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The geology of Summer Coon volcano near Del Norte, Colorado

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LOCATION AND ACCESS

The Summer Coon volcano is located about 6 mi (9.6 km) north of Del Norte, Colorado, on the western edge of the San Luis Valley (Fig. 1). The intrusive core and northern half of the volcano can be found on the Twin Mountains and Twin Mountains SE 7½-minute quadrangles. The southern part of the volcano lies in the Indian Head and Del Norte 7½-minute quadrangles. To reach the area of the volcanic core, take Colorado 112 from Del Norte to County Road 33; travel north on 33 about 6.2 mi (9.9 km); turn left on Road A32 (Forest Service road 660), marked by a small sign to "Natural Arch," and drive into the volcano.

The volcano lies almost entirely within the Rio Grande National Forest and is accessible by dirt roads, which are usually graded for passenger cars. Some areas, especially those that are near the Natural Arch and off the main road, should only be attempted during periods of clement weather or with four-wheel drive. The main road lies close to some of the radiating dikes and to good outcrops of extrusive material; it passes within 0.5 mi (0.8 km) of the heart of the intrusive complex. The round-trip time (from Del Norte) is a half-day minimum.

SIGNIFICANCE OF THE SITE

The Summer Coon volcanic complex is an Oligocene stratovolcano that has been eroded down to its base, revealing a variety of extrusive materials, hundreds of nearly perfect radiating dikes, and an intrusive core. Rock composition ranges from early mafic through middle silicic to late intermediate character. The rocks of the complex are included in the Conejos Formation, a sequence of Oligocene volcanic rocks that was extruded onto the eastern San Juan volcanic field prior to the eruption of the ash-flow tuff units that now comprise much of the San Juan Mountains. Summer Coon is one of the best-preserved relicts of that earlier sequence. The unusual petrogenesis of mafic to silicic to intermediate rocks led Zielinski and Lipman (1976) to study the trace element history of this volcano. As a result of their study, they were able to hypothesize a mantle origin for the continental-interior andesite.

GENERAL DESCRIPTION

The Summer Coon volcano is part of the San Juan volcanic field, which covers an area of about 5,000 mi^2 (13,000 km^2) in southwestern Colorado. The field was developed on a platform composed of Precambrian rock overlain by a thin veneer of Phanerozoic sedimentary strata. Most of the sedimentary rocks were removed by erosion, following the uplift of the Uncompahgre highland in the late Paleozoic or during the Laramide orogeny.

The beginning of activity in the San Juan volcanic field was marked by the eruption of numerous volcanos over this surface in the early Oligocene (Lipman, 1968). Eruptive units included intermediate lavas and breccias of the San Juan, Lake Fork, and West Elk formations in the western San Juans and of the Conejos Formation (with the Summer Coon volcano) in the eastern San Juans. Over a dozen calderas were active between 30 and 22 Ma (Lipman and others, 1970). Silicic ash-flows from these calderas covered most of the present San Juan area. It is possible that this volcanic field was at one time continuous across Colorado to the Thirty-Nine Mile volcanic field in South Park. A gravity anomaly suggests that the entire San Juan field may be underlain by a single large batholith.

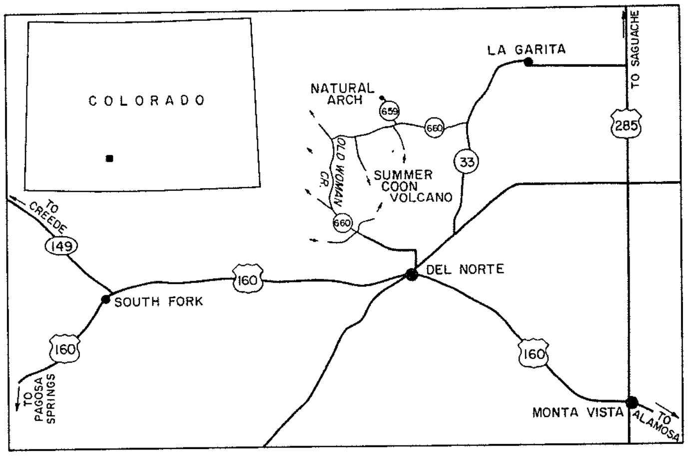

Figure 1. Map showing location of Summer Coon volcano (northwest of Alamosa) and surrounding areas.

The Rio Grande Rift began to develop in what is now the San Luis Valley at least 26 Ma, as evidenced by an early basalt flow from the Hinsdale Formation, which intruded alluvial and volcaniclastic sediments of the Los Pinos Formation. An upper limit for the beginning of rifting (at about 31 Ma) is established at Summer Coon volcano itself. The dips of extrusive material are asymmetric and change from 25–35° on the eastern side to dips of 5–15° on the western side. Assuming that the distribution of lava was initially symmetrical, the eastward tilting of the volcano (due probably to development of the Rift) occurred after the volcano was formed. Two dates (32.4 Ma and 34.7 Ma) have been determined from silicic dikes in the volcano (Lipman, 1976).

Erosion has uncovered the former stratovolcano down to its base, revealing a complete basal section of this approximately 8- to 10-mi (13- to 16-km) diameter cone. The rocks present within the volcano may be classified by structural occurrence or by chemical composition. The volcano is composed of three main structural types: (1) extrusive flows and breccias, (2) evenly distributed radial dikes, and (3) a circular intrusive complex in the center of the volcano. Due to the lack of cross-cutting relationships, correlation among these units is based largely on chemical composition as well as on observed or inferred field occurrence. The exposed rocks are classified into three main compositional types (Table 1): early mafic, middle silicic, and late intermediate compositions (Lipman, 1968; Mertzman, 1971a). Geologic maps may be found in Lipman (1976) and in Mertzman (1971a).

An obvious feature of the Summer Coon volcano is the nearly perfect radial pattern of dikes. Lipman (1968) interpreted these dikes as being the result of (1) small-scale doming and (2) radial fracturing, the result of doming due to a rising intrusion. Pre-existing horizontal stress in the area was apparently isotropic; the dikes lack any prevailing orientation. This supports the hypothesis that the volcano predates the north-south opening of the Rio Grande Rift.

There is a distinct lack of faulting in the volcano. Loken (1982) suggested that this may be the reason for the lack of mineralization in the intrusive core, which is barren, despite the existence of zones of hydrothermal alteration (which are a typical association of ore deposits).

IGNEOUS ROCKS

The volcanistratigraphy of the Summer Coon volcano includes the early mafic unit (2800 to 3100 ft; 850 to 950 m thick), which is almost entirely a poorly stratified breccia (see Fig. 2). The infrequent presence of spindle-shaped bombs suggests that this unit originated as an explosion breccia near a vent (Lipman, 1968; Mertzman, 1971a). Presence of a few scoriaceous beds supports this hypothesis. Lava flows grade into the breccia; these are petrographically identical to the breccia. The flows are thicker (to 20 ft; 6 m) and more abundant near the edges of the volcano. This circumstance may have resulted from autobrecciation of thin flows, with less-viscous portions flowing downhill while the angular blocks of breccia were left behind (Lipman, 1968).

The mafic dikes, though numerous, are easily overlooked in the field; they are typically only 1 to 2 ft (0.5 m) wide and rarely stand more than 1 ft (0.3 m) above the ground surface. These dikes are usually less than 500 ft (150 m) in length. None of the published maps attempt to show all of these dikes, though Lipman (1976) mapped many of them. Dikes range in composition from alkali olivine basalt to trachyandesite; clinopyroxene and plagioclase are the dominant phases.

Most of the mafic rocks have been classified as olivine andesites of basaltic appearance (Zielinski and Lipman, 1976). Color varies from dark gray to dark red where oxidized. These rocks contain about 30% phenocrysts (clinopyroxene, calcic andesine, and olivine) in a groundmass of plagioclase and glass, with small amounts of olivine and clinopyroxene. SiO_2 content varies from about 51 to 56 wt%.

The middle unit of the volcanic sequence is the most silicic; SiO_2 content is around 70 wt%. This unit is divided into two parts: a lower rhyodacite member and an upper rhyolite member (Mertzman, 1971a) (Table 1). The lower rhyodacite member is made up of dikes and a few lava flows that have a total thickness of about 100 ft (30 m). Flows of this member are restricted to the southern side of the volcano. The dikes of this unit trend both southeast and southwest from the central intrusive complex. Dikes are up to 50 ft (15 m) thick and may rise 150 ft (45 m) above the ground surface and extend for 2 to 3 mi (3 to 5 km). The dike rocks are rich in phenocrysts of sodic andesine and biotite; they have been classed as quartz latite (Lipman, 1968).

TABLE 1. STRATIGRAPHY OF THE SUMMER COON VOLCANO

Conejos Formation	Extrusive	Intrusive
Late	Upper Andesite Lower Pyroclastic	Augite Monzonite (minor)
Middle	Upper Rhyolite Lower Rhyodacite	Upper Breccia Lower Granodiorite
Early	Mafic (andesitic)	Mafic

The upper rhyolite member also is composed of both extrusive units and dikes. Flows may reach 330 ft (100 m) in thickness in the southwest part of the volcano. Units may show well-developed flow lamination or may be brecciated. The dikes trend northeast-southwest and may be traced for nearly 6 mi (9.6 km) across the base of the cone; they outcrop within 75 ft (23 m) of equivalent intrusive rocks in the core. A resistivity map (Mertzman, 1971a) suggests that the dike crosscuts the core.

The rhyolite unit is light tan and, in comparison with the rhyodacite, is poor in phenocrysts. The groundmass has devitrified to alkali feldspar and silica.

The late Intermediate unit is divided into two subunits: the lower pyroclastic member and the upper andesite member. Rocks of this unit have a silica content between 57 and 67 wt% and range in composition from quartz latite to rhyodacite. The lower pyroclastic member, concentrated on the southeast flank of the volcano, is a breccia of quartz latitic composition and has a minimum thickness of 600 ft (180 m); neither the top nor the bottom of this subunit is exposed. The breccia blocks are about 2 ft (0.6 m) in diameter. The large quantity of matrix material present, in addition to the lack of fiamme, led Mertzman (1971a) to hypothesize a laharic origin for this member.

The upper andesite member consists of flows, the aggregate thickness of which may reach 5,000 ft (1,500 m). Individual flows vary from 50 to 300 ft (15 to 90 m) in thickness. Basal and upper portions of the flows are brecciated, whereas the central portions are massive. The rocks are reddish-brown and average 10–20 percent phenocrysts. Plagioclase (mostly andesine) is the dominant phase. Other phases present include abundant hornblende, biotite, minor clinopyroxene, and sparse orthopyroxene and olivine.

These rocks may have been erupted from local fissures as lava lakes (Mertzman, 1971a).

Dikes of this unit radiate in all directions from the central core. Dikes may reach 200 ft (160 m) in height; most are 25 to 50 ft (8 to 15 m) wide and 2 to 4 mi (3 to 5 km) in length. Phenocrystic hornblende characterizes the dikes, although plagioclase, biotite, and augite are also common. The Natural Arch has been weathered through one of these dikes (Fig. 2).

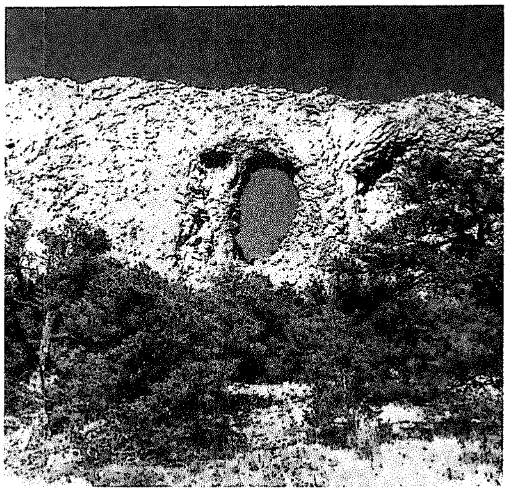

Figure 2. Natural Arch, weathered through a late andesitic dike that in turn cuts early mafic breccia.

The central intrusive complex appears as a group of low hills running north-northwest in the center of the volcano (Fig. 3). The hills are surrounded by an approximately circular, alluvium-filled valley about 2 mi (3.2 km) in diameter. All of the volcanogenic units occur within this complex.

The early mafic unit (intrusive) occurs in a variety of lithologic types, classified on the basis of composition (SiO_2 less than 58% by weight) and spatial distribution. Common phenocrysts include plagioclase, two pyroxenes, and hornblende. The groundmass is typically holocrystalline and contains abundant plagioclase, with clinopyroxene, quartz, hornblende, rare alkali feldspar, and opaques. Plagioclase composition ranges from An_{34} to An_{58}. The unit appears to be the result of a series of small intrusions that cooled at various rates.

The middle silicic unit (intrusive) consists of two subunits: a lower granodiorite porphyry member and an upper breccia member (Table 1). The lower granodiorite crops out as two distinct bodies, each about 0.5 mi (0.8 km) wide and separated by the upper breccia member. The granodiorite is the analogue of the lower rhyodacite dike member, chemically and mineralogically. It is an altered light-gray or buff porphyritic rock that contains phenocrysts of sodic oligoclase, minor biotite and hornblende, and some opaques. The groundmass consists of alkali feldspar, plagioclase, and quartz.

The lower granodiorite member becomes finer-grained near the contact with the early mafic intrusive unit; therefore, Mertzman (1971a) concluded that the granodiorite is the younger unit. However, since several early mafic dikes cut the granodiorite, the emplacement events of these two units may have overlapped.

The upper breccia member cuts between the two bodies of lower granodiorite and lies on strike with the major upper rhyolite dike. This member appears to be a poorly sorted light tan to yellow tuff breccia, which is fragmental and intensely altered. The presence of pumiceous blocks is indicated by slight changes in texture and color. Phenocrysts cannot be identified. The groundmass is mostly cryptocrystalline quartz with some vitric fragments; feldspars have altered to clay. The rock contains about 10% void space by volume, either as vesicles or as weathered-out phenocrysts.

Intrusive rocks of the late intermediate sequence occur only in a single minor pipe, about 20 ft (6 m) in diameter. This pipe is located on the southeast side of the hill, in Sec.30,T.41N.,R.6E., which is underlain by the early mafic intrusive unit (b, Fig. 3). The rock of this unit has been described as an augite monzonite porphyry (Mertzman, 1972); it can only be correlated with the late intermediate dike and flow units on the basis of chemistry and mineralogy. This single pipe could not have been the sole vent for the large volume of late flow material; other sources must exist. One such source may be Indian Head (see "Selected Stops") on the south flank of the volcano.

All of the units present in the Summer Coon complex show some degree of hydrothermal alteration. This alteration shows the classic concentric pattern, proceeding from propylitic alteration at the lithologic boundary between the early mafic and middle silic units outward through argillic and quartz-sericite zones. Despite numerous indications of mineralization, the Summer Coon complex probably does not host any economic deposits (Loken, 1982).

An interesting petrogenetic pattern is observed in the volcanic sequence exposed at Summer Coon. The rocks in this area were not extruded and deposited in order of increasing silica content. The earliest rocks in the sequence are basaltic/andesitic; the most likely model for origin of the primary magma is the partial melting at depth of a garnet-bearing, eclogitic equivalent of crustal material. Such a source might have evolved from a subducted slab of lithosphere or from conversion of mafic lower crustal material (from a depth of 25 to 30 mi; 40 to 50 km) to plagioclase-depleted garnet granulite. This supposition is supported by available Sr^{87}/Sr^{86} ratios and Pb-isotope and trace element data (Zielinski and Lipman, 1976).

The rocks in the later silicic sequence become more mafic with time (rhyodacite-rhyolite to andesite). This petrogenetic evolution may be explained by low-pressure fractional crystallization in an andesitic magma chamber. Vertical migration (settling or flotation) of phenocrysts might produce a stratified body that could then be progressively tapped to yield the observed sequence. The tapping of such a chamber at various levels can also explain some supposedly contradictory temporal relationships, in which middle rhyodacite dikes are seen cutting "late" andesite flows. This model is also supported by trace element data (Zielinski and Lipman, 1976).

SELECTED STOPS

Summer Coon can be explored with the assistance of either of the published maps and with Mertzman's road log (Mertzman, 1971b). A few of the readily accessible and interesting locations will be mentioned here.

Stop 1. Stop at the junction of County Road 33 and Road A32 (Forest Service road 660), about 9.5 mi (15.2 km) from Del

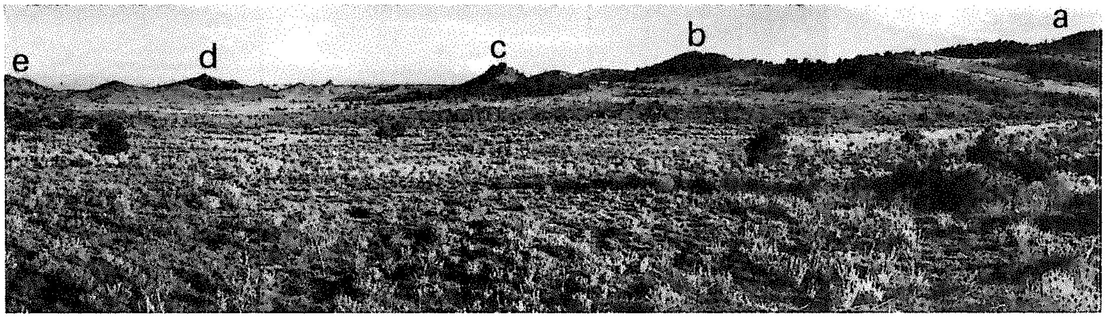

Figure 3. View to the southeast from northwest corner of intersection of Forest Roads 660 and 659 (Stop 3). Labeled points are (a) the middle silicic intrusive hills, (b) early mafic intrusive, (c) lower rhyodacite dikes cutting early mafic member, (d) upper andesite dike, and (e) early mafic extrusives.

Norte. The high ridge east of the County Road is vitrophyric Carpenter Ridge Tuff. The "elephant rocks" west of the road are outcrops of the slightly older Fish Canyon Tuff (27.8 Ma).

Stop 2. Continue west on the Forest Service road about 0.9 mi (1.4 km) from the junction. Several hundred yards to the north is a small hill with a well-exposed outcrop of early mafic extrusives. A basaltic andesite flow, which has east-dipping platy joints, overlies explosion breccia material.

Stop 3. Continue on Forest Service road 660 to the junction with the side road (659.1, or Road 35C) which leads to the Natural Arch. At this point you are 13.6 mi (21.8 km) from Del Norte, or 4.1 mi (6.5 km) from Stop 1; you are now within the intrusive complex (Fig. 3). Rocks on the hill northeast of the junction are part of the early mafic unit. The high hills to the southeast are made of middle silicic rocks. A hike to the top of these hills is recommended as the best way to view the alteration zones, the intrusive units, and the spectacular radiating pattern of the dikes. The main middle silicic–lower rhyolite dike cuts through these hills and can be traced across the road about 0.5 mi (0.8 km) east of the junction. A late intermediate dike crops out northwest of the road junction and trends north-northwest. A group of middle silicic–upper rhyodacite dikes crops out about 1.5 mi (2.4 km) south of the junction, along the four-wheel drive road.

Stop 4. About 0.4 mi (0.6 km) north of the junction in Stop 3, near the crest of a small hill, is a sharp but subtle contact between the early mafic breccia and early mafic intrusives. A small, typical early mafic dike cuts the breccia. The tall dikes west of the road belong to the late intermediate unit.

Stop 5. Continue 1.7 mi (2.7 km) north from the junction of Forest Service road 660 with Road 35C (Stop 3). This is the Natural Arch, a fine example of a late intermediate dike that cuts early mafic breccia (Fig. 2). This has been described as a porphyritic quartz latite (Mertzman, 1971a, b). The view from inside the arch includes the Sangre de Cristo Mountains and Great Sand Dunes National Monument to the east, across the San Luis Valley. Most of the Summer Coon volcano, including the intrusive complex, is visible to the east and south.

Stop 6. Return to Stop 3 and continue west on the main Forest Service road through the volcano. At about 22 mi (35 km) from Del Norte (including the 3.3-mi—5.3-km—round trip to Natural Arch), there is a large rhyodacite dike on the left. At 23.4 mi (37.5 km), a rhyolite flow occurs on the left. The next hill south (on the eastern side of the road) at the county line contains more rhyolite flows, overlain by late andesite lavas. The low hills visible to the east and north for the next few miles are also late andesites. Turn onto the paved road (a junction) at 26.8 mi (42.9 km). The outcrops immediately east of this junction are part of the lower pyroclastic member of the late intermediate flows. At mile 27.8 (44.5 km), Indian Head juts up immediately to the north; this may have been a vent for late intermediate material. Turn right across the canal at the junction with County Road 15 (29.8 mi; 47.8 km), and rejoin Colorado 112 at 30.6 mi (49 km).

REFERENCES

Lipman, P. W., 1968, Geology of the Summer Coon volcanic center, eastern San Juan Mountains, Colorado: Colorado School of Mines Quarterly, v. 63, p. 211–236.

—— , 1976, Geologic map of the Del Norte area, eastern San Juan Mountains, Colorado: U.S. Geological Survey Miscellaneous Investigations Map I-952.

Lipman, P. W., Steven, T. A., and Mehnert, H. H., 1970, Volcanic history of the San Juan Mountains, Colorado, as indicated by potassium-argon dating: Geological Society of America Bulletin, v. 81, p. 2329–2352.

Loken, T., 1982, Hydrothermal alteration and oil show at the Summer Coon intrusive center, Saguache County, Colorado [M.S. thesis]: Corvallis, Oregon State University, 91 p.

Mertzman, S. A., Jr., 1971a, The Summer Coon volcano, eastern San Juan Mountains, Colorado: New Mexico Geological Society Guide, 22nd Field Conference, p. 265–273, map and chemical analyses in pocket.

—— , 1971b, Supplemental roadlog no. 2, Del Norte to Summer Coon volcanic area and return: New Mexico Geological Society Guide, 22nd Field Conference, p. 73–75.

—— , 1972, The geology and petrology of the Summer Coon volcano, Colorado [Ph.D. thesis]: Cleveland, Ohio, Case Western Reserve University, 253 p.

Zielinski, R. A., and Lipman, P. W., 1976, Trace element variations at Summer Coon volcano, San Juan Mountains, Colorado, and the origin of continental-interior andesite: Geological Society of America Bulletin, v. 87, p. 1477–1485.