similar. Maximum grain size of the ash is about 0.4 mm within 50 km of the volcano and 0.11 to 0.13 mm in the distal samples from beyond Mount McKinley. Most of the ash is composed of dark-brown to black porphyritic volcanic rock

fragments. The rock fragments contain micrphenocrysts set in a groundmass of brown glass with abundant microlites. Isolated phenocryst fragments are also found in the ash. Plagioclase is the most common phenocryst phase, but small amounts of augite, hypersthene, hornblende, and FeTi oxides are also present in the ash and in the volcanic rock fragments. The hornblende is pleochroic from green to brown. Colorless, microlite-free blocky or microvesicular fragments of glass are rare (much less than 1 percent).

At first, shortly after the eruption, it was not clear whether juvenile magmatic material had been erupted. However, the presence of delicate shards of colorless glass (fig. 1) that could not have survived "recycling" in this eruption confirmed the presence of at least some juvenile material in the eruptive products. Subsequent geochemical work (Nye and others, this volume) shows the eruptive products are compositionally distinct from other recent Mount Spurr lavas.

The June ash is a fine-grained version of the blocks deposited near the volcano both in terms of mineralogic composition and relative abundance. Most of the proximal lapilli and blocks deposited on June 27 consist of black, vesicular andesite, but rare (much less than 1 percent) white to light-gray compositionally banded pumice lapilli are also present (Harbin and others, this volume). The dark andesite contains phenocrysts set in a matrix of brown glass with abundant microlites, whereas the light-colored pumice lapilli contain phenocrysts in a matrix of colorless, microlite-free glass. Details of the petrography are given in Harbin and others (this volume). Nye and others (this volume) discuss the bulk geochemistry of the pumice and andesite.

ERUPTION OF AUGUST 18, 1992

Strong explosive eruptions carried ash to altitudes of 15 km during the eruption of Crater Peak on August 18, 1992. Winds carried the ash east, directly over Anchorage (Neal and others, this volume) and then to the south and east over southeastern Alaska.

With the fall of ash on Anchorage, collection of ash samples was easy. One suite of samples (AVO-PAT) was collected over timed intervals (about 30 to 60 minutes) as the ash fell on the patio of the Alaska Volcano Observatory at Gould Hall, 124 km downwind from the volcano. Most of the ash fell during a period of about 3 hours.

Initial maximum grain size of the ash at Anchorage was about 0.5 mm in diameter, and it decreased to about 0.3 mm by the end of the ash fall. The color of the ash also changed from a light yellowish-brown to a darker gray-brown by the end of the eruption. The lighter color appears to be partly the result of light-gray, fine-grained ash that coats the darker, larger fragments and partly the result of a difference in vesicularity.

The ash consists of dense, dark volcanic rock fragments with phenocrysts of plagioclase, pyroxene, hornblende, and FeTi oxides in a matrix of brown glass rich in microlites. Fragments of these same phenocrysts are also found in the ash. The amount of plagioclase crystal fragments is greatest followed by pyroxene, hornblende, and FeTi oxides. These observations are based on visual estimates. About 1 percent of the ash is composed of microvesicular or blocky fragments of colorless microlite-free glass. There is no apparent variation in the proportions of these phases within the suite of ash samples collected during the 3-hour ashfall.

The August 18 ash is virtually identical to the ash from the June eruption and the variation in the ash also mimics the variation in the bombs and blocks deposited near the volcano. Black, breadcrusted bombs of andesite and lighter vesicular greenish-gray andesite blocks are the most common component in the lahar and pyroclastic-flow deposits (Miller and others, this volume) from the August eruption. This black andesite corresponds to the dark volcanic rock fragments in the ash, but the vesicular greenish-gray andesite does not have an obvious counterpart in the ash. Details of andesite petrography are given by Harbin and others (this volume), and Nye and others (this volume) discuss the bulk composition of the andesite.

Figure 1. Secondary electron image of a rhyolitic glass shard from ash of the June 27, 1992, eruption of Crater Peak taken with an electron microprobe at the University of Alaska, Fairbanks by Michelle Harbin. White scale bar is 20 μm.

Table 1. Composition of glass from volcanic ash and pumice lapilli erupted on June 27, 1992, from Crater Peak vent, Mount Spurr volcano, Alaska.

[*, total Fe as FeO; number of points analyzed in parentheses below sample number]

	Volcanic ash				Pumice lapilli			
Sample no.	SS-2 (13)	SS-2 (1)	JB-4A (9)	JB4B1 (6)	JB-4B2 (21)	JB-4B2 (15)	JB-4B3 (14)	JB-4B3 (19)
glass color	brown	colorless	colorless	colorless	colorless	light brown	colorless	brown
SiO_2	60.51±0.93	76.60	74.28±1.26	75.66±1.37	71.59±1.23	67.41±1.45	75.87±1.37	61.00±0.80
TiO_2	.60±0.25	0.37	0.40±0.18	0.19±0.13	0.33±0.13	0.44±0.12	0.22±0.14	0.62±0.14
Al_2O_3	17.22±1.00	12.60	13.40±0.95	12.16±0.87	14.41±0.48	15.06±0.55	12.45±1.47	16.97±0.69
FeO*	6.46±0.89	1.11	2.31±0.30	1.24±0.11	2.60±0.42	4.28±0.52	0.85±0.25	6.23±0.71
MgO	2.34±0.85	0.24	0.50±0.08	0.15±0.03	0.55±0.08	1.04±0.16	0.18±0.15	2.56±0.48
CaO	5.45±0.61	0.37	1.01±0.25	0.66±0.12	1.28±0.38	3.02±0.38	0.79±0.15	5.85±0.31
Na_2O	4.35±0.34	3.54	2.56±0.14	0.80±0.36	3.27±0.31	3.72±0.52	0.42±0.13	4.36±0.44
K_2O	1.36±0.10	4.99	4.40±0.14	6.83±0.40	3.99±0.30	2.67±0.16	7.06±0.33	1.43±0.45
Cl	0.21±0.04	0.17	0.02±0.01	0.04±0.02	0.03±0.03	0.15±0.04	0.11±0.03	0.21±0.03
total	98.50	99.98	98.88	98.74	98.05	97.79	97.97	98.74

Buchites, partially melted blocks of metamorphic rocks, form pumiceous blocks in the proximal August deposits (Harbin and others, this volume). Highly vesicular, colorless, microlite-free glass is present in all of the buchites, and it ranges in abundance from trace to 30 percent. The glass in the buchites is identical in appearance to the small amounts of colorless glass found in the ash.

ERUPTION OF SEPTEMBER 16–17, 1992

The major phase of the September eruption of Crater Peak began just after midnight local time on September 17, 1992. A series of violent explosions again carried ash high into the air. Winds carried ash to the east, to the north of Anchorage, and eventually into the Yukon Territory of Canada.

Ash was sampled at 45 and 110 km downwind from Crater Peak. The ash that fell 45 km downwind from the volcano had a maximum grain size of 0.7 mm, whereas the ash that fell 110 km downwind had a maximum grain size of 0.5 mm. Petrographically, the ash from both sites is very similar. Blocky fragments of porphyritic andesite (containing fragments of phenocrysts of plagioclase, hornblende, augite, hypersthene, and FeTi oxides in a matrix of brown glass with abundant microlites) were the most common constituent of the ash. Isolated grains of the phenocryst minerals were also common as angular fragments in the ash. A few grains of quartz and cordierite were also found in this ash during microprobe analysis. Fragments of colorless, microlite-free, highly vesiculated glass with a few plagioclase microphenocrysts were noted in the finer grained (about 0.5 mm) fraction of the ash.

Blocks from the September eruption show the same pattern of petrographic variation as observed in the ash. Dense, black glassy blocks of andesite contain phenocrysts in a matrix of light-brown glass with abundant microlites. Some blocks of light-gray andesite contain phenocrysts in a matrix of colorless glass rich in microlites of plagioclase, pyroxene, and FeTi oxides. Buchites, similar to those from the August deposits, were also erupted in September. Harbin and others, and Nye and others (both this volume) provide more information on the petrology and geochemistry of the andesites.

COMPOSITION OF THE 1992 VOLCANIC GLASSES

Compositions of volcanic glass from each of the Mount Spurr eruptions were determined by electron microprobe at the University of Alaska Fairbanks. Glasses from the 1992 eruptions were analyzed on a four-channel electron microprobe using an 8 μm beam at 15 Kev with a 10-sec counting time and a 0.01 microamp sample current. Natural glasses were used as standards. The analytical routine was designed to minimize alkali loss in these relatively anhydrous glasses. Experience with this same analytical routine on the Redoubt glasses (Swanson and others, 1994) showed no significant alkali loss occurs during the analytical routine when sodium is measured (first 10 seconds of the analysis). All of the analyses were made on polished grain mounts of the ash. Multiple points were selected for analysis (one point per grain) and the microprobe was run in the automated mode. Analy-

ses that obviously included mineral grains and glass were eliminated from the data set, as were analyses with totals outside of the range 98 to 101 weight percent oxide.

Compositions of the prehistoric tephra glasses were determined on a nine-channel microprobe at a U.S. Geological Survey laboratory. The glasses were analyzed at 15 keV, with a 10-second counting time, 0.01-microamp sample current, and a beam size of 10μm. Natural glasses were used as standards and rhyolitic glass was analyzed repeatedly as an internal standard. Somewhat lower analytical totals (96–99 weight percent) for the prehistoric glasses are probably related to the hydration of these glasses.

COMPOSITION OF THE JUNE 27, 1992, VOLCANIC GLASSES

Both proximal and distal tephra samples were analyzed from the eruption of June 27, 1992. The distal sample (SS-2) was collected from Manley Hot Springs, approximately 450 km north of the Crater Peak vent on Mount Spurr. Proximal samples (JB-4A, JB-4B1, JB-4B2, and JB-4B3) consisted of small pumice lapilli and were collected a few kilometers north of Crater Peak.

The ash and pumice lapilli both contain a heterogeneous suite of glass compositions (table 1). The common brown glass with abundant microlites is typically andesitic with an SiO_2 content of about 61 weight percent (columns 1 and 8, table 1). However, brown glass in one of the pumice lapilli (JBS-4B2) is dacitic (SiO_2 of 67.4 weight percent, column 6, table 1). The colorless microlite-free glass in the ash (SS-2) is rhyolitic (SiO_2 of 76.6 weight percent, column 2, table 1). Similar microlite-free colorless rhyolitic glass is found in the pumice lapilli (columns 3, 4, 5, 7; table 1).

COMPOSITION OF THE AUGUST 18, 1992, VOLCANIC GLASSES

Glass in the ash of August 18, 1992, is heterogeneous. Three distinct populations of glass compositions are found in the ash (table 2). The most common (more than 90 percent) component is a brown microlite-rich andesitic glass (SiO_2 of about 62 weight percent, column 1, table 2). A few percent of very light brown dacitic glass (SiO_2 of 65 weight percent, column 2, table 2) with abundant microlites are also present. A rare (less than 1 percent) colorless, microlite-free rhyolitic glass (SiO_2 of about 76 weight percent, column 3, table 2) is also found in the ash erupted in August.

COMPOSITIONS OF THE SEPTEMBER 16–17, 1992, VOLCANIC GLASSES

Ash analyzed from the eruption of September 16–17, 1992 (sample 19B, table 3) was collected 110 km downwind from Crater Peak. The sample is a bulk sample for the entire eruption.

Four compositionally distinct glass populations are present in the September ash (table 3). Three brown dacitic glasses (SiO_2 of about 63–69 weight percent, columns 1, 2, 3, table 3) with abundant microlites are the most common, but colorless, microlite-free rhyolitic glass is also present in the suite (column 4, table 3).

COMPARISON OF GLASS COMPOSITIONS FROM THE ASH AND BLOCKS IN THE 1992 ERUPTIONS

The pattern of glass compositional variation found in the ash is generally mimicked by the variation of matrix glass compositions measured in the blocks (Harbin and others, this volume). Similar results were

Table 2. Composition of glass from volcanic ash erupted on August 18, 1992, from Crater Peak vent, Mount Spurr volcano, Alaska, collected on a patio at Alaska Volcano Observatory in Anchorage.

[*, total Fe as FeO; number of points analyzed in parentheses below sample number; AVO-PAT, patio at Alaska Volcano Observatory]

Sample no.	AVO-PAT (107)	AVO-PAT (18)	AVO-PAT (12)
glass color	brown	light brown	colorless
SiO2 -----------------	62.25±1.32	65.4M.92	75.93±1.36
TiO2 -----------------	0.5M.17	0.59±0.11	0.35±0.17
Al2O3 ---------------	16.45±1.11	15.62±1.16	12.55±0.45
FeO* ----------------	5.62f0.96	4.82±1.11	2.2M.28
MgO -----------------	2.01M.61	1.36M.48	0.46M.05
CaO ------------------	5.37±0.58	4.42±0.51	0.91±0.10
Na2O ----------------	5.26M.33	5.32M.40	3.06M.16
K2O ------------------	1.3M.19	1.80±0.25	4.07±0.27
Cl ---------------------	0.20±0.05	0.23±0.07	0.02±0.01
Total -----------	99.14	99.62	99.64

Table 3. Composition of glass from volcanic ash erupted on September 17, 1992, from Crater Peak vent, Mount Spurr volcano, Alaska.

[*. total Fe as FeO; number of points analyzed in parentheses below sample number]

| Analysis no.	19B (159)	19B (75)	19B (14)	19B (14)
glass color	brown	light brown	light brown	colorless
SiO_2 -----------------	63.02k1.14	65.61±1.00	69.16k1.41	73.37k1.68
TiO_2 -----------------	0.53M.16	0.52M.16	0.48M.16	0.51M.24
Al_2O_3 ----------------	16.64k1.32	15.87M.92	15.71±1.68	13.28k1.02
FeO^* -----------------	5.14±1.12	4.65k1.04	3.06±1.40	2.39±1.01
MgO -----------------	1.87±0.71	1.39±0.51	0.88M.80	0.46±0.46
CaO -----------------	5.20±0.62	4.30M.58	3.20M.96	1.54M.66
Na_2O ----------------	5.34M.36	5.38M.36	5.17M.92	3.80M.89
K_2O -----------------	1.43M.25	1.80±0.51	2.45M.40	4.01±1.09
Cl ---------------------	0.20±0.06	0.21±0.06	0.14±0.08	0.15±0.16
Total -------------	99.37	99.73	100.25	99.51
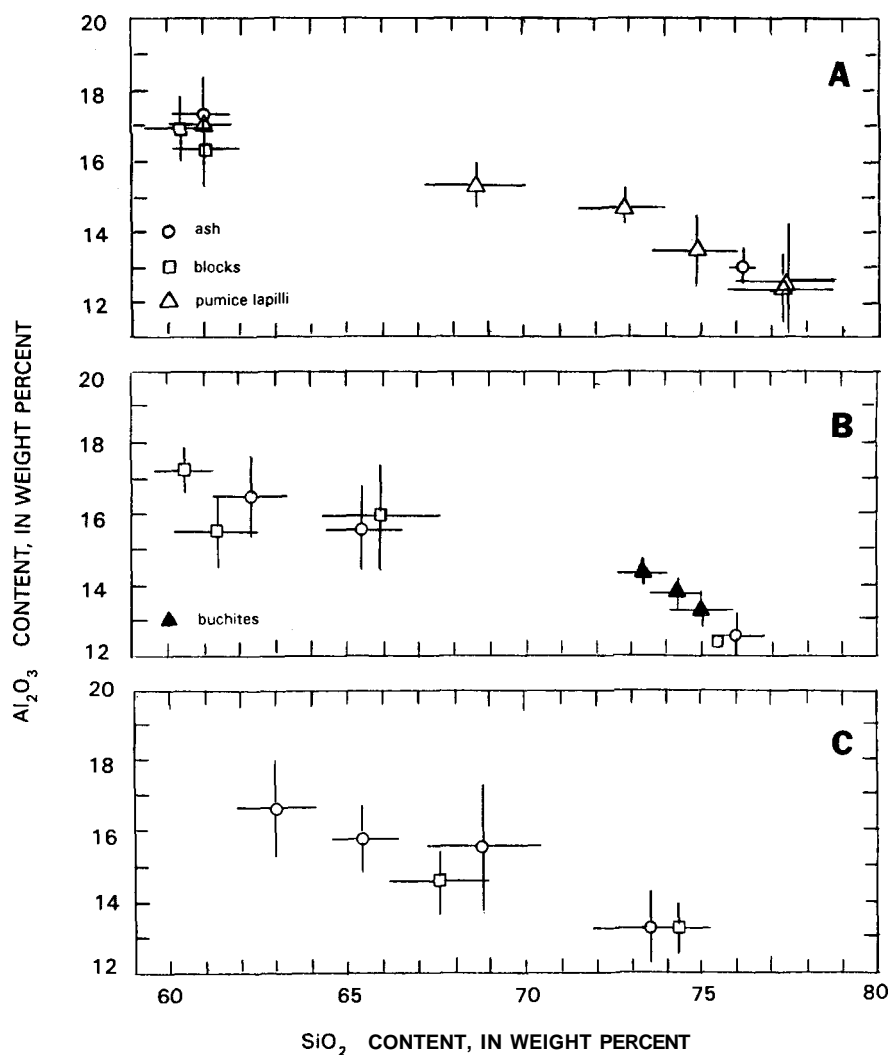
Figure 2. Glass compositions from the June 27, 1992 *(A),* 18 August 1992 (B); and September 17, 1992 (C) eruptions of Crater Peak. Bars on the points represent the one sigma standard deviations about the mean of the data. Data on blocks and buchites are from Harbin and others (this volume). Data on ash and pumice lapilli are from tables 1–3.

found in the 1989−90 Redoubt eruption (**Swanson** and others, 1991) where matrix glass and glass from volcanic ash showed similar patterns of variation on the same time scale.

The June ash contains an andesitic and rhyolitic component (table 1). Comparison of these glasses to the matrix glass in blocks from the June eruption (Harbin and others, this volume) shows that the andesitic glass is derived from the dark gray to black "cauliflower" bombs noted in the proximal June deposits (Miller and others; Harbin and others, this volume). After recognition of the rhyolitic component in the June ash, a careful search was made of the June proximal deposits for possible block equivalents. A few small lapilli of light-gray pumice were found in the proximal deposits. Some of these lapilli contained bands with brown andesitic matrix glass. However, the dominant glass in the lapilli was a colorless, **microlite**-free rhyolite ranging from 68.6 to 76.3 weight percent SiO_2 (fig. 2). The rhyolitic glass in the gray pumice lapilli is very similar to the rhyolitic glass in the ash (fig. 2).

Compositions of glass from the ash and blocks were also similar in the August eruption (fig. 2). The brown andesitic glass in the ash is represented in the blocks by the dark "cauliflower" bombs of andesite. A dacitic glass is found in the ash (table 2, column 2) and in a block of greenish andesite scoria (Harbin and others, this volume). The matrix glass in the andesitic scoria is very light brown and the glass contains abundant microlites. Rhyolitic glass is found in the ash (table 2, column 3), in vesicular, gray-green andesite, and in buchites in the August deposits. The gray-green andesite has colorless matrix glass without microlites and is very similar to the rhyolitic glass found in the ash (fig. 2). Glass in the buchites is also colorless and microlite-free, but is slightly lower in SiO_2 than either the ash or the greenish-gray andesitic glasses (fig. 2).

Rhyolitic and dacitic glasses are found in both the ash and in the matrix of blocks produced in the September eruption. The rhyolitic matrix glass is colorless and contains abundant microlites. Rhyolitic glass from the ash (column 4, table 3) is identical in composition to the rhyolitic matrix glass found in a **light**-gray prismatically-jointed andesite block (fig. 2). **High**-silica dacitic glass (about 69 weight percent SiO_2) is found in the September ash (table 3, column 3) and in the matrix of a black prismatic andesite block. The two high-silica dacitic glasses are very similar in composition (fig. 2). Brown, microlite-rich low-silica dacitic and high-silica andesitic glasses are found in the matrix of blocks from the September eruption (Harbin and others, this volume), and the low-silica dacitic matrix glass is similar to glass in the ash (fig. 2).

GLASS COMPOSITIONS OF TEPHRA FROM PREHISTORIC ERUPTIONS OF CRATER PEAK VENT, MOUNT SPURR

Brown andesitic glass, similar to that erupted in 1992, is the common glass in the prehistoric tephra from Crater Peak vent of Mount Spurr (Riehle, 1985) and is easily recognized in the Quaternary deposits of south-central Alaska (Riehle, 1985; Beget and others, 1994). These are the only Cook Inlet volcanoes that have produced andesitic glass—the other Cook Inlet volcanoes produce dacitic or rhyolitic glasses (Riehle, 1985).

A volumetrically small but persistent rhyolitic glass phase is also found in the prehistoric tephra from Crater Peak (Riehle, 1985). The rhyolitic glass is colorless and microlite-free. Commonly the rhyolitic glass is vesicular. Reexamination of microprobe analyses reveals that rhyolitic glass is present in most prehistoric Crater Peak tephra samples.

New analyses of this rhyolitic component (table 4) have been done on some prehistoric tephras to compare these rhyolitic glasses with those of the 1992 eruption. The rhyolitic glasses in the prehistoric te-

Table 4. Rhyolitic glass compositions of prehistoric basal tephras and pyroclastic-flow samples from Mount Spurr volcano, Alaska.

[*, total Fe as FeO; number of points analyzed in parentheses below sample number]

	Pyroclastic flow	Basal tephra		
SiO_2 --------------	74.58±0.75	74.06±2.35	74.61±1.75	73.46k1.95
TiO_2 ----------------	0.39±0.03	0.45±0.16	0.45H.09	0.46H.07
Al_2O_3 ----------------	11.89±0.72	12.57±0.44	13.31±0.67	12.53k1.52
FeO* ----------------	1.45±0.14	2.11H.80	1.86±0.47	2.10±0.33
MnO -----------------	0.01±0.02	0.08M.03	0.05±0.04	0.06H.03
MgO -----------------	0.13±0.06	0.04H.45	0.27±0.12	0.43-10.23
CaO -----------------	0.72±0.37	1.42±0.43	1.40±0.30	1.48M.66
Na_2O ----------------	3.00±0.21	2.97H.36	2.96±0.26	2.84M.21
K_2O ----------------	4.45±0.16	3.96±0.78	4.01H.17	3.85H.87
Total -------------	96.62	98.02	98.92	96.94

phras are very similar to those from the 1992 erup-
tions. All of the Crater Peak vent of Mount Spurr rhy-
olitic glasses are peraluminous and they show similar
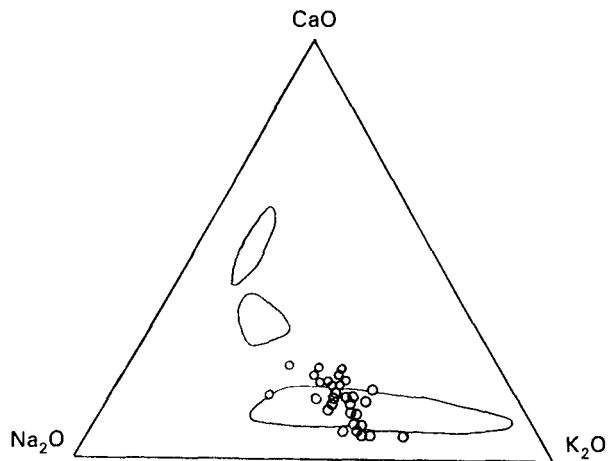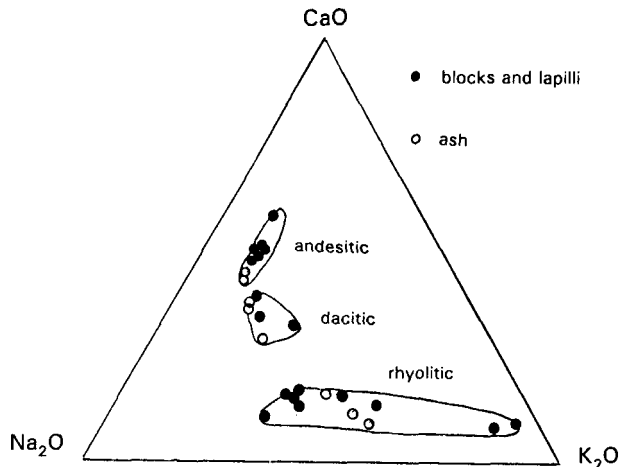ranges of alkali content (fig. 3).

DISCUSSION AND FUTURE WORK

Glass compositions in the ash from the 1992 erup-
tions of Crater Peak provided a valuable means of
monitoring changes in the magmatic system. The glass
compositions in the ash and matrix glass from blocks
all show the same patterns for each of the eruptions.

Rhyolitic glasses similar to those in the 1992
eruption occur in prehistoric tephra from Mount Spurr
and Crater Peak, indicating that the 1992 eruption was
typical of other prehistoric eruptions. Rhyolitic glass
occurs in ash, the matrix of blocks, and in buchites
from the August 1992 eruption (fig. 2). All of these
rhyolitic glasses are very similar (fig. 3), supporting
an origin of the rhyolitic melt by partial melting of
metamorphic basement rocks. The variable alkali con-
tents of the rhyolitic glasses (for example, compare
sodium and potassium of columns 3–8, table 1) are
typical of the disequilibrium melts produced in the
initial stages of melting pelitic buchites (Grapes, 1986).
The occurrence of these rhyolitic glasses in prehis-
toric deposits suggests that similar buchites should be
found in prehistoric Crater Peak deposits.

During an eruption of multiple magmas it is com-
monly difficult to estimate the relative proportions of
each of the magmas. Glass compositions in volcanic
ash provide a relatively easy technique for estimating
relative proportions of magmas in an eruption. For
example, table 3 shows averages of glass analyses that
represent over 250 individual analyses of glass in a
bulk sample of the September ash. All of the points
were selected randomly in a polished grain mount.
Most of the glass in the September sample is repre-
sented by low-silica dacitic compositions (234 out of
262 total analyses); high-silica dacitic and rhyolitic
glasses each amounted to only 14 out of 262 analy-
ses. This provides one quantitative way of determin-
ing the relative proportions of the magmatic compo-
nents that erupted in September. Some caution is needed
in the application of this technique because of the
potential for differential sorting of comagmatic phases
in the ash clouds. The fragments of crystal-rich andesite
glass might be expected to fall closer to the volcano
than the relatively crystal free shards of rhyolite glass,
but this has not been apparent in the petrographic ex-
amination of proximal and distal samples. When ash
can be sampled sequentially, either as it falls or from
well-preserved stratigraphy within the ash layer, de-
tailed analysis of the subsets provides useful clues to
magmatic variation during an eruption.

Figure 3. A, Compositions of the 1992 Crater Peak glasses
in terms of CaO-Na$_2$O-K$_2$O. Compositional fields outline
andesitic, dacitic, and rhyolitic glasses. Data sources as in
figure 2. B, Individual analyses (averages given in table 4)
of rhyolitic glasses in prehistoric Crater Peak tephras in
terms of CaO-Na$_2$O-K$_2$O. Composition fields for the 1992
glasses are reproduced from figure 3A.

CONCLUSIONS

Volcanic ash provides important clues to the nature of an erupting magmatic system. The composition of glasses in the 1992 Crater Peak ashes proved that new (different from prehistoric) magma was being erupted and that a small rhyolitic component was involved in the eruption. Because the ash was dispersed great distances from the volcano, it was possible to sample the magma at safe, distal locations.

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