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THE SUMMER COON VOLCANO, EASTERN SAN JUAN MOUNTAINS, COLORADO

by

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FIGURE 1.
Central core area of Summer Coon volcano.

INTRODUCTION

The San Juan volcanic field extends over approximately 5,000 square miles in the southwestern part of Colorado. The stratigraphic section, which is applicable to the central and eastern segments of the volcanic field, is listed in Table 1. The pioneering work in this area was performed by E. S. Larsen, Jr. and Whitman Cross, spanning nearly forty years and culminated in U.S. Geological Survey Professional Paper 258, which summarized the geology and petrology of the entire region. Since 1960 an extensive program of field mapping has been carried on by the Denver Branch of the U.S. Geological Survey. The data published by the various coworkers of this program, including R. G. Dickinson, W. R. Hansen, P. W. Lipman, R. G. Luedke, J. C. Olsen, J. C. Ratté, and T. A. Steven, are listed in the bibliography.

The specific area of interest is called the Summer Coon volcano. The intrusive rocks that appear to mark the central conduit of the volcano are located 6½ miles north of Del Norte, Colorado (fig. 1). Rocks related to the volcano underlie approximately seventy square miles, which include parts of four 1:24000 quadrangles (Twin Mountains, Twin Mountains S.E., Indian Head, and Del Norte). Previous work in the area involves only two field-based studies; a fast reconnaissance visit to the area by Larsen and Cross (1956) and a detailed reconnaissance project by Lipman (1968), which involved outlining the basic field relationships of the complex, examination of thin sections and several chemical analyses. Subsequently Doe *et al.* (1969) published lead and strontium isotope data for three samples from the Summer Coon area and Lipman *et al.* (1970) reported three potassium-argon age dates.

SUMMER COON'S RELATIONSHIP TO REGIONAL GEOLOGY

In a general manner the geologic map of the Summer Coon area (see plate 1, back pocket) shows two relationships which are important to the interpretation of the overall geologic development of the eastern San Juan volcanic field. The first is the nearly perfect pattern of radial dikes about the central intrusive area. No transverse or ring dike

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TABLE 1.

GENERALIZED VOLCANIC STRATIGRAPHY OF THE GENERAL AND EASTERN PARTS OF THE SAN JUAN MOUNTAINS COLORADO
(with mean ages of dated units).
(Modified from Lipman *et al.*, 1970)

Late Basalts and Rhyolites
Servilleta Formation of Montgomery, 1953 (3.6 to 4.5 m.y.) Hinsdale Formation Basalt (4.7 to 23.4 m.y.) Rhyolite (4.8 to 22.4 m.y.)
Lavas and Related Rocks Erupted Concurrently with the Ash-flow Tuffs
Local andesitic-quartz latitic flows and breccias that intertongue with the ash-flow sequence in and near the central San Juan complex. The Fisher Quartz Latite (26.4 m.y.) overlie the entire ash-flow sequence.
Ash-flow Tuffs
Snowshoe Mountain Quartz Latite (greater than 26.4 m.y.) Rat Creek and Nelson Mountain Quartz Latite Wason Park Rhyolite Mammoth Mountain Rhyolite (26.7 m.y.) Carpenter Ride Tuff-Bachelor Mountain Rhyolite Fish Canyon Tuff-La Garita Quartz Latite (27.8 m.y.) Tuff of Masonic Park (28.2 m.y.) Treasure Mountain Rhyolite (29.8 m.y.)
Early Intermediate Lavas and Breccias
Conejos Formation (31.1 to 34.7 m.y.)

pattern has been discovered, nor any indication that a graben type structure was ever developed in the core area. These characteristics, by analogy with a scale model study of salt dome intrusion by Parker and McDowell (1951) indicate that only the mildest doming took place during the Summer Coon intrusive and extrusive activities. In addition, the regional stress regime must have been isotropic or only mildly anistropic, otherwise one would expect the dike pattern to become more complex, as it did at Spanish Peaks where the regional stress system was at least moderatly anistropic.

The second important relationship is the asymmetrical distribution of dips about a north-northeast line through the center of the complex. To the east and southeast of the core area dips range from 25° to 35°; on the north and west sides the dip vary between 5° and 15°. This demonstrates that the Summer Coon area has been tilted east-southeastward toward the San Luis Valley. This regional warping must have occurred after the cessation of volcanic activity because the original dip of the flows and breccias around the caldera was probably essentially symmetrical. Moreover, if the volcano did form during the tilting process, the dike pattern probably would have reflected an anisotropic stress condition.

These facts demonstrate that the initial development of the Rio Grande depression could not have taken place prior to the extinction of the Summer Coon volcano (Lipman, 1968). Lipman and Mehnert (1969) have shown from other evidence that subsidence of the Rio Grande depression east of the Summer Coon area did not begin until Early Miocene, by which time Summer Coon was extinct.

FIELD GEOLOGY

The initial development of the Summer Coon volcano was upon a terrain of older volcanic rocks of rhyodacitic composition. A window of these rocks outcrops just north of La Garita Creek along the boundary between NE¼ Sec 6, T41N, R6E, and NW¼ Sec 5, T41N, R6E (see Plate 1, back pocket). A rock from this outcrop has been dated at 34.0 ± 1.5 m.y. by Lipman *et al.* (1970), which provides a maximum age for the complex.

The Summer Coon volcanics are part of the Conejos Formation as outlined in Table 1. This correlation is based on the potassium-argon dates reported in Lipman *et al.* (1970). The stratigraphic nomenclature that will be used in this paper is outlined in Table 2. This sequence

TABLE 2.

VOLCANIC STRATIGRAPHY OF THE SUMMER COON SHIELD SEQUENCE, COLORADO

Summer Coon Volcanics	Conejos Formation	Late Intermediate Unit	Upper Andesite Member
			Lower Pyroclastic Member
		Middle Silicic Unit	Upper Rhyolite Member
			Lower Rhyodacite Member
		Early Mafic Unit	

is based solely upon field geologic relationships since no radiometric dating was performed.

Rocks derived from the Summer Coon volcano can be divided into two distinct groups: a shield sequence of flows, breccias, and dikes, which can be further subdivided into three units and a central intrusive complex which includes some intra-caldera lava flows. Each of the three units of the shield sequence consists of varying proportions of breccias, flows and dikes. The lower part of this shield sequence is overlain by younger lava flows and breccias of the Conejos Formation to the northwest, by younger ash-flow tuffs to the north and east, by volcaniclastic sediments to the south (some of which is probably detritus eroded from Summer Coon itself), and is intruded and hydrothermally altered by rhyolite plugs and vents to the east.

EARLY MAFIC UNIT

The Early Mafic Unit is 2800-3100 feet thick, of which 85-90% consists of weakly stratified breccia occurring in beds 5 to 75 feet thick and having essentially uniform appearance throughout the entire sequence. In general the breccia is composed of angular blocks 10 to 15 inches across which contain few if any vesicles. A matrix of coarse tuff (Williams and McBirney, 1969) is usually present, although occasionally the intervening space between blocks is empty. The tuff contains the same minerals as those constituting the breccia blocks, as determined by oil immersion methods. Lenses of well stratified tuffaceous sandstone and siltstone occur sporadically in the Early Mafic Unit. These strata are never more than two feet thick and are usually crossbedded, clearly indicating their reworked nature. Also occasionally present are thin beds (2 to 5 feet thick) of scoracious lapilli containing large vesicles. These beds are confined to a circular area approximately one mile in diameter that lies abutted to the inferred caldera rim depicted in Plate 1. These strata infrequently contain spindle-shaped bombs which strongly suggest an origin as an explosion breccia fairly near to the volcanic vent. Lava flows, which are not plentiful in any part of the mafic unit, are petrographically equivalent to the breccia blocks and generally have a thickness of 5 feet or less, except near the margins of the volcano, where some flows reach a thickness of 20 feet. In every location where flows were mapped they grade into breccia both upward and downward. In sections north of La Garita Creek the proportion of flows to breccia increases to approximately 20 to 25%. Outcrops closer to the intrusive area, like those in the N½ Sec 7, T41N, R6E and all of Sec 17, T41N, R6E, contain only 3 to 5% lava flows. The fact that one finds a great proportion of lava flows as well as thicker flows toward the flanks of the volcano would seem to indicate that most of the breccia was formed by flow brecciation of relatively thin flows, as postulated by Lipman (1968). The less viscous part of the lava flow moved rapidly down the slopes leaving the upper part behind as a bed of angular blocks of lava. The distribution of flows and breccias and the relative proportion of one to the other agree with this interpretation.

Dikes constitute a significant part of the Early Mafic Unit and number well over 700, most of which radiate from the central core zone. All the dikes of this unit could not be included in Plate 1 because in several locations large numbers of dikes outcrop over a relatively small area. For example, along the bed of the intermittent stream in N½ SW¼ Sec 29, T41N, R6E, 27 dikes outcrop over a distance of only 1600 feet. These dikes, like many of the dikes of this unit, are 1 to 2 feet thick, have no topographic expression, and are very short (less than 500 feet). However, some mafic dikes, usually olivine bearing reach a thickness of 12 feet and are continuous over a distance of a mile or more. The radial pattern of mafic dikes is so nearly ideal that only 2 intersections between mineralogically distinct mafic dikes have been observed. The locations of these crosscuttings are: E½ SW¼ Sec 12, T41N, R5E, and E½ SW¼ Sec 17, T41N, R6E. In both cases dikes containing numerous large feldspar phenocrysts cut fine grained olivine bearing dikes. Chemical information for an intersecting pair of dikes is listed in Plate 2 in the back pocket (See 69-10 for olivine bearing dike and 69-31 for large feldspar dike).

MIDDLE SILICIC UNIT

The Middle Silicic Unit of the shield stratigraphic sequence can be conveniently subdivided into two parts: a Lower Rhyodacite Member and an Upper Rhyolite Member. The Lower Rhyodacite Member consists of dikes and a sparse number of correlative lava flows, which have an aggregate thickness of 100 feet. An intrusive stock in the core area, which probably is equivalent to the Rhyodacite Member of the shield sequence, would line-up as a likely focal point for this magmatic activity if these dikes could be extended along their strike direction. The major proportion of this member outcrops southeast of the core area in the following locations: SE¼ Sec 30, T41N, R6E; E½ Sec 31, T41N, R6E; W½ Sec 32, T41N, R6E; N½ Sec 5, T40N, R6E; W½ Sec 4, T40N, R6E. Several of these dikes are 50 feet thick and form vertical walls that occasionally rise as high as 150 feet above the surrounding topography. Two other dikes belong to this member, one of which outcrops in N½ NW¼ Sec 26, T41N, R5E; N½ Sec 27, T41N, R5E; E½ Sec 28, T41N, R5E; the second outcrops in NW¼ NE¼ Sec 14, T41N, R5E and continues to the northwest. All dikes and flows of the Rhyodacite Member either cut or rest upon only Early Mafic Unit material.

An unusual dike and lava flow outcrops in S½ Sec 26, T41N, R5E; NE¼ Sec 34, T41N, R5E; E½ Sec 4, T40N, R5E and along the boundary between NW¼ Sec 1 and NE¼ Sec 2, of T40N, R5E. These rocks have been included in the Lower Rhyodacite Member of the Middle Silicic Unit because they are chemically very similar to rocks of this subdivision; however, they are mineralogically distinct and somewhat resemble rocks of the Late Intermediate Union (see 69-12, 70-44, and 70-55 in Plate 2 for analytical data). The dike, besides cutting the mafic unit, also cuts the earliest flows of the Late Intermediate Unit of the shield stratigraphic sequence. The lava overlies mafic unit rocks; no upper contact could be seen. The flow has a minimum thickness of 50 feet.

The second subdivision of the Middle Silicic Unit consists of the Upper Rhyolite Member. This member is composed of both intrusive and extrusive rocks. With the exception of two short dikes one of which outcrops in SE¼ SE¼ Sec 14, T41N, R5E, and N½ NW¼ Sec 24, T41N, R5E; and the other which outcrops in E½ NE¼ Sec 24, T41N, R5E, all rhyolite dikes follow a distinct northeast-southwest trend (see Plate 1, back pocket). One dike is over 5 miles long and outcrops within 25 yards of the intrusive rocks on both sides of the volcanic core. Since the most intense alteration and brecciation of the core rocks occur along a line connecting the two closest rhyolite dike outcrops, it seems likely that the dike cross-cuts the entire core area. Additional credence is lent to this hypothesis by a resistivity map that was constructed by a geophysical company for the owner of the mineral rights in this area. A marked northeast-southwest surface of equipotential resistivity cuts across the core area essentially identical to a line connecting these two closest rhyolite dike outcrops. To the southeast this same rhyolite dike strikes toward a rhyolite plug, but one cannot actually trace one into the other. This plug is located in E½ SE¼ Sec 27, T41N, R5E, and is characterized by well-developed flow lineation which strikes in every conceivable direction and whose dip is vertical. The rhyolite plug can be traced into a rhyolite breccia and, a little further to the southwest, into a rhyolite flow. The flow has a maximum thickness of 330 feet and overlies mafic breccia. It is overlain by a lava flow of the Late Intermediate Unit. Therefore, in this ¼ square mile area, the relative time sequence of the shield stratigraphic units is outlined in graphic detail.

The Twin Mountains Rhyolite outcrops west of the Summer Coon volcano and covers extensive portions of Sec 17 through 20 and Sec 29 through 32, T41N, R5E. This rhyolite is younger than the Upper Rhyolite Member of the Middle Silicic Unit because it intrudes and hydrothermally alters rocks belonging to both Early Mafic and Late Intermediate Units of the Summer Coon shield sequence. Extensive silicification and some mineralization has accompanied the intrusion of parts of the Twin Mountains Rhyolite, and these areas are conspicuously marked by prospector's pits and trenches.

LATE INTERMEDIATE UNIT

The third and last division of the shield stratigraphic sequence consists of the Late Intermediate Unit, which like the Silicic Unit, can also be broken down into two smaller units. The Lower Pyroclastic Member contains mostly breccia and outcrops in the N½ Sec 33, the SW¼ Sec 28, and the SE¼ NE¼ Sec 29, all of T41N, R6E. It also outcrops in the NW¼ SE¼ Sec 14, T40N, R5E. The total thickness of this subdivision is indeterminate because nowhere are both the top and bottom of the Lower Pyroclastic Member exposed. A minimum thickness, however, is 600 feet. The part of the Lower Pyroclastic Member which outcrops in T41N, R6E consists exclusively of breccia and overlies the Early Mafic Unit. It is unconformably overlain by younger ash-flow tuffs from the central San Juan cauldron and is cut by a dike of the Upper Andesite Member of the Late Intermediate Unit. The part of the Lower Pyroclastic Member which outcrops in T40N, R5E also probably overlies the Early Mafic Unit although this contact is not actually seen in the field. It is apparently conformably overlain by 10 to 15 feet of pumiceous quartz latite, the top of which has been eroded and tuffaceous sediments of a very similar composition deposited upon it. These sediments, which are 15 to 25 feet thick, are well stratified, sorted, and cross-bedded; they are probably reworked pumiceous quartz latite. These sediments are overlain by a thick porphyritic hornblende-rich flow of the Upper Andesite Member. The length of time represented by these sediments is open to conjecture, but it does seem to mark a somewhat prolonged period of inactivity during the life of the volcano.

Most individual blocks within the breccia are two feet or less in diameter and are surrounded by a matrix that is identical in composition to the blocks. Some large blocks were noted during the course of mapping; the dimensions of the largest block were 5 feet by 5 feet by 8 feet. Taking into account the lack of air sculptured bombs and the presence of significant quantities of matrix material, it is likely the breccia was originally a lahar and formed contemporaneously with major eruptions at a time when large amounts of unconsolidated fragmental material were erupted onto the slopes of the volcano.

The Upper Andesite Member of the Late Intermediate Unit contains the youngest rocks of the Summer Coon volcano. Dikes and lava flows of this member either cut or overlie rocks belonging to both the Early Mafic and Middle Silicic Units. Dikes of the Upper Andesite Member also cut lava flows which are also part of this member. One fact is missing, however, and pertains to the relationship between the Upper Andesite Member dikes and the anomalous dike that was placed in the Lower Rhyodacite Member of the Middle Silicic Unit. Both cut Upper Andesite Member flows, but no other diagnostic relationship could be found in the field which would give a relative time stratigraphic sequence between the two. Eight of these dikes radiate about the central intrusive area, analogous to the spokes of a wheel. Most of these dikes are 25 to 50 feet wide and two to four miles long. They are usually much more resistant to weathering than the rocks they intrude and, therefore, tower 50 to 200 feet above the surrounding topography. The natural arch, which is located in the NW¼ SE¼ Sec 12, T41N, R5E, is actually a hole that has been eroded in one of these Upper Andesite Member dikes. Indian Head, named for its peculiar outline, is either a dike or a plug and probably was a vent for some of the Upper Andesite lava flows. This topographic landmark is located in the W½ SW¼ Sec 13, T40N, R5E. Upper Andesite Member flows extend about one mile south of Del Norte, Colorado, where they are overlain by volcaniclastic sediments. The best estimate of the total thickness of this member can be made in the southern portion of the complex. The aggregate thickness appears to be on the order of 4000 to 5000 feet, but in several areas the dip of the lava flows becomes indeterminate. The thickness of individual flows varies between 50 and 300 feet. The basal portion of the thicker flows is flow brecciated as is the uppermost portion; the central portion is usually quite massive. The best example of this flow structure can be found on the bluff situated on the east bank of the Rio Grande by the dam in the NW¼ NW¼ Sec 30, T40N, R6E.

Most of the Lava flows of the Upper Andesite Member were probably erupted from local fissures as lava lakes or pools. The subcircular pattern of dips one occasionally finds around some of these thick flows adds credence to this point of view. Even though an intrusive pipe of very similar composition to the Upper Andesite Member dikes is present in the caldera area, its small size (20 feet in diameter) and other characteristics make it a very unlikely source for most of these flows. It is possible, however, that some of the Upper Andesite Member flows were erupted from Indian Head, which could have been a parasitic volcano of the main Summer Coon caldera.

INTRUSIVE COMPLEX OF THE VOLCANIC CORE

The intrusive rocks that appear to mark the conduit of the volcanic outcrop as a series of low hills which are aligned in a north-northwest direction. The core rocks outcrop in the NW¼, the NE¼, and the SE¼, of Sec 24, T41N, R5E; in the NE¼ Sec 25, T41N, R5E; in the E½ Sec 19, T41N, R6E; and in the NW¼ Sec 30, T41N, R6E. The intrusives are surrounded by an ellipsoidal valley which probably marks the location of what once was a caldera rim. The interpretation of this topographic feature is based on several outcrops in the N½ SW¼ Sec 18, T41N, R6E, where a lava flow was found to have a dip which varied from horizontal to slightly southeastward. Moving northward into the NW¼ Sec 18, T41N, R6E, widespread breccia and an occasional flow of the Early Mafic Unit dip to the north at 10° to 15°. This has been interpreted to mean that the essentially horizontal flow was part of an intracaldera sequence of lava flows. Since this is the sole area where any evidence could be found to support the idea of a possible caldera structure, the whole interpretation is open to considerable debate.

The stratigraphic nomenclature that will be used to describe the Summer Coon intrusive rocks is outlined in Table 3. The time relationship between the Middle Intrusive Unit and the Late Intrusive Unit is constructed by analogy with the shield sequence because of the lack of a mutual contact between the corresponding rock units. The Late Intrusive Unit does cross-cut the Early Intrusive Unit which adds some substance to the proposed analogy with the shield sequence.

TABLE 3.
VOLCANIC STRATIGRAPHY OF THE
SUMMER COON INSTRUSIVE ROCKS, COLORADO

Summer Coon Volcanics	Conejos Formation	Late Intrusive Unit	
		Middle Intrusive Unit	Upper Breccia Member
			Lower Granodiorite Porphyry Member
		Early Intrusive Unit	

The Early Intrusive Unit is characterized by various lithologic types which vary predominately in phenocryst size and percentage groundmass, the later of which is indicative of the cooling history of the sample. Mineralogically and chemically these rocks are very similar, as indicated by nine chemical analyses listed in Plate 2 (those up to 58% SiO_2). The spatial distribution of the Early Intrusive Unit is outlined in Plate 1. A very porphyritic facies of this unit forms the southernmost hill in the W½ NW¼ Sec 30, T41N, R6E and the E½ NE¼ Sec 25, T41N, R5E. Phenocrysts are prominently developed in this stock-like body and range up to 6 mm. across. The most plutonic appearing samples are found in the extreme eastern part of the SW¼ NE¼ Sec 24, T41N, R5E. The rock has an equigranular salt and pepper type of appearance. The samples from this small area are the only ones from the entire Summer Coon complex that have completely crystallized. In this case the rate of cooling has been sufficiently slow to permit what is normally called "groundmass" to crystallize, consisting of an interlocking network of potassium feldspar and quartz.

The field relationships between the various lithologic types of the Early Intrusive Unit are obscured by poor exposures in the core region, but apparently small cupolas or chambers existed as offshoots from the main magma source. These cupolas gave rise to the different lithologies as a result of their variation in geometric shape, size, and rate of cooling. The small intrusives are probably separated from one another by intra-caldera lava flows or by masses of the Early Mafic Unit. No reliable interpretation can be made due to the lack of exposures in critical areas.

The Lower Member of the Middle Intrusive Unit consists of granodiorite porphyry and outcrops in the NW¼, NE¼ and the SE¼ Sec 24, T41N, R5E and in the W½ Sec 19, T41N, R6E. This rock type has suffered varying degrees of alteration, the maximum of which lies along a NE-SW trend which is identical to the projected strike of a rhyolite dike which outcrops on both sides of the central complex. The contact between the Lower Granodiorite Porphyry and the Early Intrusive Unit is very sharp, but on the basis of the granodiorite porphyry becoming finer grained toward the contact and the lack of such a characteristic in the Early Intrusive Unit, it is concluded that the Lower Granodiorite Porphyry Member is younger. However, several thin dikes of the Early Mafic Unit do intrude the granodiorite porphyry and indicate the time interval between the two intrusions was not large. The wide-spread alteration of the granodiorite porphyry is in all likelihood the result of the intrusion of a rhyolite dike. The Upper Breccia Member formed during this intrusive activity. The boundary lines between it and the Lower Granodiorite Porphyry Member are arbitrarily drawn on the basis of the presence or absence of significant silica veining and/or pumiceous fragments. The actual rhyolite dike does not outcrop within this strongly brecciated and silicified zone, but several small rhyolite dikes do outcrop in the E½ NE¼ Sec 24, T41N, R5E and cross-cut the Early Intrusive Unit. The actual breccia consists of granodiorite porphyry fragments in a matrix of cryptocrystalline quartz with occasional lumps or balls of pumice.

On the basis of the mineralogy and bulk chemistry (see samples 70-69 and 70-72) the Lower Granodiorite Porphyry Member of the Middle Intrusive Unit is correlated with the Lower Rhyodacite Member of the shield stratigraphic sequence. Due to the lack of a distinct rock-type in the Upper Breccia Member, no bulk chemical analyses are presented. As a result of the alteration, all mineral identification was done by x-ray diffraction because of the smallness of the grain size. Based on the field evidence and the geophysical work outlined in the section on the Middle Silicic Unit. The Upper Breccia Member is correlated with the Upper Rhyolite Member of the shield stratigraphic sequence.

The last intrusive phase of the Summer Coon complex is appropriately termed the Late Intrusive Unit. It consists of a twenty feet diameter pipe or plug which outcrops in the NW¼ NW¼ Sec 30, T41N, R6E. There is a significant amount of brecciation and veining of the Early Intrusive Unit as one approaches this outcrop. The vein material is composed of the same mineralogy as the small intrusion. No field relationship exists between this intrusion and the rocks of the Middle Intrusive Unit. Therefore, the correlation of the intrusion with the Late Intermediate Unit of the shield sequence is based on mineralogy and bulk chemistry (see sample 69-19) and is placed as the latest intrusive phase by analogy.

BULK CHEMICAL ANALYSIS

The chemical analyses reported in this paper were performed by a combination of x-ray fluorescence and atomic absorption methods. SiO_2, Al_2O_3, TiO_2, total iron, CaO, K_2O, MnO, and MgO were analyzed by fluorescence, while Na_2O was analyzed by atomic absorption. The FeO content, which one needs to know to calculate CIPW norms, was determined using the method of Reichen and Fahey (1962). Samples were ground to approximately —200 mesh, fired at 1000°C. to oxidize all the FeO to Fe_2O_3, and then diluted 2:1 with lithium tetraborate. This mixture is fused, reground, and then pressed into a pellet, using boric acid as a backing. All analyses were made under vacuum, using a Chromium target x-ray source. U.S. Geological Survey analyzed rocks were used as standards because a large compilation of data exists concerning their major constituent composition (Fleisher, 1965; Flanagan, 1967; 1969). The data was corrected for absorption and enhancement effects due to differences in sample matrix by an iterative computer program designed by John Hower (Hower *et al.*, 1964). Table 4 provides a listing of the suggested accuracies of each component in a typical analysis. These values were calculated from a series of ten analyses of one sample, 69-21, using W-1 as a standard.

The system outlined by Irvine and Baragar (1971) has been employed to chemically classify this volcanic suite. In general their approach to chemical classification is to use simple graphical plots which permit various volcanic rocks to be distinguished and named in accordance with compositional fields that are rationally consistent with current usage. The chemical analyses, which provide the basis for the following diagrams are listed in Plate 2. The locations of these samples are plotted on Plate 1.

Figure 2 is an alkalies *vs* silica plot which allows one to differentiate between alkaline and subalkaline volcanics. Subalkaline is a term introduced by Wilkinson (1968) to include both the calc-alkaline and tholeiitic series. The dividing line used in the diagram is the same one constructed by Irvine and Baragar (1971), which is based on 2500 chemical analyses. It is clearly demonstrated that the rocks of Summer Coon volcano belong to the subalkaline field.

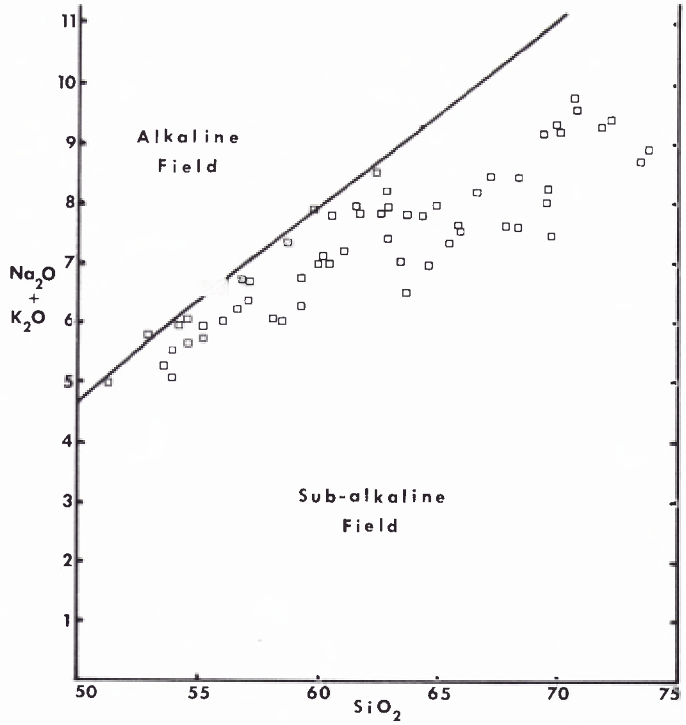

FIGURE 2.

Alkalies vs. silica plot for Summer Coon chemical analyses.

Figure 3 is an AFM diagram and in this case was used to distinguish between rocks of the calc-alkaline and tholeiitic series. The solid line provides the best separation between chemical data that was taken from areas that are more or less typical of the calc-alkaline and tholeiitic trends. It clearly shows that the Summer Coon volcanics belong to the calc-alkaline trend. Another interesting point that is brought out in this diagram is the total lack of any sign of iron enrichment in the Summer Coon rocks. If there were some tendency toward iron enrichment, the data would plot in an arcuate pattern somewhat like that of the separation line. This characteristic separates Summer Coon from some other calc-alkaline provinces, most not-

TABLE 4.
CALCULATED STANDARD DEVIATION, REPRODUCIBILITY AND THE SUGGESTED ACCURACY OF EACH REPORTED VALUE CONTAINED IN PLATE 2

	WEIGHT % (MEAN)	STD. DEVIATION	REPRODUCIBILITY	ACCURACY IN REPORTED VALUE
SiO_2	54.20	.05	0.53%	0.27%
Al_2O_3	17.06	.09	1.16%	0.21%
Fe_2O_3*	10.20	.05	0.58%	0.07%
FeO	7.08	.25	2.82%	0.20%
Fe_2O_3	2.41			
TiO_2	1.23	.01	0.77%	0.01%
MgO	3.97	.15	5.60%	0.22%
K_2O	1.88	.03	0.29%	0.01%
Na_2O	4.08	.07	2.21%	0.09%
CaO	7.30	.02	0.53%	0.04%

* Total Fe as Fe_2O_3

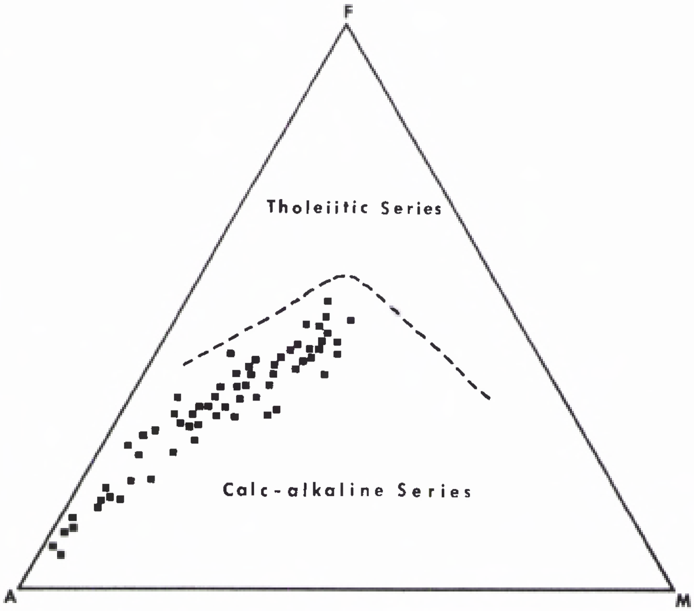

FIGURE 3.
($A = Na_2O + K_2O$; $F = FeO + 0.8998\ Fe_2O_3$; $M = MgO$)

able of which is the Aleutians. On the other hand, the trend outlined by the Summer Coon analyses is very similar to the one determined for the Cascade calc-alkaline province (Smith and Carmichael, 1968).

The third and last diagram (fig. 4) is a plot of normative anorthite (An), albite (Ab), and orthoclase (Or). The purpose of this diagram is to help one decide whether a series of rocks are potassium-poor, average, or potassium-rich and put such a determination on an objective level. The diagram indicates that the Summer Coon rocks are K-rich toward the An-Ab binary, but as the rocks approach the Ab-Or binary they have crossed the boundary into the "Average" field. It is helpful to remember when interpreting this diagram that the Na_2O content of a rock is somewhat sensitive to any alteration or weathering which may have taken place.

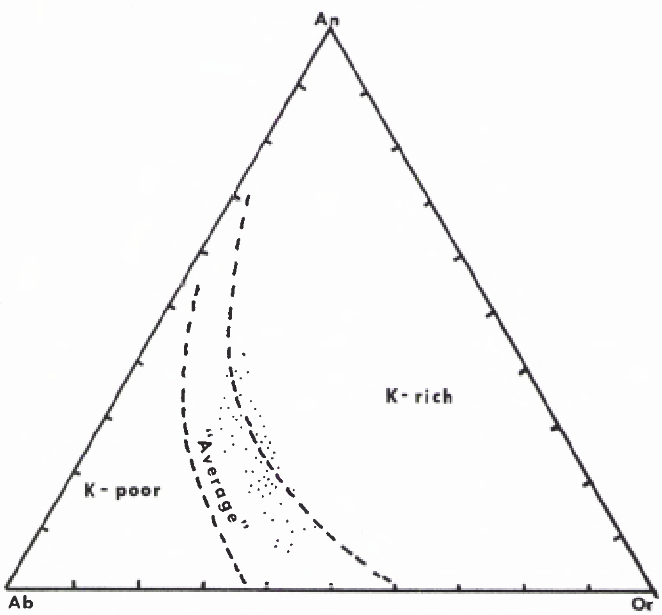

FIGURE 4.
An-Ab-Or diagram of Summer Coon analyses.

SUMMARY

The Summer Coon volcanic complex is part of the Conejos Formation and is divisible into two parts; a shield sequence and a central intrusive area. The shield sequence can be divided into three units, each containing varying proportions of lava flows, breccias, and dikes. The three units from oldest to youngest are the Early Mafic Unit, the Middle Silicic Unit, which is further subdivided into a Rhyodacite Member and an Upper Rhyolite Member, and the Late Intermediate Unit, which is further subdivided into a Lower Pyroclastic Member and an Upper Andesite Member. The subdivision of the units into members was made on the basis of optical mineralogy and bulk chemistry. The intrusive area of the volcano is also divisible into three units which can be correlated with the units of the shield stratigraphic sequence. The three units from oldest to youngest are the Early Intrusive Unit, the Middle Intrusive Unit, which is further subdivided into a Lower Granodiorite Porphyry Member, and an Upper Breccia Member, and a Late Intrusive Unit. On the basis of bulk chemistry it is demonstrated that the best classification of the Summer Coon volcanics is that they are "transitional high potassium calc-alkaline rocks."

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