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STRATIGRAPHY, PETROLOGY, AND GEOCHEMISTRY OF THE SPURR VOLCANIC COMPLEX, EASTERN ALEUTIAN ARC, ALASKA.

by

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(with an appendix describing geothermal fluid chemistry by Roman J. Motyka and
Christopher J. Nye)

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ADDENDUM AND CORRECTIONS

UAG R-311

**Stratigraphy, Petrology, and Geochemistry of the Spurr
Volcanic Complex, Eastern Aleutian Arc, Alaska**

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University of Alaska Fairbanks**

**(with an appendix describing geothermal fluid chemistry by
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ABSTRACT

The Spurr Volcanic Complex (SVC) is a calcalkaline, medium-K, sequence of andesites erupted over the last quarter of a million years by the easternmost currently active volcanic center in the Aleutian Arc. The ancestral Mt. Spurr was built mostly of andesites of uniform composition (58-60% SiO_2), although andesite production was episodically interrupted by the introduction of new batches of more mafic magma. Near the end of the Pleistocene the ancestral Mt. Spurr underwent Bezymianny-type avalanche caldera formation, resulting in the production of a volcanic debris avalanche with overlying ashflows. Immediately afterward, a large dome (the present Mt. Spurr) was emplaced in the caldera. Both the ashflows and dome are made of acid andesite more silicic than any analyzed lavas from the ancestral Mt. Spurr (60-63% SiO_2), yet contain olivine and amphibole xenocrysts derived from more mafic magma. The mafic magma (53-57% SiO_2) erupted during and after dome emplacement, forming proto-Crater Peak and Crater Peak. Hybrid pyroclastic flows and lavas were also produced. Proto-Crater Peak underwent glacial dissection prior to the formation of Crater Peak in approximately the same location. The vents for the silicic and mafic lavas are in the center and in the breach of the 5 by 6 km horseshoe shaped caldera, respectively, and are less than 4 km apart. Late Holocene eruptive activity is restricted to Crater Peak, and magmas continue to be relatively mafic and derived from deep within the crust.

SVC lavas are $\text{plag} \pm \text{ol} + \text{cpx} \pm \text{opx} + \text{mt}$ bearing. All post-caldera units contain small amounts of high Al_2O_3 , high alkali pargasite, and Proto-Crater Peak and Crater Peak lavas contain abundant pyroxenite and anorthosite clots presumably derived from an immediately pre-existing magma chamber. Ranges of mineral chemistries within individual samples are

often nearly as large as ranges of mineral chemistries throughout the SVC suite, suggesting that magma mixing is common.

SVC lavas are unlike experimentally produced cotectic liquids and are thus unlikely to be related to each other by fractional crystallization. Magmatic evolution must instead be controlled in large part by crustal assimilation. Flat Y-SiO₂ and Nb-SiO₂ trends and Rb enrichment beyond that which can be reasonably modeled by fractional crystallization also suggest extensive assimilation of lower crust, bulk upper crust, or partial melts of local batholithic material.

Since at least the mid-Holocene there has been no shallow, silicic magma chamber at the SVC. This increases the expectation that the low resistivity layer described by Turner and Wescott (1986) is a highly conductive layer of bedrock, such as a thick, altered tuff.

INTRODUCTION

The Spurr Volcanic Complex (SVC) comprises an ancestral andesitic stratovolcano, a debris avalanche deposit, and two post-caldera domes or cones with associated pyroclastic deposits and represents continuous volcanic activity over at least the last 250,000 years. The SVC is located 130 miles west of Anchorage, Alaska's biggest population center (Figure 1), and only 65 km from the nearest electrical transmission line. In part because of its proximity to a major energy market the Geophysical Institute of the University of Alaska Fairbanks and the Alaska Division of Geological and Geophysical Surveys undertook a thorough, multifaceted, study of the geothermal potential of the SVC area. Much of the funding for this study was provided by the U.S. Department of Energy Grant DE-FG07-84-ID2471.

The results of geophysical studies, soil He and Hg surveys, and K-Ar geochronology were reported by Turner and Wescott (1986). They found controlled source audio-magnetotelluric evidence of a discontinuous subhorizontal zone of anomalously low resistivity which underlies much of the southern flank of the SVC at about sea level. This zone is coincident with soil Hg and He anomalies and self-potential anomalies. Turner and Wescott (1986) interpreted the coincidence of geophysical and geochemical anomalies as strong evidence of the presence of a geothermal reservoir at depth.

Turner and Wescott (1986) also presented an abbreviated account of the geology of the SVC. This study presents an expanded treatment of SVC geology. In addition, this study presents whole-rock and mineral chemical data from all volcanic units within the SVC and analyses and interpretation of the geochemistry of waters from a hot spring on the southern flank of Crater Peak and gases from fumaroles near

Figure 1. Location of the Spurr Volcanic Complex, other Aleutian volcanic centers, and various tectonic, geographic, and geologic features of the Aleutian Arc. From Kienle et al. (1983), Jacob et al. (1977), Stephens et al. (1984), and the Circum-Pacific Council for Energy and Mineral Resources (1981a, 1981b).

the summit of Crater Peak. The whole-rock and mineral geochemistry is interpreted in terms of the nature and history of the magmatic plumbing system which has been feeding magma to the surface. Data presented herein represent the first available geochemical data from the SVC.

TECTONIC AND GEOLOGIC SETTING

The Aleutian arc is forming in response to subduction of the Kula and Pacific Plates beneath the North American Plate. At present subduction is nearly orthogonal for the central 2000 km of the arc (Jacob et al., 1977, Figure 1). The arc-trench gap progressively widens from about 200 km in the central Aleutians to about 500 km at the SVC. East of Cape Douglas (in the easternmost 265 km of the arc) the angle between the convergence vector and the volcanic front increases abruptly from 102 to 137 degrees. The angle between the convergence vector and depth contours on the Benioff zone, however, increases gradually in the eastern arc (Kienle et al., 1983). The eastward increase of the arc-trench gap is accompanied by a widening of the shallowly dipping upper portion of the subducted slab. Thus, the distance between the trench and the 50 km depth contour increases while the distance between the 50 km depth contour and the volcanic front remains fairly constant. Jacob et al. (1977) attribute the widening of the arc-trench gap to eastward-increasing amounts of offscraped material, and suggest that the offscraping has pushed the eastern portion of the trench progressively southward. Alternatively, von Huene et al. (1985) suggest that the shallowly dipping portion of the slab may reflect the subduction of a hypothetical westward extension of the Yakutat Block, which they expect to be buoyant. The von Huene et al. hypothesis, if correct, would not affect magma-genetic processes beneath the arc, because the proposed subducted portion of the Yakutat Block cannot yet have reached deep enough to be involved in magma-genesis.

The SVC is the easternmost active center of the arc, but one more center, Hayes Volcano, lies 40 km to the north-northwest along the arc. Benioff Zone seismicity, however, continues some 400 km to the northwest, where it terminates abruptly along a line parallel to the Pacific - North America convergence vector originating in easternmost Prince William Sound (Figure 1). The abrupt decrease in seismicity marks a tear in the Pacific Plate. The Wrangell volcanoes lie east of this tear, above a weakly defined Benioff zone inboard of the Yakutat Block (Stephens et al., 1984). The reason for the lack of Recent volcanism between the SVC and the Wrangells is unknown, although there are three possible contributing factors. First, P-wave travel-times obtained during the Amchitka nuclear tests outline an anomalously slow zone beneath the Cook Inlet and western Alaska Peninsula volcanoes (Biswas, 1973). If this is an expression of a low-Q zone (which appears to be a prerequisite for arc volcanism, Gill, 1981), then the termination of this zone just northeast of the SVC may provide a reason for (but not a cause of), the lack of volcanism to the east. Second, the SVC is west and south of the zone of large negative bouger anomalies of the central Alaska Range (up to -120 milligals; Barnes 1977a, 1977b). These gravity anomalies presumably reflect the thick root of the Alaska Range, and suggest that the crust is sufficiently thick in this region that no asthenospheric mantle can penetrate high enough to participate in magma production. This is the preferred explanation of Cross and Pilger (1982). Third, the arc-trench gap east of the SVC may be wide enough that the subducted slab dewateres to such an extent that it can not participate in magma genesis at depth. This explanation rests on the supposition that slab dehydration is required for the production of arc magmas, a point which is not universally agreed on.

Oceanic crust of the Pacific Plate is currently being subducted throughout the arc. Magnetic lineations are

presently subparallel to the trench in the western 85% of the arc. As recently as about 10 Ma, magnetic lineations were parallel to the trench throughout the arc (Engebretson et al., 1985). The age of the Pacific Plate at the trench is about 60 m.y., and becomes younger downdip. Extrapolating from the information about the Kula-Pacific-Farallon spreading rates preserved in magnetic lineations on the Pacific Plate today, the plate is about 56 m.y. old beneath the volcanic front. The subducted Kula Ridge is expected to be at least 600 km downdip (Engebretson et al., 1985).

The SVC is built on the continental crust of southern Alaska, which was formed by Mesozoic amalgamation and late Mesozoic or early Tertiary accretion of many independently formed terranes (see Panuska and Stone, 1985 and Coe et al., 1985, for reviews.) The terrane which underlies the eastern arc is the Peninsular terrane of Jones et al. (1981), which has been redefined (and renamed the Alaska Peninsula Terrane) by Wilson et al. (1985). The portion of the Alaska Peninsula Terrane which underlies the SVC area consists of Silurian through Early Jurassic limestone, basalt and clastic rocks, and Jurassic and/or Cretaceous flysch, all of which are intruded by the Jurassic, early Tertiary, and mid-Tertiary rocks of the Alaska-Aleutian Range batholith. Most sedimentary rocks are greenschist facies or below, but can be higher near contacts with plutons (Wilson et al., 1985).

The basement of the SVC is dominantly intrusive. Immediately east of the summit of Mt. Spurr the volcanics overlie migmatite and quartz monzonite which are approximately 57 m.y. old (Reed and Lanphere, 1972; Magoon et al., 1976). The volcanics abut this same unit west of Mt. Spurr. Immediately south of the Chakachatna River bedrock consists of two granodiorite units approximately 62 and 69 my old (Reed and Lanphere, 1972; Magoon et al., 1976). Conglomerate, sandstone, siltstone and ashflow tuff of the West Foreland Formation is faulted against the quartz monzonite just east of

Straight Creek, and underlies the SVC volcanics west of Straight Creek. The quartz monzonite intrudes the Jura-Cretaceous flysch 15 km to the NNE.

STRATIGRAPHY AND GEOLOGY

There are six main stratigraphic units within the Spurr Volcanic Complex (SVC) (Figure 2): the ancestral Mt. Spurr, Mt. Spurr, Crater Peak, a composite pyroclastic fan of uncertain origin, a debris avalanche deposit, and a series of young ash-flow tuffs. A preliminary discussion of these units, expanded herein, is given by Turner et al. (1986). Crater Peak is subdivided into two stages, "proto-Crater Peak" and "Crater Peak", which are separated by an erosional interval, which may only represent a temporary glacial overwhelming of essentially continuous Holocene Crater Peak volcanism. The ancestral Mt. Spurr was partially destroyed by Bezymianny-type avalanche caldera formation during the Late Wisconsin or Early Holocene, which produced the debris avalanche deposit and overlying ash-flow tuffs. Mt. Spurr is a silicic-andesite dome which grew in the center of the crater, while Crater Peak is a basaltic-andesite cone which occupies the breach in the ancestral Mt. Spurr.

Ancestral Mt. Spurr. The ancestral Mt. Spurr is the oldest unit of the SVC, and is composed of pyroclastic units and lavas of diverse lithologies. Stratigraphically lower portions of the pile are dominated by pyroclastic units and upper portions are dominated by lava flows. Most of the lava flows are of fairly uniform composition (58-60% SiO_2) but there are individual flows which are substantially more mafic intercalated with the acid andesites (Figure 3). There are few flows with compositions between the mafic and felsic flows. Lavas with less than 57% SiO_2 are pl+ol+cpx+mt bearing while lavas with greater than 57% SiO_2 are pl+cpx+opx+mt bearing.

Figure 2. Generalized geologic map of the Mt. Spurr region adapted from Turner and Wescott (1986) and Barnes (1966). Numbers are sample numbers referred to in the text and appendices.

Figure 3. Stratigraphic variation of SiO_2 , K_2O and MgO in SVC samples. Abbreviations used are AMS, ancestral Mt. Spurr; AF, ashflows; SP, Mt. Spurr; PF, pyroclastic fan; PCPa, eastern proto-Crater Peak; PCPb, western proto-Crater Peak; CP, Crater Peak; and PUM, pumice of the 1953 eruption. AMS, PCP, and CP samples are arranged in stratigraphic order. Relative ages of PCPa and PCPb are unknown, but they are approximately coeval. SP, PCP, and DP were in part coeruptive.

The ancestral Mt. Spurr was built during the Late Pleistocene ($>0.255 \pm 0.052$ Ma to $<0.058 \pm 0.018$ Ma, Turner and Nye, 1986, a single older date of 2.08 ± 0.20 Ma is probably from pre-Spurr volcanic bedrock), and was partially destroyed during the production of a debris avalanche. Capps (1929) was the first to recognize the fundamental aspects of the volcanic stratigraphy of the Mt. Spurr region. Juhle and Coulter (1955) however, disagreed with the interpretation that the peaks surrounding Mt. Spurr were a caldera rim and suggested that "the postulated gigantic caldera is only a fortuitous arrangement of discrete mountain peaks of dissimilar origins". Juhle and Coulter (1955) mistakenly reported that lavas of the eastern rim of the caldera proposed by Capps (1929) dipped radially outward from their respective summits, and that the peaks of the western rim were granitic. In fact, all ice-free peaks on the rim of the proposed caldera are volcanic and are composed of flows which dip radially away from Mt. Spurr, which is located near the summit of the ancestral Mt. Spurr. Riehle (1985) agreed with Capps (1929) and was the first to recognize the debris avalanche deposits and the mechanism of caldera collapse.

Debris Avalanche. The ancestral Mt. Spurr was partially destroyed by a Bezymianny-type eruption that produced a volcanic debris avalanche which traveled a minimum of 25 km east of the center of the ancestral Mt. Spurr (Figure 2). The debris avalanche lies between the Chakachatna River and Straight Creek and is composed of coherent blocks of volcanic material up to at least 100 meters in diameter. These blocks retain their internal volcanic structure but are rotated from their original attitude. Exposures are limited to the banks of the Chakachatna River, but the unit can be recognized elsewhere by the hummocky surface typical of debris avalanches. The debris avalanche is not exposed west of the southeast corner of Kidazgeni Glacier (Figure 2). Lack of exposure, uncertainty about the original areal extent of the

debris avalanche deposit and the extent of its erosion, and uncertainty about the configuration of the surface on which the debris avalanche deposit rests all make it impossible to accurately estimate the volume of the deposit. However, rough geometric estimates of the volume of both the avalanche deposit and the volume of the missing portion of the ancestral Mt. Spurr are in agreement with each other at a few km³.

Ash Flow Tuff. The debris avalanche is overlain by ash-flow tuff, which is partially welded and contains well developed fossil fumerole pipes more than 15 km from the center of the ancestral Mt. Spurr. Riehle (1985) mentioned several ash flows, but no more than one was distinguished in any given outcrop during this investigation. An outcrop in a riverbank exposure 18 km from the center of the ancestral Mt. Spurr is a single high-silica andesite ash-flow several meters thick consisting of pumice blocks as large as 1.5 m in diameter in a lightly welded to non-welded ashy matrix. The ash flow contains two juvenile lithologies, one very light grey and one dark grey. These are most often present in separate pumice blocks, but occasional bands of the dark pumice a few cm thick are included in blocks of the light pumice. Both lithologies contain pl+cpx+opx+mt, and the dark lithology contains olivine which is in reaction with the melt. Glass in the dark grey pumice is brown, while glass in the light grey pumice is clear. In spite of the strong contrast in hand specimen and thin section appearance, chemical variation between the two lithologies is slight. AF-08 and AF-09 (Appendix I) are whole rock analyses of the two lithologies from the same outcrop and differ in SiO₂ by only 1 wt%. Partial major element analyses of the glasses show that the brown glass is slightly less evolved than the clear glass (SiO₂, FeO_t, and MgO are 74%, 2.1%, and 0.35%, respectively, compared to 76%, 1.4%, and 0.17%). The ash-flows were most likely erupted during the eruption which generated the debris avalanche and breached the ancestral Mt. Spurr (Riehle, 1985).

Emplacement of the unusually silicic magma high into the volcanic edifice may have been the trigger which produced caldera formation.

The age of the emplacement of the debris avalanche and the ash-flows is not precisely known. It must be younger than the youngest dated flow on the flanks of the ancestral Mt. Spurr (0.058 ± 0.014 Ma, Turner and Nye, 1986). The debris avalanche has also not been extensively modified by glaciation and is thus probably younger than the last major ice advance down the Chakachatna River (i.e. Late Wisconsinan, Schmoll and Yehle, 1986). As Riehle (1985) has noted, there is no extensive ash-fall layer associated with the ash-flow in the vicinity of the SVC. This suggests that the debris avalanche may have formed during a period of extensive ice cover, perhaps in the Late Wisconsinan or Early Holocene.

Mt. Spurr. After the partial destruction of the ancestral Mt. Spurr two new vents formed. Mt. Spurr, the most felsic SVC vent (Figure 4), grew in the center of the ancestral Mt. Spurr, and Crater Peak, the most mafic SVC vent (Figures 3 and 4), formed in the breach of the old cone. Mt. Spurr presently has a summit elevation of 3412 m, and, if the VLF resistivity ice depth measurements of Wescott et al. (1986) are correct, stands >1000 m above its base and has a volume, calculated as a simple cone, of approximately 2 km^3 . Because of extensive ice cover, rock exposure is extremely limited on Mt. Spurr. The four samples that were obtained are identical in chemical composition to the ash-flows which overlie the debris avalanche, but differ modally in that none of the four contain olivine, two contain small amounts of hornblende, and one contains rare biotite. The chemical similarity of Mt. Spurr and the ash flows suggests that Mt. Spurr is the dome which formed immediately after collapse of the ancestral Mt. Spurr. It is likely that some of the magma which ultimately formed the dome erupted during caldera formation and formed the ashflows which overlie the debris avalanche. Riehle (1985)

Figure 4. Silica variation diagrams of all samples from the SVC. The medium-K field and TH-CA boundary are from Gill (1981). Abbreviations used are AMS, ancestral Mt. Spurr; AF, ashflows; SP, Mt. Spurr; PF, pyroclastic fan; PCP, proto-Crater Peak; CP, Crater Peak, including pumice from the 1953 eruption.

reports a minimum age of older Mt. Spurr tephra of slightly greater than 7000 years, and does not recognize Mt. Spurr tephra younger than 5200 years. While the tephra record indicates that there have been no eruptions of Mt. Spurr in the last 5000 years, the airphoto record shows periods of increased ice melt (and therefore volcanic heat flux) at the summit. During the summer of 1985 there were extensive patches of steaming ground and fields of small fumeroles on the south and southwest flanks of Mt. Spurr, although none exceeded the pressure-boiling point.

Crater Peak and Proto-Crater Peak. The youngest vent, and the site of the 1953 eruption, is Crater Peak, which occupies the breach in the ancestral Mt. Spurr. The present summit altitude is 2335 m. Because the topography of the ancestral Mt. Spurr underneath Crater Peak is unknown it is impossible to calculate the volume, but geometric constraints suggest that it is about the same as Mt. Spurr (ca. 2 km^3). Crater Peak was preceded by an earlier cone of similar composition, called proto-Crater Peak (Figure 2). The two remnants of proto-Crater Peak are nested within the breach of the ancestral Mt. Spurr and have flow attitudes which project to a point above the present summit of Crater Peak. Proto-Crater Peak was mostly destroyed, presumably by glaciation, and thus must be at least early Holocene. It is not known whether Crater Peak and proto-Crater Peak represent two discreet cone building phases or just temporary overwhelming of a continuously active vent by glaciers originating in the caldera. A single K-Ar age of $0.038 \pm 0.005 \text{ Ma}$ from a proto-Crater Peak sample (Turner and Nye, unpub. data) may provide a maximum age. However this sample contains ultramafic and anorthosite xenoliths which are older than the eruption and may carry excess argon, thus the K-Ar age may be too old. Riehle (1985) reports a minimum age of basal Crater Peak (including proto-Crater Peak) tephra of 6000 years. Thus Mt.

Spurr and the Crater Peak - proto-Crater Peak complex were, in part, coeruptive.

One of the most unusual aspects of the SVC is that even though Mt. Spurr and proto-Crater Peak were coeruptive, they extruded material of highly contrasting composition. Mt. Spurr erupted the most silicic material from the SVC, while proto-Crater Peak, simultaneously, erupted the most mafic material (except for a few flows from the ancestral Mt. Spurr, Figure 3).

Lavas from Crater Peak and proto-Crater Peak are of diverse composition and must represent the eruption of several independent batches of magma. For example, at 54% SiO₂, concentrations of Rb, MgO, and Ni vary by factors of 3, 1.6, and 4.7, respectively (Figures 4 and 7). Crater Peak and proto-Crater Peak lavas are also mineralogically complex (Appendix I). Many samples contain three or four of the possible mafic phases (ol, hb, cpx, and opx), and frequently contain one or more mafic phases in textural or chemical disequilibrium. Proto-Crater Peak, and, to a lesser extent, Crater Peak, also contain abundant inclusions of pyroxenite and metamorphic lithologies. Clinopyroxenite clots are the most common. These are externally faceted, multigrained clots with straight intragrain contacts. Clots are occasionally armored with hornblende crystals. One gabbroic clot containing about 20% interstitial brown glass contains abundant modal hornblende. Proto-Crater Peak and Crater Peak lavas have clearly ripped up pieces of a crustal or sub-crustal cumulate body, along with various other debris, on their way to the surface. While selective contamination by this material can explain some of the Mg and Ni variation, there is not a sufficient xenolith volume to explain the variation in Rb and other incompatible elements. Mixing with moderate amounts the Mt. Spurr magma may explain the incompatible element variation.

Crater Peak has undergone a systematic change over that portion of its evolution that can be sampled from the surface. The oldest samples of Crater Peak are high in silica and incompatible elements, and low in compatible elements. Successively younger samples are increasingly silica- and incompatible element- poor, and Mg- and Ni-rich through sample CP-07, then evolve back toward the composition of the lowermost samples. This cyclic evolution is interrupted by the 1953 eruption, whose products (PUM-16, PUM-17) are slightly more compatible-element rich, and incompatible-element poor, than immediately previous lavas.

Pyroclastic Fan. There is one other stratigraphic unit which is of uncertain origin. This is a fan of pyroclastic products of diverse composition which lies between the lower flanks of Crater Peak and the upper exposed limit of the debris avalanche deposit (Figure 2). The fan is composed almost completely of juvenile block and ash flows (some of which are palagonitic), which are interbedded with a few lahars, extremely blocky lava flows, and tuffs. The fan contains little of the non-juvenile material from the ancestral Mt. Spurr which characterizes the debris avalanche. Chemical compositions of juvenile blocks within the block and ash flows are variable (Figure 4), but mostly lie between Crater Peak and Mt. Spurr compositions, and have slightly lower concentrations of highly incompatible elements than ancestral Mt. Spurr samples of similar SiO_2 . Some samples from this unit contain the pyroxenite clots characteristic of proto-Crater Peak lavas.

This unit is overlain by some of the uppermost Crater Peak lavas, and is thus probably of Late Pleistocene age. The fact that most of the fan lavas are intermediate in composition between Mt. Spurr and Crater Peak suggests that the fan may have been formed during the initial stages of emplacement of proto-Crater Peak during a period of extensive mixing between the two magma reservoirs that resulted in relatively violent

eruptions, and thus block and ash flows, rather than lava flows.

GEOCHEMISTRY

Major Elements

SVC lavas are medium-K calcalkaline andesites with concentrations of major elements typical of such suites (Figure 4). TiO_2 , Al_2O_3 , CaO , Fe_2O_3 , MgO and MnO decrease linearly with increasing SiO_2 , and Na_2O and K_2O increase. Al_2O_3 and MgO concentrations are scattered, particularly at low SiO_2 , presumably reflecting accumulation of small amounts (<10%) of plagioclase, pyroxene and olivine. Scatter in the Na_2O data is mostly due to analytical uncertainty.

The trends of the major element data are compatible with a number of different evolutionary mechanisms, including fractional crystallization, magma mixing, assimilation, or combined assimilation and fractional crystallization (AFC). Major element data are not compatible with an evolutionary mechanism involving only selective crystal accumulation.

Viability of fractional crystallization as an explanation of major element trends can be demonstrated by least squares modeling. In this technique proportions of a presumed parent magma and probable fractionating phases are calculated (to provide a "calculated daughter") such that the calculated daughter composition is as close as possible to the proposed daughter. The sum of the squares of the differences between the proposed daughter and the calculated daughter (hereafter R^2) is minimized in the calculation, and is the numerical test of how good the model is. In practice R^2 of less than a few tenths indicates that for most or all major oxides the difference between the calculated daughter and the proposed daughter is within analytical error.

Results of such least squares calculations using the algorithm of leMaitre (1979) are presented in Table 1. Calculations were performed in increments along two different paths through compositional space (Figure 5) for both anhydrous and hydrous mineral assemblages, thus four different crystallization paths are represented in Table 1, 1->2b->7b->8 and 3->5b->8, each for hornblende-bearing and hornblende-free cases. The samples whose compositions were used are the most phenocryst-poor of the SVC samples ($\leq 25\%$ phenocrysts), thus maximizing the likelihood that they represent liquid compositions. The compositions of all silicate phases used in the calculations were derived from linear regressions of each element in each phase against Mg# ($\text{Mg}/\text{Mg}+\text{Fe}^{2+}$) or An ($\text{Ca}/\text{Ca}+\text{Na}$), and are thus averages, rather than "typical" analyses. (Variables of the equations describing mineral compositions are in Appendix II). Compositions of mafic phases were chosen to be in equilibrium with the average Mg# of the whole rocks in each step, and the plagioclase composition was chosen to minimize the CaO and Al_2O_3 residuals. Mg#s of pyroxene, olivine and plagioclase used in the calculations were typical of those found in the rocks. Results are presented for those calculations with lowest R^2 , and, for the hydrous cases, those which maximized the amount of hornblende crystallized.

In all cases the solutions have acceptable R^2 , and mineral proportions are similar to those observed in the rocks, with the exception that some solutions have anomalously high proportions of orthopyroxene. However, fractionation schemes calculated to reproduce the major element trends are incompatible with the observed trace element variations described below.

Additional information about the petrogenesis of the SVC lavas can be derived by transforming the data into normative plagioclase (PL), diopside (DI), olivine (OL), and silica (SI) and comparing them with other compositions from the literature

Table 1. Results of least-squares major element modelling

	ANHYDROUS							HYDROUS					
Path	1	2b	7	7b	8	3	5b	1	2b	7b	8	3	5b
Parent	AMSA04	PUM17	AMSB08	AMSA08	AF50	AMSB07	CP03	AMSA04	PUM17	AMSA08	AF50	AMSB07	CP03
Par. SiO ₂	51.28	54.08	56.19	57.46	60.72	53.13	56.91	51.28	54.08	57.46	60.72	53.13	56.91
Daughter	PUM17	AMSA08	AF50	AF50	SP04	CP03	AF50	PUM17	AMSA08	AF50	SP04	CP03	AF50
Dau. SiO ₂	54.08	57.46	60.72	60.72	62.84	56.91	60.72	54.08	57.46	60.72	62.84	56.91	60.72
SiO ₂	-0.03	-0.03	0.03	-0.02	0.04	0.02	-0.02	-0.06	-0.03	-0.07	0.01	-0.02	-0.04
TiO ₂	-0.06	0.03	-0.17	-0.02	-0.03	0.05	-0.07	0.00	0.05	0.08	0.05	0.22	-0.03
Al ₂ O ₃	-0.03	-0.02	0.00	-0.03	0.03	0.02	-0.04	-0.08	-0.05	-0.15	-0.04	-0.03	-0.05
FeO _t	-0.03	-0.04	0.06	-0.02	0.04	0.00	-0.01	-0.07	-0.06	0.10	-0.01	-0.07	-0.04
MnO	-0.04	-0.03	-0.04	-0.03	-0.02	-0.03	-0.03	-0.03	-0.02	-0.02	-0.01	-0.01	-0.02
MgO	-0.02	-0.04	-0.01	-0.01	0.01	0.00	-0.02	-0.09	-0.06	-0.06	-0.06	-0.04	-0.03
CaO	-0.02	-0.04	0.02	-0.02	0.02	-0.01	-0.02	0.00	-0.02	0.05	0.07	-0.05	-0.06
Na ₂ O	0.01	-0.16	0.04	0.08	-0.05	-0.13	0.09	0.09	-0.26	0.22	-0.05	-0.17	0.13
K ₂ O	0.04	-0.04	-0.06	-0.10	-0.13	-0.16	-0.09	0.05	0.02	-0.04	-0.06	-0.12	-0.06
sum R ²	0.01	0.04	0.06	0.02	0.03	0.05	0.03	0.03	0.08	0.13	0.02	0.10	0.03
liquid	0.74	0.69	0.65	0.78	0.78	0.63	0.64	0.73	0.75	0.80	0.82	0.63	0.66
ol	0.01					0.06							
pl	0.11	0.20	0.25	0.15	0.16	0.19	0.23	0.10	0.14	0.11	0.11	0.11	0.22
cpx	0.12	0.01	0.05	0.01	0.02	0.09	0.01	0.10				0.01	
opx		0.07	0.02	0.03	0.02		0.08		0.06			0.05	0.07
hb								0.06	0.03	0.08	0.07	0.19	0.04
mt	0.02	0.03	0.03	0.02	0.01	0.03	0.03	0.02	0.02	0.01	0.00	0.00	0.02
ol	0.04					0.15							
pl	0.42	0.64	0.72	0.69	0.74	0.52	0.66	0.36	0.58	0.55	0.60	0.30	0.62
cpx	0.44	0.05	0.14	0.07	0.10	0.25	0.04	0.36				0.03	
opx		0.23	0.05	0.15	0.11		0.23		0.24			0.14	0.21
hb								0.21	0.11	0.39	0.40	0.52	0.11
mt	0.10	0.08	0.09	0.09	0.05	0.08	0.07	0.07	0.08	0.06	0.00	0.00	0.06

Figure 5. Paths along which least-squares major element calculations were performed. Numbers refer to individual steps in Table 1.

which were formed under known conditions (Figure 6). SVC lavas fall in a band which is displaced from low to moderate pressure cotectics in both dry and water-undersaturated systems. Thus the SVC lavas cannot be related to each other solely by fractional crystallization of plagioclase, pyroxenes and olivine under conditions similar to those of the experimental runs referred to in Figure 6. The SVC lavas are also a poor match for the high-pressure, multiply-saturated, experimentally produced liquids of Elthon and Scarfe (1984) which plot on the OL side of the MORB cotectic in the projections PL-OL-SI and OL-PL-DI, instead of the PL side, where the SVC lavas plot.

Least squares modeling (Table 1) permits the interpretation that hornblende fractionation played a significant role in the genesis of SVC lavas. This possibility can be tested by comparing the relative positions of SVC data and experimental liquids known to be in equilibrium with hornblende. Such liquids from Helz (1976) are plotted in Figure 6. The higher SI and PL and lower DI and OL of hornblende equilibrated liquids compared to SVC lavas suggest that a petrogenetic model involving fractional crystallization of a hornblende-gabbro assemblage from a basaltic parent is not appropriate at Spurr.

Because the SVC lavas fall off experimentally determined cotectics, fractional crystallization cannot be a dominant process relating the lavas. The systematics of SVC lavas in PL-OL-DI-SI compositional space is very much like that of the Medicine Lake volcano lavas discussed by Grove et al. (1982). As discussed by Grove et al., the systematics suggest that crustal assimilation and/or magma mixing can be important petrogenetic processes.

Mafic SVC lavas are displaced from the low pressure MORB cotectic in the same direction as the evolved lavas, and are also displaced from compositions which are thought to be

Figure 6. Four projections in the tetrahedron PL-DI-OL-SI. Normative components were calculated by the method of Grove et al. (1982). One atmosphere MORB (pl+ol+cpx) and arc (2 px) cotectics are from Grove et al. (1982), Grove and Bryan (1983), Walker et al. (1979), and Baker and Eggler (1987). 2-5 Kbar (water undersaturated) and 8 Kbar (dry) cotectics are from Baker and Eggler (1987). Compositions of liquids equilibrated with hornblende are from Helz (1976). Analyses of McKinley sequence granites and Jura-Cretaceous flysch, from about 150 km north of the SVC, are from Lanphere and Reed (1985).

mantle-derived primary arc magmas by Kay et al. (1982) and Nye and Reid (1986) (Figure 6). As examples, when projected from OL, the proposed mantle-derived compositions of Kay et al. (1982) and Nye and Reid (1986) fall on the MORB array, while even the most mafic SVC lavas are displaced towards PL. When projected from DI all SVC lavas fall on the PL side of the MORB array, while mantle derived compositions fall on the OL side.

The most mafic SVC lavas are strikingly similar to high-Al parental compositions which, based on experimental phase equilibria, Johnston (1986) and Baker and Eggler (1983, 1987) claim are not related to mantle-derived melts by olivine dominated fractional crystallization, but are primary partial melts of the subducted slab. Evidence for these assertions is the large field of plagioclase-only at the liquidus (which requires that low-pressure olivine fractionation can not have been important in the past history of these magmas), and the fact that they are multiply saturated with clinopyroxene and garnet at high pressure (and thus can be melts of an eclogitic source). Marsh (1982 and previous papers), Myers et al. (1985, 1986), Brophy (1986) and Brophy and Marsh (1986) also advocate origin of parental Aleutian magmas by partial melting of the subducted slab.

There is, however, an alternative to fusing the slab to produce the most mafic SVC lavas and the starting materials of Johnston (1986) and Baker and Eggler (1983, 1987). Least-squares calculations show that removal of a plagioclase-poor mineral assemblage can drive mantle-derived primary arc magmas such as OK4 (Kay et al. 1982) to compositions similar to those which have a large interval of plagioclase crystallization on the liquidus (e.g. Kay et al. 1982; Conrad and Kay, 1984; Brophy, 1986; Gust and Perfit, 1987). Green and Ringwood (1967) have crystallized such an assemblage from a basalt at 9 kb, and state that the liquid produced by crystallization of such an assemblage may have only plagioclase on the liquidus

at low pressure. Gust and Perfit (1987) have also experimentally produced high-Al basalt from a high-Mg, mantle-derived basalt by moderate pressure crystallization of olivine and pyroxene. Kay et al. (1982) have previously appealed to high pressure clinopyroxene dominated crystallization to produce calcalkaline rocks from a mantle derived primary magma. A process of moderate-pressure fractionation of a plagioclase-poor assemblage may thus be able to produce the mafic SVC lavas, although the apparent conflict of this conclusion with the phase equilibria of high-Al basalt has yet to be resolved.

Trace Elements

Concentrations of Rb, Zr, Y, Nb, Sr, and Ni have been determined for all SVC samples (Appendix I). In addition this discussion will treat K as a trace element, since it is not an essential structural constituent of any precipitating phase. Rb, K and Zr increase linearly with increasing SiO_2 and Y and Nb remain constant (Figure 7). Sr and Ni are scattered, but decrease with increasing SiO_2 (Figure 7). All trace elements are scattered about their trends by amounts well in excess of analytical error. This scatter is especially evident in mafic lavas from Crater Peak and proto-Crater Peak, where, for example, Rb varies by more than a factor of 3 at constant SiO_2 . A few mafic ancestral Mt. Spurr lavas are also anomalously enriched in highly incompatible elements, and fall off the average trend of SVC lavas. Ancestral Mt. Spurr lavas are slightly higher in incompatible elements, and slightly lower in compatible elements, than other SVC lavas, although major element trends overlap with those of Crater Peak, Mt. Spurr and the pyroclastic fan, which permits the interpretation that a major discontinuity in magma supply or plumbing geometry developed just prior to caldera formation.

Numerical models of fractional crystallization have been constructed using the Raleigh fractionation equation,

Figure 7. Trace element variation diagrams. Abbreviations as in Figure 4.

proportions of minerals derived from the least-squares modeling described previously, and distribution coefficients from Gill (1981), Fujimaki et al. (1984), and Green and Pearson (1987) (Table 2). The results of these calculations are plotted in Figure 8. Variations in crystallizing mineralogy from Table 1 are reflected by inflections in the model crystallization trends.

Observed changes in concentrations of trace elements are incompatible with the interpretation that fractional crystallization is the major petrogenetic process relating SVC lavas. Specifically, Rb increases 8-fold throughout the suite although fractional crystallization can only account for a 3-fold increase (Figure 8). In contrast Y and Nb concentrations are nearly constant although fractional crystallization predicts a 2.5-fold increase with anhydrous crystallization assemblages and a 1.8-fold increase with hornblende-bearing assemblages. The range of SVC Zr concentrations is matched fairly successfully by models involving hornblende crystallization, but is less than models involving anhydrous crystallization would predict. SVC K concentrations match those predicted by the fractional crystallization models successfully.

The discrepancy in observed versus predicted Rb concentrations cannot be resolved by any changes in the input parameters of the Raleigh fractionation equation. Even if the bulk distribution coefficient for Rb were 0, least squares models with low enough proportions of liquid to explain the 8-fold increase in Rb concentrations cannot be constructed. In order to explain the lack of variation in Y and Nb concentrations distribution coefficients for pyroxenes and hornblende would have to be around 5 and 3, respectively, which far exceed experimental values. Alternatively Y and Nb concentrations could be produced by crystallization of some trace mineral with extremely high distribution coefficients

Table 2. Distribution coefficients used in trace element modelling (from Gill, 1981; Fujimaki and Tatsumoto, 1984). Y distribution coefficients are assumed to be those of Yb.

	Rb	K	Sr	Y	Zr	Nb	Ni
ol	0.01	0.01	0.01	0.01	0.01	0.01	58.00
pl	0.07	0.11	1.80	0.05	0.01	0.02	0.01
cpx	0.02	0.02	0.08	0.90	0.16	0.30	6.00
opx	0.02	0.01	0.03	0.46	0.05	0.35	8.00
hb	0.05	0.33	0.23	1.00	1.34	1.30	10.00
mt	0.01	0.01	0.01	0.25	0.40	1.00	10.00

Figure 8. Trace element fractional crystallization models. Calculations are based on the least-squares modelling of Table 1 and distribution coefficients of Table 2. Ia and Ih correspond to path 1-2b-7b-8 of Figure 5 for anhydrous and hornblende-bearing assemblages, respectively. IIa and IIh correspond to path 3-5b-8 of Figure 5, also for anhydrous and hornblende-bearing assemblages. Note that the fractional crystallization models fail to reproduce the magnitude of Rb variation and lack of Y and Nb enrichment.

for Y and Nb. However, no such phases have been identified in thin section.

The wide range of Rb concentrations is compatible with a mechanism involving multiple parental magmas with variable Rb, which have subsequently undergone fractional crystallization, but the narrow ranges of Y and Nb are not.

The wide range of Rb concentrations is also compatible with a mechanism involving mixing of Rb-rich country rock, or partial melts thereof, with the fractionating SVC lavas. Such models are difficult to evaluate numerically for two principal reasons. First, there is a lack of information about the composition of country rock in the Spurr area. The available information is compiled in Table 3. Note that there are only a few elements in common between Spurr and possible contaminants. Second, it is difficult to model partial melts of the crust, particularly for many trace elements, because the amount and nature of refractory phases with large concentrations of trace elements (e.g. zircon, sphene, etc.) are unknown and difficult to predict, and as long as such phases remain in the residue they will dominate the behavior of the elements they concentrate.

In spite of the above caveats, a few conclusions may be drawn about the possibility of contamination as a major petrogenetic process within the SVC. Table 3 presents data for four possible contaminants. McKinley sequence granites (MGR) are from the same intrusive unit that underlies the SVC, but were collected about 150 km north of Spurr (Lanphere and Reed, 1985). Jura-Cretaceous flysch samples (BC, Lanphere and Reed, 1985) are from the flysch sequence that the McKinley sequence granites intrude. The same flysch sequence is also intruded by the plutonic rocks under Mt. Spurr. The other sets of samples (CHIG, UGA) are from regional studies of the chemistry of basement rocks of all lithologies 650 km to the southeast along the arc from Spurr (Yount et al., 1978;

Table 3. Mean compositions of SVC lavas and potential crustal contaminants.
See text for descriptions of suites and references.

	SVC n=66		BC n=13		MGR n=20		CHIG n=448		UGA n=113	
	mean	sdev	mean	sdev	mean	sdev	mean	sdev	mean	sdev
SiO ₂	57.22	2.84	69.22	5.18	73.51	2.96				
TiO ₂	0.81	0.14	0.70	0.14	0.26	0.20	0.66	2.44	0.54	0.28
Al ₂ O ₃	17.80	0.60	12.78	2.96	14.15	0.82				
Fe ₂ O ₃	7.41	1.02	1.24	0.89	0.36	0.16				
FeO	4.77	1.12	1.68	0.94	8.17	4.29	5.56	3.50		
MnO	0.13	0.01	0.11	0.07	0.04	0.02				
MgO	4.25	1.17	2.34	0.88	0.37	0.32	1.73	1.08	1.73	1.16
CaO	7.31	0.99	1.26	1.67	1.33	0.64	2.38	3.16	1.89	1.91
Na ₂ O	3.52	0.30	1.80	0.77	3.17	0.26				
K ₂ O	1.33	0.35	1.61	0.61	4.57	0.45				
P ₂ O ₅	0.22	0.03	0.20	0.03	0.13	0.09				
LOI					0.51	0.25				
Cs			3.14	1.60	11.87	6.14				
Rb	27	9								
Ba							666	437		
Sr	572	68					524	545	475	333
Pb					65	3	42	224	23	15
Th			5.56	1.31	16.55	11.45				
Ce			36.4	5.5	73.4	23.4				
Yb			1.86	0.30	4.83	3.08				
Y	18	3			46	31	21	18	27	18
Nb	6.1	0.5			18	12				
Zr	109	21	127	59	153	78	131	94	96	43
Cr			133	43	7	7	90	121	73	76
Ni	23	20					38	42	48	54
V							249	135	253	136

Pickthorn et al., 1979, Detterman et al., 1980). The CHIG and UGA data sets are averages over all surface lithologies, and are assumed to represent bulk uppermost crust. Both of these data sets are from south of the Bruin Bay Fault, and are therefore from Peninsula Terrane of slightly different lithology (Wilson et al., 1985). There are few elements for which all data sets have been analyzed.

Bulk assimilation of McKinley granites is unlikely because of their high concentrations of Y and Nb. Admixture of large amounts of granite-derived partial melts is unlikely because of the high concentrations of Th and Pb in the granites. The maximum value for Th for SVC lavas was obtained by X-ray diffraction in the course of this study, but is not reported in Appendix I because of the low precision of the results, which are near the XRF detection limit. The Pb value for SVC lavas is an average value for Aleutian and Cascades high-silica calcalkaline andesites (Ewart, 1982). CHIG samples also have the low Y concentrations necessary in a contaminant, although the moderately high, although extremely variable, Pb may preclude this average as a significant contaminant. The UGA data set has lower mean Pb, but higher Y, than CHIG. There is enough variation in CHIG and UGA that a lithology with the proper composition to be a contaminant could probably be selected.

Good analyses of Pb and Th at SVC, and Rb in the contaminant suites, both to determine absolute concentrations and to determine the rate of increase throughout the suite, would provide strong constraints on the amount of crustal material that could be added. Both BC and MGR are high in radiogenic Sr and heavy O (Lanphere and Reed, 1985). Isotopic analyses of SVC lavas could also put strong constraints on possible assimilation/contamination models.

Finally, the curved nature of K and Zr vs. Rb in Figure 8 could be produced by assimilation or mixing with a crustal

contaminant, but not by fractional crystallization or mixing with an evolved lava produced by fractional crystallization of mafic SVC lavas.

PETROLOGY

Introduction

Spurr Volcanic Complex lavas are porphyritic, with most lavas containing more than 30% crystals. Plagioclase is ubiquitous and far more abundant than other mineral species. Olivine, orthopyroxene, and augite are found throughout the compositional range of the SVC, but olivine is in textural equilibrium only in the more mafic lavas, while orthopyroxene is in equilibrium in the more felsic lavas. Amphibole is volumetrically minor and confined to post-caldera units. Post-caldera units also contain abundant pyroxenite clots.

Evidence for disequilibrium is widespread, and includes petrographic evidence of textural disequilibrium, unexplainably large compositional ranges of plagioclase, small compositional range of amphibole, coexistence of phases which should not coprecipitate, and unexpectedly low Mg# pyroxenes.

Plagioclase

Plagioclase is ubiquitous in SVC lavas and is always the most common phenocryst. Modal concentrations (Appendix III) vary from 8% to 38%, and are typically 25-30% of the rock, and $75 \pm 10\%$ of the phenocrysts. Modal concentrations do not vary systematically with SiO_2 . Plagioclase textures run the full gamut typical of andesites. Crystals can be twinned, clumped, broken, rounded, or euhedral; equant or slightly elongated, but very elongated only in the groundmass; and clear or spongy. Spongy zones may be in the core, on the rim, or in between, and spongy cores may be either more or less anorthitic than surrounding clear rims. Zoning can be normal,

reverse, or oscillatory. Phenocrysts are typically a few millimeters in maximum dimension.

Core compositions show a broad trend of decreasing anorthite contents with increasing whole-rock SiO_2 (Figure 9). The most calcic cores decrease from An90 in the basalt to An58 in the Mt. Spurr and ash flow samples (with a few exceptions). More mafic samples have a greater tendency for all grains to be normally zoned. Intermediate and silicic samples have a greater tendency for grains to be both normally and reversely zoned, and very strong reversals are restricted to the most silicic rocks.

Phenocryst core compositions span at least 10 mole % An (and as much as 30 mole% An) in individual samples. Plagioclase compositions from individual samples can span in excess of 40 mole% An, including groundmass and rim compositions. The range of plagioclase compositions can be compared to experimental data in order to determine if it is possible that the plagioclase phenocrysts grew during closed-system crystallization, or if some more complex process must be invoked. Figure 10 shows curves for predicted plagioclase compositions versus the amount of material crystallized for a Spurr andesite and basalt for various $\text{CaO} - \text{Na}_2\text{O}$ exchange coefficients ($K_d = \text{wt\% } (\text{CaO}/\text{Na}_2\text{O})_{\text{pl}} / (\text{CaO}/\text{Na}_2\text{O})_{\text{liq}}$). The calculations were made by subtracting crystals of equilibrium composition from liquids in 5% crystallization increments. A proportion of clinopyroxene similar to that typical of the lavas was subtracted simultaneously in order to track the CaO composition of the evolving liquid accurately. $\text{CaO} - \text{Na}_2\text{O}$ exchange coefficients are not well known, but the data of Drake (1976, Table 2) suggest that values between 1 and 2 are appropriate. The data of Drake (1976) do contain high values of $\text{Ca}_{\text{pl}}/\text{Ca}_1$ at low temperatures, which result in exchange coefficients of 3 to 5.5, which are anomalously high compared to the rest of the data. Exchange coefficients of 2 to 3 most closely reproduce the trend of SVC lavas in CaO, Na_2O ,

Figure 9. $\text{Ca}/(\text{Ca}+\text{Na})$ of plagioclase vs. whole-rock SiO_2 of the enclosing magma. Abbreviations as in Figure 4.

$\text{CaO}/\text{Na}_2\text{O}$, and $\text{CaO}/\text{Al}_2\text{O}_3$. An exchange coefficient of less than 1 causes Na_2O contents to decrease, rather than increase as they do in the SVC (Figure 4). An exchange coefficient of more than 3 causes a much more rapid decrease in CaO and $\text{CaO}/\text{Al}_2\text{O}_3$ than is observed in SVC lavas.

In general, the range of plagioclase core compositions for individual samples exceeds that which could be produced by equilibrium, closed system crystallization. The samples for which plagioclase compositions are known average 25% plagioclase by volume. Figure 10 indicates that a maximum range of 12% An can be produced by crystallization of this amount of plagioclase. This is a maximum estimate of the range of An that could be produced, since it is calculated using the total volume of plagioclase phenocrysts, but the range of compositions of only the cores.

Variations in plagioclase chemistry beyond those compatible with crystallization could be due to several mechanisms, such as polybaric crystallization, crystallization at variable water pressures, inclusion of plagioclase xenocrysts, or removal of a portion of the plagioclase phenocrysts, so that the proportions of crystals in the lava do not reflect the total crystallization history of the magma. It is not possible to make unequivocal choices from the above mechanisms.

Olivine

Olivine is present in SVC lavas from the least to the most siliceous. In lavas with less than about 56% SiO_2 olivine is always euhedral and frequently has well developed skeletal terminations. Most, but not all, lavas in this silica range contain olivine. At higher SiO_2 contents olivine shows pronounced textural signs of disequilibrium, such as pyroxene-spinel symplectite coronas or jackets of tightly interlocked pyroxenes and plagioclase. Modal concentrations of olivine are usually near or less than 1%, with the exception of a few

Figure 10. Change in calculated plagioclase composition with fractional crystallization of SVC andesite and basalt for a range of $K_d^{\text{Ca}/\text{Na}}_{\text{pl-l}}$.

Crater Peak flows and the most mafic ancestral Mt. Spurr flows, which contain up to 5.8% olivine. Olivine crystals often contain small euhedral octahedra of translucent, brown, Cr-rich spinel. This suggests that those olivines which contain chromite crystallized before the magma became saturated with clinopyroxene, which competes effectively for Cr and drives the spinel phase to Fe-rich compositions.

Olivine compositions are in Appendix IV, and Mg# are plotted against the FeOt/MgO of the enclosing rock in Figure 11. Lines in Figure 11 are drawn for equilibrium between olivine and the whole-rock composition at the FMQ and NNO oxygen buffers, and one log unit f_{O_2} above NNO. These lines are constructed for a value of the Fe-Mg exchange coefficient $Kd^{Fe/Mg}_{ol-1}$ (moles $(FeO_{ol}/MgO_{ol})/(FeO_1/MgO_1)$) of 0.30 (Roeder 1974), and Fe_2O_3/FeO calculated for each sample using the empirical relation of Sack et al. (1980), equations of the various buffers from Chou (1978), assumed temperatures (which were derived by regressing all andesite temperature estimates from Table 4.1 of Gill (1981)), and the bulk compositions of individual samples. Inflections of the equilibrium lines are produced by variable bulk compositions and, to a much lesser extent, inferred temperatures, at constant FeOt/MgO. $Kd^{Fe/Mg}_{ol-1}$ of 0.3 is the recommended value of Roeder and Emslie (1970), Longhi et al. (1978), and Roeder (1974), and is independent of temperature. (Note that studies which find an apparent dependence of Kd on temperature have poorly controlled oxygen fugacities, which result in unknown Fe^{3+}/Fe^{2+} , and thus poor determinations of FeO/MgO_1 , as recognized by Green et al. (1975) and Usselman and Lofgren (1976)). $Kd^{Fe/Mg}_{ol-1}$ appears to increase with increasing pressure to approximately 0.33 8-10 Kbar (Ford et al., 1983; data of Bender et al., 1978, and Baker and Eggler, 1987).

Many of the rocks have olivine compositions nearly compatible with liquidus crystallization at reasonable oxygen fugacities, and successive nucleation of crystals during the

Figure 11. Olivine Mg# vs. FeO_t/MgO of the enclosing rock. Equilibrium lines are constructed for $K_d^{\text{Fe}/\text{Mg}} = 0.3$ and with whole-rock $\text{Fe}^{3+}/\text{Fe}^{2+}$ calculated as described in the text. Inflections of the equilibrium lines reflect the effect of different bulk compositions on $\text{Fe}^{3+}/\text{Fe}^{2+}$. Abbreviations as in Figure 4.

evolution of the residual liquid. Even the large range of core compositions for OFT-B07 (the sample with lowest FeO/MgO in Figure 11) can be produced by successive nucleation and growth of olivine during the growth of the 9% olivine and augite in the rock, but only if significant amounts of magnetite or hornblende are not coprecipitating and inhibiting iron enrichment in the residual melt. Olivine in PCP-A05 is too iron rich to be in equilibrium with the melt, but this sample contains dunite clots which were in the process of disaggregation when the rock cooled, thus some of the discrete crystals may have been derived from such clots and may be xenocrysts. Free olivine crystals in PCP-A05 are rounded, have thin reaction rims, and are the same composition as crystals within the dunite clots. Olivine in the AF and SP samples are in textural disequilibrium.

The fact that many samples fall slightly below the equilibrium curves can be due to our failure to analyze the most mafic crystal (which is quite likely considering the small number of analyses per sample), or could reflect crystallization at elevated, although crustal, pressure.

Olivine is normally zoned (by as much as FO_{10}) in mafic samples, where it is euhedral and in apparent equilibrium. Conversely, olivine is unzoned in more evolved samples, where it is in textural disequilibrium, and may be being resorbed. Olivine in dunite clots is, for the few crystals analyzed, unzoned.

Olivine textures and chemistry suggest that olivine is a stable precipitating phase in SVC magmas of up to about 56% SiO_2 . In more evolved lavas olivine crystals are xenocrysts, at least some of which come from deep-seated cumulate bodies.

Clinopyroxene

Clinopyroxene is ubiquitous in the SVC and comprises between 0.25 and 8.25 volume percent (3.5% on average) of the

mode (Appendix V), and $10 \pm 6\%$ of the phenocrysts. Clinopyroxene and orthopyroxene are in subequal proportions in SVC lavas. Phenocrysts are typically about a millimeter long, stubby to equant, euhedral to subhedral, and only slightly zoned. Zoning is generally, but not always, normal. Clinopyroxene also occurs as polycrystalline, monomineralic clots which are described in more detail below.

The clinopyroxenes are augites of restricted composition ($\text{En}_{40-53}\text{Fs}_{8-19}\text{Wo}_{36-44}$). The augites have compositions that are broadly typical of others from the Aleutian arc (Kay and Kay, 1985). SiO_2 and CaO remain constant with increasing $\text{Mg\#}$, Al_2O_3 increases slightly, MnO and Na_2O decrease slightly, and TiO_2 is very scattered. There are no Cr_2O_3 analyses for the most mafic augites. For the remaining samples Cr_2O_3 contents are always less than 0.10 wt%, and usually less than 0.05 wt%. Coefficients for equations describing the average chemistry of SVC clinopyroxenes are in Appendix V. Concentrations of nonquadrilateral components (calculated by the scheme of Lindsley, 1983) sum to $7 \pm 4\%$, and are independent of quadrilateral-component composition, with the exception of AlCaTs , which is slightly higher in En-rich, Wo-poor pyroxenes.

WO concentrations of pyroxenes, based on the graphical two-pyroxene thermometer of Lindsley (1983) yield temperatures between 800 and 1150 degrees C. WO concentrations are marginally higher in the ashflow samples than in the Crater Peak samples, indicating slightly lower temperatures for the more evolved samples.

Augite $\text{Mg\#s}$ are plotted against the FeO_t/MgO of the enclosing rock in Figure 12. There is broad overlap in pyroxene composition between samples, although the most magnesian core compositions tend to drop with increasing whole-rock FeO_t/MgO , as expected. With few exceptions, the most magnesian cores in individual samples have much lower $\text{Mg\#}$

Figure 12. Clinopyroxene Mg# vs FeO_t/MgO of the enclosing rock. Equilibrium lines were constructed in the same manner as for olivine. Abbreviations as in Figure 4.

than would be expected if they were in equilibrium with the whole rock. $Kd^{Fe/Mg}_{cpx-1}$ has not been studied as extensively as $Kd^{Fe/Mg}_{ol-1}$, but values of around 0.25 are typical of values observed in experimental runs at low to moderate pressure (e.g. Grove et al., 1982; Baker and Eggler, 1987).

The following are possible processes which might produce augite compositions less mafic than expected, along with brief discussions of their possible effectiveness:

1) Augite compositions less magnesian than whole rock chemistry predicts could be due to failure to analyze the most magnesian grain in each sample. However, the homogeneity of compositions within many samples suggests that the observed ranges are representative.

2) Augite might have crystallized further below the liquidus than another ferromagnesian phase. Thus it is conceivable, especially for the mafic samples, that magma cooled to the olivine saturation surface and precipitated olivine for an interval before nucleating augite. The augite would then precipitate from a liquid composition less magnesian than the whole rock. This mechanism is less appealing for more siliceous samples, where textural relations suggest that augite is the first mafic phase to crystallize (i.e. there is no mafic phase which precedes clinopyroxene during crystallization).

3) Whole-rock FeO_t/MgO could be substantially less than those of liquids because of selective phenocryst accumulation or fractionation. Accumulation of either 2.5% (by weight) olivine, 5% orthopyroxene, or 8% clinopyroxene could lower the whole-rock FeO_t/MgO by about 0.5, or accumulation of

all mafic phases together could lower the whole-rock FeO_t/MgO by about 1.5 (Figure 13). These crystal proportions equal or exceed those of the magmas, but are insufficient by about half to explain the unexpectedly low Mg# of the augites. Alternatively, selective removal of about 5% magnetite could also lower whole-rock FeO_t/MgO by about 1.5. Note that this requires that magnetite be separated from the magma, and from the pyroxenes, after pyroxene crystallization.

4) $K_d^{\text{Fe/Mg}}_{\text{cpx-1}}$ may be high. If $K_d^{\text{Fe/Mg}}_{\text{cpx-1}}$ were 0.40 (at NNO) then augites of the observed composition would be in equilibrium with the whole-rock compositions. There is no experimental support for such high values of $K_d^{\text{Fe/Mg}}_{\text{cpx-1}}$, however.

Orthopyroxene

Orthopyroxene is present in all but the most mafic SVC magmas. It comprises 0.5 to 8.5% (3.8% on average) of the mode (Appendix VI), and $10 \pm 6\%$ of the phenocrysts. On average, clinopyroxene and orthopyroxene are present in subequal amounts, although the cpx/opx ratio ranges between 0.05 and 8.0 in extreme cases. Phenocrysts are typically about a millimeter long, have aspect ratios of 2 to 3, are euhedral to subhedral, and only slightly zoned. Zoning can be normal or reversed, and is more apt to be reversed in mafic, olivine bearing, samples.

Orthopyroxenes have a wide compositional range ($\text{En}_{53-82}\text{Fs}_{15-46}\text{Wo}_{0.4-5}$), although those orthopyroxenes more iron rich than En_{60} are rare and form rounded crystal cores of unusual composition which are probably of xenocrystic origin. SiO_2 , Al_2O_3 , and CaO increase with increasing En, MnO decreases, and TiO_2 and Na_2O remain constant. Coefficients of linear equations describing orthopyroxene chemistry are in Appendix VI. Concentrations of nonquadrilateral components

Figure 13. Effect of olivine and pyroxene addition and magnetite subtraction on the FeO_t/MgO of a typical SVC andesite.

(calculated by the method of Lindsley, 1983) sum to $3.6 \pm 2.7\%$. Amounts of nonquadrilateral components whose abundances are dictated by Na and Ti are independent of En. However, as with the augites, Al_2O_3 (and thus $\text{R}^2\text{R}^3\text{AlSiO}_6$, whose abundance is controlled by Al excess over Na + Ti) increases with increasing Mg. Wo contents are independent of the composition of the enclosing rock.

The Mg#s of orthopyroxenes are plotted against whole-rock FeO_t/MgO in Figure 14. The pattern of variation of chemistry is very similar to that of the augites discussed previously. There is broad overlap in crystal chemistry between samples, but the most magnesian cores in each sample generally become less magnesian with increasing whole-rock FeO_t/MgO . As with the augites, opx crystals are more iron-rich than expected if opx were a liquidus or near-liquidus phase, if whole-rock compositions closely reflect liquid compositions, and if $K_d^{\text{Fe/Mg}}_{\text{opx-l}}$ is 0.3. $K_d^{\text{Fe/Mg}}_{\text{opx-l}}=0.3$ is derived from the composition of coexisting augite and orthopyroxene given by Lindsley (1983) and the value of $K_d^{\text{Fe/Mg}}_{\text{cpx-l}}$ given by Grove et al. (1982). Baker and Eggler (1987) give slightly lower values of $K_d^{\text{Fe/Mg}}_{\text{opx-l}}$. The same possible explanations set forward for the iron-rich nature of the augites could apply to the orthopyroxenes.

Amphibole

Amphibole occurs in minor or trace amounts in some of the samples from proto-Crater Peak, Crater Peak, the pyroclastic fan, and Mt. Spurr, but not in samples from the ancestral Mt. Spurr or the ash flows. Amphibole usually occurs in such small amounts, however, that its absence from individual thin sections may not mean that it is absent from the flow, or even the hand specimen from which the thin section was cut. It is in textural equilibrium (euhedral and without reaction rims) only in pumice from the 1953 eruption. In most samples amphibole crystals are rounded or broken and coated with heavy

Figure 14. Orthopyroxene Mg# vs FeO_t/MgO of the enclosing rock. Equilibrium lines were constructed in the same manner as for olivine. Abbreviations as in Figure 4.

opacite rims. Crystals are typically subequant and as large as 1.3 mm in maximum dimension. In sample PCP-B01, from proto-Crater Peak, amphibole occurs as large platy crystals which armour small clinopyroxenite nodules. Pleochroism of amphibole in the pumice from the 1953 eruption is in shades of green and brownish-green, while crystals in all other samples are brown to bright reddish-brown.

All SVC amphibole analyses are pargasite according to the classification scheme of Leake (1978) as modified by Hawthorne (1981). Chemical compositions of amphiboles and coefficients of linear equations describing amphibole chemistry are in Appendix VII. As Mg# decreases over the range of the samples (Mg#=72 to 96) SiO_2 , CaO, Na_2O , and K_2O remain fairly constant, Al_2O_3 decreases from about 13.5% to 11.5% (although tetrahedral Al remains constant), and TiO_2 increases from about 2.0% to 3.8%. F and Cl are independent of Mg# and average $0.11 \pm 0.06\%$ and $0.02 \pm 0.02\%$, respectively.

In most respects, SVC amphiboles overlap the fields of previously described Aleutian amphibole. In general, they are intermediate in composition between amphiboles from lavas (Daley, 1986; Kay and Kay, 1985) and mafic and ultramafic nodules proposed to have formed at lower crustal or upper mantle pressures (Conrad and Kay, 1984; DeBari et al., 1987). In their consistently high alkali and Al_2O_3 , and low SiO_2 contents, they resemble the nodule amphiboles, but in their variable Mg# and high $\text{Na}_2\text{O}/\text{K}_2\text{O}$ they resemble amphiboles from lavas. The following aspects of their chemistry are noteworthy.

First, SVC amphiboles occupy the upper end of the Aleutian Al^{IV} distribution, and, with the exception of amphibole from Mt. Spurr, have higher Na + K than other Aleutian lavas (Figure 15). In terms of Al^{IV} and alkali content the SVC amphiboles more closely resemble those of cumulate and composite xenoliths from the lower crust or upper mantle

Figure 15. Al^{IV} vs. $Na+K$ for SVC hornblendes and other Aleutian hornblendes from Daley (1986), Kay and Kay (1985), DeBari et al. (1986) and Conrad and Kay (1984).

(Conrad and Kay, 1984; DeBari et al. 1987). Al^{IV} and (Na + K) are strongly temperature dependant (see Hammarstrom and Zen, 1986, for summary) so SVC amphiboles all must have crystallized at high temperature.

Second, Na + K and Al^{IV} remain constant with decreasing Mg#, while Al_2O_3 decreases by about 2 wt%. Because Al_2O_3 can be used as a geobarometer in igneous amphibole (Hammarstrom and Zen, 1986; Hollister et al., 1987) the combined behavior of Al_2O_3 and Na + K and Al^{IV} suggest near isothermal crystallization at pressures of 8.2 ± 1 to 6.2 ± 1 kbar, or between 19 and 25 km deep in the crust. (Note that total Al does decrease with decreasing Mg#, suggesting that there was polybaric crystallization even though it cannot be statistically resolved with the error estimates of Hollister et al., 1987).

Third, TiO_2 concentrations correlate negatively (and strongly - $R=0.833$) with Mg#. TiO_2 concentrations of iron-rich SVC amphiboles are greater, by up to 1 wt%, than previously reported Aleutian amphiboles, and TiO_2 concentrations at the magnesian end of the SVC array are higher than most other Aleutian amphiboles. TiO_2 concentrations of SVC lavas are not, however high with respect to other Aleutian magmas. The significance of the TiO_2 concentrations is unclear, but the negative correlation with Mg# is not expected during falling temperature during magma crystallization. A lack of correlation of TiO_2 with the temperature indicators (alkalies and Al^{IV}), confirms that SVC TiO_2 systematics are not temperature related. The TiO_2 increase may be related to closed system crystallization of a single batch of magma, although the TiO_2 variation of over a factor of two would probably require substantial amounts of crystallization. Alternatively, the TiO_2 variations may reflect, in some as yet unspecified way, competition for Ti between amphibole and an oxide phase.

Finally, SVC amphiboles are of very constant composition regardless of the composition of the surrounding magma (unlike the Augustine amphiboles of Daley, 1986). This suggests that all the pargasite crystals had a similar origin, and the high Na + K, Al^{IV} , and Al_2O_3 suggest that the magma that crystallized them was at high T and moderate P. It seems most likely that the amphibole crystallized from the mafic Crater Peak and proto-Crater Peak magmas, and was then mixed into the silicic Mt. Spurr magmas immediately prior to eruption.

Spinel

There are two main types of magmatic spinels within the SVC - titanomagnetite and Fe^{3+} -rich Cr-spinel. The titanomagnetite occurs in most samples and consists of phenocrysts and microphenocrysts and as inclusions in pyroxenes.

The Cr-spinel, in contrast, occurs only as well formed octahedra included in olivine. Compositions of the Cr-spinels are listed in Appendix VIII. The less evolved spinels (those with highest Mg#) are characterized by 30-35% Cr_2O_3 , 20-25% Al_2O_3 , and 15-20% Fe_2O_3 . With decreasing Mg#, $\text{Al}/(\text{Al}+\text{Cr}+\text{Fe}^{3+})$ decreases and $\text{Fe}^{3+}/(\text{Al}+\text{Cr}+\text{Fe}^{3+})$ increases (Figure 16). Cr/(Cr+Al) variation as Mg# decreases is more complicated. In sample OFT-B07 (one of the mafic ancestral Mt. Spurr samples) Cr/(Cr+Al) increases dramatically as Mg# drops, which presumably reflects change of spinel composition with successive crystallization. Note that the high Cr/(Cr+Al) spinels are preserved in the rim of the olivine studied, while the high $\text{Al}/(\text{Al}+\text{Cr}+\text{Fe}^{3+})$ spinels are preserved in the core. Because Al solubility in spinel is a function of pressure, this trend in spinel composition is probably produced by crystallization during ascent of the magma body. Spinel in acid andesite from Mt. Spurr have low Cr/(Cr+Al), low Mg#, and Fe. This may reflect protracted crystallization, and hence removal of Cr from the liquid, at moderate pressures.

Figure 16. $\text{Cr}/(\text{Cr} + \text{Al})$, Y Al ($\text{Al}/(\text{Al} + \text{Cr} + \text{Fe}^{3+})$), and Y Fe^{3+} ($\text{Fe}^{3+}/(\text{Al} + \text{Cr} + \text{Fe}^{3+})$) vs. $\text{Mg\#}$ for SVC spinels and other Aleutian spinels from Nye and Reid (1986), DeBari et al. (1986), and Conrad and Kay (1984).

Compositions of refractory SVC spinels fall within the spectrum of previously described Aleutian spinels but are notable in that they have $\text{Cr}/(\text{Cr}+\text{Al})$, $\text{Al}/(\text{Al}+\text{Cr}+\text{Fe}^{3+})$ and Al_2O_3 contents intermediate between plagioclase-bearing (thus relatively low pressure) and plagioclase-free, Al-spinel-bearing (thus relatively high pressure) xenoliths (Figure 16 and references therein). SVC spinels are also more aluminous than those included in olivine phenocrysts from Okmok, a tholeiitic volcano from the central Aleutians. The aluminous nature of refractory SVC spinels, and the fact that $\text{Al}/(\text{Al}+\text{Cr}+\text{Fe}^{3+})$ is higher than low-pressure spinels for all Mg#s, probably reflects moderate to high initial pressure of crystallization and moderate pressure of crystallization of derivative liquids, at the SVC. In this sense, the implications of spinel composition are similar to the implications of amphibole composition discussed previously.

Crystal Clots

Clots of crystals occur in samples of lavas from proto-Crater Peak, the pyroclastic fan, and less commonly Crater Peak, and even less commonly in the mafic ancestral Mt. Spurr samples. These clots are of three basic lithologies - pyroxenite, anorthosite, and plagioclase-hercynite aggregates. Gabbroic clots, which are common in many calcalkaline volcanoes, are rare.

Pyroxenite clots are most frequently orthopyroxenite or clinopyroxenite, less frequently websterite, and even less frequently olivine websterite. Clots with primary lherzolitic lithology have not been found. Clots attain maximum diameters of only a few centimeters, and are composed of tightly interlocked, coarse, equant, grains. Individual clinopyroxene grains have pronounced oscillatory zoning, although chemical differences between individual zones are small. Orthopyroxene grains frequently contain patches (presumably exolved) of clinopyroxene. Pyroxenite clots are frequently surrounded by

reaction rims of small, equant, olivine grains, which can incorporate interstitial melt as well as other crystals, such as plagioclase. In some cases pyroxenite clots are surrounded by millimeter-sized amphibole crystals whose long axes tangential to the clots.

The field of clinopyroxene composition from the clots overlaps the field of SVC phenocryst composition completely, although clot clinopyroxenes are, on average, lower in SiO_2 and higher in TiO_2 , Al_2O_3 , and Na_2O than phenocryst pyroxenes. Orthopyroxene from clots and megacrysts falls within the range of phenocryst opx compositions but is of restricted $\text{Mg\#}$ (70-75) and, on average, higher in CaO and Wo .

Anorthosite clots are similar in size and shape to the pyroxenite clots and are composed of tightly interlocked, slightly elongated crystals similar in composition to phenocrysts.

The pyroxenite and anorthosite clots together appear to be fragments of a layered mafic/ultramafic body. Crystals within the clots are completely unaltered, which suggests that they are very young. The clots were probably ripped from the floor of a recently crystallized or still active magma chamber.

Plagioclase-hercynite clots are extremely corroded, rounded clots composed of primary plagioclase with disseminated hercynite crystals throughout. The hercynite appears to be produced during breakdown of the plagioclase. These clots may be crustal xenoliths that are being digested by the magma or may be older anorthosite clots. Plagioclase-hercynite clots are much more uncommon than anorthosite clots. There is no petrographic gradation between the plag-hercynite clots and anorthosite clots.

SYNTHESIS AND INTERPRETATION

For most of the lifetime of the Spurr Volcanic Complex high silica magmas of uniform composition were erupted from the ancestral Mt. Spurr stratovolcano. K-Ar ages of Turner and Nye (1986) indicate that such andesite production occurred over the interval of slightly more than 0.255 Ma to slightly less than 0.058 Ma. Andesite production was periodically interrupted by the injection of new, mafic, magma, and resultant eruptions of more mafic andesites. Intervals between resupply were a minimum of 50,000 years, which is the interval between eruption of anomalously mafic material (Figure 3; Turner and Nye, unpublished K-Ar ages). Note that this is a minimum estimate since other mafic flows may not have been sampled.

The building of ancestral Mt. Spurr ended by avalanche caldera formation sometime before 7,000 years ago (Riehle, 1985), and perhaps before 38,000 years ago (Turner and Nye, unpublished data), but after 58,000 years ago. Magmatism subsequent to caldera formation was of an entirely different nature and reflects simultaneous eruption of two magmas and mixtures thereof. One of the magmas was more silicic than anything previously erupted, and one more mafic. The silicic magma is preserved as ashflow(s) resting on top of the debris avalanche and as the present Mt. Spurr. The mafic magma forms proto-Crater Peak and Crater Peak. The pyroclastic fan south of Crater Peak is a mixture of the two magmas. Eruption of silicic material ended around 5,000 years ago (Riehle, 1985). Since then mafic material has been erupted from Crater Peak. The chamber feeding Crater Peak is at a minimum depth of 23 km, as shown by the aluminum content of hornblende contained in ejecta from the 1953 eruption.

The geological history is consistent with a scenario in which for the bulk of the lifetime of the volcano magma is supplied to the surface from a periodically reinjected mid-

crustal or lower crustal magma chamber. Protracted crystallization (accompanied by crustal contamination) resulted in a chamber mostly filled with layered pyroxenite and anorthosite overlain by atypically silicic magma. This chamber was injected by new mafic material from depth resulting in a stratified chamber with mafic magma overlain by cumulate debris overlain by silicic magma. There was mixing between the basalt and the crystal debris and the basalt-crystal mixture and the silicic magma. The injection and mixing process destabilized the chamber and it vented to the surface to produce the ashflow(s), Mt. Spurr, the pyroclastic apron, and proto-Crater Peak. The mechanism of mixing and ascent must have been complex because all three units were coeruptive. The mixing-eruption event must have removed all of the silicic magma, because none has erupted in the last 5,000 years (Riehle, 1985). Crater Peak lavas have much less crystal debris than proto-Crater Peak lavas.

The location of the magma chamber, and the depth from which Holocene magmas rise is constrained by the aluminum concentration of the most aluminous hornblende to be at least 25 km deep (see previous discussion of hornblende chemistry). The aluminous nature of spinel inclusions in olivine also suggest derivation from moderate depths.

The above scenario is the simplest description of the history of the SVC. Certain aspects of the chemistry require that fine-scale details are considerably more complex. The large variation in Rb, Zr, and K at constant SiO_2 , decoupled major elements (e.g. decreasing SiO_2 with increasing K_2O) in proto-Crater Peak lavas, and the mafic-felsic-mafic trend in Crater Peak lavas cannot be produced during the mixing and crystal accumulation event described above. This suggests either that the mafic magma was added in at least a few different batches of different composition, that some magma body was in chemical disequilibrium, or that some other component (such as a crustal melt) was added during eruption

or near enough to the time of eruption that homogenization could not occur.

At a given SiO_2 ancestral Mt. Spurr lavas have slightly higher incompatible element concentrations than post-caldera units. This suggests some fundamental shift in either parent magma composition or petrogenetic processes at the time of caldera collapse.

Certain aspects of major and trace element geochemistry are not consistent with an evolutionary mechanism dominated by crystal fractionation. SVC lavas are displaced from dry and water undersaturated low to moderate pressure cotectics in the direction away from normative DI. Olivine plus plagioclase crystallization of such magmas would drive their composition back towards the cotectic. Instead, the SVC magmas form a broad band parallel to the cotectic extending toward SI. As discussed by Grove et al. (1982), this suggests the mixing with a silicic crustal component or partial melt thereof. Also, the lack of increase of Y and Nb concentrations with increasing SiO_2 is inconsistent with fractional crystallization and suggests mixing with a low Y, low Nb, end member. It is not possible to specify what the silicic mixing end member is, or if it is liquid or solid, without determination of the isotopic composition of SVC lavas and trace element and isotopic composition of possible crustal end members. The information at hand suggests assimilation of continental sediments or partial melts of McKinley granites rather than bulk assimilation of the granites.

It seems most likely that contamination happened as the magmas were residing in their mid-crustal magma chambers.

IMPLICATIONS FOR GEOTHERMAL RESOURCES

Of critical interest to geothermal exploration at Mt. Spurr is the question of whether there is a large, shallow, magma chamber supplying heat to the geothermal system, or if there has been such a magma chamber recently enough to significantly increase the local geothermal gradient. As summarized above, for the past 5,000 years volcanism at the SVC has been dominated by eruptions of basaltic andesite which are newly arrived from depths of at least 25 km. These magmas have not had sufficient shallow residence time for hornblende to dissolve, in fact, hornblende in the 1953 ejecta does not even have reaction rims. This suggests pre-eruption residence time on the order of years, at most. Not all of the magma which comes to the surface in any eruptive cycle need erupt, however, so the possibility that some mafic magma remains near the surface as a result of the 1953 eruption cannot be discounted. In many volcanoes a significant fraction of all available magma erupts. Since the 1953 eruption was only of moderate size relatively little magma probably remains near the surface, perhaps on the order of 10^{-2} km^3 .

During and after caldera formation there was a relatively large body of high-silica andesite which ultimately erupted to form the Mt. Spurr dome. By virtue of its higher silica content this magma was less dense than other SVC magma, and thus may have resided at more shallow depths. In early Holocene time there was apparently extensive hybridization between the silicic magma and the deeply derived mafic magma. These hybrid magmas form the pyroclastic fan. The fact that hybrid magmas have not erupted during the last 5,000 years indicates that the (potentially) shallow body has either crystallized or erupted or been effectively isolated from the plumbing system by which mafic magmas reach the surface. The most straightforward interpretation is that the lack of eruptive products of a shallow silicic body means that there is no such body.

While the volcanic history suggests that there is not a large, shallow, silicic magma chamber, enough heat must somehow be being supplied to the volcanic edifice to produce the hot springs and fumeroles that exist on the surface. These include the Crater Peak fumerole field, the field of steaming ground and diffuse fumeroles on Mt. Spurr, and the zone of warm springs at the base of Crater Peak. There is presumably also enough geothermal heat being provided to account for the soil Hg and He anomalies.

The chemistry of the geothermal fluids is discussed in Appendix IX. The waters from the warm springs appear to be a mixture of waters from diverse sources causing interpretation of chemical geothermometers to be problematic. The fumarole gases, on the other hand, contain chemical information suggesting a reservoir temperature on the order of 200°C. The heat driving these geothermal phenomena may be derived from either residual magma from the 1953 eruption, from residual heat from the emplacement of the Mt. Spurr dome, or both.

Geophysical and geochemical data of Turner and Wescott (1986) have described a subsurface layer with very low resistivity which they suggest may be a geothermal aquifer. This layer coincides with positive surface Hg and He anomalies and self potential anomalies. The concordance of geophysical and geochemical anomalies provides evidence that the subsurface layer is a geothermal aquifer. However, the apparent lack of a shallow magmatic body to provide heat to such an aquifer, and the apparent absence of any magma body in the upper 25 km of crust provides reason to find an alternative explanation for the low resistivity layer. This layer may, then, be one of the large (up to a few tens of meters thick) ashflow-tuffs associated with the Tertiary sediments immediately to the east of the SVC. These ashflows are extensively altered to clays, and are presumably excellent electrical conductors. The low-resistivity layer is structurally similar to the Tertiary sediments immediately

east of Straight Creek Glacier (Barnes, 1966) in that it dips southward near the projection of the normal fault on Figure 1 and then flattens out south of the fault projection.

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APPENDIX I - Whole-rock chemistry and point-count data

Whole rock chemistry was determined by analyzing all samples in duplicate on the Alaska Division of Geological and Geophysical Surveys fully automated Rigaku 3064 spectrometer. Data reduction software was modified from that developed for the Rigaku 3064 at New Mexico Tech by B. Farris.

Major element concentrations were determined on fused pellets fluxed with a $\text{Li}_2\text{B}_4\text{O}_7$ - LiCO_3 - La_2O_3 mixture. Mean analytical precision of duplicate fusions of single samples (1 st. dev./mean) is between 0.2 and 0.7% (or 0.01 wt.%) except for Na_2O , which is less than 3%.

Trace element concentrations were determined on boric acid-backed pressed powder pellets bound with polyvinylalcohol. Trace element determinations have mean analytical precision of better than 1% relative or 0.5 ppm, with the exception of Ni, for which precision is better than 2 ppm at concentrations of 10 to 50 ppm.

Analytical results compare extremely favorably with analyses of the same unknowns by isotope dilution, atomic absorption spectrometry, instrumental neutron activation analysis and XRF spectrometry at MIT, UC Santa Cruz and the Memorial University, Newfoundland. These comparisons, together with analyses of known compositions, indicate that whole rock data are accurate to better than 2% relative for major elements, and 5% relative, or a few ppm, for trace elements.

Modes were determined by counting 300 points on single thin sections from each sample.

Spurr Volcanic Complex whole rock data, major elements normalized anhydrous

strat# field#	AMS-26 85cns26	AMS-B01 85cns59	AMS-B02 85cns58	AMS-B03 85cns57	AMS-B04 85cns56	AMS-B05 85cns55b	AMS-B06 85cns44	AMS-B07 85cns43	AMS-B08 85cns42	AMS-B09 85cns41n	AMS-B10 85cns40	AMS-A01 85cns25	AMS-A02 85cns24	AMS-A03 85cns23	AMS-A04 85cns22
SiO2	53.90	59.12	58.01	59.52	58.06	59.43	59.60	53.13	56.19	59.50	58.46	59.57	59.56	59.91	51.28
TiO2	0.97	0.69	0.83	0.70	0.76	0.79	0.79	0.88	1.00	0.80	0.76	0.71	0.73	0.72	1.07
Al2O3	17.29	16.79	18.61	16.95	17.61	17.33	18.11	17.02	18.83	18.09	18.26	17.32	17.33	17.37	17.94
Fe2O3	8.52	6.71	7.10	6.58	7.08	6.77	6.41	8.66	7.25	6.48	7.09	6.70	6.78	6.64	9.37
MnO	0.14	0.12	0.12	0.11	0.12	0.11	0.11	0.14	0.13	0.12	0.12	0.12	0.13	0.13	0.16
MgO	5.24	4.78	3.46	4.17	4.20	3.50	2.97	7.20	3.38	3.02	3.39	3.44	3.50	3.11	6.01
CaO	9.30	6.57	6.94	6.46	7.11	6.47	6.31	8.49	8.17	6.27	6.66	6.56	6.64	6.65	10.30
Na2O	3.03	3.38	3.29	3.61	3.33	3.63	3.76	3.31	3.56	3.79	3.64	3.63	3.43	3.53	2.92
K2O	1.40	1.66	1.42	1.72	1.54	1.75	1.70	0.96	1.25	1.69	1.39	1.74	1.70	1.74	0.71
P2O5	0.21	0.19	0.22	0.19	0.20	0.22	0.24	0.21	0.25	0.24	0.24	0.20	0.20	0.20	0.24
LOI	1.25	-0.09	-0.16	-0.09	-0.14	-0.11	0.58	-0.24	0.17	0.63	-0.19	-0.15	-0.16	-0.17	-0.26
TOTAL	100.07	100.54	100.28	100.03	100.61	99.86	100.10	99.66	100.48	100.36	100.33	100.40	100.38	99.82	100.77
CaO/Al2O3	0.54	0.39	0.37	0.38	0.40	0.37	0.35	0.50	0.43	0.35	0.36	0.38	0.38	0.38	0.57
FeO/MgO	1.46	1.26	1.84	1.42	1.52	1.74	1.94	1.08	1.93	1.93	1.88	1.75	1.74	1.92	1.40
FMQ FeO/MgO	1.24	1.06	1.55	1.18	1.27	1.44	1.60	0.93	1.62	1.60	1.57	1.45	1.44	1.58	1.21
NNO FeO/MgO	1.17	1.00	1.46	1.11	1.20	1.35	1.51	0.88	1.52	1.50	1.48	1.36	1.36	1.49	1.14
NNO+1 FeO/MgO	1.03	0.87	1.29	0.97	1.05	1.18	1.32	0.79	1.34	1.31	1.30	1.19	1.19	1.30	1.02
Rb	28.6	35.6	33.0	38.7	33.8	40.1	39.9	17.9	24.1	39.8	32.5	35.6	35.7	37.2	6.3
K	11593	13777	11819	14262	12772	14541	14097	7978	10345	14068	11562	14448	14119	14446	5916
Sr	635	498	518	460	504	486	563	473	525	567	507	511	517	510	681
Y	18.6	18.7	20.1	20.4	20.4	22.1	19.9	18.3	21.0	19.5	19.7	20.4	20.4	20.6	17.5
Zr	108	135	115	138	120	141	138	82	111	138	117	137	134	135	68
Nb	6.3	6.5	6.7	6.3	6.3	7.1	7.0	5.6	7.5	7.3	6.6	6.6	6.3	6.1	5.5
Ni	15	26	7	18	14	11	8	38	10	7	9	12	11	10	21
K/Rb	404.9	387.3	358.3	368.1	377.4	362.5	353.3	445.9	430.1	353.5	355.5	405.5	395.2	388.8	937.6
K/Y	623.3	735.2	588.9	700.8	624.8	657.2	709.5	435.0	492.9	722.2	588.1	709.3	692.1	702.6	337.7
Zr/Y	5.8	7.2	5.7	6.8	5.9	6.4	6.9	4.5	5.3	7.1	5.9	6.7	6.5	6.6	3.9
Rb/Zr	0.264	0.264	0.288	0.282	0.282	0.285	0.290	0.217	0.217	0.289	0.279	0.261	0.267	0.275	0.092
K/Zr	106.9	102.2	103.2	103.6	106.4	103.5	102.5	96.7	93.3	102.2	99.0	105.8	105.7	107.0	86.6
ol	5.0							5.8	1.3						
pl	12.8	23.0	29.8	33.0	20.0	32.3	33.0	8.5	13.3	27.3	22.0	37.8	33.5	36.0	27.3
cpx	8.0	5.8	1.8	6.0	5.3	3.8	2.5	3.3	1.5	1.0	2.3	6.3	3.8	8.3	5.5
opx	1.0	3.5	8.5	5.5	6.0	5.3	6.0			5.5	5.0	6.0	5.5	3.8	4.3
hb															
mt	0.3	0.5	0.3	0.8	0.3	1.3	0.0				1.0	0.8	2.0	2.3	
gms	73.0	67.3	59.8	54.8	68.5	57.5	58.5	82.5	84.0	66.3	69.8	49.3	55.3	49.8	63.0
notes	oalt														

WHOLE ROCK 1

strat#	AMS-A05	AMS-A06	AMS-A07	AMS-A08	AF-06	AF-08	AF-09	AF-50	S85TRS5	SP-01	SP-02	SP-03	SP-04	PF-01	PF-03
field#	85cns21	85cns37	85cns36	85cns35	85cns06f	85cns08	85cns09	85cns30	s85trs5	sp-rs1	sp-rs2	sp-rs3	sp-rs4	85cns01	85cns03
SiO2	58.15	58.23	59.41	57.46	62.55	61.42	62.45	60.72	62.75	60.93	61.89	61.76	62.84	56.65	56.21
TiO2	0.75	0.75	0.74	0.80	0.56	0.63	0.58	0.65	0.59	0.66	0.59	0.65	0.60	0.79	0.87
Al2O3	17.27	17.27	17.54	18.34	17.22	17.41	16.93	17.38	16.73	17.32	17.26	17.67	16.70	17.60	17.69
Fe2O3	7.14	7.09	6.69	7.20	5.49	5.89	5.33	6.01	5.43	6.61	5.77	5.60	5.75	7.32	7.81
MnO	0.13	0.13	0.12	0.13	0.12	0.11	0.10	0.12	0.10	0.12	0.11	0.10	0.11	0.13	0.13
MgO	3.85	3.88	3.29	3.67	2.43	2.74	2.27	3.16	2.63	2.88	2.70	2.83	2.71	4.98	4.91
CaO	7.26	7.24	6.72	7.44	5.61	5.90	5.47	6.33	5.50	5.84	5.69	5.79	5.67	7.33	7.81
Na2O	3.65	3.59	3.61	3.41	3.89	3.79	4.57	3.85	3.89	3.61	3.93	3.55	3.63	3.92	3.23
K2O	1.59	1.63	1.68	1.35	1.90	1.89	2.08	1.58	2.21	1.82	1.84	1.83	1.76	1.03	1.14
P2O5	0.21	0.21	0.20	0.21	0.22	0.21	0.20	0.21	0.18	0.21	0.21	0.21	0.24	0.24	0.20
LOI	-0.14	-0.16	-0.21	-0.21	0.79	0.97	0.96	-0.06	0.26	0.57	0.34	1.47	1.37	-0.15	-0.08
TOTAL	100.41	100.44	100.12	99.98	100.03	99.88	100.34	100.33	99.56	100.26	100.30	100.03	100.31	100.53	100.47
CaO/Al2O3	0.42	0.42	0.38	0.41	0.33	0.34	0.32	0.36	0.33	0.34	0.33	0.33	0.34	0.42	0.44
FeOt/MgO	1.67	1.65	1.83	1.76	2.03	1.94	2.11	1.71	1.86	2.07	1.92	1.78	1.91	1.32	1.43
FMQ FeO/MgO	1.39	1.37	1.51	1.48	1.65	1.58	1.69	1.40	1.50	1.70	1.56	1.46	1.55	1.12	1.21
NNO FeO/MgO	1.30	1.28	1.42	1.39	1.55	1.48	1.58	1.32	1.40	1.60	1.47	1.37	1.46	1.05	1.15
NNO+1 FeO/MgO	1.14	1.12	1.24	1.23	1.34	1.29	1.35	1.15	1.21	1.39	1.27	1.19	1.26	0.93	1.01
Rb	31.9	32.0	34.6	29.0	38.9	36.8	39.9	30.4	47.8	40.5	38.8	36.2	36.8	19.0	22.2
K	13210	13533	13984	11186	15810	15695	17292	13148	18309	15073	15281	15204	14600	8575	9495
Sr	547	546	513	533	556	559	523	614	506	507	535	610	522	682	592
Y	19.1	19.9	19.8	18.4	17.4	19.9	18.7	16.3	16.8	17.4	17.0	17.8	15.5	12.1	16.3
Zr	127	127	131	110	145	141	144	129	148	135	140	133	131	92	95
Nb	6.2	6.4	6.1	5.6	6.7	6.4	6.2	5.6	6.4	7.2	6.7	6.1	5.8	5.5	5.3
Ni	12	12	8	8	8	8	6	17	10	7	11	9	10	43	16
K/Rb	414.1	423.2	404.5	386.3	406.3	426.3	433.6	432.4	382.9	372.0	393.5	419.5	397.1	451.8	427.7
K/Y	690.2	679.7	706.2	607.6	906.8	787.9	923.2	809.1	1087.2	864.3	896.8	855.6	942.5	706.4	581.8
Zr/Y	6.6	6.4	6.6	6.0	8.3	7.1	7.7	7.9	8.8	7.7	8.2	7.5	8.5	7.6	5.8
Rb/Zr	0.252	0.253	0.265	0.262	0.268	0.261	0.278	0.236	0.322	0.301	0.277	0.273	0.280	0.205	0.233
K/Zr	104.2	106.9	107.0	101.3	109.0	111.4	120.4	101.9	123.4	111.8	109.2	114.7	111.4	92.7	99.7
ol	0.3				tr	tr		0.3							
pl	34.3	31.8	37.5	18.8	24.8	21.8	32.5	22.5	22.8	25.3	28.0	20.0	20.0	31.0	26.3
cpx	6.0	4.0	6.8	2.5	2.5	2.3	4.5	3.3		4.3	2.3	3.3	2.3	3.8	5.3
opx	5.5	5.8	5.0	2.3	2.3	2.3	2.0	2.5		3.0	1.8	1.8	1.5	5.5	1.8
hb									14.3	0.3			0.3		
mt	1.3	1.0	1.8	0.3	0.5	0.8	0.5	0.3	0.8	1.0	0.8	1.3	0.5		0.8
gms	52.8	57.5	49.0	76.3	70.0	73.0	60.5	71.3	62.3	66.3	67.3	73.8	75.5	59.8	66.0
notes	osy				mvg	orxn	mvg		hop		cr,d			p,spph	p

WHOLE ROCK 2

strat#	PF-05	PF-07	PF-34	PF-38	PF-39	PF-45	PF-46	PF-47	PF-48	PCP-A01	PCP-A02	PCP-A03	PCP-A04	PCP-A05	PCP-A06
field#	85cns05	85cns07	85cns34	85cns38b	85cns39	85cns45	85cns46f	85cns47	85cns48	85cns54	85cns53	85cns52	85cns51b	85cns50	85cns49
SiO2	55.79	60.21	59.49	58.13	58.54	57.40	55.68	58.11	58.73	56.33	56.18	55.78	54.02	53.95	53.85
TiO2	0.93	0.67	0.73	0.75	0.83	0.81	0.81	0.82	0.71	0.77	0.77	0.77	1.03	1.10	1.09
Al2O3	17.97	17.49	17.83	17.93	17.59	17.94	18.90	18.03	17.91	17.31	17.24	17.05	17.61	18.83	18.70
Fe2O3	8.13	6.34	6.21	6.96	7.66	8.01	8.00	7.17	7.13	7.63	7.74	7.87	8.84	8.65	8.79
MnO	0.14	0.12	0.11	0.13	0.15	0.15	0.16	0.14	0.14	0.13	0.14	0.14	0.14	0.14	0.15
MgO	4.50	3.02	3.76	4.22	2.97	3.13	3.87	3.46	3.59	6.01	6.14	6.45	5.46	4.25	4.37
CaO	7.85	6.46	6.48	6.79	6.55	7.25	8.22	7.26	7.13	7.53	7.54	7.66	8.35	8.28	8.22
Na2O	3.34	3.71	3.76	3.66	4.12	3.88	3.20	3.41	3.28	3.08	3.07	3.14	3.20	3.33	3.37
K2O	1.16	1.75	1.42	1.22	1.36	1.24	0.95	1.42	1.19	1.00	0.97	0.94	1.14	1.21	1.23
P2O5	0.21	0.23	0.20	0.23	0.23	0.20	0.21	0.18	0.20	0.20	0.20	0.20	0.22	0.25	0.25
LOI	-0.27	0.14	0.32	0.01	-0.26	-0.03	0.46	0.25	0.36	0.20	-0.28	-0.24	-0.17	-0.27	-0.12
TOTAL	100.15	100.43	100.19	99.95	100.49	99.75	100.43	100.63	100.41	100.15	100.47	100.36	100.18	99.67	100.16
CaO/Al2O3	0.44	0.37	0.36	0.38	0.37	0.40	0.44	0.40	0.40	0.44	0.44	0.45	0.47	0.44	0.44
FeO/MgO	1.62	1.89	1.48	1.48	2.32	2.30	1.86	1.87	1.79	1.14	1.13	1.10	1.46	1.83	1.81
FMQ FeO/MgO	1.38	1.55	1.23	1.25	1.92	1.92	1.58	1.56	1.50	0.98	0.97	0.94	1.24	1.56	1.54
NNO FeO/MgO	1.30	1.46	1.16	1.18	1.80	1.80	1.49	1.47	1.41	0.93	0.92	0.89	1.18	1.47	1.46
NNO+1 FeO/MgO	1.15	1.27	1.02	1.04	1.57	1.58	1.32	1.29	1.24	0.82	0.82	0.79	1.04	1.30	1.29
Rb	21.1	34.3	30.7	26.0	30.1	26.8	16.6	32.9	23.3	18.1	18.9	17.2	19.7	24.1	25.5
K	9590	14569	11804	10135	11289	10317	7889	11826	9874	8306	8075	7839	9431	10051	10182
Sr	592	562	593	652	495	485	562	475	506	578	557	585	525	560	558
Y	16.1	19.6	12.8	14.5	19.8	20.5	18.8	19.6	16.8	13.8	14.1	13.5	18.8	19.7	19.5
Zr	94	144	117	102	108	97	89	108	103	91	91	89	90	100	97
Nb	5.1	6.5	5.9	6.0	6.3	5.6	5.9	5.5	5.8	6.0	5.2	5.6	5.9	7.0	6.1
Ni	11	7	19	35	7	7	8	7	9	81	80	82	22	19	18
K/Rb	454.9	424.6	385.1	389.5	375.4	384.5	474.1	359.8	424.1	459.9	427.9	455.8	478.5	417.9	399.5
K/Y	595.3	742.5	919.3	700.6	570.1	504.5	419.5	602.8	587.0	601.9	574.7	579.8	500.8	511.5	523.3
Zr/Y	5.8	7.3	9.1	7.1	5.5	4.7	4.7	5.5	6.1	6.6	6.5	6.6	4.8	5.1	5.0
Rb/Zr	0.225	0.239	0.263	0.255	0.277	0.277	0.187	0.305	0.227	0.199	0.206	0.193	0.219	0.240	0.264
K/Zr	102.2	101.3	101.1	99.3	104.1	106.5	88.8	109.9	96.3	91.5	88.3	88.0	104.6	100.4	105.3
ol						1.0								1.0	1.0
pl	23.5	29.8	29.3	33.8	12.5	29.5	25.0	27.0	30.0	28.5	24.0	27.8	32.3	36.3	34.3
cpx	4.3	4.8	2.3	4.0	0.3	1.8	2.5	2.5	3.8	4.5	3.5	4.3	0.3	0.8	2.3
opx	4.8	3.5	6.8	4.8	1.3	2.3	6.0	5.0	4.3	6.8	6.3	7.0	1.8	1.5	3.3
hb				tr	tr						0.5				
mt	0.3	1.5	0.3	1.0	0.3	1.3	1.8	0.8	0.8	0.3					0.5
gms	67.3	60.5	61.5	56.5	85.8	64.3	64.8	64.8	61.3	60.0	65.8	61.0	65.8	60.5	58.8
notes	p,plc			ps	hrxn					plc	plc	plc,ps,p	p	ps,p,d,pp	ps,p,d

WHOLE ROCK 3

strat# field#	PCP-B01 85cns33	PCP-B02 85cns32	PCP-B03 85cns31	PCP-B05 85cns29	PCP-B06 85cns28	PCP-B07 85cns27f	CP-01 85cns15	CP-02 85cns14	CP-03 85cns13b	CP-04 85cns12	CP-05 85cns11	CP-06 85cns10	CP-07 85cns60	CP-08 85cns61	CP-09 85cns62
SiO2	57.19	53.73	53.61	53.63	53.52	53.58	56.43	56.64	56.91	54.20	54.11	53.81	53.89	54.15	55.17
TiO2	0.82	1.12	1.10	1.12	1.12	1.10	0.84	0.83	0.83	0.83	0.83	0.81	0.81	0.83	0.73
Al2O3	17.21	19.07	18.40	18.31	18.25	18.60	18.18	18.00	17.95	17.40	17.53	17.67	17.69	18.19	18.27
Fe2O3	7.58	8.73	9.03	9.08	9.19	8.89	7.94	7.63	7.46	8.24	8.19	8.12	8.08	7.96	7.62
MnO	0.13	0.14	0.15	0.15	0.15	0.15	0.14	0.14	0.13	0.15	0.14	0.14	0.15	0.15	0.14
MgO	4.89	4.07	4.62	4.79	4.78	4.63	4.57	4.54	4.69	6.63	6.55	6.61	6.52	5.48	4.81
CaO	7.43	8.29	8.30	8.34	8.38	8.35	7.19	7.33	7.07	8.25	8.37	8.61	8.62	8.44	8.21
Na2O	3.27	3.36	3.33	3.16	3.17	3.26	3.30	3.35	3.53	3.21	3.22	3.27	3.27	3.74	3.87
K2O	1.26	1.24	1.20	1.18	1.20	1.20	1.19	1.27	1.18	0.86	0.84	0.73	0.74	0.79	0.95
P2O5	0.22	0.26	0.25	0.24	0.24	0.25	0.23	0.27	0.27	0.22	0.22	0.23	0.23	0.26	0.24
LOI	-0.24	-0.45	-0.39	-0.04	-0.06	-0.23	-0.34	-0.16	-0.06	-0.20	-0.40	-0.40	-0.43	-0.27	0.10
TOTAL	100.58	100.61	100.11	99.49	100.27	100.01	100.10	100.35	100.35	100.52	100.09	100.56	100.23	100.70	100.45
CaO/Al2O3	0.43	0.43	0.45	0.46	0.46	0.45	0.40	0.41	0.39	0.47	0.48	0.49	0.49	0.46	0.45
FeOt/MgO	1.39	1.93	1.76	1.71	1.73	1.73	1.56	1.51	1.43	1.12	1.13	1.11	1.12	1.31	1.43
FMQ FeO/MgO	1.18	1.64	1.50	1.46	1.48	1.48	1.33	1.28	1.21	0.96	0.97	0.95	0.96	1.12	1.21
NNO FeO/MgO	1.11	1.55	1.42	1.38	1.40	1.39	1.26	1.21	1.14	0.91	0.92	0.90	0.91	1.05	1.14
NNO+1 FeO/MgO	0.98	1.38	1.26	1.22	1.24	1.24	1.11	1.07	1.01	0.81	0.82	0.81	0.81	0.94	1.01
Rb	25.8	21.4	21.3	23.0	23.6	22.5	24.8	27.6	25.3	15.8	14.2	9.9	11.3	8.5	15.4
K	10457	10268	9995	9759	9929	9938	9918	10572	9756	7171	6939	6085	6103	6577	7859
Sr	583	570	554	544	547	549	571	631	666	558	584	618	631	755	666
Y	17.4	20.0	21.6	20.3	19.4	19.6	17.3	16.5	14.7	15.2	15.6	13.5	14.2	14.7	14.2
Zr	103	99	94	95	95	97	99	102	102	83	81	77	75	80	85
Nb	5.7	6.5	6.6	6.4	6.6	5.8	5.6	6.4	6.6	5.8	6.2	5.6	5.7	5.2	5.4
Ni	20	14	15	14	15	14	27	25	43	71	67	67	63	43	27
K/Rb	405.2	480.0	470.4	425.0	420.9	442.7	399.4	383.7	385.8	454.7	488.7	612.8	538.7	772.0	512.0
K/Y	602.7	514.7	463.4	481.4	510.8	506.8	572.6	641.9	663.2	472.7	444.0	452.4	430.4	448.2	554.6
Zr/Y	5.9	5.0	4.4	4.7	4.9	4.9	5.7	6.2	6.9	5.5	5.2	5.7	5.3	5.5	6.0
Rb/Zr	0.251	0.216	0.225	0.243	0.247	0.233	0.252	0.269	0.248	0.190	0.176	0.129	0.152	0.106	0.181
K/Zr	101.7	103.8	105.8	103.2	104.1	102.9	100.5	103.2	95.7	86.5	86.1	79.3	81.6	82.1	92.7
ol		0.3	1.0	0.5	0.5	tr	0.5		0.3	4.5	5.0	3.3	5.5		1.0
pl	14.0	33.5	31.8	32.5	30.0	31.5	26.0	29.3	19.0	17.5	22.3	16.5	22.0	31.3	34.3
cpx	7.0	5.3	1.3	0.3	1.3	2.0	3.0	4.0	2.5	8.0	3.5	7.3	3.8	0.8	5.5
opx	6.3	2.5	3.8	4.8	4.5	2.8	3.3	7.0	5.5	1.8	0.5		0.5	1.0	1.5
hb	tr														
mt		0.8		0.3	0.3	0.5			0.3						0.5
gms	72.8	57.8	62.3	61.8	63.5	63.3	67.3	59.8	72.5	68.3	68.8	73.0	68.3	67.0	57.3
notes	p	p			p		olr				cr	cr	cr	p	

WHOLE ROCK 4

strat# field#	CP-10 85cns18	CP-11 85cns19	CP-12 85cns20	CP-54 85cns04	PUM-16 85cns16	PUM-17 85cns17
SiO2	55.74	55.60	55.46	59.69	54.64	54.08
TiO2	0.76	0.77	0.76	0.69	0.83	0.86
Al2O3	18.82	18.65	18.78	17.22	18.62	18.61
Fe2O3	7.73	8.06	7.85	6.28	8.50	8.40
MnO	0.14	0.14	0.14	0.11	0.15	0.14
MgO	4.25	4.27	4.26	4.39	4.52	4.83
CaO	7.42	7.49	7.41	6.54	7.95	8.08
Na2O	3.82	3.70	4.01	3.66	3.57	3.71
K2O	1.04	1.04	1.06	1.23	0.96	1.01
P2O5	0.28	0.28	0.28	0.20	0.27	0.27
LOI	-0.08	-0.17	-0.18	-0.19	-0.03	0.05
TOTAL	99.68	99.42	100.29	100.46	100.49	99.93
CaO/Al2O3	0.39	0.40	0.39	0.38	0.43	0.43
FeO/MgO	1.64	1.70	1.66	1.29	1.69	1.57
FMQ FeO/MgO	1.39	1.44	1.40	1.07	1.44	1.33
NNO FeO/MgO	1.31	1.36	1.33	1.01	1.36	1.26
NNO+1 FeO/MgO	1.16	1.21	1.17	0.89	1.21	1.12
Rb	17.4	18.6	18.0	21.3	15.0	15.9
K	8654	8669	8801	10228	8011	8395
Sr	710	714	711	676	640	708
Y	14.9	14.7	14.3	11.0	15.8	14.6
Zr	90	90	91	107	88	91
Nb	6.1	5.8	6.0	5.6	5.8	6.3
Ni	26	27	24	45	20	31
K/Rb	497.7	465.3	488.3	479.7	535.1	528.0
K/Y	582.4	588.9	616.7	929.8	508.6	575.0
Zr/Y	6.1	6.1	6.3	9.7	5.6	6.2
Rb/Zr	0.193	0.207	0.199	0.199	0.170	0.175
K/Zr	95.9	96.5	97.2	95.5	90.8	92.7
ol	0.5	0.5	tr			
pl	27.0	25.5	26.3	31.5	14.0	12.0
cpx	2.8	3.0	1.5	3.8	3.8	2.3
opx	2.8	2.0	1.0	5.0	3.0	1.8
hb	0.5		0.8		0.5	1.5
mt						
gms	66.5	69.0	70.5	59.8	78.8	82.5
notes		p/h	hrxn			

explanation of "notes"

cr - chromite inclusions in olivine
d - dunite clots
hop - hornblende altered to opaque minerals, some cores unalter
hrxn - reaction rims around hornblende
mvg - microvesicular groundmass, gms may be overestimated
oalt - olivine altered to green fibrous minerals
olr - olivine is resorbed
orxn - reaction rims around olivine
osy - symplectic spinel/pyroxene rims on olivine
p - pyroxenite clots and cpx and opx megacrysts
plc - anomalously pleochroic cores of orthopyroxenes
pp - plagioclase peridotite clots
ps - aluminous spinel + plag +/- cpx clots
p/h - pyroxenite clots coated with hornblende
spph - Al-spinel + plagioclase clots, phlogopite bearing

APPENDIX II - Summary of mineral compositions

The following table contains coefficients of regression lines of individual elements plotted against Mg# or $\text{Ca}/(\text{Ca}+\text{Na})$. Diagrams following the table are plots of the compositions of each mineral species. Notice that the elements described by equations with low correlation coefficients are present in minor amounts or do not vary throughout the compositional ranges of the minerals.

Coefficients of equations of the form $Y = m \cdot \text{Mg\# (or An)} + b$ for major rock forming minerals of the Spurr Volcanic Complex. The equation for K2O in plagioclase is $\text{K2O} = b + (m \cdot \text{An}) + m^2 \cdot \text{An}^2$. Graphs of mineral compositions follow.

	SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	K2O
PLAGIOCLASE									
m ²									0.00026
m	-0.25997	-0.00035	0.17376	0.00165			0.20194	-0.10595	-0.04316
b	68.80400	0.06410	19.03200	0.43076			0.08251	10.69600	1.86430
r	0.99422	0.13776	0.99104	0.17346			0.99890	0.99871	0.93179
OLIVINE									
m	0.09685	-0.00134	0.00000	-0.83493	-0.01162	0.66254	-0.00133		
b	30.01827	0.12663	0.04000	85.54356	1.23132	-10.7750	0.23953		
r	0.80823	0.27496	0.12596	0.99880	0.78662	0.99694	0.22817		
CLINOPYROXENE									
m	-0.05224	0.01464	0.18039	-0.34990	-0.01652	0.18007	0.02516	-0.00552	
b	55.95000	-0.61286	-0.11629	35.99200	1.56660	1.15500	18.70100	0.75962	
r	0.21202	0.25975	0.59154	0.94537	0.72212	0.80599	0.13192	0.37875	
ORTHOPYROXENE									
m	0.00863	-0.00221	-0.00313	-0.56820	-0.02245	0.39640	-0.02787	-0.00206	
b	47.24600	0.39502	-0.97339	58.84200	2.10000	-0.34237	-0.55267	0.17821	
r	0.55910	0.11358	0.27222	0.98138	0.70434	0.97884	0.43942	0.13905	
HORNBLende									
m	0.01919	-0.07650	0.08042	-0.16380	-0.00340	0.11598	0.00481	0.00077	-0.00460
b	40.37270	9.40623	5.76434	25.64760	0.44704	4.27083	10.87210	2.44757	0.73472
r	0.12422	0.83337	0.77753	0.91109	0.52844	0.94103	0.18700	0.04958	0.40242

APPENDIX III - Plagioclase compositions

Plagioclase compositions were determined on the JEOL JXA-733 microprobe at Southern Methodist University using standard analytical strategies and instrumental settings.

Spurr Volcanic Complex plagioclase analyses

Strat#	AMS-803	AMS-803	AMS-803	AMS-803	AMS-803	AMS-803	AMS-803	AMS-803	AMS-803	AMS-803	AMS-803	AMS-803	AMS-803	AMS-803	AMS-803	AMS-803	AMS-807	AMS-807
Field#	85cns57	85cns57	85cns57	85cns57	85cns57	85cns57	85cns57	85cns57	85cns57	85cns57	85cns57	85cns57	85cns57	85cns57	85cns57	85cns57	85cns43	85cns43
Grain	pl1c	pl1r	pl2c	pl2r	pl3c	pl3r	pl4c	pl4r	pl4sm	pl5c	pl5r	pl6c	pl6r	pl7g	pl8c	pl8r	pl1r	pl2c
Anal#	3	4	5	6	7	8	9	11	10	12	13	14	15	16	17	18	20	21
wt% oxides																		
SiO2	54.02	53.13	52.32	56.84	53.45	56.22	51.13	49.56	50.57	47.92	51.66	51.21	51.88	52.95	56.19	55.89	46.74	46.00
TiO2	0.00	0.07	0.00	0.00	0.04	0.07	0.00	0.03	0.02	0.04	0.04	0.01	0.07	0.00	0.00	0.02	0.00	0.01
Al2O3	28.67	29.37	29.70	27.01	28.76	27.31	30.72	31.68	31.50	32.55	30.25	30.54	30.07	29.55	27.46	27.15	33.46	33.72
Fe2O3	0.27	0.63	0.33	0.23	0.39	0.42	0.55	0.42	0.34	0.42	0.56	0.58	0.47	0.58	0.46	0.41	0.53	0.56
FeO	0.18	0.02	0.11	0.23	0.08	0.01	0.06	0.08	0.16	0.22	0.04	0.00	0.10	0.19	0.09	0.07	0.14	0.00
CaO	11.18	12.31	12.57	9.31	11.48	9.87	14.01	14.94	14.42	15.75	13.30	13.82	13.08	12.35	10.10	9.83	17.06	17.43
Na2O	4.94	4.45	4.19	5.83	4.80	5.66	3.46	2.90	3.20	2.38	3.92	3.65	3.88	4.41	5.56	5.61	1.73	1.63
K2O	0.29	0.25	0.21	0.43	0.27	0.38	0.16	0.09	0.16	0.11	0.17	0.16	0.18	0.29	0.38	0.40	0.07	0.04
tot	99.56	100.22	99.43	99.87	99.27	99.94	100.10	99.70	100.37	99.39	99.95	99.97	99.73	100.32	100.24	99.38	99.73	99.40
FeO meas.	0.43	0.58	0.41	0.43	0.43	0.39	0.56	0.46	0.47	0.60	0.55	0.52	0.52	0.71	0.50	0.44	0.62	0.51
atoms/8 O																		
Si	2.4547	2.4088	2.3895	2.5588	2.4392	2.5343	2.3304	2.2727	2.2996	2.2132	2.3550	2.3367	2.3667	2.4008	2.5280	2.5345	2.1593	2.1351
Ti	0.0000	0.0024	0.0000	0.0000	0.0014	0.0024	0.0000	0.0010	0.0007	0.0014	0.0014	0.0003	0.0024	0.0000	0.0000	0.0007	0.0000	0.0003
Al	1.5359	1.5698	1.5991	1.4335	1.5473	1.4513	1.6507	1.7127	1.6887	1.7723	1.6257	1.6429	1.6172	1.5795	1.4565	1.4515	1.8223	1.8452
Fe3+	0.0094	0.0213	0.0114	0.0077	0.0135	0.0144	0.0189	0.0145	0.0116	0.0145	0.0193	0.0198	0.0161	0.0197	0.0154	0.0141	0.0184	0.0197
Fe2+	0.0069	0.0006	0.0042	0.0085	0.0029	0.0003	0.0025	0.0031	0.0063	0.0087	0.0016	0.0000	0.0037	0.0072	0.0034	0.0026	0.0055	0.0001
Ca	0.5444	0.5980	0.6151	0.4491	0.5613	0.4767	0.6842	0.7341	0.7026	0.7794	0.6496	0.6757	0.6394	0.6000	0.4869	0.4776	0.8445	0.8669
Na	0.4353	0.3912	0.3710	0.5089	0.4247	0.4947	0.3058	0.2579	0.2822	0.2131	0.3465	0.3229	0.3432	0.3877	0.4850	0.4933	0.1550	0.1467
K	0.0168	0.0145	0.0122	0.0247	0.0157	0.0219	0.0093	0.0053	0.0093	0.0065	0.0099	0.0093	0.0105	0.0168	0.0218	0.0231	0.0041	0.0024
tot	5.0034	5.0067	5.0026	4.9912	5.0060	4.9960	5.0018	5.0014	5.0010	5.0091	5.0090	5.0077	4.9992	5.0117	4.9971	4.9973	5.0091	5.0164
An	0.5463	0.5958	0.6161	0.4570	0.5603	0.4799	0.6847	0.7361	0.7068	0.7802	0.6458	0.6704	0.6438	0.5973	0.4900	0.4805	0.8415	0.8533
Ab	0.4368	0.3898	0.3716	0.5179	0.4240	0.4981	0.3060	0.2586	0.2838	0.2133	0.3444	0.3204	0.3456	0.3860	0.4881	0.4962	0.1544	0.1444
Or	0.0169	0.0144	0.0123	0.0251	0.0157	0.0220	0.0093	0.0053	0.0093	0.0065	0.0098	0.0092	0.0105	0.0167	0.0219	0.0233	0.0041	0.0023

Strat#	AMS-B07	AMS-B07	AMS-B07	AMS-B07	AMS-B07	AMS-B07	AMS-B07	AMS-B07	AMS-B07	AMS-B07	AMS-A03	AMS-A03	AMS-A03	AMS-A03	AMS-A03	AMS-A03	AMS-A03	AMS-A03	AMS-A03
Field#	85cns43	85cns43	85cns43	85cns43	85cns43	85cns43	85cns43	85cns43	85cns43	85cns43	85cns23	85cns23	85cns23	85cns23	85cns23	85cns23	85cns23	85cns23	85cns23
Grain	pl2r	pl2sc	pl3c	pl3r	pl4c	pl4r	pl5c	pl5r	pl6g	pl1c	pl1r	pl2c1	pl2c2	pl2r	pl3c	pl3r	pl4c	pl4r	pl4r
Anal#	23	22	24	25	26	27	28	29	30	44	45	46	48	47	49	50	51	52	52
wt% oxide																			
SiO2	47.17	50.83	46.52	47.96	46.21	46.80	46.73	47.99	51.73	50.73	54.82	55.48	55.50	56.32	55.44	54.77	50.92	49.34	
TiO2	0.03	0.00	0.00	0.00	0.05	0.00	0.04	0.07	0.07	0.01	0.05	0.00	0.00	0.01	0.03	0.00	0.00	0.02	
Al2O3	33.06	30.74	34.13	33.36	33.90	33.74	33.28	32.64	29.82	30.94	28.28	27.78	27.92	27.41	28.17	28.11	31.05	32.15	
Fe2O3	0.67	0.60	0.55	0.55	0.41	0.55	0.53	0.58	0.73	0.31	0.37	0.25	0.20	0.35	0.19	0.32	0.54	0.51	
FeO	0.05	0.22	0.01	0.16	0.14	0.14	0.22	0.05	0.15	0.21	0.15	0.29	0.23	0.19	0.31	0.17	0.12	0.10	
CaO	16.80	13.86	17.84	16.71	17.36	17.22	16.80	16.11	12.89	13.77	10.86	10.44	10.41	9.84	10.38	10.71	14.24	15.31	
Na2O	1.91	3.47	1.43	2.06	1.52	1.75	1.79	2.29	4.05	3.53	5.05	5.07	5.19	5.61	5.29	5.12	3.34	2.82	
K2O	0.08	0.27	0.04	0.07	0.03	0.06	0.05	0.07	0.25	0.16	0.34	0.34	0.35	0.42	0.30	0.35	0.17	0.13	
tot	99.78	99.99	100.52	100.86	99.62	100.27	99.44	99.80	99.68	99.66	99.93	99.64	99.80	100.15	100.11	99.55	100.38	100.37	
FeO meas.	0.66	0.76	0.50	0.65	0.51	0.64	0.70	0.57	0.80	0.49	0.49	0.51	0.41	0.50	0.48	0.46	0.61	0.55	
atoms/8 O																			
Si	2.1774	2.3231	2.1347	2.1874	2.1373	2.1519	2.1643	2.2089	2.3666	2.3207	2.4794	2.5100	2.5067	2.5341	2.4975	2.4853	2.3163	2.2524	
Ti	0.0010	0.0000	0.0000	0.0000	0.0017	0.0000	0.0014	0.0024	0.0024	0.0003	0.0017	0.0000	0.0000	0.0003	0.0010	0.0000	0.0000	0.0007	
Al	1.7992	1.6563	1.8464	1.7938	1.8485	1.8290	1.8172	1.7711	1.6084	1.6686	1.5079	1.4817	1.4867	1.4540	1.4961	1.5038	1.6652	1.7303	
Fe3+	0.0234	0.0206	0.0190	0.0188	0.0142	0.0191	0.0185	0.0200	0.0250	0.0107	0.0128	0.0084	0.0066	0.0118	0.0064	0.0108	0.0185	0.0174	
Fe2+	0.0021	0.0084	0.0002	0.0060	0.0056	0.0055	0.0087	0.0020	0.0056	0.0081	0.0058	0.0109	0.0088	0.0070	0.0117	0.0066	0.0047	0.0036	
Ca	0.8310	0.6787	0.8772	0.8166	0.8604	0.8484	0.8337	0.7945	0.6319	0.6750	0.5263	0.5061	0.5038	0.4744	0.5010	0.5207	0.6941	0.7489	
Na	0.1710	0.3075	0.1272	0.1822	0.1363	0.1560	0.1608	0.2044	0.3593	0.3131	0.4429	0.4448	0.4545	0.4895	0.4621	0.4505	0.2946	0.2496	
K	0.0047	0.0157	0.0023	0.0041	0.0018	0.0035	0.0030	0.0041	0.0146	0.0093	0.0196	0.0196	0.0202	0.0241	0.0172	0.0203	0.0099	0.0076	
tot	5.0098	5.0104	5.0069	5.0088	5.0057	5.0134	5.0075	5.0074	5.0137	5.0059	4.9962	4.9814	4.9873	4.9953	4.9931	4.9981	5.0033	5.0104	
An	0.8255	0.6774	0.8713	0.8143	0.8617	0.8417	0.8359	0.7921	0.6283	0.6767	0.5323	0.5215	0.5149	0.4802	0.5111	0.5252	0.6951	0.7444	
Ab	0.1698	0.3069	0.1264	0.1817	0.1365	0.1548	0.1612	0.2038	0.3572	0.3139	0.4479	0.4583	0.4645	0.4954	0.4713	0.4544	0.2950	0.2481	
Or	0.0047	0.0157	0.0023	0.0041	0.0018	0.0035	0.0030	0.0041	0.0145	0.0094	0.0198	0.0202	0.0206	0.0244	0.0176	0.0204	0.0099	0.0075	

Strat#	AMS-A03	AMS-A03	AMS-A03	AMS-A03	AMS-A03	AMS-A03	AMS-A03	AMS-A03	AMS-A04	AMS-A04	AMS-A04	AMS-A04	AMS-A04	AMS-A04	AMS-A04	AMS-A04	AMS-A04	AMS-A04	AMS-A04
Field#	85cns23	85cns23	85cns23	85cns23	85cns23	85cns23	85cns23	85cns23	85cns22	85cns22	85cns22	85cns22	85cns22	85cns22	85cns22	85cns22	85cns22	85cns22	85cns22
Grain	pl6c	pl6r	pl7c	pl7r	pl8g	PL.pl5c	PL.pl5r	pl1c	pl1r	pl2c	pl2r	pl3c	pl3r	pl4c	pl4r	pl5c	pl5m	pl5r	
Anal#	55	56	57	58	59	53	54	31	32	33	34	35	36	39	38	40	42	41	
wt% oxide																			
SiO2	56.20	56.07	50.92	55.34	54.70	46.54	50.35	46.06	51.96	46.84	52.27	45.27	50.97	47.97	51.78	47.30	47.93	51.26	
TiO2	0.04	0.03	0.07	0.07	0.07	0.00	0.07	0.03	0.00	0.04	0.04	0.01	0.16	0.04	0.07	0.11	0.04	0.07	
Al2O3	27.17	27.46	30.71	28.41	28.35	33.82	31.12	34.21	29.11	33.67	29.71	34.56	30.58	32.70	30.00	33.27	32.97	30.68	
Fe2O3	0.46	0.37	0.31	0.27	0.29	0.52	0.65	0.54	0.72	0.66	0.70	0.46	0.89	0.56	0.78	0.69	0.49	0.58	
FeO	0.07	0.19	0.18	0.22	0.34	0.07	0.05	0.17	0.24	0.00	0.31	0.18	0.04	0.24	0.10	0.01	0.26	0.27	
CaO	9.86	9.97	13.34	10.68	10.65	17.50	14.39	17.89	12.52	17.59	12.89	18.23	13.83	16.09	13.38	16.88	16.33	13.77	
Na2O	5.63	5.52	3.80	5.15	5.08	1.54	3.30	1.23	4.11	1.63	3.96	1.03	3.64	2.22	3.79	1.89	2.07	3.48	
K2O	0.34	0.36	0.16	0.35	0.33	0.04	0.11	0.03	0.15	0.03	0.11	0.03	0.11	0.07	0.11	0.05	0.04	0.09	
tot	99.77	99.97	99.49	100.50	99.81	100.03	100.04	100.16	98.81	100.46	99.99	99.78	100.22	99.89	100.01	100.20	100.13	100.20	
FeO meas.	0.48	0.52	0.46	0.47	0.60	0.54	0.63	0.66	0.89	0.59	0.94	0.60	0.84	0.74	0.80	0.63	0.70	0.79	
atoms/8 O																			
Si	2.5380	2.5279	2.3315	2.4861	2.4767	2.1446	2.3010	2.1226	2.3939	2.1508	2.3807	2.0968	2.3250	2.2070	2.3608	2.1737	2.1994	2.3336	
Ti	0.0014	0.0010	0.0024	0.0024	0.0024	0.0000	0.0024	0.0010	0.0000	0.0014	0.0014	0.0003	0.0055	0.0014	0.0024	0.0038	0.0014	0.0024	
Al	1.4465	1.4595	1.6578	1.5047	1.5133	1.8373	1.6767	1.8586	1.5812	1.8227	1.5953	1.8871	1.6445	1.7737	1.6125	1.8025	1.7836	1.6466	
Fe3+	0.0155	0.0126	0.0107	0.0092	0.0100	0.0181	0.0223	0.0187	0.0249	0.0227	0.0240	0.0161	0.0305	0.0193	0.0267	0.0237	0.0170	0.0197	
Fe2+	0.0026	0.0070	0.0069	0.0084	0.0127	0.0027	0.0018	0.0067	0.0094	0.0000	0.0118	0.0071	0.0016	0.0091	0.0038	0.0005	0.0099	0.0103	
Ca	0.4771	0.4816	0.6545	0.5141	0.5167	0.8641	0.7047	0.8834	0.6181	0.8655	0.6291	0.9047	0.6760	0.7932	0.6536	0.8312	0.8029	0.6717	
Na	0.4930	0.4826	0.3374	0.4486	0.4460	0.1376	0.2924	0.1099	0.3672	0.1451	0.3497	0.0925	0.3220	0.1980	0.3351	0.1684	0.1842	0.3072	
K	0.0196	0.0207	0.0093	0.0201	0.0191	0.0024	0.0064	0.0018	0.0088	0.0018	0.0064	0.0018	0.0064	0.0041	0.0064	0.0029	0.0023	0.0052	
tot	4.9937	4.9930	5.0105	4.9935	4.9968	5.0067	5.0077	5.0028	5.0035	5.0099	4.9983	5.0065	5.0114	5.0059	5.0013	5.0069	5.0007	4.9969	
An	0.4821	0.4890	0.6537	0.5231	0.5263	0.8606	0.7022	0.8878	0.6218	0.8549	0.6385	0.9056	0.6731	0.7969	0.6569	0.8291	0.8115	0.6825	
Ab	0.4981	0.4900	0.3370	0.4565	0.4543	0.1370	0.2914	0.1105	0.3694	0.1434	0.3550	0.0926	0.3206	0.1990	0.3367	0.1680	0.1861	0.3121	
Or	0.0198	0.0210	0.0093	0.0204	0.0194	0.0023	0.0064	0.0018	0.0089	0.0017	0.0065	0.0018	0.0064	0.0041	0.0064	0.0029	0.0024	0.0053	

Strat#	AMS-A04	AF-08	AF-08	AF-08	AF-08	AF-08	AF-08	AF-08	AF-08	AF-08	AF-08	AF-08	AF-08	AF-08	AF-08	AF-08	AF-08	AF-08	AF-08
Field#	85cns22	85cns08	85cns08	85cns08	85cns08	85cns08	85cns08	85cns08	85cns08	85cns08	85cns08	85cns08	85cns08	85cns08	85cns08	85cns08	85cns08	85cns08	85cns08
Grain	pl6g	pl1c	pl1r	pl2r	pl2sc	pl3c	pl3r	pl4c	pl4r	pl5c	pl5m	pl5r	pl6c	pl6m	pl6r	pl7g	pl8g	pl9g	pl9g
Anal#	43	132	133	135	134	136	137	138	139	140	141	142	143	144	145	146	147	148	148
wt% oxide																			
SiO2	56.80	57.19	57.54	50.06	58.14	56.23	58.78	54.25	59.07	56.60	57.02	54.02	57.79	53.59	49.42	50.36	53.93	54.33	
TiO2	0.05	0.03	0.00	0.07	0.04	0.03	0.07	0.00	0.04	0.00	0.03	0.02	0.07	0.05	0.03	0.05	0.04	0.07	
Al2O3	26.50	26.78	26.81	31.52	26.83	28.00	25.99	29.18	25.61	27.70	27.12	29.27	26.62	29.52	32.66	31.50	29.32	28.77	
Fe2O3	0.90	0.28	0.29	0.70	0.30	0.28	0.29	0.23	0.18	0.38	0.17	0.32	0.39	0.30	0.21	0.52	0.37	0.47	
FeO	0.21	0.27	0.23	0.01	0.22	0.18	0.28	0.23	0.29	0.20	0.30	0.28	0.20	0.22	0.44	0.16	0.30	0.20	
CaO	9.53	8.95	9.04	14.86	8.92	10.32	8.32	11.65	7.86	10.01	9.39	11.85	8.96	12.00	15.38	14.50	11.80	11.19	
Na2O	5.78	6.07	6.06	3.06	6.14	5.42	6.16	4.67	6.36	5.66	5.69	4.53	5.99	4.44	2.53	3.23	4.59	5.01	
K2O	0.36	0.39	0.41	0.16	0.45	0.33	0.50	0.27	0.54	0.36	0.38	0.23	0.48	0.32	0.10	0.13	0.25	0.30	
tot	100.13	99.96	100.38	100.44	101.04	100.79	100.39	100.48	99.95	100.91	100.10	100.52	100.50	100.44	100.77	100.45	100.60	100.35	
FeO meas.	1.02	0.52	0.49	0.64	0.49	0.43	0.54	0.44	0.45	0.54	0.45	0.57	0.55	0.49	0.63	0.63	0.63	0.63	
atoms/8 O																			
Si	2.5609	2.5712	2.5756	2.2820	2.5841	2.5144	2.6229	2.4430	2.6430	2.5285	2.5592	2.4341	2.5837	2.4189	2.2443	2.2920	2.4300	2.4527	
Ti	0.0017	0.0010	0.0000	0.0024	0.0013	0.0010	0.0023	0.0000	0.0013	0.0000	0.0010	0.0007	0.0024	0.0017	0.0010	0.0017	0.0014	0.0024	
Al	1.4086	1.4194	1.4148	1.6940	1.4059	1.4761	1.3672	1.5491	1.3509	1.4589	1.4350	1.5549	1.4031	1.5709	1.7485	1.6901	1.5575	1.5312	
Fe3+	0.0305	0.0094	0.0096	0.0240	0.0101	0.0095	0.0099	0.0079	0.0061	0.0126	0.0057	0.0110	0.0131	0.0102	0.0072	0.0179	0.0126	0.0161	
Fe2+	0.0080	0.0102	0.0087	0.0004	0.0082	0.0066	0.0103	0.0087	0.0107	0.0075	0.0112	0.0105	0.0074	0.0083	0.0167	0.0061	0.0112	0.0077	
Ca	0.4604	0.4312	0.4336	0.7258	0.4248	0.4945	0.3978	0.5621	0.3768	0.4792	0.4516	0.5721	0.4292	0.5804	0.7484	0.7071	0.5697	0.5413	
Na	0.5053	0.5292	0.5260	0.2705	0.5292	0.4700	0.5330	0.4078	0.5518	0.4903	0.4952	0.3958	0.5193	0.3886	0.2228	0.2850	0.4010	0.4386	
K	0.0207	0.0224	0.0234	0.0093	0.0255	0.0188	0.0285	0.0155	0.0308	0.0205	0.0218	0.0132	0.0274	0.0184	0.0058	0.0075	0.0144	0.0173	
tot	4.9961	4.9939	4.9917	5.0085	4.9890	4.9909	4.9719	4.9941	4.9715	4.9975	4.9807	4.9923	4.9857	4.9974	4.9947	5.0075	4.9976	5.0072	
An	0.4667	0.4388	0.4411	0.7218	0.4337	0.5029	0.4147	0.5705	0.3928	0.4840	0.4663	0.5831	0.4398	0.5878	0.7660	0.7073	0.5783	0.5429	
Ab	0.5123	0.5385	0.5351	0.2690	0.5402	0.4780	0.5556	0.4138	0.5751	0.4953	0.5113	0.4034	0.5321	0.3936	0.2280	0.2851	0.4071	0.4398	
Or	0.0210	0.0228	0.0238	0.0093	0.0261	0.0191	0.0297	0.0157	0.0321	0.0207	0.0225	0.0135	0.0281	0.0187	0.0059	0.0076	0.0146	0.0173	

Strat#	AF-09	AF-09	AF-09	AF-09	AF-09	AF-09	AF-09	AF-09	AF-09	AF-09	AF-09	AF-09	AF-09	AF-09	AF-09	AF-09	SP-02	SP-02	SP-02
Field#	85cns09	85cns09	85cns09	85cns09	85cns09	85cns09	85cns09	85cns09	85cns09	85cns09	85cns09	85cns09	85cns09	85cns09	85cns09	85cns09	sp-rs2	sp-rs2	sp-rs2
Grain	pl1c	pl1r	pl2c	pl2r	pl3c	pl3r	pl4c	pl4r	pl4r2	pl5c	pl5r	pl6c	pl6r	pl7g	pl7g	pl7g	pl1c	pl1r	pl2c
Anal#	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	163	164	165	166
wt% oxide																			
SiO2	54.25	60.32	54.10	60.41	55.40	60.11	56.05	57.00	57.74	49.58	58.89	56.23	55.45	56.59	55.69	55.33	57.86	55.48	
TiO2	0.00	0.00	0.07	0.07	0.07	0.04	0.03	0.04	0.03	0.00	0.07	0.03	0.04	0.00	0.07	0.00	0.07	0.04	
Al2O3	29.57	25.16	29.14	25.04	28.39	24.79	28.19	27.41	26.78	32.68	26.16	27.95	28.30	28.22	27.84	27.78	26.75	28.07	
Fe2O3	0.04	0.08	0.22	0.23	0.12	0.29	0.11	0.30	0.10	0.28	0.00	0.00	0.13	0.04	0.24	0.21	0.37	0.35	
FeO	0.40	0.34	0.30	0.24	0.19	0.19	0.34	0.18	0.36	0.30	0.40	0.43	0.32	0.47	0.31	0.30	0.13	0.08	
CaO	11.64	6.98	11.47	6.94	10.63	7.09	10.19	9.61	8.85	15.42	7.73	10.13	10.46	10.20	10.13	10.10	9.09	10.57	
Na2O	4.61	6.82	4.66	6.88	5.12	6.70	5.36	5.77	5.88	2.70	6.39	5.15	5.16	5.22	5.24	5.41	6.06	5.35	
K2O	0.29	0.81	0.28	0.81	0.33	0.82	0.39	0.45	0.53	0.13	0.69	0.36	0.38	0.44	0.46	0.33	0.34	0.26	
tot	100.80	100.51	100.23	100.62	100.25	100.03	100.66	100.76	100.27	101.09	100.33	100.28	100.23	101.17	99.97	99.46	100.67	100.21	
FeO meas.	0.44	0.41	0.49	0.45	0.30	0.45	0.44	0.45	0.45	0.55	0.40	0.43	0.43	0.50	0.52	0.49	0.46	0.40	
atoms/8 O																			
Si	2.4343	2.6796	2.4420	2.6818	2.4909	2.6848	2.5088	2.5463	2.5837	2.2455	2.6261	2.5220	2.4947	2.5183	2.5117	2.5083	2.5809	2.4981	
Ti	0.0000	0.0000	0.0024	0.0023	0.0024	0.0013	0.0010	0.0013	0.0010	0.0000	0.0023	0.0010	0.0014	0.0000	0.0024	0.0000	0.0023	0.0014	
Al	1.5643	1.3177	1.5507	1.3105	1.5049	1.3054	1.4876	1.4435	1.4128	1.7450	1.3753	1.4779	1.5010	1.4805	1.4803	1.4847	1.4067	1.4901	
Fe3+	0.0014	0.0027	0.0073	0.0076	0.0042	0.0098	0.0036	0.0102	0.0035	0.0095	0.0000	0.0001	0.0043	0.0012	0.0081	0.0071	0.0124	0.0119	
Fe2+	0.0151	0.0126	0.0112	0.0091	0.0071	0.0070	0.0129	0.0066	0.0133	0.0113	0.0149	0.0160	0.0119	0.0174	0.0116	0.0115	0.0048	0.0032	
Ca	0.5597	0.3323	0.5548	0.3301	0.5121	0.3393	0.4887	0.4600	0.4243	0.7483	0.3694	0.4868	0.5042	0.4864	0.4895	0.4906	0.4345	0.5100	
Na	0.4011	0.5875	0.4079	0.5922	0.4464	0.5803	0.4652	0.4998	0.5102	0.2371	0.5525	0.4479	0.4501	0.4504	0.4582	0.4755	0.5241	0.4671	
K	0.0166	0.0459	0.0161	0.0459	0.0189	0.0467	0.0223	0.0256	0.0303	0.0075	0.0393	0.0206	0.0218	0.0250	0.0265	0.0191	0.0193	0.0149	
tot	4.9924	4.9782	4.9923	4.9796	4.9869	4.9746	4.9901	4.9934	4.9791	5.0043	4.9798	4.9723	4.9894	4.9792	4.9882	4.9967	4.9851	4.9965	
An	0.5726	0.3441	0.5668	0.3410	0.5240	0.3512	0.5006	0.4668	0.4398	0.7536	0.3843	0.5096	0.5165	0.5057	0.5025	0.4980	0.4443	0.5141	
Ab	0.4104	0.6084	0.4167	0.6117	0.4567	0.6005	0.4765	0.5072	0.5288	0.2388	0.5749	0.4688	0.4611	0.4683	0.4704	0.4827	0.5360	0.4709	
Or	0.0170	0.0475	0.0165	0.0474	0.0194	0.0484	0.0228	0.0260	0.0314	0.0076	0.0408	0.0216	0.0223	0.0260	0.0272	0.0194	0.0198	0.0151	

Strat#	SP-02	SP-02	SP-02	SP-02	SP-02	SP-02	SP-02	SP-02	SP-02	SP-02	SP-02	SP-02	SP-02	PF-38	PF-38	PF-38	PF-38	PF-38	PF-38
Field#	sp-rs2	sp-rs2	sp-rs2	sp-rs2	sp-rs2	sp-rs2	sp-rs2	sp-rs2	sp-rs2	sp-rs2	sp-rs2	sp-rs2	sp-rs2	85cns38	85cns38	85cns38	85cns38	85cns38	85cns38
Grain	pl2r	pl3c	pl3r	pl4c	pl4r	pl5c	pl5r	pl6c	pl6r	pl7g	pl8g	pl9g	pl9g	pl1r	pl1sc	pl2c1	pl2c2	pl2r	pl3c
Anal#	167	168	169	170	171	172	173	174	175	176	177	178	178	120	119	121	121	122	123
wt% oxide																			
SiO2	55.74	53.81	56.53	56.96	56.91	55.85	57.23	55.02	56.64	54.13	55.09	54.70	49.28	54.06	53.21	50.66	53.51	53.83	
TiO2	0.00	0.04	0.05	0.02	0.02	0.00	0.07	0.04	0.07	0.08	0.04	0.07	0.00	0.10	0.07	0.07	0.04	0.07	
Al2O3	27.82	28.70	27.24	26.81	26.64	27.70	26.93	28.32	26.73	28.62	28.51	28.32	32.79	28.90	28.89	31.33	30.00	29.77	
Fe2O3	0.40	0.51	0.29	0.10	0.27	0.13	0.27	0.14	0.25	0.41	0.49	0.36	0.16	0.42	0.62	0.50	0.01	0.14	
FeO	0.09	0.00	0.29	0.31	0.16	0.25	0.21	0.28	0.24	0.18	0.24	0.23	0.24	0.39	0.00	0.25	0.44	0.37	
CaO	10.44	11.66	9.50	8.89	8.91	9.92	9.04	10.49	9.02	11.24	10.89	10.82	15.45	12.45	12.31	14.50	11.96	11.85	
Na2O	5.45	4.84	5.75	6.01	6.15	5.55	6.09	5.23	5.92	4.84	5.24	5.08	2.75	3.29	4.24	2.96	4.50	4.59	
K2O	0.25	0.22	0.33	0.37	0.37	0.33	0.32	0.30	0.37	0.27	0.26	0.23	0.05	0.54	0.16	0.20	0.14	0.14	
tot	100.19	99.78	99.98	99.47	99.43	99.73	100.17	99.82	99.25	99.77	100.76	99.82	100.72	100.14	99.50	100.47	100.60	100.76	
FeO meas.	0.45	0.46	0.55	0.40	0.40	0.37	0.46	0.41	0.47	0.55	0.68	0.56	0.38	0.76	0.56	0.70	0.45	0.50	
atoms/8 O																			
Si	2.5096	2.4439	2.5445	2.5703	2.5716	2.5212	2.5668	2.4864	2.5645	2.4554	2.4740	2.4762	2.2385	2.4450	2.4257	2.3034	2.4080	2.4184	
Ti	0.0000	0.0014	0.0017	0.0007	0.0007	0.0000	0.0024	0.0014	0.0024	0.0027	0.0014	0.0024	0.0000	0.0034	0.0024	0.0024	0.0014	0.0024	
Al	1.4767	1.5367	1.4455	1.4263	1.4192	1.4742	1.4240	1.5088	1.4268	1.5305	1.5094	1.5114	1.7560	1.5409	1.5527	1.6794	1.5916	1.5768	
Fe3+	0.0137	0.0175	0.0100	0.0034	0.0092	0.0046	0.0092	0.0048	0.0087	0.0140	0.0166	0.0123	0.0055	0.0141	0.0214	0.0172	0.0004	0.0048	
Fe2+	0.0033	0.0000	0.0107	0.0117	0.0059	0.0094	0.0080	0.0107	0.0091	0.0068	0.0090	0.0089	0.0089	0.0146	0.0000	0.0094	0.0165	0.0140	
Ca	0.5037	0.5674	0.4582	0.4299	0.4314	0.4798	0.4344	0.5080	0.4376	0.5463	0.5240	0.5248	0.7520	0.6033	0.6013	0.7064	0.5767	0.5705	
Na	0.4758	0.4262	0.5019	0.5259	0.5389	0.4858	0.5296	0.4583	0.5197	0.4257	0.4563	0.4459	0.2422	0.2885	0.3748	0.2610	0.3927	0.3999	
K	0.0144	0.0127	0.0190	0.0213	0.0213	0.0190	0.0183	0.0173	0.0214	0.0156	0.0149	0.0133	0.0029	0.0312	0.0093	0.0116	0.0080	0.0080	
tot	4.9971	5.0059	4.9914	4.9894	4.9982	4.9941	4.9928	4.9956	4.9902	4.9972	5.0055	4.9953	5.0060	4.9410	4.9876	4.9908	4.9952	4.9947	
An	0.5068	0.5638	0.4680	0.4400	0.4351	0.4873	0.4422	0.5165	0.4471	0.5531	0.5265	0.5334	0.7542	0.6537	0.6102	0.7216	0.5900	0.5831	
Ab	0.4788	0.4235	0.5126	0.5382	0.5434	0.4934	0.5391	0.4660	0.5310	0.4310	0.4585	0.4531	0.2429	0.3126	0.3803	0.2666	0.4017	0.4087	
Or	0.0144	0.0127	0.0194	0.0218	0.0215	0.0193	0.0186	0.0176	0.0218	0.0158	0.0150	0.0135	0.0029	0.0338	0.0094	0.0119	0.0082	0.0082	

Strat#	PF-38	PF-38	PF-38	PF-38	PF-38	PF-38	PF-38	PF-38	PCP-A03	PCP-A03	PCP-A03	PCP-A03	PCP-A03	PCP-A03	PCP-A03	PCP-A03	PCP-A03	PCP-A03
Field#	85cns38	85cns38	85cns38	85cns38	85cns38	85cns38	85cns38	85cns38	85cns52	85cns52	85cns52	85cns52	85cns52	85cns52	85cns52	85cns52	85cns52	85cns52
Grain	pl3r	pl4c	pl4r	pl5c	pl5r	pl6r	pl6sc	pl7g	pl1c	pl1r	pl1sm	pl2c	pl2r	pl3c	pl3r	pl4r	pl4sc	pl5c
Anal#	124	125	126	127	128	130	129	131	60	62	61	63	64	65	66	68	67	69
wt% oxide																		
SiO2	51.45	48.78	51.92	51.68	53.20	53.13	49.44	54.23	52.12	52.49	50.20	52.36	52.38	47.56	52.19	52.35	47.30	51.44
TiO2	0.03	0.00	0.01	0.02	0.07	0.09	0.05	0.00	0.03	0.02	0.02	0.07	0.08	0.04	0.07	0.05	0.00	0.03
Al2O3	30.51	32.39	29.90	30.79	30.13	29.67	32.13	29.12	30.20	29.91	31.60	29.58	29.65	33.10	29.88	29.55	33.38	29.93
Fe2O3	0.21	0.29	0.42	0.22	0.10	0.25	0.36	0.31	0.44	0.46	0.46	0.38	0.51	0.12	0.70	0.48	0.36	0.46
FeO	0.19	0.12	0.19	0.32	0.32	0.28	0.14	0.23	0.01	0.17	0.07	0.00	0.11	0.12	0.03	0.12	0.10	0.12
CaO	13.23	15.60	13.16	13.31	12.26	12.05	15.28	11.61	13.20	12.95	14.84	12.74	12.72	16.23	13.11	12.63	16.89	12.89
Na2O	3.82	2.52	3.71	3.80	4.35	4.43	2.68	4.81	3.97	3.97	3.00	4.10	4.05	2.07	4.00	4.11	1.79	4.08
K2O	0.10	0.09	0.11	0.11	0.18	0.16	0.07	0.17	0.13	0.13	0.12	0.14	0.15	0.07	0.13	0.13	0.05	0.12
tot	99.54	99.79	99.41	100.25	100.61	100.07	100.16	100.48	100.10	100.10	100.31	99.37	99.65	99.31	100.11	99.42	99.88	99.08
FeO meas.	0.38	0.38	0.56	0.52	0.41	0.51	0.47	0.51	0.41	0.58	0.48	0.34	0.57	0.23	0.66	0.55	0.43	0.54
atoms/8 O																		
Si	2.3499	2.2380	2.3739	2.3452	2.3964	2.4068	2.2578	2.4429	2.3676	2.3833	2.2870	2.3918	2.3885	2.1949	2.3738	2.3919	2.1765	2.3630
Ti	0.0010	0.0000	0.0003	0.0007	0.0024	0.0031	0.0017	0.0000	0.0010	0.0007	0.0007	0.0024	0.0027	0.0014	0.0024	0.0017	0.0000	0.0010
Al	1.6428	1.7519	1.6117	1.6473	1.6001	1.5846	1.7298	1.5465	1.6173	1.6010	1.6972	1.5930	1.5939	1.8009	1.6022	1.5917	1.8108	1.6209
Fe3+	0.0073	0.0101	0.0143	0.0075	0.0035	0.0086	0.0124	0.0107	0.0150	0.0157	0.0157	0.0130	0.0176	0.0042	0.0239	0.0164	0.0126	0.0160
Fe2+	0.0072	0.0045	0.0071	0.0122	0.0119	0.0107	0.0055	0.0086	0.0005	0.0063	0.0026	0.0000	0.0042	0.0046	0.0012	0.0046	0.0039	0.0047
Ca	0.6475	0.7669	0.6447	0.6472	0.5917	0.5849	0.7477	0.5604	0.6425	0.6300	0.7244	0.6236	0.6215	0.8026	0.6389	0.6183	0.8328	0.6345
Na	0.3383	0.2242	0.3289	0.3344	0.3799	0.3891	0.2373	0.4201	0.3497	0.3495	0.2650	0.3631	0.3581	0.1852	0.3528	0.3641	0.1597	0.3634
K	0.0058	0.0053	0.0064	0.0064	0.0103	0.0092	0.0041	0.0098	0.0075	0.0075	0.0070	0.0082	0.0087	0.0041	0.0075	0.0076	0.0029	0.0070
tot	4.9998	5.0008	4.9875	5.0008	4.9963	4.9970	4.9963	4.9988	5.0013	4.9941	4.9997	4.9950	4.9952	4.9980	5.0028	4.9964	4.9994	5.0107
An	0.6530	0.7697	0.6578	0.6551	0.6026	0.5949	0.7559	0.5659	0.6427	0.6383	0.7270	0.6268	0.6288	0.8091	0.6394	0.6246	0.8366	0.6314
Ab	0.3412	0.2250	0.3356	0.3385	0.3869	0.3957	0.2399	0.4243	0.3498	0.3541	0.2660	0.3650	0.3623	0.1867	0.3530	0.3678	0.1604	0.3616
Or	0.0059	0.0053	0.0065	0.0064	0.0105	0.0094	0.0041	0.0099	0.0075	0.0076	0.0070	0.0082	0.0088	0.0042	0.0075	0.0077	0.0029	0.0070

Strat#	PCP-A03	PCP-A03	PCP-A03	PCP-A03	PCP-A05	PCP-A05	PCP-A05	PCP-A05	PCP-A05	PCP-A05	PCP-A05	PCP-A05	PCP-A05	PCP-A05	PCP-A05	PCP-A05	PCP-A05	PCP-A05	PCP-A05
Field#	85cns52	85cns52	85cns52	85cns52	85cns50	85cns50	85cns50	85cns50	85cns50	85cns50	85cns50	85cns50	85cns50	85cns50	85cns50	85cns50	85cns50	85cns50	85cns50
Grain	pl5r	pl6c	pl6r	pl7g	pl1c	pl1r	pl2r	pl2sc	pl3c	pl3r	pl4c	pl4r	pl5r	pl5sc	pl6c	pl6r	pl7g	pl7g	PS1
Anal#	70	71	72	73	74	78	77	76	79	80	81	82	86	85	87	88	89	83	
wt% oxide																			
SiO2	51.95	53.26	51.70	57.12	51.62	55.55	52.46	48.89	51.77	53.61	49.88	53.41	52.89	47.92	48.95	53.03	56.16	56.64	
TiO2	0.13	0.10	0.02	0.15	0.00	0.14	0.07	0.04	0.05	0.13	0.07	0.05	0.07	0.09	0.04	0.04	0.10	0.04	
Al2O3	29.84	28.96	30.09	26.44	29.63	27.66	29.27	31.74	29.14	28.71	31.66	28.81	29.63	32.97	32.57	29.30	26.83	27.39	
Fe2O3	0.69	0.36	0.51	0.55	0.70	0.67	0.56	0.36	0.63	0.57	0.61	0.67	0.46	0.64	0.42	0.55	0.76	0.00	
FeO	0.02	0.14	0.18	0.16	0.22	0.00	0.13	0.20	0.06	0.10	0.00	0.00	0.17	0.00	0.21	0.08	0.01	0.28	
CaO	12.94	11.62	13.08	8.78	13.17	10.50	12.48	15.11	12.50	11.59	14.99	12.13	12.57	16.50	15.75	12.41	9.74	9.36	
Na2O	4.08	4.64	3.95	6.16	3.67	5.36	4.07	2.57	4.14	4.64	3.01	4.40	4.09	2.23	2.42	4.25	5.66	5.70	
K2O	0.13	0.19	0.15	0.41	0.21	0.38	0.22	0.11	0.19	0.25	0.13	0.23	0.20	0.07	0.09	0.22	0.48	0.41	
tot	99.78	99.27	99.67	99.78	99.22	100.26	99.26	99.03	98.48	99.60	100.35	99.70	100.09	100.42	100.45	99.89	99.75	99.82	
FeO meas.	0.64	0.46	0.63	0.66	0.85	0.60	0.63	0.53	0.63	0.61	0.55	0.60	0.59	0.58	0.59	0.58	0.70	0.28	
atoms/8 O																			
Si	2.3707	2.4300	2.3620	2.5756	2.3713	2.5048	2.4013	2.2587	2.3912	2.4400	2.2753	2.4311	2.3995	2.1950	2.2335	2.4108	2.5422	2.5481	
Ti	0.0045	0.0034	0.0007	0.0051	0.0000	0.0047	0.0024	0.0014	0.0017	0.0044	0.0024	0.0017	0.0024	0.0031	0.0014	0.0014	0.0034	0.0014	
Al	1.6054	1.5578	1.6207	1.4056	1.6047	1.4704	1.5795	1.7287	1.5868	1.5405	1.7026	1.5460	1.5848	1.7804	1.7520	1.5703	1.4318	1.4527	
Fe3+	0.0238	0.0122	0.0174	0.0188	0.0241	0.0226	0.0192	0.0126	0.0220	0.0195	0.0210	0.0228	0.0158	0.0222	0.0145	0.0189	0.0260	0.0000	
Fe2+	0.0006	0.0054	0.0067	0.0061	0.0086	0.0000	0.0050	0.0079	0.0023	0.0037	0.0000	0.0000	0.0066	0.0000	0.0080	0.0031	0.0005	0.0105	
Ca	0.6327	0.5681	0.6403	0.4242	0.6482	0.5073	0.6121	0.7480	0.6186	0.5652	0.7327	0.5916	0.6110	0.8098	0.7700	0.6045	0.4724	0.4512	
Na	0.3610	0.4105	0.3499	0.5386	0.3269	0.4686	0.3612	0.2302	0.3708	0.4095	0.2662	0.3883	0.3598	0.1981	0.2141	0.3746	0.4968	0.4972	
K	0.0076	0.0111	0.0087	0.0236	0.0123	0.0219	0.0128	0.0065	0.0112	0.0145	0.0076	0.0134	0.0116	0.0041	0.0052	0.0128	0.0277	0.0235	
tot	5.0064	4.9984	5.0063	4.9976	4.9960	5.0005	4.9936	4.9939	5.0047	4.9973	5.0078	4.9950	4.9914	5.0128	4.9988	4.9964	5.0008	4.9846	
An	0.6319	0.5740	0.6410	0.4301	0.6565	0.5084	0.6207	0.7596	0.6183	0.5714	0.7280	0.5956	0.6220	0.8002	0.7783	0.6094	0.4739	0.4642	
Ab	0.3605	0.4148	0.3503	0.5460	0.3310	0.4697	0.3663	0.2338	0.3706	0.4139	0.2645	0.3910	0.3662	0.1957	0.2164	0.3777	0.4983	0.5116	
Or	0.0076	0.0112	0.0088	0.0239	0.0125	0.0219	0.0130	0.0066	0.0112	0.0147	0.0075	0.0134	0.0118	0.0040	0.0053	0.0129	0.0278	0.0242	

Strat#	PCP-A05	PCP-A05	PCP-A05	CP-07	CP-07	CP-07	CP-07	CP-07	CP-07	CP-07	CP-07	CP-07	CP-07	CP-07	CP-07	CP-07	CP-12	CP-12
Field#	85cns50	85cns50	85cns50	85cns60	85cns60	85cns60	85cns60	85cns60	85cns60	85cns60	85cns60	85cns60	85cns60	85cns60	85cns60	85cns60	85cns20	85cns20
Grain	PS1	PS2	PS2	pl1c	pl1r	pl2r1	pl2r2	pl2sc	pl3r	pl3sc	pl4c	pl4r	pl5r	pl5sc	pl6c	pl7g	pl1c	pl1r
Anal#	84	1	2	90	91	93	97	94	96	95	98	99	101	100	102	103	104	105
wt% oxide																		
SiO2	55.36	57.23	54.71	49.21	48.83	47.87	47.98	49.48	51.47	50.20	48.83	54.81	51.87	48.12	53.96	56.26	47.36	52.91
TiO2	0.07	0.04	0.04	0.02	0.07	0.07	0.00	0.00	0.05	0.01	0.08	0.08	0.07	0.00	0.07	0.13	0.00	0.04
Al2O3	29.03	25.18	28.05	32.55	32.51	33.15	33.29	32.32	30.46	31.73	32.80	28.63	30.41	33.48	29.04	27.21	33.91	29.58
Fe2O3	0.09	0.26	0.34	0.35	0.48	0.48	0.14	0.40	0.58	0.23	0.25	0.11	0.43	0.32	0.74	0.68	0.15	0.41
FeO	0.10	0.00	0.00	0.13	0.14	0.00	0.33	0.16	0.15	0.26	0.13	0.20	0.25	0.26	0.02	0.33	0.26	0.12
CaO	11.10	8.57	11.14	15.56	15.64	16.58	16.23	15.43	13.58	14.64	15.74	10.72	13.18	16.58	11.87	9.63	17.00	12.44
Na2O	5.07	6.10	4.95	2.67	2.59	2.07	2.10	2.68	3.69	2.96	2.43	5.18	3.86	2.01	4.82	5.73	1.71	4.30
K2O	0.29	nd	nd	0.08	0.06	0.05	0.04	0.14	0.09	0.14	0.11	0.25	0.11	0.07	0.25	0.33	0.02	0.14
tot	101.11	97.41	99.31	100.56	100.32	100.27	100.11	100.61	100.07	100.17	100.38	99.98	100.18	100.84	100.76	100.30	100.40	99.94
FeO meas.	0.18	0.23	0.31	0.44	0.57	0.43	0.46	0.52	0.67	0.47	0.36	0.30	0.64	0.55	0.68	0.94	0.39	0.49
atoms/8 O																		
Si	2.4700	2.6258	2.4844	2.2407	2.2317	2.1930	2.1976	2.2520	2.3445	2.2875	2.2274	2.4733	2.3565	2.1914	2.4320	2.5328	2.1663	2.4025
Ti	0.0023	0.0014	0.0014	0.0007	0.0024	0.0024	0.0000	0.0000	0.0017	0.0003	0.0027	0.0027	0.0024	0.0000	0.0024	0.0044	0.0000	0.0014
Al	1.5270	1.3620	1.5017	1.7473	1.7517	1.7904	1.7976	1.7342	1.6357	1.7045	1.7639	1.5231	1.6287	1.7975	1.5430	1.4441	1.8286	1.5834
Fe3+	0.0031	0.0088	0.0118	0.0119	0.0166	0.0165	0.0049	0.0138	0.0197	0.0080	0.0086	0.0037	0.0148	0.0110	0.0250	0.0231	0.0051	0.0141
Fe2+	0.0036	0.0000	0.0000	0.0048	0.0052	0.0000	0.0127	0.0060	0.0058	0.0099	0.0051	0.0076	0.0096	0.0099	0.0007	0.0123	0.0098	0.0045
Ca	0.5307	0.4213	0.5420	0.7592	0.7659	0.8139	0.7965	0.7525	0.6628	0.7148	0.7693	0.5183	0.6416	0.8091	0.5732	0.4645	0.8332	0.6052
Na	0.4386	0.5427	0.4359	0.2357	0.2295	0.1839	0.1865	0.2365	0.3259	0.2615	0.2149	0.4532	0.3400	0.1775	0.4212	0.5002	0.1517	0.3786
K	0.0165	nd	nd	0.0046	0.0035	0.0029	0.0023	0.0081	0.0052	0.0081	0.0064	0.0144	0.0064	0.0041	0.0144	0.0190	0.0012	0.0081
tot	4.9918	4.9632	4.9813	5.0051	5.0065	5.0028	4.9981	5.0032	5.0015	4.9947	4.9985	4.9963	4.9999	5.0006	5.0119	5.0003	4.9958	4.9978
An	0.5383	0.4371	0.5543	0.7595	0.7667	0.8133	0.8084	0.7547	0.6668	0.7261	0.7766	0.5257	0.6494	0.8167	0.5682	0.4722	0.8450	0.6102
Ab	0.4449	0.5629	0.4457	0.2358	0.2298	0.1838	0.1893	0.2372	0.3279	0.2657	0.2170	0.4597	0.3442	0.1792	0.4175	0.5085	0.1538	0.3817
Or	0.0167	0.0000	0.0000	0.0046	0.0035	0.0029	0.0024	0.0082	0.0053	0.0083	0.0065	0.0146	0.0065	0.0041	0.0142	0.0193	0.0012	0.0082

Strat#	CP-12	CP-12	CP-12	CP-12	CP-12	CP-12	CP-12	CP-12	CP-12	CP-12	CP-12	CP-12	PUM-17	PUM-17	PUM-17	PUM-17	PUM-17	PUM-17	PUM-17
Field#	85cns20	85cns20	85cns20	85cns20	85cns20	85cns20	85cns20	85cns20	85cns20	85cns20	85cns20	85cns20	85cns17	85cns17	85cns17	85cns17	85cns17	85cns17	85cns17
Grain	pl2r	pl3c	pl3r	pl4c	pl4r	pl5c	pl5r	pl6c	pl6r	pl6sr	pl7g	pl10g	pl1c	pl1r	pl2r	pl2sc	pl3r	pl3sc	pl3sc
Anal#	107	108	109	110	111	113	114	115	117	116	118	198	180	181	183	182	185	184	184
wt% oxide																			
SiO2	51.98	48.30	53.76	46.98	51.90	46.84	52.26	46.52	48.39	47.93	52.36	51.86	52.64	51.43	52.08	48.95	52.00	48.48	
TiO2	0.03	0.00	0.08	0.04	0.00	0.03	0.00	0.08	0.00	0.11	0.07	0.00	0.05	0.03	0.07	0.04	0.02	0.07	
Al2O3	30.29	33.40	29.69	33.82	30.78	34.73	30.28	34.43	33.25	33.44	30.21	30.47	29.60	30.55	30.26	32.40	30.36	33.00	
Fe2O3	0.42	0.00	0.46	0.26	0.28	0.10	0.36	0.35	0.33	0.45	0.49	0.46	0.24	0.53	0.40	0.40	0.35	0.55	
FeO	0.12	0.33	0.28	0.23	0.32	0.29	0.30	0.08	0.18	0.10	0.18	0.20	0.22	0.13	0.25	0.19	0.21	0.01	
CaO	13.27	16.03	12.25	16.86	13.40	17.45	13.00	17.68	16.36	16.54	13.09	13.41	12.39	13.66	12.94	15.54	13.18	16.32	
Na2O	3.85	2.26	4.41	1.84	3.76	1.59	3.99	1.45	2.21	2.11	3.96	3.82	4.16	3.66	4.01	2.58	3.87	2.29	
K2O	0.11	0.07	0.14	0.04	0.13	0.03	0.11	0.03	0.04	0.05	0.09	0.10	0.10	0.10	0.11	0.05	0.12	0.07	
tot	100.07	100.39	101.08	100.07	100.58	101.06	100.31	100.63	100.76	100.74	100.45	100.32	99.40	100.09	100.12	100.15	100.12	100.78	
FeO meas.	0.50	0.33	0.70	0.46	0.58	0.38	0.63	0.40	0.48	0.51	0.62	0.61	0.44	0.61	0.61	0.55	0.53	0.50	
atoms/8 O																			
Si	2.3626	2.2036	2.4132	2.1589	2.3484	2.1325	2.3692	2.1297	2.2036	2.1862	2.3707	2.3539	2.4004	2.3419	2.3658	2.2390	2.3621	2.2088	
Ti	0.0010	0.0000	0.0027	0.0014	0.0000	0.0010	0.0000	0.0028	0.0000	0.0038	0.0024	0.0000	0.0017	0.0010	0.0024	0.0014	0.0007	0.0024	
Al	1.6231	1.7964	1.5712	1.8323	1.6419	1.8641	1.6184	1.8582	1.7851	1.7982	1.6126	1.6305	1.5913	1.6400	1.6205	1.7472	1.6259	1.7725	
Fe3+	0.0143	0.0000	0.0156	0.0088	0.0097	0.0034	0.0124	0.0121	0.0114	0.0155	0.0167	0.0156	0.0084	0.0181	0.0137	0.0139	0.0120	0.0187	
Fe2+	0.0047	0.0126	0.0107	0.0089	0.0123	0.0111	0.0115	0.0032	0.0069	0.0039	0.0068	0.0076	0.0084	0.0051	0.0095	0.0072	0.0081	0.0003	
Ca	0.6463	0.7836	0.5892	0.8302	0.6497	0.8513	0.6315	0.8673	0.7983	0.8084	0.6351	0.6522	0.6054	0.6665	0.6298	0.7616	0.6415	0.7967	
Na	0.3393	0.1999	0.3838	0.1640	0.3299	0.1404	0.3507	0.1287	0.1951	0.1866	0.3477	0.3362	0.3678	0.3232	0.3532	0.2288	0.3409	0.2023	
K	0.0064	0.0041	0.0080	0.0023	0.0075	0.0017	0.0064	0.0018	0.0023	0.0029	0.0052	0.0058	0.0058	0.0058	0.0064	0.0029	0.0070	0.0041	
tot	4.9977	5.0002	4.9944	5.0067	4.9993	5.0055	5.0001	5.0037	5.0026	5.0056	4.9971	5.0018	4.9891	5.0016	5.0013	5.0019	4.9982	5.0058	
An	0.6515	0.7934	0.6006	0.8331	0.6582	0.8569	0.6388	0.8692	0.8017	0.8101	0.6428	0.6560	0.6184	0.6695	0.6366	0.7667	0.6484	0.7943	
Ab	0.3421	0.2024	0.3913	0.1645	0.3342	0.1413	0.3548	0.1290	0.1960	0.1870	0.3519	0.3382	0.3757	0.3246	0.3570	0.2303	0.3445	0.2017	
Or	0.0064	0.0041	0.0082	0.0024	0.0076	0.0018	0.0064	0.0018	0.0023	0.0029	0.0053	0.0058	0.0059	0.0058	0.0064	0.0029	0.0070	0.0041	

Strat# Field# Grain Anal#	PUM-17 85cns17 pl4c 186	PUM-17 85cns17 pl4r 187	PUM-17 85cns17 pl5r 190	PUM-17 85cns17 pl5r 189	PUM-17 85cns17 pl5sc 188	PUM-17 85cns17 pl6r 192	PUM-17 85cns17 pl6sc 191	PUM-17 85cns17 pl7c 193	PUM-17 85cns17 pl7r 194	PUM-17 85cns17 pl8c 195	PUM-17 85cns17 pl8r 196	PUM-17 85cns17 pl9g 197	min	max	mean	sdev
wt% oxide																
SiO2	49.63	51.36	50.95	46.01	46.01	46.46	46.45	46.83	52.44	50.71	51.54	51.71	45.27	60.41	52.34	3.52
TiO2	0.00	0.10	0.07	0.00	0.04	0.03	0.04	0.07	0.03	0.00	0.07	0.07	0.00	0.16	0.04	0.03
Al2O3	31.62	30.34	30.84	34.16	34.29	34.23	33.87	32.76	29.84	31.08	30.05	30.84	24.79	34.73	30.03	2.36
Fe2O3	0.30	0.62	0.40	0.24	0.25	0.37	0.35	0.56	0.24	0.36	0.33	0.53	0.00	0.90	0.39	0.19
FeO	0.20	0.07	0.23	0.29	0.33	0.23	0.27	0.12	0.28	0.17	0.30	0.26	0.00	0.47	0.18	0.11
CaO	14.64	13.40	13.71	17.41	17.53	17.49	17.17	16.27	12.62	14.10	12.82	13.63	6.94	18.23	12.87	2.72
Na2O	3.07	3.84	3.55	1.46	1.31	1.50	1.57	2.13	4.03	3.39	3.93	3.71	1.03	6.88	3.99	1.43
K2O	0.06	0.09	0.09	0.01	0.02	0.03	0.04	0.04	0.10	0.08	0.09	0.08	0.00	0.82	0.21	0.16
tot	99.52	99.82	99.84	99.57	99.79	100.34	99.75	98.79	99.58	99.89	99.13	100.83	97.41	101.17	100.06	0.52
FeO meas.	0.47	0.63	0.59	0.50	0.56	0.56	0.58	0.63	0.50	0.49	0.60	0.74	0.18	1.02	0.54	0.13
atoms/8 O																
Si	2.2783	2.3454	2.3261	2.1286	2.1245	2.1339	2.1444	2.1813	2.3890	2.3150	2.3638	2.3380	2.0968	2.6848	2.3768	0.1405
Ti	0.0000	0.0034	0.0024	0.0000	0.0014	0.0010	0.0014	0.0025	0.0010	0.0000	0.0024	0.0024	0.0000	0.0055	0.0014	0.0012
Al	1.7113	1.6334	1.6599	1.8631	1.8667	1.8535	1.8434	1.7990	1.6026	1.6728	1.6248	1.6439	1.3054	1.8871	1.6097	0.1389
Fe3+	0.0105	0.0213	0.0139	0.0083	0.0088	0.0126	0.0121	0.0197	0.0084	0.0122	0.0114	0.0180	0.0000	0.0305	0.0134	0.0064
Fe2+	0.0076	0.0028	0.0086	0.0110	0.0128	0.0089	0.0103	0.0049	0.0107	0.0065	0.0116	0.0100	0.0000	0.0174	0.0069	0.0041
Ca	0.7201	0.6557	0.6707	0.8630	0.8673	0.8607	0.8494	0.8120	0.6160	0.6897	0.6300	0.6603	0.3301	0.9047	0.6276	0.1376
Na	0.2733	0.3400	0.3143	0.1310	0.1173	0.1336	0.1405	0.1924	0.3560	0.3001	0.3495	0.3253	0.0925	0.5922	0.3502	0.1232
K	0.0035	0.0052	0.0052	0.0006	0.0012	0.0018	0.0024	0.0024	0.0058	0.0047	0.0053	0.0046	0.0000	0.0467	0.0119	0.0090
tot	5.0045	5.0071	5.0012	5.0056	5.0000	5.0060	5.0039	5.0141	4.9896	5.0010	4.9988	5.0025	4.9410	5.0164	4.9980	0.0097
An	0.7224	0.6551	0.6773	0.8677	0.8798	0.8641	0.8560	0.8066	0.6300	0.6936	0.6398	0.6669	0.3410	0.9056	0.6332	0.1347
Ab	0.2741	0.3397	0.3174	0.1317	0.1190	0.1341	0.1416	0.1911	0.3641	0.3018	0.3549	0.3285	0.0926	0.6117	0.3547	0.1270
Or	0.0035	0.0052	0.0053	0.0006	0.0012	0.0018	0.0024	0.0024	0.0059	0.0047	0.0053	0.0047	0.0000	0.0484	0.0121	0.0092

APPENDIX IV - Olivine compositions

Olivine compositions were determined on the JEOL JXA-733 microprobe at Southern Methodist University using standard analytical strategies and instrumental settings. No attempt was specifically made to optimize the instrumental settings for the determination of minor elements.

Spurr Volcanic Complex olivine analyses

Strat#	AMS-A04	AMS-A04	AMS-A04	AMS-A04	AMS-A04	AMS-A04	AMS-A04	AMS-A04	AMS-A04	AMS-A04	AMS-B07	AMS-B07	AMS-B07	AMS-B07	AMS-B07	AMS-B07	AMS-B07	AMS-B07
Field#	85cns22	85cns22	85cns22	85cns22	85cns22	85cns22	85cns22	85cns22	85cns22	85cns22	85cns43	85cns43	85cns43	85cns43	85cns43	85cns43	85cns43	85cns43
Grain	ol1c	ol1r	ol2c	ol2r	ol3c	ol3r	ol4c	ol4r	ol5c	ol5r	ol1c	ol1r	ol2c	ol2r	ol3c	ol3r	ol4c	ol4r
Anal#	306	307	308	309	310	311	312	313	314	315	296	297	298	299	300	301	302	303
wt%																		
SiO2	37.15	36.88	37.60	36.15	37.33	36.88	37.06	36.47	38.42	36.87	37.93	37.13	37.27	36.32	38.13	37.40	38.44	37.41
TiO2	0.06	0.05	0.01	0.05	0.00	0.02	0.00	0.11	0.02	0.03	0.01	0.01	0.00	0.02	0.00	0.01	0.03	0.00
Al2O3	0.32	0.05	0.02	0.05	0.04	0.05	0.05	0.05	0.02	0.04	0.04	0.02	0.05	0.04	0.04	0.02	0.04	0.04
FeO	20.51	21.85	16.85	26.55	20.49	22.07	19.14	24.30	18.61	20.49	18.27	23.27	23.14	26.21	16.10	18.47	14.38	18.06
MnO	0.34	0.38	0.25	0.42	0.35	0.39	0.32	0.48	0.35	0.29	0.25	0.45	0.35	0.49	0.29	0.37	0.25	0.34
MgO	40.26	39.86	43.61	35.40	40.41	38.62	41.30	37.14	41.97	40.32	43.05	38.74	39.45	36.25	44.14	42.61	46.15	42.52
CaO	0.24	0.17	0.13	0.23	0.15	0.21	0.15	0.19	0.13	0.17	0.12	0.12	0.15	0.19	0.11	0.15	0.14	0.14
Cr2O3																		
tot	98.50	99.14	98.44	98.75	98.73	98.17	97.97	98.58	99.53	98.14	99.62	99.71	100.36	99.46	98.77	99.00	99.36	98.47
atoms/4 O																		
Si	0.9734	0.9699	0.9723	0.9768	0.9788	0.9805	0.9740	0.9759	0.9886	0.9734	0.9743	0.9770	0.9729	0.9730	0.9781	0.9697	0.9722	0.9729
Ti	0.0012	0.0010	0.0002	0.0010	0.0000	0.0004	0.0000	0.0022	0.0004	0.0006	0.0002	0.0002	0.0000	0.0004	0.0000	0.0002	0.0006	0.0000
Al	0.0099	0.0016	0.0006	0.0016	0.0012	0.0016	0.0015	0.0016	0.0006	0.0012	0.0012	0.0006	0.0015	0.0013	0.0012	0.0006	0.0012	0.0012
Fe2+	0.4495	0.4806	0.3644	0.6000	0.4493	0.4907	0.4207	0.5438	0.4005	0.4524	0.3925	0.5121	0.5052	0.5873	0.3454	0.4005	0.3042	0.3928
Mn	0.0075	0.0085	0.0055	0.0096	0.0078	0.0088	0.0071	0.0109	0.0076	0.0065	0.0054	0.0100	0.0077	0.0111	0.0063	0.0081	0.0054	0.0075
Mg	1.5722	1.5622	1.6806	1.4256	1.5791	1.5303	1.6176	1.4812	1.6095	1.5864	1.6480	1.5192	1.5348	1.4474	1.6874	1.6465	1.7394	1.6481
Ca	0.0067	0.0048	0.0036	0.0067	0.0042	0.0060	0.0042	0.0054	0.0036	0.0048	0.0033	0.0034	0.0042	0.0055	0.0030	0.0042	0.0038	0.0039
Ni	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cr	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
tot	3.0204	3.0284	3.0272	3.0213	3.0205	3.0183	3.0252	3.0211	3.0107	3.0254	3.0249	3.0225	3.0263	3.0259	3.0213	3.0298	3.0267	3.0264
Fa	0.2223	0.2352	0.1782	0.2962	0.2215	0.2428	0.2064	0.2686	0.1992	0.2219	0.1923	0.2521	0.2476	0.2886	0.1699	0.1957	0.1488	0.1925
Fo	0.7777	0.7648	0.8218	0.7038	0.7785	0.7572	0.7936	0.7314	0.8008	0.7781	0.8077	0.7479	0.7524	0.7114	0.8301	0.8043	0.8512	0.8075
Mg#	77.77	76.48	82.18	70.38	77.85	75.72	79.36	73.14	80.08	77.81	80.77	74.79	75.24	71.14	83.01	80.43	85.12	80.75

Strat#	AMS-B07	AMS-B07	AMS-B07	AMS-B07	AF-08	AF-08	AF-08	AF-08	SP-02	SP-02	SP-02	SP-02	PCP-A05	PCP-A05	PCP-A05	PCP-A05	PCP-A05	PCP-A05
Field#	85cns43	85cns43	85cns43	85cns43	85cns08	85cns08	85cns08	85cns08	sp-rs2	sp-rs2	sp-rs2	sp-rs2	85cns50	85cns50	85cns50	85cns50	85cns50	85cns50
Grain	ol5c	ol5r	ol6c	ol6r	ol1c	ol1r	ol2c	ol2r	ol1c	ol1r	ol2c	ol2r	D.ol7c	D.ol8c	D.ol8r	ol1c	ol1r	ol2c
Anal#	304	305	26	27	342	343	344	345	346	347	348	349	325	326	327	319	320	321
wt%																		
SiO2	38.12	37.71	38.39	38.67	36.90	36.63	36.88	36.89	38.20	37.80	38.12	37.70	37.10	36.82	36.63	36.67	35.56	36.60
TiO2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.02	0.04	0.00	0.05	0.04	0.04	0.05	0.05	0.08	0.00
Al2O3	0.05	0.04	0.06	0.08	0.02	0.04	0.04	0.04	0.02	0.04	0.05	0.02	0.04	0.02	0.04	0.05	0.16	0.02
FeO	14.39	17.97	25.01	24.82	27.17	28.58	27.33	27.66	20.24	23.04	22.59	22.22	25.59	26.18	25.10	29.16	34.57	28.15
MnO	0.22	0.37	0.45	0.47	0.51	0.60	0.54	0.49	0.26	0.41	0.36	0.38	0.35	0.34	0.40	0.46	0.49	0.37
MgO	45.68	43.24	37.30	36.89	35.96	34.90	35.15	35.21	41.96	39.84	40.44	40.51	36.48	36.40	36.56	33.95	29.61	34.43
CaO	0.11	0.12	0.16	0.15	0.08	0.07	0.07	0.07	0.07	0.10	0.10	0.12	0.17	0.18	0.14	0.14	0.22	0.14
Cr2O3					0.01	0.07	0.02	0.01	0.02	0.07	0.00	0.03						
tot	98.52	99.41	101.38	101.11	100.62	100.78	99.97	100.32	100.73	101.19	101.61	100.93	99.69	99.92	98.83	100.38	100.45	99.69
atoms/4 O																		
Si	0.9728	0.9706	0.9975	1.0059	0.9796	0.9774	0.9859	0.9837	0.9779	0.9760	0.9781	0.9732	0.9855	0.9795	0.9809	0.9843	0.9795	0.9855
Ti	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0006	0.0004	0.0008	0.0000	0.0010	0.0008	0.0008	0.0010	0.0010	0.0017	0.0000
Al	0.0015	0.0012	0.0018	0.0025	0.0006	0.0013	0.0013	0.0013	0.0006	0.0012	0.0015	0.0006	0.0013	0.0006	0.0013	0.0016	0.0052	0.0006
Fe2+	0.3071	0.3868	0.5435	0.5399	0.6032	0.6378	0.6110	0.6169	0.4333	0.4975	0.4847	0.4797	0.5685	0.5825	0.5621	0.6546	0.7964	0.6339
Mn	0.0048	0.0081	0.0099	0.0104	0.0115	0.0136	0.0122	0.0111	0.0056	0.0090	0.0078	0.0083	0.0079	0.0077	0.0091	0.0105	0.0114	0.0084
Mg	1.7373	1.6587	1.4444	1.4301	1.4227	1.3878	1.4004	1.3993	1.6009	1.5331	1.5463	1.5585	1.4442	1.4432	1.4591	1.3581	1.2155	1.3816
Ca	0.0030	0.0033	0.0045	0.0042	0.0023	0.0020	0.0020	0.0020	0.0019	0.0028	0.0027	0.0033	0.0048	0.0051	0.0040	0.0040	0.0065	0.0040
Ni	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cr	0.0000	0.0000	0.0000	0.0000	0.0002	0.0015	0.0004	0.0002	0.0004	0.0014	0.0000	0.0006	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
tot	3.0265	3.0288	3.0016	2.9929	3.0200	3.0213	3.0133	3.0150	3.0212	3.0219	3.0212	3.0252	3.0130	3.0194	3.0175	3.0139	3.0162	3.0142
Fa	0.1502	0.1891	0.2734	0.2741	0.2978	0.3149	0.3038	0.3060	0.2130	0.2450	0.2387	0.2354	0.2825	0.2876	0.2781	0.3252	0.3958	0.3145
Fo	0.8498	0.8109	0.7266	0.7259	0.7022	0.6851	0.6962	0.6940	0.7870	0.7550	0.7613	0.7646	0.7175	0.7124	0.7219	0.6748	0.6042	0.6855
Mg#	84.98	81.09	72.66	72.59	70.22	68.51	69.62	69.40	78.70	75.50	76.13	76.46	71.75	71.24	72.19	67.48	60.42	68.55

Strat#	PCP-A05	PCP-A05	PCP-A05	PCP-A05	PCP-A05	PCP-A05	PCP-A05	PCP-A05	PCP-A05	PCP-A05	PCP-A03	PCP-A03	CP-07	CP-07	CP-07	CP-07	CP-07	CP-07	CP-07
Field#	85cns50	85cns50	85cns50	85cns50	85cns50	85cns50	85cns50	85cns50	85cns50	85cns50	85cns52	85cns52	85cns60	85cns60	85cns60	85cns60	85cns60	85cns60	85cns60
Grain	ol2r	ol3c	ol3r	ol4c	ol4r	ol5c	ol5r	P1.ol6j	P2.ol9.c	ol1c	ol1r	ol1c	ol1r	ol1c	ol1r	ol2c	ol2r	ol3c	ol3r
Anal#	322	323	324	328	329	330	331	100	332	316	317	333	334	335	336	337	338	339	339
wt%																			
SiO2	35.90	36.98	37.26	37.25	35.94	36.92	35.97	37.29	37.19	38.30	37.59	38.00	36.97	38.44	36.87	38.11	36.63	38.30	
TiO2	0.02	0.00	0.17	0.00	0.07	0.05	0.04	0.00	0.00	0.00	0.00	0.04	0.07	0.04	0.05	0.00	0.00	0.01	
Al2O3	0.04	0.67	0.65	0.05	0.05	0.05	0.05	0.04	0.00	0.04	0.05	0.05	0.04	0.05	0.02	0.04	0.05	0.04	
FeO	33.06	25.85	25.58	25.57	33.31	26.66	30.50	25.53	26.97	13.93	15.90	15.23	22.90	12.87	24.95	13.55	25.83	14.99	
MnO	0.47	0.34	0.34	0.34	0.42	0.32	0.36	0.33	0.37	0.20	0.29	0.18	0.30	0.20	0.36	0.22	0.35	0.23	
MgO	30.72	36.79	36.45	37.20	30.49	35.51	32.35	37.20	35.52	45.75	44.03	44.88	39.01	46.64	37.66	45.52	36.43	45.08	
CaO	0.18	0.15	0.18	0.10	0.16	0.15	0.16	0.15	0.19	0.14	0.10	0.13	0.10	0.10	0.14	0.11	0.14	0.15	
Cr2O3																			
tot	100.33	100.11	99.81	100.46	100.32	99.56	99.34	101.83	100.24	98.32	97.91	98.42	99.28	98.25	99.98	97.51	99.38	98.75	
atoms/4 O																			
Si	0.9841	0.9729	0.9797	0.9815	0.9853	0.9868	0.9836	0.9821	0.9892	0.9769	0.9730	0.9740	0.9744	0.9758	0.9748	0.9786	0.9788	0.9773	
Ti	0.0004	0.0000	0.0034	0.0000	0.0014	0.0010	0.0008	0.0000	0.0000	0.0000	0.0000	0.0008	0.0014	0.0008	0.0010	0.0000	0.0000	0.0002	
Al	0.0013	0.0208	0.0201	0.0016	0.0016	0.0016	0.0016	0.0012	0.0000	0.0012	0.0015	0.0015	0.0012	0.0015	0.0006	0.0012	0.0016	0.0012	
Fe2+	0.7579	0.5688	0.5625	0.5635	0.7638	0.5959	0.6975	0.5623	0.5999	0.2972	0.3442	0.3265	0.5048	0.2732	0.5517	0.2910	0.5773	0.3199	
Mn	0.0109	0.0076	0.0076	0.0076	0.0098	0.0072	0.0083	0.0074	0.0083	0.0043	0.0064	0.0039	0.0067	0.0043	0.0081	0.0048	0.0079	0.0050	
Mg	1.2550	1.4425	1.4284	1.4608	1.2458	1.4145	1.3183	1.4601	1.4080	1.7391	1.6985	1.7143	1.5323	1.7644	1.4839	1.7421	1.4508	1.7143	
Ca	0.0053	0.0042	0.0051	0.0028	0.0047	0.0043	0.0047	0.0042	0.0054	0.0038	0.0028	0.0036	0.0028	0.0027	0.0040	0.0030	0.0040	0.0041	
Ni	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
Cr	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
tot	3.0149	3.0167	3.0068	3.0177	3.0124	3.0114	3.0148	3.0173	3.0108	3.0225	3.0263	3.0245	3.0236	3.0227	3.0239	3.0208	3.0204	3.0219	
Fa	0.3765	0.2828	0.2825	0.2784	0.3801	0.2964	0.3460	0.2780	0.2988	0.1459	0.1685	0.1600	0.2478	0.1341	0.2710	0.1431	0.2846	0.1573	
Fe	0.6235	0.7172	0.7175	0.7216	0.6199	0.7036	0.6540	0.7220	0.7012	0.8541	0.8315	0.8400	0.7522	0.8659	0.7290	0.8569	0.7154	0.8427	
Mg#	62.35	71.72	71.75	72.16	61.99	70.36	65.40	72.20	70.12	85.41	83.15	84.00	75.22	86.59	72.90	85.69	71.54	84.27	

Strat#	CP-07	CP-07	CP-07	CP-07	CP-07	CP-07	CP-12	CP-12	CP-12	CP-12	CP-12				
Field#	85cns60	85cns60	85cns60	85cns60	85cns60	85cns60	85cns20	85cns20	85cns20	85cns20	85cns20				
Grain	ol4r	ol5c	ol5r	ol6c	ol6r	ol7c	ol1g	ol1r	ol2c	ol2r	ol3g				
Anal#		340	341	356	357	355	350	351	352	353	354	min	max	mean	sdev
wt%															
SiO2	38.54	38.60	37.11	37.93	36.89	38.48	37.06	35.92	36.98	36.33	38.18	35.56	38.67	37.29	0.77
TiO2	0.00	0.04	0.00	0.03	0.02	0.00	0.00	0.03	0.00	0.09	0.04	0.00	0.17	0.03	0.03
Al2O3	0.02	0.02	0.04	0.05	0.02	0.05	0.11	0.09	0.04	0.04	0.04	0.00	0.67	0.07	0.11
FeO	23.88	14.39	25.36	14.11	23.91	15.99	25.22	30.81	26.24	32.01	19.17	12.87	34.57	22.81	5.39
MnO	0.30	0.16	0.36	0.23	0.34	0.29	0.44	0.47	0.47	0.52	0.23	0.16	0.60	0.36	0.10
MgO	38.44	45.88	37.30	45.29	38.75	44.91	37.15	32.08	36.83	32.36	42.68	29.61	46.64	39.00	4.29
CaO	0.16	0.11	0.15	0.13	0.17	0.14	0.12	0.15	0.10	0.08	0.12	0.07	0.24	0.14	0.04
Cr2O3				0.03	0.03	0.03	0.02	0.00	0.08	0.02	0.03	0.00	0.08	0.03	0.02
tot	101.35	99.14	100.28	97.69	100.06	99.81	99.99	99.43	100.62	101.30	100.38	97.51	101.83	99.63	1.03
atoms/4 O															
Si	0.9959	0.9775	0.9794	0.9747	0.9702	0.9755	0.9798	0.9829	0.9766	0.9792	0.9759	0.9697	1.0059	0.9788	0.0066
Ti	0.0000	0.0008	0.0000	0.0006	0.0004	0.0000	0.0000	0.0006	0.0000	0.0018	0.0008	0.0000	0.0034	0.0005	0.0006
Al	0.0006	0.0006	0.0012	0.0015	0.0006	0.0015	0.0034	0.0029	0.0012	0.0013	0.0012	0.0000	0.0208	0.0021	0.0035
Fe2+	0.5161	0.3048	0.5598	0.3032	0.5259	0.3390	0.5576	0.7051	0.5795	0.7215	0.4098	0.2732	0.7964	0.5033	0.1286
Mn	0.0066	0.0034	0.0080	0.0050	0.0076	0.0062	0.0099	0.0109	0.0105	0.0119	0.0050	0.0034	0.0136	0.0080	0.0022
Mg	1.4803	1.7315	1.4672	1.7345	1.5188	1.6968	1.4638	1.3082	1.4495	1.2998	1.6259	1.2155	1.7644	1.5229	0.1379
Ca	0.0044	0.0030	0.0042	0.0036	0.0048	0.0038	0.0034	0.0044	0.0028	0.0023	0.0033	0.0019	0.0067	0.0039	0.0011
Ni	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cr	0.0000	0.0000	0.0000	0.0006	0.0006	0.0006	0.0004	0.0000	0.0017	0.0004	0.0006	0.0000	0.0017	0.0001	0.0004
tot	3.0038	3.0215	3.0199	3.0237	3.0288	3.0234	3.0183	3.0150	3.0219	3.0182	3.0224	2.9929	3.0298	3.0196	0.0068
Fa	0.2585	0.1497	0.2762	0.1488	0.2572	0.1665	0.2759	0.3502	0.2856	0.3570	0.2013	0.1341	0.3958	0.2487	0.0645
Fo	0.7415	0.8503	0.7238	0.8512	0.7428	0.8335	0.7241	0.6498	0.7144	0.6430	0.7987	0.6042	0.8659	0.7513	0.0645
Mg#	74.15	85.03	72.38	85.12	74.28	83.35	72.41	64.98	71.44	64.30	79.87	60.4	86.6	75.1	6.5

APPENDIX V - Clinopyroxene compositions

Plagioclase compositions were determined on the JEOL JXA-733 microprobe at Southern Methodist University using standard analytical strategies and instrumental settings. No attempt was specifically made to optimize the instrumental settings for the determination of minor elements.

Spurr Volcanic Complex clinopyroxene analyses

Strat# Field# Grain Anal#	AMS-B03 85cns57 c1c 1	AMS-B03 85cns57 c1r 2	AMS-B03 85cns57 c2c 3	AMS-B03 85cns57 c2r 4	AMS-B03 85cns57 c6c 10	AMS-B03 85cns57 c6r 11	AMS-B03 85cns57 c7c 12	AMS-B03 85cns57 c7r 13	AMS-B03 85cns57 c8c 14	AMS-B03 85cns57 c8r 15	AMS-B07 85cns43 c1c 22	AMS-B07 85cns43 c1r 23	AMS-B07 85cns43 c2c 24	AMS-B07 85cns43 c2r 25	AMS-B07 85cns43 c3c 28	AMS-B07 85cns43 c3r 29
wt%																
SiO2	50.80	51.79	50.81	51.88	52.61	52.20	52.75	52.30	52.87	52.25	53.07	53.28	51.21	51.79	52.02	52.88
TiO2	0.72	0.48	0.52	0.45	0.47	0.40	0.35	0.44	0.26	0.36	0.45	0.41	0.72	0.63	0.60	0.38
Al2O3	4.96	1.85	4.06	1.90	1.41	2.82	2.41	1.91	1.20	1.10	2.34	2.52	3.22	2.17	3.19	2.05
Fe2O3	0.98	0.95	1.40	1.00	0.82	0.84	0.36	0.57	0.38	0.08	0.37	0.47	1.26	1.27	1.02	0.61
FeO	6.46	8.47	6.78	8.73	8.43	6.51	4.81	9.24	9.37	11.25	5.18	5.28	6.61	6.57	4.63	6.39
MnO	0.18	0.33	0.20	0.25	0.34	0.25	0.16	0.30	0.47	0.36	0.17	0.17	0.20	0.23	0.12	0.21
MgO	15.74	15.21	15.03	15.84	15.45	16.47	17.21	15.65	14.38	13.56	17.20	17.55	15.20	15.93	16.20	16.63
CaO	19.74	20.04	20.62	19.14	20.44	20.02	20.77	19.09	20.74	20.11	21.19	20.79	21.09	20.78	22.18	20.72
Na2O	0.40	0.26	0.36	0.25	0.26	0.30	0.28	0.28	0.34	0.28	0.19	0.20	0.33	0.27	0.25	0.23
Cr2O3	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
tot	99.98	99.38	99.78	99.44	100.22	99.80	99.10	99.78	100.01	99.35	100.16	100.67	99.84	99.64	100.21	100.10
FeO meas	7.34	9.32	8.04	9.63	9.16	7.26	5.13	9.75	9.71	11.32	5.51	5.70	7.74	7.71	5.55	6.94
atoms/6 O																
Si	1.8729	1.9416	1.8898	1.9404	1.9540	1.9267	1.9430	1.9479	1.9733	1.9743	1.9389	1.9355	1.9036	1.9268	1.9092	1.9447
Ti	0.0200	0.0135	0.0145	0.0127	0.0131	0.0111	0.0097	0.0123	0.0073	0.0102	0.0124	0.0112	0.0201	0.0176	0.0166	0.0105
Al t	0.1271	0.0584	0.1102	0.0596	0.0460	0.0733	0.0570	0.0521	0.0267	0.0257	0.0611	0.0645	0.0964	0.0732	0.0908	0.0553
Al o	0.0885	0.0234	0.0678	0.0242	0.0157	0.0494	0.0477	0.0317	0.0261	0.0233	0.0397	0.0434	0.0447	0.0219	0.0473	0.0336
Fe3+	0.0273	0.0268	0.0392	0.0282	0.0228	0.0232	0.0099	0.0159	0.0106	0.0024	0.0102	0.0128	0.0352	0.0355	0.0282	0.0170
Fe2+	0.1990	0.2654	0.2109	0.2730	0.2617	0.2009	0.1482	0.2878	0.2925	0.3554	0.1581	0.1603	0.2054	0.2043	0.1422	0.1964
Mn	0.0056	0.0105	0.0063	0.0079	0.0107	0.0078	0.0050	0.0095	0.0149	0.0115	0.0053	0.0052	0.0063	0.0072	0.0037	0.0065
Mg	0.8648	0.8498	0.8331	0.8829	0.8552	0.9060	0.9448	0.8687	0.7999	0.7636	0.9365	0.9501	0.8421	0.8832	0.8861	0.9115
Ca	0.7798	0.8050	0.8218	0.7671	0.8134	0.7918	0.8198	0.7618	0.8294	0.8142	0.8295	0.8092	0.8400	0.8284	0.8723	0.8165
Na	0.0286	0.0189	0.0260	0.0181	0.0187	0.0215	0.0200	0.0202	0.0246	0.0205	0.0135	0.0141	0.0238	0.0195	0.0178	0.0164
Ni	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cr	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
tot	4.0136	4.0134	4.0196	4.0141	4.0114	4.0116	4.0049	4.0080	4.0053	4.0012	4.0051	4.0064	4.0176	4.0178	4.0141	4.0085
Ac	0.0273	0.0189	0.0260	0.0181	0.0187	0.0215	0.0099	0.0159	0.0106	0.0024	0.0102	0.0128	0.0238	0.0195	0.0178	0.0164
Jd	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	0.0101	0.0043	0.0140	0.0181	0.0032	0.0012	0.0000	0.0000	0.0000	0.0000
FeCaTs	0.0000	0.0079	0.0133	0.0101	0.0041	0.0017	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0114	0.0161	0.0104	0.0006
CrCaTs	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
AlCaTs	0.0872	0.0234	0.0678	0.0242	0.0157	0.0494	0.0376	0.0275	0.0121	0.0052	0.0364	0.0421	0.0447	0.0219	0.0473	0.0336
Wo	0.3600	0.3963	0.3833	0.3755	0.4062	0.3811	0.3960	0.3752	0.4140	0.4057	0.4017	0.3900	0.4038	0.4049	0.4162	0.3993
En	0.5203	0.4600	0.4921	0.4770	0.4547	0.5066	0.5221	0.4694	0.4291	0.4056	0.5119	0.5220	0.4793	0.4833	0.5031	0.4942
Fs	0.1197	0.1437	0.1246	0.1475	0.1391	0.1123	0.0819	0.1555	0.1569	0.1887	0.0864	0.0881	0.1169	0.1118	0.0807	0.1065
Mg#	81.3	76.2	79.8	76.4	76.6	81.9	86.4	75.1	73.2	68.2	85.6	85.6	80.4	81.2	86.2	82.3

mineral calculations after Lindsley (1983)

Strat# Field# Grain Anal#	AMS-B07 85cns43 c4c 30	AMS-B07 85cns43 c4r 31	AMS-B07 85cns43 c5c 32	AMS-B07 85cns43 c5r 33	AMS-A03 85cns23 c1c 44	AMS-A03 85cns23 c1r 45	AMS-A03 85cns23 c2c 46	AMS-A03 85cns23 c2r 47	AMS-A03 85cns23 c3c 48	AMS-A03 85cns23 c3r 49	AMS-A03 85cns23 c4c 52	AMS-A03 85cns23 c4r 53	AMS-A03 85cns23 c5c 54	AMS-A03 85cns23 c5r 55	AMS-A03 85cns23 c8=02j 61	AMS-A03 85cns23 P.c6c 50
wt%																
SiO2	51.62	50.97	51.93	51.15	51.86	52.38	52.66	51.95	51.93	52.27	52.85	53.32	51.52	52.40	51.64	52.44
TiO2	0.66	0.65	0.70	0.53	0.48	0.49	0.38	0.45	0.42	0.37	0.34	0.36	0.55	0.43	0.32	0.49
Al2O3	2.44	3.84	2.91	4.32	1.77	1.75	1.57	1.55	1.45	1.43	1.17	1.44	2.13	1.78	0.99	2.13
Fe2O3	1.48	1.42	1.01	1.19	1.25	0.91	0.94	0.65	1.71	1.33	0.82	0.47	1.58	1.18	1.82	0.78
FeO	7.87	5.90	7.89	4.92	9.11	9.59	9.14	8.45	7.86	8.44	8.87	8.54	8.26	8.50	7.30	7.57
MnO	0.27	0.20	0.28	0.16	0.34	0.35	0.42	0.38	0.35	0.37	0.38	0.34	0.38	0.39	0.45	0.30
MgO	14.78	15.89	15.48	15.65	14.17	14.06	14.28	14.29	14.52	14.50	14.60	14.85	14.56	14.66	14.69	14.69
CaO	20.94	20.57	20.35	21.63	20.82	20.82	21.04	21.17	21.52	21.23	21.20	21.36	20.72	20.98	21.70	21.82
Na2O	0.36	0.30	0.29	0.32	0.35	0.39	0.38	0.30	0.34	0.34	0.31	0.34	0.36	0.36	0.29	0.32
Cr2O3	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
tot	100.43	99.74	100.84	99.87	100.15	100.74	100.80	99.20	100.10	100.28	100.54	101.02	100.06	100.68	99.20	100.54
FeO meas	9.21	7.18	8.80	5.99	10.23	10.41	9.98	9.04	9.40	9.64	9.61	8.96	9.68	9.56	8.94	8.27
atoms/6 O																
Si	1.9202	1.8890	1.9137	1.8864	1.9425	1.9492	1.9556	1.9546	1.9444	1.9517	1.9645	1.9644	1.9284	1.9456	1.9512	1.9406
Ti	0.0185	0.0181	0.0194	0.0147	0.0135	0.0137	0.0106	0.0127	0.0118	0.0104	0.0095	0.0100	0.0155	0.0120	0.0091	0.0136
Al t	0.0798	0.1110	0.0863	0.1136	0.0575	0.0508	0.0444	0.0454	0.0556	0.0483	0.0355	0.0356	0.0716	0.0544	0.0488	0.0594
Al o	0.0272	0.0568	0.0402	0.0742	0.0207	0.0260	0.0244	0.0233	0.0084	0.0147	0.0158	0.0270	0.0224	0.0235	0.0000	0.0335
Fe3+	0.0415	0.0396	0.0280	0.0329	0.0351	0.0255	0.0262	0.0185	0.0481	0.0374	0.0230	0.0130	0.0444	0.0328	0.0519	0.0216
Fe2+	0.2450	0.1830	0.2432	0.1519	0.2853	0.2984	0.2838	0.2659	0.2462	0.2636	0.2757	0.2631	0.2586	0.2640	0.2306	0.2343
Mn	0.0085	0.0063	0.0087	0.0050	0.0108	0.0110	0.0132	0.0121	0.0111	0.0117	0.0120	0.0106	0.0120	0.0123	0.0144	0.0094
Mg	0.8194	0.8777	0.8502	0.8602	0.7910	0.7798	0.7903	0.8013	0.8103	0.8069	0.8088	0.8154	0.8122	0.8112	0.8272	0.8102
Ca	0.8347	0.8169	0.8036	0.8547	0.8356	0.8302	0.8372	0.8535	0.8634	0.8494	0.8444	0.8432	0.8310	0.8347	0.8786	0.8652
Na	0.0260	0.0216	0.0207	0.0229	0.0254	0.0281	0.0274	0.0219	0.0247	0.0246	0.0223	0.0243	0.0261	0.0259	0.0212	0.0230
Ni	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cr	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
tot	4.0208	4.0198	4.0140	4.0164	4.0176	4.0128	4.0131	4.0093	4.0241	4.0187	4.0115	4.0065	4.0222	4.0164	4.0330	4.0108
Ac	0.0260	0.0216	0.0207	0.0229	0.0254	0.0255	0.0262	0.0185	0.0247	0.0246	0.0223	0.0130	0.0261	0.0259	0.0212	0.0216
Jd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0026	0.0012	0.0034	0.0000	0.0000	0.0000	0.0113	0.0000	0.0000	0.0000	0.0013
FeCaTs	0.0156	0.0180	0.0073	0.0100	0.0097	0.0000	0.0000	0.0000	0.0235	0.0128	0.0007	0.0000	0.0183	0.0069	0.0306	0.0000
CrCaTs	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
AlCaTs	0.0272	0.0568	0.0402	0.0742	0.0207	0.0234	0.0232	0.0200	0.0084	0.0147	0.0158	0.0156	0.0224	0.0235	0.0000	0.0322
Wo	0.4089	0.3818	0.3884	0.3967	0.4153	0.4162	0.4201	0.4260	0.4281	0.4233	0.4251	0.4203	0.4082	0.4151	0.4346	0.4273
En	0.4551	0.5115	0.4756	0.5128	0.4297	0.4222	0.4267	0.4310	0.4386	0.4347	0.4287	0.4383	0.4489	0.4413	0.4421	0.4442
Fs	0.1361	0.1067	0.1360	0.0905	0.1550	0.1616	0.1532	0.1430	0.1333	0.1420	0.1461	0.1414	0.1429	0.1436	0.1233	0.1285
Mg#	77.0	82.7	77.8	85.0	73.5	72.3	73.6	75.1	76.7	75.4	74.6	75.6	75.9	75.4	78.2	77.6

Strat# Field# Grain Anal#	AMS-A03 85cns23 P.c7r 51	AMS-A04 85cns22 c1c 34	AMS-A04 85cns22 c1r 35	AMS-A04 85cns22 c2c 36	AMS-A04 85cns22 c2r 37	AMS-A04 85cns22 c3c 38	AMS-A04 85cns22 c3r 39	AMS-A04 85cns22 c4c 40	AMS-A04 85cns22 c4r 41	AMS-A04 85cns22 c5c 42	AMS-A04 85cns22 c5r 43	SP-02 sp-rs2 c1c 210	SP-02 sp-rs2 c1r 211	SP-02 sp-rs2 c2c 212	SP-02 sp-rs2 c2r 213	SP-02 sp-rs2 c3c 214
wt%																
SiO2	52.64	51.77	50.88	51.07	51.69	51.13	52.13	51.90	51.82	50.57	50.18	52.70	53.53	52.46	52.75	53.02
TiO2	0.30	0.73	0.82	0.74	0.66	0.84	0.45	0.71	0.50	0.74	1.23	0.29	0.30	0.48	0.31	0.21
Al2O3	1.45	2.99	3.07	2.47	2.94	3.16	2.07	2.01	2.68	3.63	4.03	1.32	1.32	1.63	1.21	1.24
Fe2O3	0.49	1.45	1.92	1.90	1.03	1.30	0.88	1.29	1.17	2.64	1.57	1.18	0.91	1.24	1.66	1.34
FeO	9.05	5.88	6.45	7.00	6.07	7.93	7.28	7.72	5.52	4.32	7.33	8.41	8.57	9.46	7.69	8.82
MnO	0.40	0.20	0.18	0.25	0.20	0.23	0.28	0.30	0.18	0.21	0.21	0.35	0.40	0.33	0.38	0.43
MgO	14.34	15.91	15.41	15.64	15.41	15.14	16.01	15.86	15.68	15.66	14.74	14.75	15.18	14.50	15.98	14.80
CaO	20.92	21.52	21.07	20.28	21.76	20.03	20.27	20.02	21.89	22.27	20.77	21.14	21.25	20.36	20.67	21.06
Na2O	0.35	0.26	0.29	0.32	0.27	0.36	0.23	0.29	0.27	0.29	0.30	0.36	0.31	0.43	0.23	0.34
Cr2O3	na	na	na	na	na	na	na	na	na	na	na	0.02	0.00	0.04	0.07	0.00
tot	99.94	100.71	100.09	99.67	100.03	100.12	99.61	100.10	99.71	100.34	100.37	100.53	101.77	100.93	100.95	101.25
FeO meas	9.49	7.18	8.18	8.71	7.00	9.10	8.08	8.88	6.57	6.70	8.75	9.48	9.39	10.58	9.18	10.02
atoms/6 O																
Si	1.9654	1.9042	1.8933	1.9096	1.9128	1.9020	1.9380	1.9285	1.9209	1.8737	1.8661	1.9591	1.9616	1.9485	1.9492	1.9607
Ti	0.0084	0.0202	0.0229	0.0208	0.0184	0.0235	0.0126	0.0198	0.0139	0.0206	0.0344	0.0081	0.0083	0.0134	0.0086	0.0058
Al t	0.0346	0.0958	0.1067	0.0904	0.0872	0.0980	0.0620	0.0715	0.0791	0.1263	0.1339	0.0409	0.0384	0.0515	0.0508	0.0393
Al o	0.0293	0.0339	0.0280	0.0184	0.0411	0.0406	0.0287	0.0166	0.0380	0.0323	0.0427	0.0169	0.0187	0.0198	0.0019	0.0148
Fe3+	0.0138	0.0401	0.0537	0.0536	0.0288	0.0363	0.0247	0.0362	0.0327	0.0736	0.0440	0.0331	0.0252	0.0347	0.0461	0.0372
Fe2+	0.2825	0.1808	0.2009	0.2188	0.1879	0.2468	0.2265	0.2398	0.1710	0.1340	0.2281	0.2616	0.2626	0.2940	0.2376	0.2727
Mn	0.0127	0.0062	0.0057	0.0079	0.0063	0.0072	0.0088	0.0094	0.0057	0.0066	0.0066	0.0110	0.0124	0.0104	0.0119	0.0135
Mg	0.7979	0.8722	0.8546	0.8715	0.8499	0.8394	0.8870	0.8783	0.8662	0.8647	0.8169	0.8172	0.8290	0.8026	0.8800	0.8157
Ca	0.8369	0.8482	0.8401	0.8125	0.8628	0.7984	0.8074	0.7971	0.8694	0.8841	0.8276	0.8421	0.8344	0.8103	0.8184	0.8345
Na	0.0253	0.0185	0.0209	0.0232	0.0194	0.0260	0.0166	0.0209	0.0194	0.0208	0.0216	0.0259	0.0220	0.0310	0.0165	0.0244
Ni	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cr	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0006	0.0000	0.0012	0.0020	0.0000
tot	4.0069	4.0200	4.0268	4.0268	4.0144	4.0182	4.0124	4.0181	4.0163	4.0368	4.0220	4.0166	4.0126	4.0173	4.0231	4.0186
Ac	0.0138	0.0185	0.0209	0.0232	0.0194	0.0260	0.0166	0.0209	0.0194	0.0208	0.0216	0.0259	0.0220	0.0310	0.0165	0.0244
Jd	0.0115	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
FeCaTs	0.0000	0.0215	0.0328	0.0304	0.0094	0.0104	0.0081	0.0153	0.0133	0.0528	0.0224	0.0072	0.0032	0.0037	0.0296	0.0128
CrCaTs	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0006	0.0000	0.0012	0.0020	0.0000
AlCaTs	0.0177	0.0339	0.0280	0.0184	0.0411	0.0406	0.0287	0.0166	0.0380	0.0323	0.0427	0.0169	0.0187	0.0198	0.0019	0.0148
Wo	0.4165	0.4057	0.4001	0.3934	0.4159	0.3867	0.3936	0.3931	0.4188	0.4100	0.3920	0.4217	0.4173	0.4083	0.4007	0.4157
En	0.4309	0.4923	0.4857	0.4848	0.4784	0.4740	0.4831	0.4767	0.4854	0.5109	0.4753	0.4381	0.4425	0.4331	0.4719	0.4379
Fs	0.1526	0.1021	0.1142	0.1217	0.1058	0.1393	0.1233	0.1302	0.0958	0.0792	0.1327	0.1402	0.1402	0.1586	0.1274	0.1464
Mg#	73.9	82.8	81.0	79.9	81.9	77.3	79.7	78.6	83.5	86.6	78.2	75.8	75.9	73.2	78.7	74.9

Strat#	SP-02	SP-02	SP-02	SP-02	AF-08	AF-08	AF-08	AF-08	AF-08	AF-08	AF-08	AF-08	AF-08	AF-08	AF-09	AF-09
Field#	sp-rs2	sp-rs2	sp-rs2	sp-rs2	85cns08	85cns08	85cns08	85cns08	85cns08	85cns08	85cns08	85cns08	85cns08	85cns08	85cns09	85cns09
Grain	c3r	c4g	c5c	c5r	c1c	c1r	c2c	c2r	c3c	c3r	c4c	c4r	c5c	c5r	c1c	c1r
Anal#	215	216	217	218	163	164	165	167	168	169	170	171	172	173	189	190
wt%																
SiO2	52.52	52.00	53.46	53.11	52.96	53.01	52.44	52.27	52.59	52.32	52.46	51.91	51.88	52.48	52.43	52.33
TiO2	0.55	0.37	0.23	0.31	0.39	0.21	0.38	0.43	0.25	0.26	0.22	0.32	0.48	0.30	0.59	0.48
Al2O3	1.82	1.71	0.80	1.27	1.48	0.97	1.68	1.54	1.02	1.18	1.04	0.87	1.86	0.91	2.02	1.48
Fe2O3	1.53	1.66	0.97	1.39	1.04	0.25	0.97	0.80	1.37	1.05	1.05	1.08	1.19	1.45	0.91	1.17
FeO	7.61	8.46	7.61	7.81	8.68	10.01	8.39	9.10	8.41	8.33	9.03	8.77	8.25	8.99	8.25	9.23
MnO	0.32	0.31	0.23	0.36	0.41	0.41	0.35	0.42	0.32	0.36	0.35	0.30	0.30	0.35	0.27	0.38
MgO	15.00	14.54	15.24	15.05	14.59	14.23	14.53	14.24	14.59	14.34	13.82	13.91	14.36	14.49	14.96	14.59
CaO	21.58	20.78	21.99	21.73	21.44	20.73	21.28	20.86	21.43	21.31	21.74	21.64	21.29	21.02	20.83	20.49
Na2O	0.36	0.42	0.30	0.34	0.34	0.29	0.34	0.35	0.33	0.37	0.33	0.27	0.34	0.34	0.38	0.36
Cr2O3	0.06	0.03	0.00	0.02	0.02	0.00	0.05	0.00	0.05	0.01	0.00	0.01	0.02	0.03	0.04	0.05
tot	101.34	100.29	100.83	101.39	101.35	100.12	100.42	100.01	100.37	99.54	100.05	99.08	99.97	100.36	100.68	100.56
FeO meas	8.98	9.96	8.48	9.06	9.62	10.24	9.27	9.82	9.65	9.28	9.98	9.74	9.32	10.29	9.07	10.28
atoms/6 O																
Si	1.9360	1.9433	1.9735	1.9564	1.9544	1.9797	1.9504	1.9553	1.9625	1.9650	1.9679	1.9659	1.9408	1.9630	1.9399	1.9499
Ti	0.0152	0.0104	0.0064	0.0086	0.0108	0.0059	0.0106	0.0121	0.0070	0.0073	0.0062	0.0091	0.0135	0.0084	0.0164	0.0135
Al t	0.0640	0.0567	0.0265	0.0436	0.0456	0.0203	0.0496	0.0447	0.0375	0.0350	0.0321	0.0341	0.0592	0.0370	0.0601	0.0501
Al o	0.0151	0.0186	0.0083	0.0116	0.0188	0.0224	0.0241	0.0233	0.0073	0.0172	0.0139	0.0047	0.0228	0.0032	0.0280	0.0149
Fe3+	0.0423	0.0468	0.0269	0.0386	0.0289	0.0072	0.0272	0.0226	0.0385	0.0298	0.0297	0.0307	0.0334	0.0407	0.0254	0.0329
Fe2+	0.2345	0.2645	0.2349	0.2405	0.2680	0.3127	0.2611	0.2846	0.2626	0.2617	0.2834	0.2778	0.2582	0.2812	0.2553	0.2875
Mn	0.0100	0.0098	0.0072	0.0112	0.0128	0.0130	0.0110	0.0133	0.0101	0.0115	0.0111	0.0096	0.0095	0.0111	0.0085	0.0120
Mg	0.8241	0.8098	0.8384	0.8262	0.8024	0.7920	0.8054	0.7939	0.8114	0.8026	0.7726	0.7851	0.8006	0.8078	0.8249	0.8102
Ca	0.8524	0.8321	0.8698	0.8577	0.8478	0.8295	0.8481	0.8361	0.8569	0.8576	0.8739	0.8781	0.8534	0.8425	0.8258	0.8181
Na	0.0257	0.0304	0.0215	0.0243	0.0243	0.0210	0.0245	0.0254	0.0239	0.0269	0.0240	0.0198	0.0247	0.0247	0.0273	0.0260
Ni	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cr	0.0017	0.0009	0.0000	0.0006	0.0006	0.0000	0.0015	0.0000	0.0015	0.0003	0.0000	0.0003	0.0006	0.0009	0.0012	0.0015
tot	4.0212	4.0234	4.0134	4.0193	4.0145	4.0036	4.0136	4.0113	4.0193	4.0149	4.0149	4.0153	4.0167	4.0204	4.0127	4.0164
Ac	0.0257	0.0304	0.0215	0.0243	0.0243	0.0072	0.0245	0.0226	0.0239	0.0269	0.0240	0.0198	0.0247	0.0247	0.0254	0.0260
Jd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0138	0.0000	0.0028	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0019	0.0000
FeCaTs	0.0166	0.0164	0.0054	0.0143	0.0046	0.0000	0.0027	0.0000	0.0147	0.0029	0.0057	0.0108	0.0087	0.0161	0.0000	0.0069
CrCaTs	0.0017	0.0009	0.0000	0.0006	0.0006	0.0000	0.0015	0.0000	0.0015	0.0003	0.0000	0.0003	0.0006	0.0009	0.0012	0.0015
AlCaTs	0.0151	0.0186	0.0083	0.0116	0.0188	0.0085	0.0241	0.0205	0.0073	0.0172	0.0139	0.0047	0.0228	0.0032	0.0261	0.0149
Wo	0.4223	0.4133	0.4388	0.4278	0.4241	0.4141	0.4222	0.4191	0.4286	0.4321	0.4391	0.4410	0.4229	0.4235	0.4120	0.4104
En	0.4497	0.4422	0.4384	0.4432	0.4317	0.4201	0.4364	0.4276	0.4317	0.4283	0.4104	0.4128	0.4363	0.4276	0.4491	0.4352
Fs	0.1280	0.1444	0.1228	0.1290	0.1442	0.1658	0.1415	0.1533	0.1397	0.1396	0.1505	0.1461	0.1407	0.1489	0.1390	0.1544
Mg#	77.8	75.4	78.1	77.5	75.0	71.7	75.5	73.6	75.5	75.4	73.2	73.9	75.6	74.2	76.4	73.8

Strat#	AF-09	AF-09	AF-09	AF-09	AF-09	AF-09	AF-09	AF-09	AF-09	PF-38	PF-38	PF-38	PF-38	PF-38	PF-38	PF-38
Field#	85cns09	85cns09	85cns09	85cns09	85cns09	85cns09	85cns09	85cns09	85cns09	85cns38	85cns38	85cns38	85cns38	85cns38	85cns38	85cns38
Grain	c2c	c2r	c3c	c3r	c4c	c4r	c5c	c5r	c6c=04j	c1c	c1r	c2c	c2r	c3g	c4c	c4r
Anal#	191	192	193	194	195	196	197	198	207	141	142	145	147	150	151	152
wt%																
SiO2	53.24	52.30	52.12	52.02	52.95	52.59	52.07	52.82	53.38	49.73	52.35	51.45	51.71	51.93	50.39	51.62
TiO2	0.20	0.45	0.47	0.39	0.35	0.26	0.43	0.27	0.42	0.90	0.43	0.51	0.61	0.36	0.66	0.53
Al2O3	1.08	1.74	1.61	1.70	1.39	1.38	1.77	0.98	1.24	2.85	2.05	3.07	1.88	1.84	2.94	2.29
Fe2O3	1.07	1.79	1.96	1.14	0.47	1.44	1.56	0.00	0.58	1.47	1.08	1.28	1.45	1.32	2.13	2.08
FeO	8.83	8.59	7.77	9.02	9.19	8.59	8.64	8.70	8.79	8.34	8.60	8.45	9.46	7.80	7.81	8.14
MnO	0.35	0.30	0.39	0.35	0.41	0.34	0.31	0.49	0.36	0.24	0.28	0.25	0.25	0.27	0.25	0.24
MgO	14.66	14.73	14.77	14.30	14.54	14.82	14.50	14.56	15.52	14.15	14.85	15.23	14.63	14.63	15.30	14.66
CaO	21.49	20.81	21.37	20.75	20.91	20.81	20.91	19.11	20.32	19.70	20.68	19.36	20.18	21.37	19.11	21.11
Na2O	0.32	0.42	0.38	0.35	0.33	0.38	0.38	0.37	0.35	0.41	0.35	0.41	0.30	0.32	0.43	0.34
Cr2O3	0.04	0.05	0.01	0.00	0.00	0.02	0.00	0.02	0.06	na	na	na	na	na	na	na
tot	101.28	101.18	100.85	100.02	100.54	100.62	100.58	97.32	101.02	97.79	100.67	100.01	100.48	99.84	99.02	101.01
FeO meas	9.79	10.20	9.53	10.05	9.61	9.88	10.05	8.70	9.31	9.66	9.57	9.60	10.77	8.99	9.73	10.01
atoms/6 O																
Si	1.9669	1.9388	1.9377	1.9481	1.9652	1.9558	1.9409	2.0055	1.9650	1.9038	1.9408	1.9153	1.9319	1.9423	1.9013	1.9183
Ti	0.0056	0.0125	0.0131	0.0110	0.0098	0.0073	0.0121	0.0077	0.0116	0.0259	0.0120	0.0143	0.0171	0.0101	0.0187	0.0148
Al t	0.0331	0.0612	0.0623	0.0519	0.0348	0.0442	0.0591	-0.0055	0.0350	0.0962	0.0592	0.0847	0.0681	0.0577	0.0987	0.0817
Al o	0.0139	0.0148	0.0083	0.0231	0.0260	0.0163	0.0187	0.0493	0.0189	0.0324	0.0304	0.0500	0.0147	0.0235	0.0321	0.0186
Fe3+	0.0298	0.0501	0.0548	0.0322	0.0130	0.0403	0.0438	0.0000	0.0161	0.0424	0.0300	0.0357	0.0408	0.0371	0.0606	0.0580
Fe2+	0.2727	0.2662	0.2415	0.2825	0.2853	0.2670	0.2695	0.2763	0.2705	0.2669	0.2667	0.2632	0.2957	0.2441	0.2464	0.2531
Mn	0.0110	0.0094	0.0123	0.0111	0.0129	0.0107	0.0098	0.0158	0.0112	0.0078	0.0088	0.0079	0.0079	0.0086	0.0080	0.0076
Mg	0.8072	0.8138	0.8184	0.7981	0.8042	0.8214	0.8055	0.8239	0.8515	0.8073	0.8205	0.8450	0.8146	0.8155	0.8604	0.8119
Ca	0.8507	0.8266	0.8513	0.8326	0.8315	0.8292	0.8351	0.7774	0.8015	0.8081	0.8215	0.7722	0.8078	0.8565	0.7726	0.8406
Na	0.0229	0.0302	0.0274	0.0254	0.0237	0.0274	0.0275	0.0272	0.0250	0.0304	0.0252	0.0296	0.0217	0.0232	0.0315	0.0245
Ni	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cr	0.0012	0.0015	0.0003	0.0000	0.0000	0.0006	0.0000	0.0006	0.0017	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
tot	4.0149	4.0250	4.0274	4.0161	4.0065	4.0201	4.0219	3.9782	4.0080	4.0212	4.0150	4.0179	4.0204	4.0186	4.0303	4.0290
Ac	0.0229	0.0302	0.0274	0.0254	0.0130	0.0274	0.0275	0.0000	0.0161	0.0304	0.0252	0.0296	0.0217	0.0232	0.0315	0.0245
Jd	0.0000	0.0000	0.0000	0.0000	0.0107	0.0000	0.0000	0.0272	0.0089	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
FeCaTs	0.0069	0.0199	0.0274	0.0068	0.0000	0.0129	0.0163	0.0000	0.0000	0.0120	0.0049	0.0061	0.0191	0.0139	0.0291	0.0335
CrCaTs	0.0012	0.0015	0.0003	0.0000	0.0000	0.0006	0.0000	0.0006	0.0017	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
AlCaTs	0.0139	0.0148	0.0083	0.0231	0.0153	0.0163	0.0187	0.0221	0.0100	0.0324	0.0304	0.0500	0.0147	0.0235	0.0321	0.0186
Wo	0.4258	0.4103	0.4214	0.4140	0.4146	0.4135	0.4138	0.3774	0.4029	0.3971	0.4057	0.3728	0.3979	0.4211	0.3714	0.4065
En	0.4292	0.4443	0.4468	0.4328	0.4321	0.4426	0.4392	0.4663	0.4531	0.4531	0.4485	0.4782	0.4418	0.4455	0.4886	0.4525
Fs	0.1450	0.1453	0.1319	0.1532	0.1533	0.1439	0.1470	0.1563	0.1440	0.1498	0.1458	0.1489	0.1603	0.1333	0.1400	0.1410
Mg#	74.7	75.4	77.2	73.9	73.8	75.5	74.9	74.9	75.9	75.2	75.5	76.3	73.4	77.0	77.7	76.2

Strat#	PF-38	PF-38	PF-38	PF-38	PCP-B01	PCP-B01	PCP-B01	PCP-B01	PCP-B01	PCP-B01	PCP-A03	PCP-A03	PCP-A03	PCP-A03	PCP-A03	PCP-A03
Field#	85cns38	85cns38	85cns38	85cns38	85cns33	85cns33	85cns33	85cns33	85cns33	85cns33	85cns52	85cns52	85cns52	85cns52	85cns52	85cns52
Grain	c5c	c5r	c7=05r	P.c6c	c1c	c1r	c2c	c2r	c3c	c3r	c1c	c1r	c2c	c2r	c3c	c3r
Anal#	153	154	144	148	278	279	280	281	282	283	69	70	71	72	73	74
wt%																
SiO2	50.78	51.14	52.11	51.22	50.74	52.67	50.41	51.39	49.59	51.00	51.60	50.67	52.77	51.80	52.32	51.88
TiO2	0.68	0.44	0.48	0.56	0.75	0.50	0.90	0.53	1.00	0.71	0.66	0.78	0.43	0.69	0.46	0.46
Al2O3	2.67	2.06	1.91	1.92	4.02	2.55	4.41	2.55	5.16	3.29	4.20	4.84	2.32	2.41	2.23	3.16
Fe2O3	2.04	2.18	1.52	1.33	1.23	0.00	1.08	1.57	1.49	1.35	0.48	0.68	0.31	0.84	0.76	1.08
FeO	7.58	7.68	8.14	9.19	6.99	7.59	7.32	8.05	7.23	7.69	5.82	5.91	7.28	8.55	7.73	5.10
MnO	0.25	0.29	0.32	0.24	0.23	0.17	0.16	0.23	0.15	0.20	0.18	0.19	0.24	0.30	0.25	0.22
MgO	14.80	14.71	15.56	14.48	14.82	15.92	14.52	15.02	14.21	14.76	15.86	15.63	16.13	15.13	15.87	16.51
CaO	20.51	20.82	20.02	20.00	20.76	20.30	20.76	20.37	20.53	20.54	20.96	20.34	20.23	20.19	19.85	21.03
Na2O	0.38	0.36	0.34	0.32	0.36	0.27	0.35	0.32	0.40	0.37	0.30	0.34	0.31	0.27	0.35	0.27
Cr2O3	na	na	na	na	0.13	0.09	0.13	0.05	0.13	0.04	na	na	na	na	na	na
tot	99.68	99.68	100.40	99.26	100.03	100.06	100.04	100.08	99.89	99.96	100.06	99.39	100.02	100.17	99.82	99.71
FeO meas	9.41	9.64	9.51	10.39	8.10	7.59	8.29	9.46	8.57	8.91	6.25	6.53	7.56	9.30	8.41	6.07
atoms/6 O																
Si	1.9068	1.9241	1.9358	1.9342	1.8848	1.9395	1.8738	1.9178	1.8501	1.9016	1.8949	1.8754	1.9445	1.9259	1.9404	1.9132
Ti	0.0192	0.0125	0.0134	0.0159	0.0210	0.0138	0.0252	0.0149	0.0281	0.0199	0.0182	0.0217	0.0119	0.0193	0.0128	0.0128
Al t	0.0932	0.0759	0.0642	0.0658	0.1152	0.0605	0.1262	0.0822	0.1499	0.0984	0.1051	0.1246	0.0555	0.0741	0.0596	0.0868
Al o	0.0250	0.0155	0.0194	0.0196	0.0609	0.0502	0.0670	0.0300	0.0771	0.0462	0.0767	0.0866	0.0452	0.0316	0.0379	0.0506
Fe3+	0.0575	0.0618	0.0424	0.0378	0.0345	0.0000	0.0303	0.0440	0.0418	0.0380	0.0133	0.0191	0.0086	0.0234	0.0212	0.0301
Fe2+	0.2380	0.2415	0.2530	0.2903	0.2172	0.2337	0.2274	0.2512	0.2256	0.2399	0.1787	0.1831	0.2244	0.2658	0.2397	0.1571
Mn	0.0080	0.0092	0.0101	0.0077	0.0072	0.0053	0.0050	0.0073	0.0047	0.0063	0.0056	0.0060	0.0075	0.0094	0.0079	0.0069
Mg	0.8282	0.8248	0.8615	0.8149	0.8205	0.8737	0.8044	0.8354	0.7901	0.8202	0.8680	0.8621	0.8858	0.8384	0.8772	0.9074
Ca	0.8252	0.8393	0.7969	0.8092	0.8263	0.8010	0.8268	0.8146	0.8207	0.8206	0.8248	0.8066	0.7987	0.8043	0.7888	0.8310
Na	0.0277	0.0263	0.0245	0.0234	0.0259	0.0193	0.0252	0.0232	0.0289	0.0267	0.0214	0.0244	0.0221	0.0195	0.0252	0.0193
Ni	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cr	0.0000	0.0000	0.0000	0.0000	0.0038	0.0026	0.0038	0.0015	0.0038	0.0012	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
tot	4.0288	4.0309	4.0212	4.0189	4.0172	3.9996	4.0152	4.0220	4.0209	4.0190	4.0066	4.0095	4.0043	4.0117	4.0106	4.0150
Ac	0.0277	0.0263	0.0245	0.0234	0.0259	0.0000	0.0252	0.0232	0.0289	0.0267	0.0133	0.0191	0.0086	0.0195	0.0212	0.0193
Jd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0193	0.0000	0.0000	0.0000	0.0000	0.0081	0.0053	0.0135	0.0000	0.0040	0.0000
FeCaTs	0.0298	0.0356	0.0179	0.0144	0.0085	0.0000	0.0051	0.0209	0.0128	0.0112	0.0000	0.0000	0.0000	0.0039	0.0000	0.0108
CrCaTs	0.0000	0.0000	0.0000	0.0000	0.0038	0.0026	0.0038	0.0015	0.0038	0.0012	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
AlCaTs	0.0250	0.0155	0.0194	0.0196	0.0609	0.0309	0.0670	0.0300	0.0771	0.0462	0.0686	0.0812	0.0317	0.0316	0.0339	0.0506
Wo	0.3990	0.4073	0.3920	0.3993	0.3895	0.3837	0.3881	0.3927	0.3779	0.3944	0.3847	0.3722	0.3878	0.3942	0.3880	0.3945
En	0.4668	0.4585	0.4700	0.4429	0.4827	0.4862	0.4771	0.4669	0.4839	0.4686	0.5103	0.5178	0.4885	0.4600	0.4806	0.5161
Fs	0.1341	0.1342	0.1380	0.1578	0.1278	0.1301	0.1349	0.1404	0.1382	0.1370	0.1050	0.1100	0.1237	0.1458	0.1313	0.0894
Mg#	77.7	77.4	77.3	73.7	79.1	78.9	78.0	76.9	77.8	77.4	82.9	82.5	79.8	75.9	78.5	85.2

Strat#	PCP-A03	PCP-A03	PCP-A03	PCP-A03	PCP-A05	PCP-A05	PCP-A05	PCP-A05	PCP-A05	PCP-A05	CP-07	CP-07	CP-07	CP-07	CP-07	CP-07
Field#	85cns52	85cns52	85cns52	85cns52	85cns50	85cns50	85cns50	85cns50	85cns50	85cns50	85cns60	85cns60	85cns60	85cns60	85cns60	85cns60
Grain	c4c	c4r	c5c	c5r	P1.c3c	P2.c1c	P2.c1r	P2.c2c	P2.c2r	P2.c2r	c1c	c1r	c2c	c2r	c3c	c3r
Anal#	75	76	77	78	95	114	115	118	119	124	125	126	127	128	129	130
Wt%																
SiO2	50.73	51.97	52.66	51.19	49.79	50.90	50.75	50.30	50.11	50.77	53.06	51.00	53.00	51.20	53.23	52.61
TiO2	0.74	0.64	0.25	0.63	1.11	0.99	0.81	0.66	0.65	0.81	0.37	0.75	0.38	0.79	0.35	0.48
Al2O3	3.21	1.85	2.40	4.06	5.46	3.27	3.56	4.05	3.74	4.59	2.53	4.86	2.55	4.78	2.64	2.68
Fe2O3	1.50	0.81	0.37	0.88	1.40	1.55	1.75	1.91	2.26	0.84	0.44	0.76	0.18	0.58	0.09	0.13
FeO	7.06	9.19	6.42	5.45	7.63	8.74	7.03	5.28	6.62	5.78	6.07	6.44	6.42	6.33	6.41	7.88
MnO	0.22	0.30	0.20	0.13	0.16	0.24	0.25	0.16	0.19	0.20	0.22	0.20	0.20	0.20	0.17	0.16
MgO	14.87	15.04	16.53	15.80	14.38	15.13	15.12	15.55	15.04	15.28	17.07	15.79	16.67	15.61	16.94	15.54
CaO	20.58	19.75	20.42	21.07	20.14	19.46	20.49	21.04	20.48	21.02	20.34	19.94	20.39	20.43	20.32	20.61
Na2O	0.40	0.32	0.24	0.31	0.42	0.34	0.37	0.32	0.36	0.36	0.26	0.36	0.29	0.36	0.26	0.27
Cr2O3	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
tot	99.31	99.87	99.50	99.52	100.49	100.62	100.14	99.27	99.45	99.65	100.36	100.11	100.08	100.28	100.41	100.36
FeO meas	8.41	9.92	6.76	6.24	8.89	10.13	8.61	7.00	8.65	6.54	6.47	7.13	6.58	6.85	6.49	8.00
atoms/6 O																
Si	1.9015	1.9415	1.9442	1.8929	1.8453	1.8913	1.8881	1.8772	1.8801	1.8785	1.9385	1.8761	1.9423	1.8796	1.9415	1.9364
Ti	0.0209	0.0180	0.0069	0.0175	0.0309	0.0277	0.0227	0.0185	0.0183	0.0225	0.0102	0.0207	0.0105	0.0218	0.0096	0.0133
Al t	0.0985	0.0585	0.0558	0.1071	0.1547	0.1087	0.1119	0.1228	0.1199	0.1215	0.0615	0.1239	0.0577	0.1204	0.0585	0.0636
Al o	0.0434	0.0229	0.0487	0.0699	0.0838	0.0345	0.0442	0.0554	0.0456	0.0788	0.0474	0.0869	0.0524	0.0864	0.0551	0.0527
Fe3+	0.0424	0.0228	0.0104	0.0244	0.0392	0.0433	0.0490	0.0536	0.0638	0.0235	0.0122	0.0212	0.0050	0.0160	0.0026	0.0036
Fe2+	0.2212	0.2871	0.1984	0.1685	0.2364	0.2715	0.2189	0.1649	0.2076	0.1789	0.1855	0.1982	0.1967	0.1943	0.1954	0.2427
Mn	0.0070	0.0095	0.0063	0.0041	0.0050	0.0076	0.0079	0.0051	0.0060	0.0063	0.0068	0.0062	0.0062	0.0062	0.0053	0.0050
Mg	0.8307	0.8373	0.9095	0.8707	0.7943	0.8378	0.8383	0.8649	0.8410	0.8426	0.9294	0.8657	0.9104	0.8540	0.9208	0.8524
Ca	0.8266	0.7906	0.8078	0.8348	0.7998	0.7748	0.8168	0.8413	0.8234	0.8334	0.7962	0.7860	0.8007	0.8036	0.7942	0.8128
Na	0.0291	0.0232	0.0172	0.0222	0.0302	0.0245	0.0267	0.0232	0.0262	0.0258	0.0184	0.0257	0.0206	0.0256	0.0184	0.0193
Ni	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cr	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
tot	4.0212	4.0114	4.0052	4.0122	4.0196	4.0217	4.0245	4.0268	4.0319	4.0117	4.0061	4.0106	4.0025	4.0080	4.0013	4.0018
Ac	0.0291	0.0228	0.0104	0.0222	0.0302	0.0245	0.0267	0.0232	0.0262	0.0235	0.0122	0.0212	0.0050	0.0160	0.0026	0.0036
Jd	0.0000	0.0003	0.0068	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0024	0.0062	0.0045	0.0156	0.0096	0.0158	0.0157
FeCaTs	0.0133	0.0000	0.0000	0.0022	0.0090	0.0188	0.0223	0.0304	0.0376	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CrCaTs	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
AlCaTs	0.0434	0.0226	0.0419	0.0699	0.0838	0.0345	0.0442	0.0554	0.0456	0.0764	0.0412	0.0824	0.0368	0.0768	0.0393	0.0370
Wo	0.3995	0.3954	0.3882	0.3925	0.3686	0.3729	0.3885	0.3894	0.3832	0.3902	0.3836	0.3624	0.3844	0.3714	0.3787	0.3897
En	0.4742	0.4502	0.5023	0.5090	0.4866	0.4736	0.4849	0.5129	0.4947	0.5030	0.5139	0.5188	0.5062	0.5121	0.5125	0.4751
Fs	0.1263	0.1544	0.1096	0.0985	0.1448	0.1534	0.1266	0.0978	0.1221	0.1068	0.1025	0.1188	0.1094	0.1165	0.1088	0.1352
Mg#	79.0	74.5	82.1	83.8	77.1	75.5	79.3	84.0	80.2	82.5	83.4	81.4	82.2	81.5	82.5	77.8

Strat#	CP-07	CP-07	CP-07	CP-07	CP-12	CP-12	CP-12	CP-12	CP-12	CP-12	CP-12	PUM-17	PUM-17	PUM-17	PUM-17	PUM-17
Field#	85cns60	85cns60	85cns60	85cns60	85cns20	85cns20	85cns20	85cns20	85cns20	85cns20	85cns20	85cns17	85cns17	85cns17	85cns17	85cns17
Grain	c4r	c5c	c6-o3j	pg1c	c1c	c1r	c2c	c2r	c3c	c3r	c4g	c1c	c1r	c2c	c2r	c3c
Anal#	131	139	133	138	254	255	256	257	258	259	260	246	247	248	249	250
wt%																
SiO2	51.75	51.10	51.76	51.21	51.45	52.59	50.04	52.36	51.47	51.88	52.21	51.17	51.04	51.03	51.43	52.62
TiO2	0.50	0.71	0.38	0.65	0.72	0.39	0.95	0.32	0.50	0.53	0.56	0.66	0.82	0.82	0.59	0.42
Al2O3	4.23	4.07	2.38	1.88	2.50	1.78	4.08	1.79	2.75	1.82	1.83	3.39	3.52	3.62	2.63	1.78
Fe2O3	0.70	1.40	1.55	1.42	1.99	0.98	2.12	0.85	1.70	1.48	0.99	1.65	1.37	1.61	1.32	1.42
FeO	6.32	6.72	5.88	9.93	7.27	8.66	7.00	8.34	7.40	7.45	8.11	7.41	8.04	7.97	7.67	7.93
MnO	0.19	0.17	0.22	0.29	0.26	0.32	0.24	0.27	0.26	0.29	0.32	0.25	0.34	0.31	0.33	0.33
MgO	16.54	15.61	16.91	13.96	15.72	16.34	14.57	15.82	15.66	15.93	16.08	14.88	14.97	14.77	14.79	16.18
CaO	19.68	20.43	19.82	19.94	20.25	19.09	20.71	19.79	19.95	20.20	19.43	20.60	19.95	20.42	20.68	19.64
Na2O	0.31	0.32	0.28	0.39	0.34	0.24	0.41	0.24	0.35	0.25	0.30	0.42	0.38	0.37	0.38	0.36
Cr2O3	na	na	na	na	0.00	0.03	0.02	0.01	0.00	0.00	0.01	0.00	0.04	0.00	0.01	0.02
tot	100.22	100.53	99.18	99.67	100.50	100.42	100.14	99.80	100.04	99.83	99.84	100.44	100.47	100.92	99.83	100.70
FeO meas	6.95	7.98	7.27	11.21	9.06	9.54	8.91	9.11	8.93	8.78	9.00	8.90	9.27	9.42	8.86	9.21
atoms/6 O																
Si	1.8963	1.8839	1.9256	1.9338	1.9096	1.9449	1.8683	1.9484	1.9146	1.9335	1.9411	1.8994	1.8941	1.8890	1.9206	1.9425
Ti	0.0138	0.0197	0.0106	0.0185	0.0201	0.0108	0.0267	0.0090	0.0140	0.0149	0.0157	0.0184	0.0229	0.0228	0.0166	0.0117
Al t	0.1037	0.1161	0.0744	0.0662	0.0904	0.0551	0.1317	0.0516	0.0854	0.0665	0.0589	0.1006	0.1059	0.1110	0.0794	0.0575
Al o	0.0790	0.0608	0.0300	0.0175	0.0190	0.0225	0.0479	0.0269	0.0352	0.0135	0.0213	0.0478	0.0481	0.0470	0.0364	0.0200
Fe3+	0.0192	0.0388	0.0433	0.0404	0.0557	0.0272	0.0596	0.0238	0.0475	0.0414	0.0276	0.0462	0.0382	0.0449	0.0371	0.0394
Fe2+	0.1938	0.2072	0.1829	0.3136	0.2255	0.2678	0.2186	0.2597	0.2303	0.2323	0.2522	0.2301	0.2495	0.2467	0.2396	0.2450
Mn	0.0059	0.0053	0.0069	0.0093	0.0082	0.0100	0.0076	0.0085	0.0082	0.0092	0.0101	0.0079	0.0107	0.0097	0.0104	0.0103
Mg	0.9032	0.8577	0.9376	0.7856	0.8695	0.9006	0.8107	0.8773	0.8682	0.8848	0.8910	0.8232	0.8279	0.8148	0.8231	0.8902
Ca	0.7727	0.8070	0.7901	0.8068	0.8053	0.7565	0.8285	0.7891	0.7952	0.8067	0.7740	0.8193	0.7933	0.8099	0.8275	0.7769
Na	0.0220	0.0229	0.0202	0.0286	0.0245	0.0172	0.0297	0.0173	0.0252	0.0181	0.0216	0.0302	0.0273	0.0266	0.0275	0.0258
Ni	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cr	0.0000	0.0000	0.0000	0.0000	0.0000	0.0009	0.0006	0.0003	0.0000	0.0000	0.0003	0.0000	0.0012	0.0000	0.0003	0.0006
tot	4.0096	4.0194	4.0216	4.0202	4.0278	4.0136	4.0298	4.0119	4.0237	4.0207	4.0138	4.0231	4.0191	4.0225	4.0185	4.0197
Ac	0.0192	0.0229	0.0202	0.0286	0.0245	0.0172	0.0297	0.0173	0.0252	0.0181	0.0216	0.0302	0.0273	0.0266	0.0275	0.0258
Jd	0.0028	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
FeCaTs	0.0000	0.0160	0.0231	0.0119	0.0312	0.0100	0.0299	0.0065	0.0222	0.0233	0.0060	0.0160	0.0109	0.0184	0.0096	0.0136
CrCaTs	0.0000	0.0000	0.0000	0.0000	0.0000	0.0009	0.0006	0.0003	0.0000	0.0000	0.0003	0.0000	0.0012	0.0000	0.0003	0.0006
AlCaTs	0.0762	0.0608	0.0300	0.0175	0.0190	0.0225	0.0479	0.0269	0.0352	0.0135	0.0213	0.0478	0.0481	0.0470	0.0364	0.0200
Wo	0.3579	0.3766	0.3786	0.4030	0.3898	0.3701	0.3899	0.3863	0.3815	0.3940	0.3840	0.3929	0.3802	0.3856	0.4044	0.3842
En	0.5287	0.5021	0.5200	0.4267	0.4845	0.4855	0.4805	0.4735	0.4888	0.4800	0.4801	0.4745	0.4762	0.4716	0.4613	0.4829
Fs	0.1134	0.1213	0.1014	0.1703	0.1257	0.1444	0.1296	0.1402	0.1297	0.1260	0.1359	0.1326	0.1435	0.1428	0.1343	0.1329
Mg#	82.3	80.5	83.7	71.5	79.4	77.1	78.8	77.2	79.0	79.2	77.9	78.2	76.8	76.8	77.5	78.4

Strat#	PUM-17	PUM-17	PUM-17				
Field#	85cns17	85cns17	85cns17				
Grain	c3r	c4c	c4r				
Anal#	251	252	253	min	max	mean	sdev
wt%							
SiO2	51.97	51.78	51.10	49.59	53.53	51.88	0.87
TiO2	0.46	0.54	0.68	0.20	1.23	0.53	0.20
Al2O3	2.84	2.77	3.04	0.80	5.46	2.44	1.08
Fe2O3	1.44	1.84	2.31	0.00	2.64	1.17	0.53
FeO	7.36	6.60	6.47	4.32	11.25	7.66	1.27
MnO	0.36	0.29	0.30	0.12	0.49	0.28	0.08
MgO	15.04	15.12	15.09	13.56	17.55	15.19	0.79
CaO	20.97	21.56	21.22	19.09	22.27	20.66	0.67
Na2O	0.39	0.38	0.41	0.19	0.43	0.33	0.05
Cr2O3	0.03	0.02	0.02	0.00	0.13	0.01	0.03
tot	100.86	100.90	100.63	97.32	101.77	100.14	0.63
FeO meas	8.66	8.26	8.54	5.13	11.32	8.71	1.31
atoms/6 O							
Si	1.9189	1.9124	1.8968	1.8453	2.0055	1.9274	0.0304
Ti	0.0128	0.0150	0.0190	0.0056	0.0344	0.0148	0.0056
Al t	0.0811	0.0876	0.1032	-0.0055	0.1547	0.0726	0.0304
Al o	0.0425	0.0331	0.0298	0.0000	0.0885	0.0340	0.0201
Fe3+	0.0401	0.0511	0.0644	0.0000	0.0736	0.0327	0.0148
Fe2+	0.2273	0.2040	0.2007	0.1340	0.3554	0.2381	0.0404
Mn	0.0113	0.0091	0.0094	0.0037	0.0158	0.0088	0.0026
Mg	0.8276	0.8323	0.8348	0.7636	0.9501	0.8412	0.0392
Ca	0.8296	0.8532	0.8440	0.7565	0.8841	0.8226	0.0266
Na	0.0279	0.0272	0.0295	0.0135	0.0315	0.0237	0.0038
Ni	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cr	0.0009	0.0006	0.0006	0.0000	0.0038	0.0003	0.0007
tot	4.0200	4.0256	4.0322	3.9782	4.0368	4.0162	0.0081
Ac	0.0279	0.0272	0.0295	0.0000	0.0315	0.0216	0.0066
Jd	0.0000	0.0000	0.0000	0.0000	0.0272	0.0021	0.0049
FeCaTs	0.0122	0.0239	0.0349	0.0000	0.0528	0.0111	0.0107
CrCaTs	0.0009	0.0006	0.0006	0.0000	0.0038	0.0003	0.0007
AlCaTs	0.0425	0.0331	0.0298	0.0000	0.0872	0.0319	0.0195
Wo	0.4010	0.4114	0.4041	0.3579	0.4410	0.4004	0.0182
En	0.4699	0.4727	0.4804	0.4056	0.5287	0.4677	0.0298
Fs	0.1291	0.1159	0.1155	0.0792	0.1887	0.1319	0.0199
Mg#	78.4	80.3	80.6	68.2	86.6	78.0	3.5

APPENDIX VI - Orthopyroxene compositions

Plagioclase compositions were determined on the JEOL JXA-733 microprobe at Southern Methodist University using standard analytical strategies and instrumental settings. No attempt was specifically made to optimize the instrumental settings for the determination of minor elements.

Spurr Volcanic Complex orthopyroxene analyses

Strat# Field# Grain Anal#	AMS-B03 85cns57 o3c 5	AMS-B03 85cns57 o3r 6	AMS-B03 85cns57 o5c 8	AMS-B03 85cns57 o5r 9	AMS-B03 85cns57 o6c 16	AMS-B03 85cns57 o6r 17	AMS-B03 85cns57 o7c 18	AMS-B03 85cns57 o7r 19	AMS-B03 85cns57 o8c 20	AMS-B03 85cns57 o8r 21	AMS-A03 85cns23 o1c 56	AMS-A03 85cns23 o1r 57	AMS-A03 85cns23 o2c 59	AMS-A03 85cns23 o2r 60	AMS-A03 85cns23 o3c 62	AMS-A03 85cns23 o3r 63
wt%																
SiO2	54.96	54.07	55.01	55.02	52.39	52.79	52.93	53.97	53.96	53.36	52.59	52.68	51.95	53.08	52.57	52.80
TiO2	0.13	0.23	0.10	0.18	0.25	0.20	0.10	0.12	0.08	0.09	0.24	0.22	0.20	0.05	0.18	0.23
Al2O3	1.88	2.39	2.72	1.86	1.09	0.83	3.25	1.08	1.57	1.27	0.89	0.89	1.49	0.64	0.93	0.95
Fe2O3	0.62	0.93	0.00	0.09	0.89	1.00	1.89	0.90	0.54	0.00	0.94	0.26	1.42	0.64	1.12	0.70
FeO	11.55	11.72	9.73	12.17	20.08	19.48	10.67	14.35	13.50	19.11	18.86	20.08	20.22	19.81	17.94	19.01
MnO	0.30	0.29	0.24	0.25	0.63	0.66	0.27	0.36	0.30	0.48	0.66	0.66	0.70	0.86	0.66	0.56
MgO	29.27	28.70	30.20	28.89	22.90	23.52	28.85	27.02	27.37	23.83	23.82	22.91	22.81	23.30	24.27	23.76
CaO	1.60	1.44	1.51	1.48	1.29	1.28	1.39	1.63	1.65	1.12	1.29	1.24	1.02	1.14	1.29	1.21
Na2O	0.01	0.06	0.03	0.04	0.02	0.04	0.02	0.02	0.03	0.03	0.01	0.03	0.01	0.03	0.01	0.04
Cr2O3	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
tot	100.32	99.83	99.54	99.98	99.54	99.80	99.37	99.45	99.00	99.29	99.30	98.98	99.82	99.54	98.97	99.26
FeO	12.11	12.56	9.73	12.25	20.88	20.38	12.37	15.16	13.99	19.11	19.71	20.32	21.50	20.38	18.95	19.64
atoms/6 O																
Si	1.9493	1.9330	1.9418	1.9564	1.9572	1.9623	1.9035	1.9620	1.9579	1.9734	1.9593	1.9716	1.9420	1.9767	1.9588	1.9644
Ti	0.0035	0.0062	0.0027	0.0048	0.0070	0.0056	0.0027	0.0033	0.0022	0.0025	0.0067	0.0062	0.0056	0.0014	0.0050	0.0064
Al t	0.0507	0.0670	0.0582	0.0436	0.0428	0.0364	0.0965	0.0380	0.0421	0.0266	0.0391	0.0284	0.0580	0.0233	0.0409	0.0356
Al o	0.0279	0.0337	0.0550	0.0344	0.0052	0.0000	0.0413	0.0083	0.0251	0.0288	0.0000	0.0108	0.0076	0.0048	0.0000	0.0061
Fe3+	0.0165	0.0251	0.0000	0.0023	0.0251	0.0281	0.0511	0.0246	0.0147	0.0000	0.0264	0.0074	0.0399	0.0178	0.0315	0.0196
Fe2+	0.3427	0.3504	0.2872	0.3620	0.6273	0.6055	0.3209	0.4363	0.4098	0.5911	0.5878	0.6286	0.6323	0.6169	0.5590	0.5915
Mn	0.0090	0.0088	0.0072	0.0075	0.0199	0.0208	0.0082	0.0111	0.0092	0.0150	0.0208	0.0209	0.0222	0.0271	0.0208	0.0176
Mg	1.5472	1.5291	1.5887	1.5310	1.2750	1.3029	1.5463	1.4639	1.4801	1.3135	1.3226	1.2778	1.2708	1.2932	1.3478	1.3174
Ca	0.0608	0.0552	0.0571	0.0564	0.0516	0.0510	0.0536	0.0635	0.0642	0.0444	0.0515	0.0497	0.0409	0.0455	0.0515	0.0482
Na	0.0007	0.0042	0.0021	0.0028	0.0014	0.0029	0.0014	0.0014	0.0021	0.0022	0.0007	0.0022	0.0007	0.0022	0.0007	0.0029
Ni	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cr	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
tot	4.0083	4.0126	4.0000	4.0012	4.0125	4.0154	4.0256	4.0123	4.0074	3.9974	4.0148	4.0037	4.0199	4.0089	4.0161	4.0098
NaR3Si2O6	0.0007	0.0042	0.0021	0.0028	0.0014	0.0029	0.0014	0.0014	0.0021	0.0022	0.0007	0.0022	0.0007	0.0022	0.0007	0.0029
NaTiAlSiO6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
R2TiAl2O6	0.0035	0.0062	0.0027	0.0048	0.0070	0.0056	0.0027	0.0033	0.0022	0.0025	0.0067	0.0062	0.0056	0.0014	0.0050	0.0064
R2R3AlSiO6	0.0438	0.0547	0.0529	0.0340	0.0288	0.0252	0.0911	0.0315	0.0377	0.0215	0.0256	0.0160	0.0468	0.0205	0.0308	0.0227
Wo	0.0319	0.0294	0.0304	0.0295	0.0269	0.0264	0.0293	0.0329	0.0335	0.0231	0.0267	0.0257	0.0216	0.0235	0.0268	0.0250
En	0.7925	0.7896	0.8211	0.7849	0.6522	0.6647	0.8038	0.7450	0.7569	0.6737	0.6738	0.6530	0.6533	0.6611	0.6879	0.6729
Fs	0.1755	0.1809	0.1485	0.1856	0.3209	0.3089	0.1668	0.2220	0.2096	0.3032	0.2995	0.3213	0.3251	0.3154	0.2853	0.3021
Mg#	81.9	81.4	84.7	80.9	67.0	68.3	82.8	77.0	78.3	69.0	69.2	67.0	66.8	67.7	70.7	69.0

mineral calculations after Lindsley (1983)

Strat#	AMS-A03	AMS-A03	AMS-A03	AMS-A03	AMS-A03	AF-08	AF-08	AF-08	AF-08	AF-08	AF-08	AF-08	AF-08	AF-08	AF-08	AF-09
Field#	85cns23	85cns23	85cns23	85cns23	85cns23	85cns08	85cns08	85cns08	85cns08	85cns08	85cns08	85cns08	85cns08	85cns08	85cns08	85cns09
Grain	o4c	o4r	o5c	o5r	o6g	o1c	o1r	o2c	o2r	o3c	o3r	o4c	o4r	o5c	o5r	o1c
Anal#	64	65	66	67	58	174	175	176	177	178	179	180	181	182	183	199
wt%																
SiO2	53.69	52.85	52.07	52.65	52.49	53.02	53.31	53.15	53.05	53.68	53.19	53.05	53.01	53.15	53.67	52.84
TiO2	0.18	0.19	0.21	0.18	0.25	0.21	0.21	0.18	0.16	0.18	0.22	0.22	0.29	0.18	0.11	0.17
Al2O3	0.70	0.92	0.91	0.86	1.04	0.86	0.62	0.55	0.60	0.69	0.62	0.93	0.70	0.68	0.43	1.10
Fe2O3	0.81	0.69	1.08	1.07	1.12	0.86	0.52	0.53	0.62	0.40	0.57	1.03	0.58	0.29	0.48	0.64
FeO	18.68	19.92	20.27	19.89	18.86	20.61	21.17	23.09	21.55	20.10	20.90	20.48	20.95	22.89	21.69	20.34
MnO	0.64	0.78	0.68	0.71	0.70	0.77	0.68	0.78	0.71	0.70	0.70	0.75	0.68	0.68	0.68	0.66
MgO	24.57	23.13	22.53	23.22	23.58	22.94	22.95	21.94	22.60	23.54	22.82	23.08	22.81	21.72	23.09	22.88
CaO	1.53	1.29	1.33	1.34	1.45	1.22	1.10	1.07	1.10	1.27	1.38	1.27	1.27	1.18	1.00	1.29
Na2O	0.03	0.02	0.03	0.03	0.01	0.03	0.00	0.01	0.02	0.03	0.02	0.02	0.03	0.01	0.01	0.04
Cr2O3	na	na	na	na	na	0.00	0.03	0.00	0.05	0.00	0.01	0.03	0.01	0.07	0.00	0.03
tot	100.83	99.79	99.11	99.95	99.49	100.52	100.59	101.29	100.46	100.59	100.44	100.86	100.34	100.85	101.16	99.99
FeO	19.41	20.54	21.24	20.85	19.86	21.38	21.64	23.56	22.11	20.46	21.42	21.41	21.48	23.15	22.12	20.92
atoms/6 O																
Si	1.9649	1.9656	1.9595	1.9597	1.9549	1.9645	1.9729	1.9714	1.9717	1.9756	1.9720	1.9596	1.9678	1.9754	1.9776	1.9632
Ti	0.0050	0.0053	0.0059	0.0050	0.0070	0.0059	0.0058	0.0050	0.0045	0.0050	0.0061	0.0061	0.0081	0.0050	0.0030	0.0048
Al t	0.0302	0.0344	0.0404	0.0377	0.0451	0.0355	0.0271	0.0241	0.0263	0.0244	0.0271	0.0404	0.0306	0.0246	0.0187	0.0368
Al o	0.0000	0.0059	0.0000	0.0000	0.0006	0.0021	0.0000	0.0000	0.0000	0.0056	0.0000	0.0001	0.0000	0.0052	0.0000	0.0114
Fe3+	0.0224	0.0193	0.0307	0.0298	0.0313	0.0239	0.0145	0.0147	0.0173	0.0110	0.0160	0.0286	0.0163	0.0080	0.0133	0.0179
Fe2+	0.5717	0.6196	0.6378	0.6192	0.5873	0.6386	0.6553	0.7161	0.6699	0.6188	0.6482	0.6328	0.6506	0.7115	0.6684	0.6321
Mn	0.0198	0.0246	0.0217	0.0224	0.0221	0.0242	0.0213	0.0245	0.0224	0.0218	0.0220	0.0235	0.0214	0.0214	0.0212	0.0208
Mg	1.3401	1.2821	1.2636	1.2880	1.3088	1.2667	1.2658	1.2128	1.2518	1.2912	1.2609	1.2706	1.2619	1.2031	1.2680	1.2669
Ca	0.0600	0.0514	0.0536	0.0534	0.0579	0.0484	0.0436	0.0425	0.0438	0.0501	0.0548	0.0503	0.0505	0.0470	0.0395	0.0514
Na	0.0021	0.0014	0.0022	0.0022	0.0007	0.0022	0.0000	0.0007	0.0014	0.0021	0.0014	0.0014	0.0022	0.0007	0.0007	0.0029
Ni	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cr	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0009	0.0000	0.0015	0.0000	0.0003	0.0009	0.0003	0.0021	0.0000	0.0009
tot	4.0161	4.0096	4.0154	4.0175	4.0156	4.0119	4.0073	4.0119	4.0107	4.0055	4.0089	4.0143	4.0097	4.0040	4.0104	4.0090
NaR3Si2O6	0.0021	0.0014	0.0022	0.0022	0.0007	0.0022	0.0000	0.0007	0.0014	0.0021	0.0014	0.0014	0.0022	0.0007	0.0007	0.0029
NaTiAlSiO6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
R2TiAl2O6	0.0050	0.0053	0.0059	0.0050	0.0070	0.0059	0.0058	0.0050	0.0045	0.0050	0.0061	0.0061	0.0081	0.0050	0.0030	0.0048
R2R3AlSiO6	0.0203	0.0238	0.0285	0.0277	0.0311	0.0238	0.0154	0.0140	0.0173	0.0144	0.0148	0.0282	0.0144	0.0146	0.0126	0.0273
Wo	0.0308	0.0267	0.0279	0.0277	0.0302	0.0252	0.0224	0.0218	0.0225	0.0258	0.0282	0.0262	0.0260	0.0242	0.0201	0.0268
En	0.6794	0.6562	0.6460	0.6566	0.6694	0.6481	0.6441	0.6151	0.6367	0.6586	0.6418	0.6500	0.6427	0.6132	0.6416	0.6493
Fs	0.2898	0.3171	0.3261	0.3157	0.3004	0.3267	0.3335	0.3632	0.3407	0.3156	0.3299	0.3238	0.3313	0.3626	0.3382	0.3240
Mg#	70.1	67.4	66.5	67.5	69.0	66.5	65.9	62.9	65.1	67.6	66.0	66.8	66.0	62.8	65.5	66.7

Strat#	AF-09	AF-09	AF-09	AF-09	AF-09	AF-09	AF-09	AF-09	AF-09	AF-09	SP-02	SP-02	SP-02	SP-02	SP-02	SP-02
Field#	85cns09	85cns09	85cns09	85cns09	85cns09	85cns09	85cns09	85cns09	85cns09	85cns09	sp-rs2	sp-rs2	sp-rs2	sp-rs2	sp-rs2	sp-rs2
Grain	o1r	o2c	o2r	o3c	o3r	o4c	o4r	o5c	o5r	o5r	o1c	o1r	o2c	o2r	o3c	o3r
Anal#	200	201	202	203	204	205	206	208	209	209	219	220	221	222	223	224
wt%																
SiO2	53.04	53.74	54.34	53.38	53.45	53.67	54.24	53.77	53.92	53.44	53.78	54.32	53.68	52.56	52.85	53.66
TiO2	0.20	0.15	0.11	0.27	0.24	0.20	0.20	0.19	0.20	0.25	0.21	0.23	0.18	0.18	0.27	0.20
Al2O3	0.69	0.89	0.45	0.87	0.99	0.70	0.76	0.75	0.47	0.83	0.79	0.66	0.76	0.78	0.88	0.84
Fe2O3	0.63	1.09	0.01	0.54	0.00	0.73	0.71	0.42	0.39	0.80	0.79	0.00	0.43	0.93	0.84	0.29
FeO	21.39	20.31	21.48	20.54	20.46	19.96	19.27	21.53	21.17	21.08	20.82	21.30	21.04	20.24	20.85	22.02
MnO	0.87	0.64	0.82	0.66	0.75	0.66	0.69	0.67	0.79	0.74	0.78	0.73	0.70	0.70	0.67	0.64
MgO	22.47	23.83	23.05	23.20	22.58	23.90	24.45	22.90	23.13	23.40	23.75	22.74	22.97	22.70	22.98	22.50
CaO	1.31	1.31	1.25	1.27	1.24	1.25	1.34	1.17	1.43	1.11	1.02	1.34	1.34	2.59	1.34	1.23
Na2O	0.01	0.02	0.02	0.03	0.01	0.03	0.02	0.03	0.02	0.02	0.01	0.01	0.03	0.03	0.01	0.03
Cr2O3	0.07	0.05	0.02	0.06	0.07	0.04	0.03	0.02	0.00	0.05	0.05	0.02	0.00	0.01	0.02	0.03
tot	100.68	102.03	101.55	100.81	99.79	101.14	101.71	101.45	101.52	101.72	102.00	101.35	101.13	100.72	100.71	101.44
FeO	21.96	21.29	21.49	21.02	20.46	20.62	19.91	21.91	21.52	21.80	21.53	21.30	21.43	21.08	21.61	22.28
atoms/6 O																
Si	1.9682	1.9586	1.9875	1.9664	1.9817	1.9669	1.9689	1.9735	1.9768	1.9584	1.9616	1.9880	1.9737	1.9510	1.9572	1.9728
Ti	0.0056	0.0041	0.0030	0.0075	0.0067	0.0055	0.0055	0.0052	0.0055	0.0069	0.0058	0.0063	0.0050	0.0050	0.0075	0.0055
Al t	0.0302	0.0382	0.0125	0.0336	0.0183	0.0302	0.0311	0.0265	0.0203	0.0359	0.0340	0.0120	0.0263	0.0341	0.0384	0.0272
Al o	0.0000	0.0000	0.0069	0.0041	0.0250	0.0000	0.0014	0.0059	0.0000	0.0000	0.0000	0.0165	0.0066	0.0000	0.0000	0.0092
Fe3+	0.0177	0.0300	0.0003	0.0149	0.0000	0.0202	0.0193	0.0117	0.0107	0.0221	0.0217	0.0000	0.0119	0.0259	0.0235	0.0081
Fe2+	0.6638	0.6190	0.6570	0.6326	0.6344	0.6118	0.5851	0.6609	0.6491	0.6461	0.6351	0.6519	0.6471	0.6285	0.6458	0.6769
Mn	0.0273	0.0198	0.0254	0.0206	0.0236	0.0205	0.0212	0.0208	0.0245	0.0230	0.0241	0.0226	0.0218	0.0220	0.0210	0.0199
Mg	1.2427	1.2944	1.2565	1.2737	1.2477	1.3054	1.3227	1.2526	1.2638	1.2780	1.2910	1.2403	1.2587	1.2558	1.2683	1.2328
Ca	0.0521	0.0512	0.0490	0.0501	0.0493	0.0491	0.0521	0.0460	0.0562	0.0436	0.0399	0.0525	0.0528	0.1030	0.0532	0.0485
Na	0.0007	0.0014	0.0014	0.0021	0.0007	0.0021	0.0014	0.0021	0.0014	0.0014	0.0007	0.0007	0.0021	0.0022	0.0007	0.0021
Ni	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cr	0.0021	0.0014	0.0006	0.0017	0.0021	0.0012	0.0009	0.0006	0.0000	0.0014	0.0014	0.0006	0.0000	0.0003	0.0006	0.0009
tot	4.0104	4.0181	4.0002	4.0075	3.9893	4.0129	4.0096	4.0058	4.0083	4.0168	4.0153	3.9915	4.0059	4.0278	4.0162	4.0041
NaR3Si2O6	0.0007	0.0014	0.0014	0.0021	0.0007	0.0021	0.0014	0.0021	0.0014	0.0014	0.0007	0.0007	0.0021	0.0022	0.0007	0.0021
NaTiAlSiO6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
R2TiAl2O6	0.0056	0.0041	0.0030	0.0075	0.0067	0.0055	0.0055	0.0052	0.0055	0.0069	0.0058	0.0060	0.0050	0.0050	0.0075	0.0055
R2R3AlSiO6	0.0190	0.0300	0.0064	0.0187	0.0049	0.0192	0.0202	0.0160	0.0093	0.0221	0.0224	0.0000	0.0164	0.0241	0.0234	0.0161
Wo	0.0269	0.0265	0.0251	0.0260	0.0257	0.0253	0.0269	0.0237	0.0287	0.0225	0.0206	0.0271	0.0273	0.0526	0.0275	0.0250
En	0.6343	0.6586	0.6402	0.6508	0.6459	0.6637	0.6746	0.6391	0.6417	0.6493	0.6565	0.6377	0.6425	0.6314	0.6444	0.6294
Fs	0.3388	0.3149	0.3348	0.3232	0.3284	0.3111	0.2984	0.3372	0.3296	0.3282	0.3229	0.3352	0.3303	0.3160	0.3281	0.3456
Mg#	65.2	67.7	65.7	66.8	66.3	68.1	69.3	65.5	66.1	66.4	67.0	65.5	66.0	66.6	66.3	64.6

Strat# Field# Grain Anal#	SP-02 sp-rs2 o4r 226	SP-02 sp-rs2 o5c 227	SP-02 sp-rs2 o5c 230	SP-02 sp-rs2 o5r 228	SP-02 sp-rs2 o6pc.o5c 229	PF-38 85cns38 o1c 155	PF-38 85cns38 o1r 156	PF-38 85cns38 o2c 157	PF-38 85cns38 o2r 158	PF-38 85cns38 o3c 159	PF-38 85cns38 o3r 160	PF-38 85cns38 o4c 161	PF-38 85cns38 o4r 162	PF-38 85cns38 o5c.c1c 143	PF-38 85cns38 P.o6c 149	PCP-B06 85cns28 P.o1c 291
wt%																
SiO2	54.22	53.09	53.27	54.09	53.42	53.39	52.60	52.29	53.61	53.88	52.38	53.66	53.84	53.84	53.31	53.97
TiO2	0.24	0.11	0.07	0.08	0.09	0.41	0.25	0.28	0.33	0.20	0.26	0.25	0.23	0.25	0.20	0.24
Al2O3	0.84	0.53	0.59	0.41	0.54	1.72	1.89	1.25	1.25	2.21	1.58	1.44	1.39	1.40	0.99	1.23
Fe2O3	0.21	0.60	0.38	0.46	0.00	0.38	1.35	1.06	0.00	1.06	1.39	1.16	0.89	0.45	1.09	0.45
FeO	20.12	23.24	23.59	21.42	23.68	18.17	16.82	18.33	19.26	14.67	17.39	19.08	18.05	18.22	17.79	16.68
MnO	0.73	0.91	0.91	0.73	0.87	0.37	0.34	0.35	0.39	0.30	0.39	0.42	0.39	0.38	0.39	0.41
MgO	23.72	22.03	21.67	23.46	21.59	24.64	25.16	23.98	23.97	27.43	24.46	24.50	25.08	24.81	24.68	25.46
CaO	1.43	0.62	0.63	1.00	0.64	1.36	1.24	1.36	1.32	0.89	1.51	1.25	1.33	1.41	1.57	1.83
Na2O	0.04	0.02	0.00	0.00	0.01	0.04	0.03	0.02	0.03	0.02	0.04	0.03	0.03	0.04	0.05	0.03
Cr2O3	0.05	0.06	0.00	0.02	0.03	na	na	na	na	na	na	na	na	na	na	0.07
tot	101.60	101.21	101.11	101.68	100.87	100.48	99.68	98.93	100.16	100.66	99.40	101.80	101.23	100.80	100.07	100.38
FeO	20.31	23.78	23.93	21.84	23.68	18.51	18.03	19.29	19.26	15.62	18.64	20.13	18.85	18.62	18.77	17.09
atoms/6 O																
Si	1.9732	1.9720	1.9798	1.9793	1.9861	1.9479	1.9345	1.9504	1.9670	1.9342	1.9403	1.9476	1.9530	1.9584	1.9598	1.9610
Ti	0.0066	0.0031	0.0020	0.0022	0.0025	0.0113	0.0069	0.0079	0.0091	0.0054	0.0072	0.0068	0.0063	0.0068	0.0055	0.0066
Al t	0.0268	0.0232	0.0202	0.0177	0.0139	0.0521	0.0655	0.0496	0.0330	0.0658	0.0597	0.0524	0.0470	0.0416	0.0402	0.0390
Al o	0.0092	0.0000	0.0056	0.0000	0.0098	0.0219	0.0165	0.0054	0.0210	0.0277	0.0093	0.0092	0.0124	0.0184	0.0027	0.0137
Fe3+	0.0059	0.0167	0.0107	0.0127	0.0000	0.0104	0.0373	0.0299	0.0000	0.0287	0.0388	0.0317	0.0242	0.0123	0.0300	0.0124
Fe2+	0.6123	0.7220	0.7331	0.6557	0.7363	0.5544	0.5173	0.5719	0.5910	0.4403	0.5387	0.5793	0.5476	0.5541	0.5471	0.5070
Mn	0.0225	0.0286	0.0286	0.0226	0.0274	0.0114	0.0106	0.0111	0.0121	0.0091	0.0122	0.0129	0.0120	0.0117	0.0121	0.0126
Mg	1.2865	1.2195	1.2003	1.2794	1.1963	1.3398	1.3791	1.3330	1.3107	1.4675	1.3503	1.3252	1.3558	1.3449	1.3522	1.3787
Ca	0.0558	0.0247	0.0251	0.0392	0.0255	0.0532	0.0489	0.0544	0.0519	0.0342	0.0599	0.0486	0.0517	0.0550	0.0618	0.0712
Na	0.0028	0.0014	0.0000	0.0000	0.0007	0.0028	0.0021	0.0014	0.0021	0.0014	0.0029	0.0021	0.0021	0.0028	0.0036	0.0021
Ni	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cr	0.0014	0.0018	0.0000	0.0006	0.0009	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0020
tot	4.0029	4.0131	4.0054	4.0094	3.9994	4.0052	4.0186	4.0149	3.9980	4.0143	4.0194	4.0159	4.0121	4.0061	4.0150	4.0062
NaR3Si2O6	0.0028	0.0014	0.0000	0.0000	0.0007	0.0028	0.0021	0.0014	0.0021	0.0014	0.0029	0.0021	0.0021	0.0028	0.0036	0.0021
NaTiAlSiO6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
R2TiAl2O6	0.0066	0.0031	0.0020	0.0022	0.0025	0.0113	0.0069	0.0079	0.0091	0.0054	0.0072	0.0068	0.0063	0.0068	0.0055	0.0066
R2R3AlSiO6	0.0137	0.0171	0.0163	0.0133	0.0088	0.0295	0.0516	0.0338	0.0148	0.0550	0.0452	0.0388	0.0345	0.0279	0.0292	0.0259
Wo	0.0288	0.0127	0.0129	0.0200	0.0131	0.0279	0.0259	0.0283	0.0269	0.0182	0.0316	0.0255	0.0270	0.0286	0.0321	0.0370
En	0.6580	0.6202	0.6128	0.6479	0.6109	0.6876	0.7084	0.6800	0.6707	0.7552	0.6922	0.6781	0.6931	0.6879	0.6891	0.7041
Fs	0.3132	0.3672	0.3743	0.3321	0.3760	0.2845	0.2657	0.2917	0.3024	0.2266	0.2762	0.2964	0.2799	0.2834	0.2788	0.2589
Mg#	67.8	62.8	62.1	66.1	61.9	70.7	72.7	70.0	68.9	76.9	71.5	69.6	71.2	70.8	71.2	73.1

Strat#	PCP-B06	PCP-B06	PCP-B06	PCP-B06	PCP-A03	PCP-A03	PCP-A03	PCP-A03	PCP-A03	PCP-A03	PCP-A03	PCP-A03	PCP-A03	PCP-A03	PCP-A03	PCP-A05
Field#	85cns28	85cns28	85cns28	85cns28	85cns52	85cns52	85cns52	85cns52	85cns52	85cns52	85cns52	85cns52	85cns52	85cns52	85cns52	85cns50
Grain	P.o1r1	P.o1r2	P.o2c	P.o2r	o1c	o1r	o2c	o2r	o3c	o3r	o4c	o4r	o5c	o5r	o6=c6j	o1c
Anal#	292	293	294	295	80	81	83	84	85	86	89	90	91	92	88	102
wt%																
SiO2	54.75	54.64	53.20	53.85	53.03	53.00	53.01	53.84	53.70	53.77	54.51	54.25	52.50	53.70	52.70	54.65
TiO2	0.31	0.34	0.34	0.28	0.35	0.53	0.22	0.23	0.26	0.28	0.11	0.14	0.34	0.30	0.31	0.63
Al2O3	1.24	1.19	1.73	1.53	1.50	1.70	2.40	2.19	1.49	1.21	1.72	1.73	1.83	0.93	1.83	4.43
Fe2O3	0.26	0.00	0.60	0.00	0.67	0.77	1.68	1.15	0.34	1.12	0.00	0.78	1.09	0.46	0.85	0.00
FeO	17.13	17.32	16.85	17.37	16.07	15.26	11.65	11.91	13.75	14.63	12.21	12.32	14.66	15.18	14.79	19.98
MnO	0.35	0.34	0.30	0.35	0.41	0.35	0.30	0.28	0.34	0.34	0.32	0.31	0.37	0.39	0.38	0.30
MgO	25.78	25.25	25.08	24.93	25.51	25.80	28.33	28.61	27.20	26.89	28.52	28.50	25.88	26.25	25.94	16.05
CaO	1.76	1.74	1.68	1.69	1.55	1.96	1.34	1.39	1.48	1.54	1.38	1.36	1.63	1.71	1.70	2.04
Na2O	0.04	0.04	0.04	0.04	0.02	0.02	0.04	0.03	0.03	0.04	0.02	0.04	0.07	0.03	0.02	0.92
Cr2O3	0.01	0.03	0.01	0.03	na	na	na	na	na	na	na	na	na	na	na	na
tot	101.63	100.89	99.83	100.07	99.11	99.39	98.97	99.64	98.58	99.81	98.79	99.43	98.37	98.96	98.53	99.00
FeO	17.36	17.32	17.39	17.37	16.67	15.95	13.16	12.95	14.05	15.63	12.21	13.02	15.64	15.60	15.56	19.98
atoms/6 O																
Si	1.9632	1.9721	1.9464	1.9619	1.9493	1.9389	1.9212	1.9329	1.9573	1.9526	1.9618	1.9504	1.9382	1.9664	1.9406	2.0235
Ti	0.0084	0.0092	0.0094	0.0077	0.0097	0.0146	0.0060	0.0062	0.0071	0.0076	0.0030	0.0038	0.0094	0.0083	0.0086	0.0175
Al t	0.0368	0.0279	0.0536	0.0381	0.0507	0.0611	0.0788	0.0671	0.0427	0.0474	0.0382	0.0496	0.0618	0.0336	0.0594	-0.0235
Al o	0.0156	0.0227	0.0210	0.0276	0.0143	0.0122	0.0238	0.0256	0.0213	0.0044	0.0348	0.0237	0.0178	0.0065	0.0201	0.2169
Fe3+	0.0070	0.0000	0.0165	0.0000	0.0184	0.0211	0.0458	0.0311	0.0093	0.0305	0.0000	0.0212	0.0302	0.0127	0.0236	0.0000
Fe2+	0.5136	0.5228	0.5156	0.5293	0.4940	0.4669	0.3531	0.3577	0.4190	0.4442	0.3675	0.3703	0.4527	0.4650	0.4556	0.6187
Mn	0.0106	0.0104	0.0093	0.0108	0.0128	0.0108	0.0092	0.0085	0.0105	0.0105	0.0098	0.0094	0.0116	0.0121	0.0119	0.0094
Mg	1.3776	1.3582	1.3675	1.3536	1.3975	1.4066	1.5302	1.5308	1.4775	1.4553	1.5297	1.5270	1.4239	1.4325	1.4236	0.8857
Ca	0.0676	0.0673	0.0659	0.0660	0.0611	0.0768	0.0520	0.0535	0.0578	0.0599	0.0532	0.0524	0.0645	0.0671	0.0671	0.0809
Na	0.0028	0.0028	0.0028	0.0028	0.0014	0.0014	0.0028	0.0021	0.0021	0.0028	0.0014	0.0028	0.0050	0.0021	0.0014	0.0661
Ni	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cr	0.0003	0.0009	0.0003	0.0009	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
tot	4.0035	3.9943	4.0082	3.9986	4.0092	4.0106	4.0229	4.0155	4.0046	4.0152	3.9994	4.0106	4.0151	4.0064	4.0118	3.8953
NaR3Si2O6	0.0028	0.0028	0.0028	0.0028	0.0014	0.0014	0.0028	0.0021	0.0021	0.0028	0.0014	0.0028	0.0050	0.0021	0.0014	0.0661
NaTiAlSiO6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-0.0235
R2TiAl2O6	0.0084	0.0092	0.0094	0.0077	0.0097	0.0146	0.0060	0.0062	0.0071	0.0076	0.0030	0.0038	0.0094	0.0083	0.0086	0.0000
R2R3AlSiO6	0.0201	0.0094	0.0349	0.0228	0.0313	0.0319	0.0668	0.0546	0.0285	0.0321	0.0322	0.0421	0.0430	0.0171	0.0422	0.0000
Wo	0.0350	0.0349	0.0346	0.0344	0.0319	0.0404	0.0279	0.0284	0.0301	0.0312	0.0278	0.0275	0.0341	0.0346	0.0354	0.0511
En	0.7029	0.6969	0.7011	0.6942	0.7152	0.7205	0.7898	0.7875	0.7556	0.7422	0.7839	0.7827	0.7329	0.7288	0.7307	0.5587
Fs	0.2620	0.2682	0.2644	0.2714	0.2528	0.2391	0.1822	0.1840	0.2143	0.2266	0.1883	0.1898	0.2330	0.2366	0.2339	0.3903
Mg#	72.8	72.2	72.6	71.9	73.9	75.1	81.3	81.1	77.9	76.6	80.6	80.5	75.9	75.5	75.8	58.9

Strat# Field# Grain Anal#	PCP-A05 85cns50 o1r 103	PCP-A05 85cns50 o2c 106	PCP-A05 85cns50 o2r 107	PCP-A05 85cns50 o3c 108	PCP-A05 85cns50 o3r 109	PCP-A05 85cns50 o4c 110	PCP-A05 85cns50 o4r 111	PCP-A05 85cns50 o5c 112	PCP-A05 85cns50 o5r 113	PCP-A05 85cns50 P1.o6c 96	PCP-A05 85cns50 P1.o7c 97	PCP-A05 85cns50 P1.o8c 98	PCP-A05 85cns50 P1.o9r 99	CP-07 85cns60 o1c 134	CP-07 85cns60 o1r 135	CP-07 85cns60 o2c 136
wt%																
SiO2	53.55	54.12	53.57	52.28	53.47	53.11	53.97	49.80	53.61	53.90	53.78	53.78	53.28	52.37	52.79	53.47
TiO2	0.46	0.24	0.52	0.61	0.50	0.48	0.36	0.21	0.32	0.23	0.48	0.31	0.30	0.42	0.34	0.25
Al2O3	1.35	0.84	1.04	1.20	1.26	1.68	0.77	2.68	0.74	1.12	1.42	1.65	1.98	1.34	0.55	1.41
Fe2O3	0.51	0.49	0.38	0.59	0.16	0.48	0.00	0.88	0.57	0.37	0.08	0.41	0.69	0.68	0.23	0.42
FeO	18.05	17.56	17.94	21.43	18.25	18.26	18.00	27.26	17.82	16.69	17.45	16.61	15.84	21.64	22.25	18.38
MnO	0.44	0.41	0.41	0.45	0.38	0.39	0.39	0.64	0.38	0.38	0.43	0.36	0.29	0.38	0.41	0.35
MgO	24.46	25.09	24.54	21.70	24.14	24.02	24.62	17.83	24.62	25.51	24.85	25.42	25.75	22.43	21.62	24.59
CaO	1.98	1.85	1.96	2.02	2.08	1.96	1.84	0.28	1.95	1.64	1.89	1.87	1.63	0.95	1.91	1.36
Na2O	0.01	0.02	0.02	0.04	0.03	0.04	0.02	0.02	0.02	0.04	0.04	0.02	0.04	0.02	0.02	0.01
Cr2O3	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
tot	100.81	100.62	100.39	100.32	100.27	100.42	99.97	99.60	100.03	99.88	100.42	100.43	99.80	100.23	100.12	100.24
FeO	18.51	18.00	18.29	21.96	18.39	18.69	18.00	28.05	18.33	17.02	17.52	16.98	16.46	22.25	22.46	18.76
atoms/6 O																
Si	1.9518	1.9694	1.9587	1.9497	1.9579	1.9453	1.9756	1.9209	1.9678	1.9660	1.9567	1.9514	1.9412	1.9500	1.9737	1.9573
Ti	0.0126	0.0066	0.0143	0.0171	0.0138	0.0132	0.0099	0.0061	0.0088	0.0063	0.0131	0.0085	0.0082	0.0118	0.0096	0.0069
Al t	0.0482	0.0306	0.0413	0.0503	0.0421	0.0547	0.0244	0.0791	0.0320	0.0340	0.0433	0.0486	0.0588	0.0500	0.0242	0.0427
Al o	0.0098	0.0055	0.0035	0.0024	0.0123	0.0178	0.0088	0.0428	0.0000	0.0142	0.0176	0.0220	0.0262	0.0088	0.0000	0.0181
Fe3+	0.0139	0.0134	0.0106	0.0166	0.0043	0.0133	0.0000	0.0255	0.0158	0.0101	0.0022	0.0111	0.0190	0.0191	0.0066	0.0115
Fe2+	0.5504	0.5344	0.5487	0.6683	0.5588	0.5593	0.5511	0.8793	0.5469	0.5091	0.5309	0.5042	0.4825	0.6738	0.6957	0.5628
Mn	0.0136	0.0126	0.0127	0.0142	0.0118	0.0121	0.0121	0.0209	0.0118	0.0117	0.0133	0.0111	0.0089	0.0120	0.0130	0.0109
Mg	1.3287	1.3607	1.3372	1.2060	1.3174	1.3112	1.3431	1.0250	1.3468	1.3867	1.3475	1.3746	1.3982	1.2447	1.2047	1.3415
Ca	0.0773	0.0721	0.0768	0.0807	0.0816	0.0769	0.0722	0.0116	0.0767	0.0641	0.0737	0.0727	0.0636	0.0379	0.0765	0.0533
Na	0.0007	0.0014	0.0014	0.0029	0.0021	0.0028	0.0014	0.0015	0.0014	0.0028	0.0028	0.0014	0.0028	0.0014	0.0014	0.0007
Ni	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cr	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
tot	4.0069	4.0067	4.0053	4.0083	4.0022	4.0066	3.9986	4.0128	4.0081	4.0050	4.0011	4.0055	4.0095	4.0095	4.0054	4.0057
NaR3Si2O6	0.0007	0.0014	0.0014	0.0029	0.0021	0.0028	0.0014	0.0015	0.0014	0.0028	0.0028	0.0014	0.0028	0.0014	0.0014	0.0007
NaTiAlSiO6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
R2TiAl2O6	0.0126	0.0066	0.0143	0.0171	0.0138	0.0132	0.0099	0.0061	0.0088	0.0063	0.0131	0.0085	0.0082	0.0118	0.0096	0.0069
R2R3AlSiO6	0.0230	0.0175	0.0127	0.0161	0.0145	0.0283	0.0046	0.0669	0.0144	0.0214	0.0170	0.0317	0.0424	0.0265	0.0051	0.0289
Wo	0.0403	0.0371	0.0397	0.0420	0.0423	0.0404	0.0370	0.0063	0.0394	0.0332	0.0383	0.0380	0.0336	0.0198	0.0390	0.0278
En	0.6786	0.6914	0.6809	0.6164	0.6724	0.6727	0.6829	0.5349	0.6832	0.7072	0.6899	0.7038	0.7185	0.6360	0.6092	0.6849
Fs	0.2811	0.2715	0.2794	0.3416	0.2853	0.2869	0.2802	0.4589	0.2774	0.2596	0.2718	0.2582	0.2479	0.3443	0.3518	0.2873
Mg#	70.7	71.8	70.9	64.3	70.2	70.1	70.9	53.8	71.1	73.1	71.7	73.2	74.3	64.9	63.4	70.4

Strat#	CP-07	CP-07	CP-12	CP-12	CP-12	CP-12	CP-12	CP-12	CP-12	CP-12	CP-12	CP-12	CP-12	CP-12	PUM-17	PUM-17	PUM-17
Field#	85cns60	85cns60	85cns20	85cns20	85cns20	85cns20	85cns20	85cns20	85cns20	85cns20	85cns20	85cns20	85cns20	85cns20	85cns17	85cns17	85cns17
Grain	o2r	o3pc	o6=ol2j	o1c	o1r	o2c	o2r	o3c	o3r	o4c	o4r	o5c	o5r	o1c	o1r	o2c	
Anal#	137	132		261	262	263	264	265	266	267	268	269	270	240	241	242	
wt%																	
SiO2	52.35	54.43	53.18	53.99	54.75	51.50	55.02	54.30	54.39	54.47	55.03	53.02	54.14	54.81	54.88	53.56	
TiO2	0.48	0.21	0.24	0.25	0.25	0.29	0.18	0.16	0.28	0.23	0.20	0.25	0.10	0.23	0.16	0.18	
Al2O3	0.93	1.61	1.57	1.88	0.70	2.80	0.86	0.93	0.82	1.00	0.95	1.10	0.82	0.93	1.10	1.94	
Fe2O3	0.65	0.46	0.67	0.83	0.35	0.52	0.46	0.55	0.26	0.95	0.52	0.09	0.95	0.35	0.01	1.22	
FeO	20.75	13.76	20.01	14.53	16.87	23.31	15.66	15.92	16.90	16.96	15.60	22.91	16.93	16.06	16.16	16.41	
MnO	0.41	0.32	0.64	0.38	0.43	0.49	0.38	0.42	0.46	0.43	0.41	0.44	0.48	0.54	0.59	0.50	
MgO	22.19	27.68	23.45	26.88	26.01	21.09	26.86	26.36	25.81	26.03	26.98	21.72	25.68	26.50	26.45	26.00	
CaO	1.82	1.54	1.22	1.68	1.64	0.50	1.68	1.49	1.56	1.51	1.62	1.21	1.55	1.47	1.39	1.03	
Na2O	0.06	0.02	0.02	0.04	0.02	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.04	0.02	0.04	
Cr2O3	na	na	0.04	0.04	0.00	0.10	0.06	0.04	0.05	0.02	0.02	0.05	0.00	0.00	0.04	0.07	
tot	99.63	100.04	101.04	100.50	101.01	100.60	101.19	100.19	100.54	101.62	101.33	100.80	100.67	100.94	100.80	100.94	
FeO	21.33	14.18	20.61	15.28	17.18	23.77	16.08	16.41	17.13	17.82	16.06	22.99	17.78	16.38	16.17	17.50	
atoms/6 O																	
Si	1.9591	1.9547	1.9504	1.9429	1.9743	1.9219	1.9706	1.9684	1.9710	1.9597	1.9677	1.9674	1.9674	1.9707	1.9724	1.9376	
Ti	0.0135	0.0057	0.0066	0.0068	0.0068	0.0081	0.0048	0.0044	0.0076	0.0062	0.0054	0.0070	0.0027	0.0062	0.0043	0.0049	
Al t	0.0409	0.0453	0.0496	0.0571	0.0257	0.0781	0.0294	0.0316	0.0290	0.0403	0.0323	0.0326	0.0326	0.0293	0.0276	0.0624	
Al o	0.0001	0.0229	0.0183	0.0227	0.0041	0.0451	0.0069	0.0082	0.0060	0.0022	0.0078	0.0155	0.0026	0.0101	0.0190	0.0203	
Fe3+	0.0182	0.0125	0.0184	0.0225	0.0094	0.0145	0.0125	0.0150	0.0070	0.0258	0.0139	0.0024	0.0260	0.0095	0.0002	0.0331	
Fe2+	0.6494	0.4134	0.6138	0.4374	0.5087	0.7274	0.4692	0.4826	0.5121	0.5104	0.4664	0.7111	0.5144	0.4830	0.4858	0.4964	
Mn	0.0130	0.0097	0.0199	0.0116	0.0131	0.0155	0.0115	0.0129	0.0141	0.0131	0.0124	0.0138	0.0148	0.0164	0.0180	0.0153	
Mg	1.2376	1.4815	1.2817	1.4416	1.3978	1.1730	1.4337	1.4241	1.3939	1.3957	1.4378	1.2011	1.3908	1.4200	1.4167	1.4018	
Ca	0.0730	0.0593	0.0479	0.0648	0.0634	0.0200	0.0645	0.0579	0.0606	0.0582	0.0621	0.0481	0.0604	0.0566	0.0535	0.0399	
Na	0.0044	0.0014	0.0014	0.0028	0.0014	0.0007	0.0014	0.0014	0.0007	0.0007	0.0007	0.0007	0.0014	0.0028	0.0014	0.0028	
Ni	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
Cr	0.0000	0.0000	0.0012	0.0011	0.0000	0.0030	0.0017	0.0011	0.0014	0.0006	0.0006	0.0015	0.0000	0.0000	0.0011	0.0020	
tot	4.0091	4.0063	4.0092	4.0113	4.0047	4.0072	4.0062	4.0075	4.0035	4.0129	4.0069	4.0012	4.0130	4.0048	4.0001	4.0165	
NaR3Si2O6	0.0044	0.0014	0.0014	0.0028	0.0014	0.0007	0.0014	0.0014	0.0007	0.0007	0.0007	0.0007	0.0014	0.0028	0.0014	0.0028	
NaTiAlSiO6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
R2TiAl2O6	0.0135	0.0057	0.0066	0.0068	0.0068	0.0081	0.0048	0.0044	0.0076	0.0062	0.0054	0.0070	0.0027	0.0062	0.0043	0.0049	
R2R3AlSiO6	0.0139	0.0340	0.0364	0.0435	0.0121	0.0618	0.0197	0.0229	0.0138	0.0278	0.0215	0.0187	0.0271	0.0169	0.0190	0.0526	
Wo	0.0378	0.0310	0.0252	0.0342	0.0325	0.0108	0.0332	0.0299	0.0311	0.0302	0.0320	0.0249	0.0312	0.0292	0.0277	0.0212	
En	0.6311	0.7576	0.6591	0.7410	0.7094	0.6106	0.7284	0.7246	0.7085	0.7101	0.7309	0.6125	0.7072	0.7244	0.7240	0.7228	
Fs	0.3312	0.2114	0.3156	0.2248	0.2581	0.3786	0.2384	0.2455	0.2603	0.2597	0.2371	0.3626	0.2616	0.2464	0.2483	0.2560	
Mg#	65.6	78.2	67.6	76.7	73.3	61.7	75.3	74.7	73.1	73.2	75.5	62.8	73.0	74.6	74.5	73.8	

Strat#	PUM-17	PUM-17	PUM-17	PUM-17	PUM-17				
Field#	85cns17	85cns17	85cns17	85cns17	85cns17				
Grain	o2r	o3c	o3r	o4j	o4pc				
Anal#	243	244	245	239	238	min	max	mean	sdev
wt%									
SiO2	54.48	54.72	54.38	53.92	49.88	49.80	55.03	53.48	0.89
TiO2	0.16	0.14	0.27	0.05	0.21	0.05	0.63	0.24	0.11
Al2O3	0.87	0.96	1.13	0.96	3.07	0.41	4.43	1.23	0.65
Fe2O3	0.80	0.36	0.06	1.31	1.63	0.00	1.89	0.62	0.40
FeO	16.02	16.44	18.44	14.57	26.78	9.73	27.26	18.33	3.28
MnO	0.50	0.49	0.63	0.45	0.77	0.24	0.91	0.52	0.18
MgO	26.47	26.18	24.99	26.92	18.34	16.05	30.20	24.45	2.27
CaO	1.45	1.48	1.28	1.54	0.18	0.18	2.59	1.41	0.36
Na2O	0.02	0.05	0.01	0.03	0.02	0.00	0.92	0.03	0.08
Cr2O3	0.00	0.02	0.00	0.00	0.04	0.00	0.10	0.01	0.02
tot	100.77	100.85	101.19	99.75	100.91	98.37	102.03	100.32	0.84
FeO	16.74	16.77	18.49	15.75	28.24	9.73	28.24	18.89	3.25
atoms/6 O									
Si	1.9670	1.9723	1.9681	1.9611	1.9018	1.9018	2.0235	1.9598	0.0166
Ti	0.0043	0.0038	0.0073	0.0014	0.0060	0.0014	0.0175	0.0066	0.0030
Al t	0.0330	0.0277	0.0319	0.0389	0.0982	-0.0235	0.0982	0.0396	0.0168
Al o	0.0040	0.0131	0.0163	0.0023	0.0398	0.0000	0.2169	0.0135	0.0222
Fe3+	0.0217	0.0099	0.0016	0.0359	0.0466	0.0000	0.0511	0.0171	0.0112
Fe2+	0.4837	0.4956	0.5580	0.4432	0.8538	0.2872	0.8793	0.5632	0.1071
Mn	0.0153	0.0150	0.0193	0.0139	0.0249	0.0072	0.0286	0.0162	0.0057
Mg	1.4243	1.4063	1.3479	1.4592	1.0421	0.8857	1.5887	1.3340	0.1081
Ca	0.0561	0.0572	0.0496	0.0600	0.0074	0.0074	0.1030	0.0552	0.0139
Na	0.0014	0.0035	0.0007	0.0021	0.0015	0.0000	0.0661	0.0024	0.0060
Ni	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cr	0.0000	0.0006	0.0000	0.0000	0.0012	0.0000	0.0030	0.0004	0.0007
tot	4.0109	4.0049	4.0008	4.0180	4.0233	3.8953	4.0278	4.0080	0.0124
NaR3Si2O6	0.0014	0.0035	0.0007	0.0021	0.0015	0.0000	0.0661	0.0024	0.0060
NaTiAlSiO6	0.0000	0.0000	0.0000	0.0000	0.0000	-0.0235	0.0000	-0.0002	0.0022
R2TiAl2O6	0.0043	0.0038	0.0073	0.0014	0.0060	0.0000	0.0171	0.0065	0.0029
R2R3AlSiO6	0.0243	0.0201	0.0172	0.0361	0.0862	0.0000	0.0911	0.0268	0.0156
Wo	0.0290	0.0295	0.0257	0.0312	0.0041	0.0041	0.0526	0.0288	0.0074
En	0.7248	0.7176	0.6890	0.7431	0.5474	0.5349	0.8211	0.6828	0.0529
Fs	0.2462	0.2529	0.2853	0.2257	0.4485	0.1485	0.4589	0.2885	0.0557
Mg#	74.6	73.9	70.7	76.7	55.0	53.8	84.7	70.3	5.6

APPENDIX VII - Hornblende compositions

Plagioclase compositions were determined on the JEOL JXA-733 microprobe at Southern Methodist University using standard analytical strategies and instrumental settings.

Spurr Volcanic Complex hornblende analyses

Strat# Field# Grain Anal#	SP-04 sp-rs4 hb1c 33	SP-04 sp-rs4 hb1r 34	SP-04 sp-rs4 hb3c 38	SP-04 sp-rs4 hb3r 39	PF-38 85cns38 hb1c 1	PF-38 85cns38 hb2c 2	PF-38 85cns38 hb3c 3	PCP-B01 85cns33 hb1c 27	PCP-B01 85cns33 hb1r 28	PCP-B01 85cns33 hb2c 29	PCP-B01 85cns33 hb2r 30	PCP-B01 85cns33 hb3c 31	PCP-B01 85cns33 hb3r 32	CP-12 85cns20 hb1c 23	CP-12 85cns20 hb1r 24	CP-12 85cns20 hb2c 25	CP-12 85cns20 hb2r 26	PUM-17 85cns17 hb1c1 13
wt%																		
SiO2	42.75	43.00	43.00	42.86	41.15	41.79	41.21	41.44	40.30	38.93	41.11	41.10	40.50	42.73	41.82	42.96	42.93	42.30
TiO2	1.93	2.41	1.61	1.70	2.16	2.46	2.38	3.62	3.72	3.40	2.59	2.95	3.48	3.46	3.34	3.15	3.28	2.39
Al2O3	13.40	12.83	13.00	12.66	14.86	14.31	14.02	12.34	12.23	12.79	12.90	14.01	12.42	11.73	11.72	12.03	11.80	13.20
Fe2O3	9.63	9.42	10.33	8.83	11.38	10.44	12.40	6.64	8.43	9.21	9.97	8.63	9.22	5.29	7.09	6.91	6.74	8.65
FeO	2.47	1.38	0.87	1.84	3.47	5.08	3.57	6.55	5.55	3.35	1.82	3.06	4.16	7.51	6.14	6.01	7.00	3.17
MnO	0.12	0.17	0.11	0.12	0.20	0.16	0.16	0.16	0.12	0.15	0.18	0.13	0.14	0.23	0.17	0.09	0.17	0.16
MgO	14.56	15.11	15.42	15.47	12.23	12.29	12.53	13.28	13.38	13.96	14.80	14.17	13.86	13.50	13.57	13.99	13.27	14.64
CaO	11.13	11.11	11.11	11.44	10.36	10.74	10.52	11.28	11.30	11.34	11.16	11.12	11.24	11.35	11.18	11.37	11.06	11.32
BaO	na	na	na	na	0.07	0.10	0.07	na	na	na	na	na	na	0.00	0.03	0.07	0.09	0.08
Na2O	2.35	2.47	2.40	2.28	2.36	2.47	2.45	2.45	2.46	2.45	2.44	2.43	2.39	2.60	2.50	2.58	2.57	2.62
Cr2O3	0.03	0.36	0.05	0.04	na	na	na	0.09	0.07	0.13	0.08	0.04	0.08	0.05	0.03	0.07	0.05	0.07
K2O	0.32	0.38	0.27	0.34	0.26	0.28	0.28	0.46	0.39	0.46	0.38	0.45	0.45	0.30	0.31	0.27	0.36	0.25
F	0.15	0.00	0.15	0.09	0.09	0.05	0.07	0.16	0.09	0.02	0.17	0.11	0.19	0.14	0.28	0.13	0.18	0.11
Cl	0.00	0.00	0.02	0.00	0.03	0.00	0.02	0.01	0.02	0.02	0.00	0.02	0.00	0.03	0.06	0.01	0.03	0.00
total	98.83	98.64	98.33	97.67	98.62	100.18	99.68	98.48	98.05	96.21	97.61	98.21	98.13	98.92	98.24	99.64	99.54	98.96
FeO meas.	11.13	9.86	10.16	9.79	13.71	14.48	14.73	12.52	13.13	11.64	10.80	10.82	12.46	12.27	12.52	12.23	13.07	10.95
atoms/23 O																		
Si	6.0967	6.1149	6.1303	6.1586	5.9318	5.9627	5.9076	6.0360	5.9098	5.7880	5.9623	5.9251	5.9103	6.1848	6.1053	6.1504	6.1822	6.0486
Ti	0.2070	0.2577	0.1726	0.1837	0.2342	0.2640	0.2566	0.3965	0.4103	0.3802	0.2825	0.3198	0.3819	0.3766	0.3667	0.3392	0.3552	0.2570
Al t	1.9033	1.8851	1.8697	1.8414	2.0682	2.0373	2.0924	1.9640	2.0902	2.2120	2.0377	2.0749	2.0897	1.8152	1.8947	1.8496	1.8178	1.9514
Al o	0.3497	0.2658	0.3152	0.3032	0.4572	0.3698	0.2771	0.1551	0.0241	0.0298	0.1681	0.3062	0.0472	0.1863	0.1225	0.1809	0.1855	0.2739
Fe3+	1.0334	1.0085	1.1081	0.9550	1.2348	1.1213	1.3380	0.7278	0.9301	1.0305	1.0887	0.9361	1.0126	0.5757	0.7790	0.7445	0.7306	0.9304
Fe2+	0.2941	0.1642	0.1033	0.2215	0.4181	0.6066	0.4279	0.7974	0.6802	0.4169	0.2213	0.3684	0.5081	0.9096	0.7496	0.7199	0.8435	0.3791
Mn	0.0145	0.0205	0.0133	0.0146	0.0244	0.0193	0.0194	0.0197	0.0149	0.0189	0.0221	0.0159	0.0173	0.0282	0.0210	0.0109	0.0207	0.0194
Mg	3.0946	3.2023	3.2762	3.3129	2.6274	2.6134	2.6770	2.8828	2.9242	3.0932	3.1990	3.0444	3.0144	2.9121	2.9525	2.9850	2.8480	3.1199
Ca	1.7008	1.6929	1.6971	1.7614	1.6002	1.6420	1.6159	1.7605	1.7756	1.8066	1.7343	1.7177	1.7576	1.7603	1.7489	1.7442	1.7066	1.7344
Ba	0.0000	0.0000	0.0000	0.0000	0.0040	0.0056	0.0039	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0017	0.0039	0.0051	0.0045
Na	0.6498	0.6811	0.6634	0.6352	0.6596	0.6833	0.6810	0.6919	0.6995	0.7063	0.6862	0.6792	0.6763	0.7297	0.7077	0.7162	0.7176	0.7264
Ni	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cr	0.0034	0.0405	0.0056	0.0045	0.0000	0.0000	0.0000	0.0104	0.0081	0.0153	0.0092	0.0046	0.0092	0.0057	0.0035	0.0079	0.0057	0.0079
K	0.0582	0.0689	0.0491	0.0623	0.0478	0.0510	0.0512	0.0855	0.0730	0.0873	0.0703	0.0828	0.0838	0.0554	0.0577	0.0493	0.0661	0.0456
F	0.0677	0.0000	0.0676	0.0409	0.0410	0.0226	0.0317	0.0737	0.0417	0.0094	0.0780	0.0502	0.0877	0.0641	0.1293	0.0589	0.0820	0.0497
Cl	0.0000	0.0000	0.0048	0.0000	0.0073	0.0000	0.0049	0.0025	0.0050	0.0050	0.0000	0.0049	0.0000	0.0074	0.0148	0.0024	0.0073	0.0000
tot	15.4054	15.4024	15.4040	15.4544	15.3076	15.3763	15.3481	15.5275	15.5399	15.5848	15.4816	15.4752	15.5084	15.5396	15.5108	15.5018	15.4846	15.4985
Na+K	0.70804	0.74999	0.71252	0.69756	0.70744	0.73430	0.73220	0.77741	0.77243	0.79353	0.75647	0.76201	0.76005	0.78507	0.76541	0.76550	0.78373	0.77202
Al+Fe3+Ti	1.59005	1.53207	1.59594	1.44191	1.92616	1.75504	1.87171	1.27936	1.36450	1.44047	1.53921	1.56216	1.44170	1.13871	1.26822	1.26447	1.27134	1.46135
mg#	91.3	95.1	96.9	93.7	86.3	81.2	86.2	78.3	81.1	88.1	93.5	89.2	85.6	76.2	79.8	80.6	77.2	89.2

Mineral reduction assumes:

1: Sum of cations without Ca, Na, or K is 13.

2: SiO2 + Al t = 8.

3: Fe3+/Fe2+ determined by charge balance.

Strat#	PUM-17	PUM-17	PUM-17	PUM-17	PUM-17	PUM-17	PUM-17	PUM-17	PUM-17	PUM-17				
Field#	85cns17	85cns17	85cns17	85cns17	85cns17	85cns17	85cns17	85cns17	85cns17	85cns17				
Grain	hb1c2	hb1r	hb2c	hb2r	hb3c	hb4c	hb4r	hb5c	hb5r					
Anal#	14	15	16	17	18	19	20	21	22	min	max	mean	sdev	
wt%														
SiO2	42.35	42.28	43.02	42.36	42.95	42.92	42.30	42.34	42.88	38.93	42.88	42.05	1.01	
TiO2	2.39	2.43	2.26	2.23	2.29	3.41	2.13	2.43	2.23	1.61	2.23	2.66	0.60	
Al2O3	12.96	13.62	12.59	13.95	13.23	11.53	13.50	13.62	13.33	11.53	13.33	12.98	0.84	
Fe2O3	9.48	9.23	9.97	8.16	9.37	6.02	8.53	8.68	8.18	5.29	8.18	8.77	1.57	
FeO	2.28	3.03	2.87	2.24	1.12	8.56	2.52	2.37	2.98	0.87	2.98	3.74	2.04	
MnO	0.19	0.17	0.18	0.10	0.10	0.27	0.09	0.11	0.10	0.09	0.10	0.15	0.04	
MgO	14.89	14.61	14.63	15.25	15.87	12.59	15.30	15.17	15.01	12.23	15.01	14.20	1.03	
CaO	11.14	11.35	11.06	11.63	11.52	11.20	11.64	11.63	11.38	10.36	11.38	11.21	0.29	
BaO	0.00	0.02	0.04	0.06	0.00	0.10	0.03	0.06	0.07	0.00	0.07	0.03	0.04	
Na2O	2.59	2.61	2.57	2.64	2.68	2.41	2.63	2.62	2.63	2.28	2.63	2.51	0.11	
Cr2O3	0.07	0.02	0.04	0.16	0.20	0.05	0.05	0.15	0.05	0.00	0.05	0.08	0.07	
K2O	0.27	0.27	0.26	0.26	0.23	0.43	0.27	0.21	0.24	0.21	0.24	0.32	0.08	
F	0.17	0.11	0.02	0.00	0.14	0.09	0.09	0.03	0.05	0.00	0.05	0.11	0.06	
Cl	0.00	0.00	0.01	0.00	0.00	0.06	0.02	0.04	0.02	0.00	0.02	0.02	0.02	
total	98.78	99.75	99.52	99.05	99.70	99.64	99.10	99.46	99.15	96.21	99.15	98.82	0.84	
FeO meas.	10.81	11.34	11.84	9.59	9.55	13.98	10.20	10.18	10.34	9.55	10.34	11.63	1.50	
atoms/23 O														
Si	6.0547	6.0001	6.1122	6.0123	6.0487	6.2079	6.0219	6.0024	6.0935	5.7880	6.0935	6.0392	0.1020	
Ti	0.2570	0.2593	0.2415	0.2380	0.2425	0.3709	0.2280	0.2591	0.2383	0.1726	0.2383	0.2880	0.0682	
Al t	1.9453	1.9999	1.8878	1.9877	1.9513	1.7921	1.9781	1.9976	1.9065	1.7921	1.9065	1.9608	0.1020	
Al o	0.2391	0.2788	0.2210	0.3465	0.2453	0.1739	0.2876	0.2787	0.3267	0.0241	0.3267	0.2376	0.1028	
Fe3+	1.0199	0.9859	1.0658	0.8720	0.9932	0.6553	0.9139	0.9262	0.8749	0.5757	0.8749	0.9479	0.1675	
Fe2+	0.2726	0.3600	0.3411	0.2664	0.1316	1.0358	0.3005	0.2808	0.3540	0.1033	0.3540	0.4508	0.2483	
Mn	0.0230	0.0204	0.0217	0.0120	0.0119	0.0331	0.0109	0.0132	0.0120	0.0109	0.0120	0.0183	0.0053	
Mg	3.1726	3.0900	3.0978	3.2258	3.3309	2.7139	3.2461	3.2051	3.1789	2.6134	3.1789	3.0385	0.2036	
Ca	1.7065	1.7259	1.6837	1.7687	1.7384	1.7358	1.7756	1.7666	1.7328	1.6002	1.7328	1.7256	0.0475	
Ba	0.0000	0.0011	0.0022	0.0033	0.0000	0.0057	0.0017	0.0033	0.0039	0.0000	0.0039	0.0018	0.0020	
Na	0.7180	0.7182	0.7080	0.7265	0.7318	0.6759	0.7260	0.7202	0.7247	0.6352	0.7247	0.6978	0.0264	
Ni	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
Cr	0.0079	0.0022	0.0045	0.0180	0.0223	0.0057	0.0056	0.0168	0.0056	0.0000	0.0056	0.0085	0.0082	
K	0.0492	0.0489	0.0471	0.0471	0.0413	0.0793	0.0490	0.0380	0.0435	0.0380	0.0435	0.0588	0.0146	
F	0.0769	0.0494	0.0090	0.0000	0.0624	0.0412	0.0405	0.0135	0.0225	0.0000	0.0225	0.0486	0.0296	
Cl	0.0000	0.0000	0.0024	0.0000	0.0000	0.0147	0.0048	0.0096	0.0048	0.0000	0.0048	0.0038	0.0042	
tot	15.4658	15.4907	15.4344	15.5244	15.4893	15.4853	15.5449	15.5080	15.4954	15.3076	15.4954	15.4737	0.0631	
Na+K	0.76721	0.76705	0.75511	0.77361	0.77314	0.75522	0.77500	0.75815	0.76817	0.6976	0.7682	0.7566	0.0248	
Al+Fe3+Ti	1.51595	1.52400	1.52824	1.45656	1.48108	1.20014	1.42955	1.46393	1.43998	1.1387	1.4400	1.4735	0.1789	
mg#	92.1	89.6	90.1	92.4	96.2	72.4	91.5	91.9	90.0	72.4	90.0	87.2	6.5	

APPENDIX VIII - Spinel compositions

Plagioclase compositions were determined on the JEOL JXA-733 microprobe at Southern Methodist University using standard analytical strategies and instrumental settings.

Spurr Volcanic Complex spinel analyses

Strat#	AMS-B07	AMS-B07	AMS-B07	AMS-B07	AMS-B07	AMS-B07	AMS-B07	PCP-A05	PCP-A05	PCP-A05	CP-07	CP-07	CP-07	CP-07	SP-02	SP-02
Field#	85cns43	85cns43	85cns43	85cns43	85cns43	85cns43	85cns43	85cns50	85cns50	85cns50	85cns60	85cns60	85cns60	85cns60	sp-rs2	sp-rs2
Grain	sp1.ol5c	sp2.ol5c	sp3.ol5c	sp4.ol5m	sp5.ol5r	sp6.ol5r	sp7.ol5r	P2.sp2.	PS1.sp5	PS2.sp4	sp1.ol7c	sp2	sp3	sp4.ol6c	sp1.ol2	sp2.ol2
Anal#	284	285	286	287	290	288	289	117	120	121	271	273	274	275	235	236
wt%																
SiO2	0.06	0.06	0.06	0.05	0.05	0.25	0.07	0.08	0.06	0.03	0.08	0.10	0.08	0.07	0.15	0.09
TiO2	0.93	0.84	0.76	0.61	1.38	0.80	2.78	20.55	0.31	0.59	3.16	0.63	0.63	0.62	1.33	3.85
Al2O3	25.38	23.67	24.44	22.27	12.00	23.61	8.61	3.85	53.70	54.43	17.98	21.58	21.05	22.10	11.75	7.95
Fe2O3	17.41	17.89	17.57	17.58	21.08	17.11	28.60	23.33	9.34	7.29	24.21	17.37	17.67	17.43	48.24	51.13
FeO	14.04	13.56	13.73	13.18	18.81	15.59	22.34	43.56	22.45	25.48	19.31	13.94	15.70	12.68	25.55	29.16
MnO	0.20	0.25	0.27	0.27	0.36	0.29	0.34	0.35	0.23	0.19	0.34	0.23	0.29	0.22	0.24	0.30
MgO	11.56	11.30	11.08	10.92	6.03	9.74	4.77	3.61	11.23	9.57	9.01	10.50	9.25	11.23	5.01	3.88
CaO	0.02	0.01	0.03	0.01	0.07	0.03	0.04	0.02	0.05	0.04	0.02	0.00	0.02	0.02	0.02	0.16
Cr2O3	31.00	32.03	30.21	34.29	40.05	29.17	30.16	0.00	0.00	0.00	26.59	35.89	35.48	34.84	8.44	3.47
SUM	100.61	99.61	98.15	99.18	99.83	96.58	97.72	95.35	97.37	97.62	100.70	100.24	100.16	99.21	100.73	99.98
FeO meas.	29.71	29.66	29.54	29.00	37.78	30.98	48.08	64.55	30.85	32.04	41.09	29.57	31.59	28.36	68.95	75.16
atoms/4 O																
Si	0.0021	0.0022	0.0022	0.0018	0.0021	0.0093	0.0029	0.0030	0.0017	0.0008	0.0029	0.0037	0.0030	0.0026	0.0054	0.0033
Ti	0.0246	0.0228	0.0207	0.0170	0.0432	0.0223	0.0873	0.5813	0.0066	0.0126	0.0867	0.0176	0.0178	0.0173	0.0359	0.1049
Al	1.0536	1.0071	1.0431	0.9714	0.5892	1.0319	0.4236	0.1707	1.7852	1.8177	0.7730	0.9449	0.9322	0.9647	0.4965	0.3396
Fe3+	0.4614	0.4860	0.4787	0.4894	0.6607	0.4774	0.8983	0.6605	0.1982	0.1554	0.6644	0.4855	0.4993	0.4856	1.3012	1.3941
Fe2+	0.4135	0.4093	0.4157	0.4080	0.6554	0.4832	0.7799	1.3702	0.5294	0.6037	0.5888	0.4330	0.4931	0.3926	0.7659	0.8836
Mn	0.0060	0.0076	0.0083	0.0085	0.0127	0.0091	0.0120	0.0112	0.0055	0.0046	0.0105	0.0072	0.0092	0.0069	0.0073	0.0092
Mg	0.6066	0.6078	0.5978	0.6021	0.3743	0.5382	0.2967	0.2024	0.4719	0.4040	0.4897	0.5812	0.5178	0.6197	0.2676	0.2095
Ca	0.0008	0.0004	0.0012	0.0004	0.0031	0.0012	0.0018	0.0008	0.0015	0.0012	0.0008	0.0000	0.0008	0.0008	0.0008	0.0062
Cr	0.4315	0.4569	0.4323	0.5015	0.6594	0.4275	0.4975	0.0000	0.0000	0.0000	0.3833	0.5269	0.5268	0.5099	0.1196	0.0497
total	3.0000	3.0000	3.0000	3.0000	3.0001	3.0000	3.0001	3.0001	3.0000	3.0000	3.0001	3.0000	3.0000	3.0000	3.0001	3.0001
mol % usp	9.38	8.35	7.74	6.31	11.38	8.32	16.13	63.71	5.75	12.67	20.41	6.58	6.48	6.46	5.20	13.05
Mg#	59.5	59.8	59.0	59.6	36.4	52.7	27.6	12.9	47.1	40.1	45.4	57.3	51.2	61.2	25.9	19.2
Cr/Cr+Al	29.1	31.2	29.3	34.0	52.8	29.3	54.0	0.0	0.0	0.0	33.1	35.8	36.1	34.6	19.4	12.8
YFe	23.7	24.9	24.5	24.9	34.6	24.6	49.4	79.5	10.0	7.9	36.5	24.8	25.5	24.8	67.9	78.2
YCr	22.2	23.4	22.1	25.6	34.5	22.1	27.3	0.0	0.0	0.0	21.1	26.9	26.9	26.0	6.2	2.8
YAl	54.1	51.6	53.4	49.5	30.9	53.3	23.3	20.5	90.0	92.1	42.5	48.3	47.6	49.2	25.9	19.0

APPENDIX IX

THERMAL WATER AND FUMAROLE GAS CHEMISTRY, MOUNT SPURR, ALASKA

by

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INTRODUCTION

Fumarolic gas samples were collected in August 1982 during a reconnaissance investigation of the 1953 volcanic crater located at an elevation of 7700 ft, just below Crater Peak (see fig. 2, Nye, this report). This crater was the source of the 1953 Mount Spurr ash eruption (Juhle and Coulter, 1955). The fumarole field consisted of a series of diffuse to moderately pressurized boiling point fumarolic vents that issued from a mound of volcanic ash perched above the crater lake. Warm vapor was visibly rising from the 100 m diameter milky-blue lake. Steep ashy crater walls made descent down onto the lake too hazardous and no lake water samples were collected. By the summer of 1985 fumarolic activity along the rim of the crater lake had decreased to diffuse emissions, and a large (several meters in diameter) fumarolic vent had formed in the talus on the north slope of the crater lake.

A kilometer-long zone of warm springs was discovered in 1985 in the bottom of the valley immediately south of Crater Peak, at an elevation of 2000 ft (see fig. 2, Nye, this report). We sampled 40 C water issuing from a seep in the eastern wall of the canyon. Most of the springs are in the valley bottom and are extensively diluted with stream water. Total warm water flow for the entire valley bottom is probably on the order of a thousand liters per minute.

METHODS

The procedures followed for collection and treatment of water samples for geochemical analyses and for field determination of pH and HCO_3 and H_2S concentration are described in Presser and Barnes (1974). Major, minor and trace cation concentrations were determined using a Model 4000 Perkin-Elmer atomic absorption spectrometer with HGA 400 graphite furnace following standard procedures outlined in Skougstad and others (1979) and in the

Perkin-Elmer reference manual. Sulfates, bromide, and iodide were determined using a Dionex model 2010i ion chromatograph. Fluorides were determined by specific ion electrode; Cl by Mohr titration; and boron by the carminic acid method. Silica concentrations were determined by the molybdate blue method.

Gases were collected using a funnel emplaced over the fumarolic vent and connected to the collecting flask with tygon tubing. Gases were collected in evacuated sodium-hydroxide charged flasks for determination of gas composition and in evacuated uncharged flasks made from helium impermeable Corning 1720 glass for determination of $^3\text{He}/^4\text{He}$ ratios and $\delta^{13}\text{C}-\text{CO}_2$. Head-space gases in the sodium-hydroxide charged flasks (H_2 , CH_4 , O_2 , N_2 , and Ar) were analyzed on a dual-column gas chromatograph using helium and nitrogen carrier gases. The total moles of gas not absorbed in the sodium-hydroxide solution were determined by measuring the gas pressure and head space volume. CO_2 and H_2S molar concentrations in the solution were determined by titration and by gravimetric means respectively, following procedures outlined in Sheppard and Giggenbach (1985). Adjustments were made for head space gases dissolved in the solution using Henry's Law. Moles of each constituent collected were then determined and the mole percent of each constituent calculated.

Stable isotope compositions of water samples were analyzed under contract at the Stable Isotope Laboratory, Southern Methodist University. $^{13}\text{C}/^{12}\text{C}$ ratios in CO_2 were determined at U.S. Geological Survey, Menlo Park. $^3\text{He}/^4\text{He}$ ratios were analyzed by R. Poreda at the Stable Isotope Laboratory, Scripps Institution of Oceanography.

GAS CHEMISTRY

The fumarolic gases are water rich (97.9 % steam) with the residual gases consisting almost entirely of CO_2 with minor to trace amounts of N_2 , Ar, H_2S , H_2 , and CH_4 (table 1), a composition typical of boiling-point fumarolic vents associated

with volcanos elsewhere in the Aleutian arc (Motyka, 1983). The fumarolic vents at the active crater are probably associated with the degassing of residual magma associated with the 1953 eruption. Much of the steam is probably meteoric water that has infiltrated into the zone of elevated temperatures below the active crater. The N_2/Ar ratio is nearly that of air indicating that the source of most of the N_2 and Ar in the fumarolic gases is atmospheric contamination with oxygen removed in oxidation reactions. The remaining constituents are probably derived either from the magmatic source or from high-temperature interactions with country rocks.

The helium isotope ratio of $R/R_a = 6.6$ (table 1) lies within the range of values (5 - 8) found at other Aleutian arc volcanos (Poreda, 1983; Motyka, 1983), and is indicative of the magmatic influence on the Crater Peak hydrothermal system. The $\delta^{13}C-CO_2$ values of -12 and -14 per mil are significantly lighter than mantle-derived CO_2 , which is estimated to range from -4 to -9, but lie at the upper end of the range of values estimated for carbon dioxide derived from organic-sedimentary sources (Truesdell and Hulston, 1980). The light $\delta^{13}C-CO_2$ values therefore suggests an organic sedimentary origin for some of the CO_2 . The presence of CH_4 in the fumarolic gases also suggests a thermogenic sedimentary origin for some of the carbon. The West Foreland Formation of mid-Tertiary age is exposed east and south of Crater Peak and probably underlies Crater Peak (Nye, this report). The formation is non-marine but contains abundant plant fossils and scattered coal seams (Calderwood and Fackler, 1972), which are likely sources of thermogenically generated organic-sedimentary carbon gases.

D'Amore and Panichi (1980) have proposed a gas geothermometer for estimating geothermal reservoir temperatures based on the proportions of CO_2 , H_2S , H_2 , and CH_4 in fumarolic gases. Application of this geothermometer to the gas analysis of the Crater Peak fumarole for assumed CO_2 partial pressures of 0.5 and

1 bar suggests the source region for equilibration of these gases has a temperature on the order of 200 C (table 1).

WATER CHEMISTRY

The thermal water sampled near the base of Crater Peak is slightly acidic, relatively low in Cl^- but rich in HCO_3^- and $\text{SO}_4^{=}$, and has a relatively high concentration of Mg^{++} (table 2). The setting and chemistry of the Crater Peak thermal spring water is very similar to Mother Goose hot springs located on the Alaska Peninsula (Motyka and others, 1981). Both sites are typified by large rates of discharge of HCO_3^- - $\text{SO}_4^{=}$ rich, Cl^- poor thermal spring water and are located at or near the base of a volcanic peak with an active fumarole field. The high concentrations of HCO_3^- and $\text{SO}_4^{=}$ suggest the influence of volcanic gases on the thermal waters. Condensation of steam and interaction of fumarolic gases with cold ground waters would produce an acidic moderate- to low-enthalpy thermal water. The cation constituents and silica present in the water could have been largely derived through acid breakdown of country rock which would in turn buffer the water to its near-neutral but slightly acidic pH. The relatively large concentration of Mg^{++} present in the water is also indicative of a moderate- to low-enthalpy water because Mg^{++} is usually removed from high temperature waters through hydrothermal reactions (Fournier, 1981).

The source of the Cl^- and Br^- present in the water is problematic. Volcanic rocks normally contain these anions in only minor to trace amounts. Marine sediments do not appear to underlie Crater Peak and in any event the Br/Cl ratio in the thermal water (0.0020) is substantially lower than in seawater (0.0036). The chloride and bromide could have been derived from connate terrestrial waters in which these anions have become concentrated. Alternately, the Cl^- and Br^- could have been derived from a deep reservoir of Cl-rich hot-water or possibly as gases emanating directly from the magmatic source.

The stable isotope composition of the thermal water and two local stream waters are plotted on fig. A1. Sample S_1 was obtained from a stream adjacent to the area of thermal spring activity. S_2 was collected from a stream of run-off waters on top of Kidazgeni Glacier at an elevation of 2600 ft (see fig. 2, Nye, this report). The meteoric water line of Craig (1961) is also plotted for comparison. All three samples plot to the right of the Craig meteoric water line and both of the sampled local stream waters are substantially lighter than the thermal water. Although the data are insufficient to constrain the origins of the thermal water isotopic composition some observations can nevertheless be made.

The source of water charging the majority of hydrothermal systems is considered to be meteoric water (Truesdall and Hulston, 1980). If this is also the case at Crater Peak then the sources of differences in isotopic compositions between S_1 , S_2 , and the thermal waters need to be examined. The temperature dependency of isotopic composition in precipitation produces seasonal variations (winter precipitation is depleted in heavy isotopes with respect to summer precipitation) and altitude variations (the heavy isotope content of precipitation decreases with increasing elevation) (Panichi and Gonfianti, 1978). The surface streams that were sampled derive most of their water as run-off from higher elevations. Much of this run-off is probably meltwater from winter snowfall. These sources of stream water would account for the apparent depletion of heavy isotopes.

If meteoric water is a substantial component of the Crater Peak thermal water then the meteoric water charging the groundwater system would have to be derived from either 1) precipitation falling at substantially lower elevations than either site S_1 or S_2 or 2) from summer precipitation or both. An alternative model is that the thermal water is a mixture of meteoric waters similar to S_1 and S_2 and waters having a

substantially heavier isotopic composition. The source of this component of heavier water could be a thermal water from a deep reservoir or possibly connate formation water.

Table 3 gives the results of applying commonly used thermal water geothermometers (Fournier, 1981) and the K^+-Mg^{++} geothermometer proposed by Giggenbach and others (1983). However, because of the uncertainty in mixing relationships and the probability of disequilibrium reactions caused by acid gases, we urge caution be used in interpreting these chemical geothermometers in estimating temperatures of any deep reservoir. We do wish to point out that thermal spring waters with somewhat similar chemical characteristics have been found to be indicative of shallow vapor-dominated zones overlying boiling Cl-rich hot-water reservoirs. In particular, HCO_3^- - $SO_4^{=}$ rich, Cl^- poor thermal springs were found at the Makushin geothermal area on Unalaska Island. The area was subsequently drilled and found to house a substantial Cl-rich, hot-water reservoir (Motyka and others, 1983; Motyka and others, 1985). However, given the results of the accompanying study on the petrology and geochemistry of the Mount Spurr Volcanic Complex which found no evidence for a geothermally significant large-scale, shallow-lying magma system (Nye, this report), the Crater Peak thermal waters are more likely associated with localized residual degassing of magma underlying Crater Peak.

CONCLUSIONS

Fumaroles surrounding the active crater on Crater Peak are probably associated with the cooling and degassing of magma associated with the 1953 eruption. Infiltration of meteoric waters into the hot subsurface region overlying the magma is probably the source of much of the steam being emitted from the fumaroles. Acid gases and steam escaping from this hot subsurface region form a shallow vapor-dominated zone and interact with shallow ground waters and country rocks to produce

the thermal springs in valley south of Crater Peak. These spring waters may also contain either a minor component of deep reservoir Cl-rich thermal waters or connate formation waters. Because the thermal spring water appears to be a mixture from diverse sources, we consider interpretation of the results of the thermal water geothermometers to be problematic. Gas geothermometry suggests that the equilibration temperature for fumarolic gases is on the order of 200 C.

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Table 1. Analysis of gases from fumarole located on rim of active crater, Mt. Spurr, Alaska.

Date sampled	8-04-82
Sampling T, C	94
Steam, mole per cent	97.87
Composition of Residual Gases, mole per cent:	
CO ₂	95.6
H ₂ S	0.78
H ₂	0.25
CH ₄	0.03
N ₂	3.28
Ar	0.044
N ₂ /Ar	75
C/S	123
del ¹³ C-CO ₂ , per mil ^a	-14.2, -12.3
³ He/ ⁴ He, R/R _a ^b	6.6

Gas Geothermometer of D'Amore and Panichi (1980):

T, C (PCO ₂ =1.0 bar)	215
T, C (PCO ₂ =0.5 bar)	195

a) Value with respect to PDB. Analyses performed at U.S. Geological Survey, Menlo Park, CA.

b) Ratio of ³He/⁴He in sample over that in air. R. Poreda, Isotope Laboratory, Scripps Institution of Oceanography, analyst.

Table 2. Chemical analyses of waters collected from Mt Spurr hot springs, 1985^a. Concentrations in mg/l unless otherwise specified.

Sample	Spurr-85
Cations	
Na	266
K	75
Ca	95
Mg	99
Li	0.42
Sr	0.68
Cs	0.04
NH ₄	nd
Anions	
HCO ₃ ^b	622
SO ₄	477
F	1.0
Cl	254
Br	0.5
I	0.1
Balance % ^c	-3.4
SiO ₂ ^b	125
H ₂ S ^b	0.1
B	7.7
Al	nd
As	0.021
Fe	<0.1
TDS (calc.)	1708
T, C	40.2
pH ^b	6.4
del ¹⁸ O ^d	-16.7
delD ^d	-138
Date Sampled	8-03-85

a) Alaska Division of Geological and Geophysical Surveys, Fairbanks, M.A. Moorman, S.A. Liss and R.J. Motyka, analysts.

b) Determined in the field.

c) Computed from $\frac{1}{2}(C - A)/(C + A)$ where C and A are the total cations and anions in milliequivalents/liter, respectively.

d) Values in per mil with respect to standard mean ocean water (SMOW). For comparison, del¹⁸O and delD values for a nearby cold stream are -19.9 and -155; values for a supra-glacial stream are -18.1 and -146. Analyses performed at the Stable Isotope Laboratory, Southern Methodist University.

Table 3. Geothermometry of Mount Spurr hot springs. Temperatures in degrees celsius.

Quartz Conductive	150
Chalcedony	125
Amorphous SiO ₂	29
Na-K	325
Na-K-Ca (4/3)	155
Na-K-Ca (1/3)	237
Na-K-Ca, Mg corrected	17
K-Mg	88

Figure A1. Stable isotope compositions of waters from Crater Peak, Mount Spurr. S_1 and S_2 are stream waters. T is a thermal spring water located near the base of Crater Peak.