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Guidebook to Rio Grande rift in New Mexico and Colorado

compiled by J. W. Hawley
in cooperation with 42 other coauthors

prepared especially for
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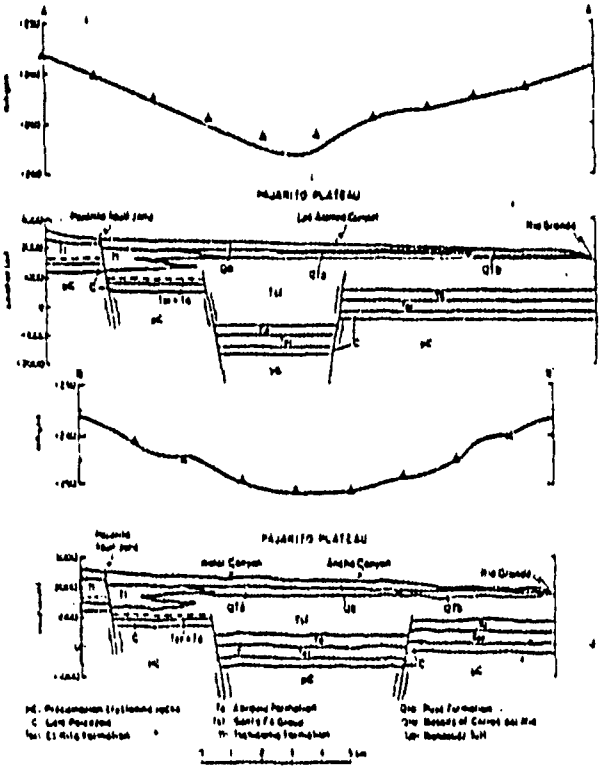

FIGURE 4—CROSS SECTIONS AA' AND BB' SHOWING THE GRAVITY PROFILE AND INTERPRETED GEOLOGY. Triangles indicate the calculated gravity anomaly based on mass distribution in the geologic profile.

GEOLOGY OF CERROS DEL RIO VOLCANIC FIELD

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Geologic setting

The Cerros del Rio field (fig. 1) is located on the La Bajada-Jemez constriction, which separates the Española and Santo Domingo Basins of the Rio Grande rift (Kelley, 1952; Kelley and others, 1976). At this point, the rift is laterally offset 19 mi (30 km) to the right. Elevations range from 7,471 ft to 5,358 ft (2,277 m to 1,633 m). Approximately 70 sq mi (180 sq km), including part of White Rock Canyon, have been mapped in detail (Aubele, 1978).

The early Pliocene to Pleistocene rocks of the Jemez Mountains partially cover the west boundary faults of the Española Basin. The upper Tshirege Member of the Bandelier Tuff, which erupted from the Valles caldera of the Jemez Mountains, overlies the distal northern edge of the Cerros del Rio flows (Bailey and others, 1969).

The Cerros del Rio field ends in an abrupt escarpment, on the southwest, 525 ft (160 m) above the fan deposits and stream gravels of the Santo Domingo Basin. To the east, the base of the Cerros flows is visible where it overlies the Pojoaque Member of the Tesuque Formation, Santa Fe Group (Galusha and Blick, 1971, fig. 38).

Stratigraphy

The activity of the Cerros del Rio field is younger than the deposition of the Santa Fe Group as defined by Galusha and Blick (1971). The volcanic activity is in part contemporaneous with the deposition of gravel conglomerate lenses, which are possibly equivalent to the Puye Formation (mid-Pliocene) (Bailey and others, 1969). The activity is also contemporaneous with the deposition of the Otowi Member of the Bandelier Tuff (Smith and others, 1970).

Approximately 60 vents have been identified within the Cerros del Rio volcanic field, and the majority of these are marked by cinder-spatter cone formation. The cones vary in size, shape, and state of degradation; however, all of them have the same general structure (Crumpler and Aubele, 1977). There were probably two stages of cinder-cone formation in the Cerros del Rio: 1) early-stage cinder cones predating the major flows and 2) late-stage cinder cones marking the final eruptive activity in the area. Early-stage cinder cones are now exposed by erosion, especially along the east edge of White Rock Canyon. A northeast-trending line of early cones occurs near the southern boundary of the Ceja del Rio Grant and is one of the few examples of possible fissure alignment of vents in the volcanic field. Late-stage cinder cones were erupted during the final activity of vents that had previously extruded lava flows.

Intrusions in the area include several plugs, dikes consistently trending to the northeast, and one sill exposed on the east side of White Rock Canyon.

The eruptive rocks of the Cerros del Rio field consist of alkali basalt (hawaiite), basaltic andesite, and andesite. Activity began with the extrusion of hawaiite, which forms extensive flows on the south and north margins of the area. The basal flow unit in the north has been dated at 2.6 ± 0.4 m.y. (Bachman and Mehnert, 1978, no. 2) and is exposed in White Rock Canyon. Cinder cones and phreatomagmatic eruptions occurred simultaneously, and remnants of these vents are ex-

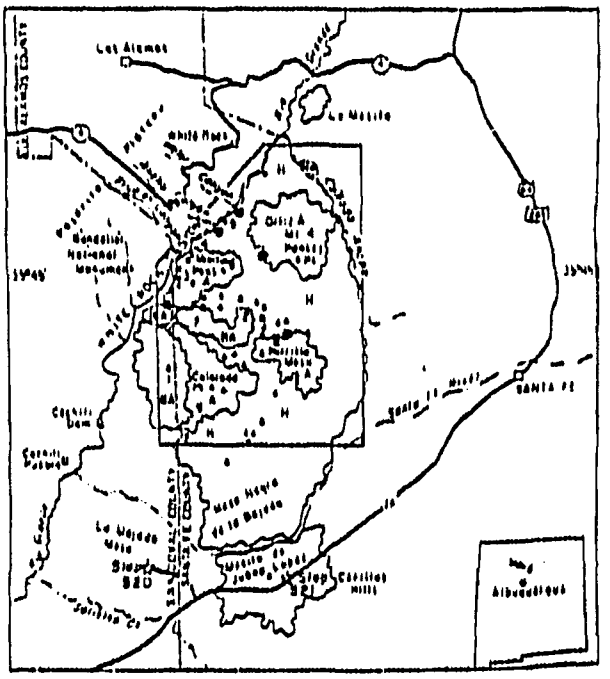

FIGURE 1—INDEX AND GEOLOGIC MAP OF THE CERROS DEL RIO VOLCANIC FIELD. Vents designated by asterisks; maars and tuff rings designated by circled asterisks; A—andesite; BA—basaltic andesite; H—hawaiite. Numbers refer to sample locations; see table 1. Rectangle outlines area mapped in detail.

posed in and near White Rock Canyon and in the southern part of the field. This activity was followed by eruptions of andesite flow-domes, first in the south and then in the north. Throughout these eruptions, less voluminous extrusions of hawaiite occurred along a zone of vents trending northwest-southeast in the center of the field. Following the andesitic eruptions, hawaiite activity continued along the central zone. One of the two stratigraphically youngest flows has been dated at 2.5 ± 0.2 m.y. (Bachman and Mehnert, 1978, no. 4).

Volcanic activity in the Cerros del Rio field had almost ceased before the formation of the Valles caldera in the Jemez Mountains. The upper member of the Bandelier Tuff, extruded from the caldera, overlies the hawaiite west of White Rock Canyon and is exposed in one location on the east side. Here an eroded valley in the hawaiite served as a channel for the tuff, which contacts the underlying basalt and ash unconformably. The tuff then appears to lap up on the east wall of the canyon as a wedge, and it thins rapidly to the east.

Extensive air-fall deposition of pumice from the Valles eruption must have covered the entire Cerros del Rio field. The pumice probably helped to preserve some of the original volcanic landforms (now being exhumed) and contributed to the development of Quaternary soils. In most cases the blanket of pumice has been eroded and redeposited as small surface deposits scattered throughout the field.

White Rock Canyon

White Rock Canyon, a 1,000-ft (300-m) gorge, was cut by the Rio Grande after the eruption of the Tshirege Member of the Bandelier Tuff (1.4 m.y.; Bailey and others, 1969). The present configuration of the canyon is the result of extensive toreva-block slumping, which has widened the canyon and repeated the stratigraphic section (fig. 2).

The cutting of the canyon has exposed an area of intercalated phreatomagmatic deposits and basalt flows. The yellow-tan phreatomagmatic deposits, designated as Santa Fe Group or stream-and-lake deposits by previous workers, are predominantly accidental materials of sedimentary origin. These materials include 1) thinly-layered sand and silt with basaltic ash; 2) palagonite; and 3) fragments of basalt, cinder, chert, quartzite, and Precambrian granitic and metamorphic rocks. The chert, quartzite, and granitic fragments are probably from early stream deposits underlying the phreatomagmatic deposits. In a few places the layered sand and silt grades into finely laminated clay, which also contains volcanic and Precambrian fragments and is interpreted as reworked tuff deposited in small lakes or ponds. The phreatomagmatic deposits vary in thickness from a meter to tens of meters. Bomb sags, cauliflower bombs, and crossbeds formed by base surge are common.

These deposits are clearly related to the activity of the Cerros del Rio field, because they are interbedded with hawaiite flows. The source of the deposits must have been a series of maar craters that paralleled the present White Rock Canyon. At least five of these vents are exposed in varying degrees of dissection in side canyons along the Rio Grande, including Montoso Arroyo and Frijoles Canyon.

North of Montoso Peak, a deeply dissected maar is exposed on the east edge of White Rock Canyon and has been informally named Montoso maar (fig. 3). This previously unknown maar has been described in preliminary reports by Aubele (1976) and Aubele and others (1976) and is the best exposed maar described to date in the literature (Lorenz, 1973; personal communication, 1977). Total relief is over 655 ft (200 m), and dissection has exposed several stratigraphic levels and a well-defined ring-fracture zone.

Several other phreatomagmatic vents identified as maars, tuff rings, and tuff cones have been discovered within the volcanic field south of White Rock Canyon, and explosive activity appears to have occurred throughout the eruptive history of the field.

FIGURE 2—TOREVA BLOCKS IN WHITE ROCK CANYON, NORTH OF ANCHO CANYON; view to the north. The Rio Grande is approximately 10 m wide here; the canyon rim is about 300 m above the river. Two old river terraces also visible.

FIGURE 3—AERIAL VIEW OF MONTOSO MAAR LOOKING SOUTH ACROSS THE RIO GRANDE; crater approximately 1 km in diameter.

Petrology and petrogenesis

Chemical analyses and norms, calculated by the Niggli method, are given for 10 representative samples in table 1. The petrologic classifications and terms used throughout this study have been based on Irvine and Baragar (1971). The classification systems of Middlemost (1972), Lipman and Mehnert (1975), and Carmichael and others (1974) also agree with Irvine and Baragar's rock nomenclature for these samples. Average modes for all the units and feldspar determinations have aided in the classification.

Regional setting and geologic implications

No modern perennial streams flow through the Cerros del Rio volcanic plateau, although intermittent runoff toward the Rio Grande has cut deep arroyos in the pumiceous soil cover and in the interior of flows. Phreatomagmatic deposits in the vicinity of White Rock Canyon could be cited as evidence for a through-going stream in the area at the time of the eruptive activity of the Cerros. Additional evidence for a depression, probably a valley cut by a stream, is based on the thickness of the Cerros del Rio flows. To the east and southeast, the volcanic section thins to 100 ft (30 m) and 10 ft (3 m) respectively, while to the north and west, along White Rock Canyon, the exposed section is consistently 1,000 ft (300 m) thick. The thin western edge of the flows appears to be about 1 mi (1.5 to 2 km) west of the present Rio Grande (Kelley, 1948). This distribution pattern implies that the flows filled in a valley or depression in the vicinity of the modern White Rock Canyon. These flows were later eroded into valleys, which were filled by the distal edge of the Bandelier Tuff. Finally, White Rock Canyon was formed by continued stream incision.

The flows of the Cerros del Rio appear to have followed two distinct gradients. A northwest-trending line of vents in the center of the area appears to have acted as a divide for the two gradients. Flows from its south side flow west or south, while flows to the north consistently head north. These gradients may relate to the regional gradients caused by the Española Basin to the north and the Santo Domingo Basin to the southwest. If so, then the northwest-trending vents may be aligned along an extensional zone between the basins. The dominant volcanism along this trend is hawaiite, which is generally thought to represent relatively deep magma genera-

TABLE 1—CHEMICAL ANALYSES AND CALCULATED NORMS OF THE VOLCANIC ROCKS OF THE CERROS DEL RIO VOLCANIC FIELD, NEW MEXICO (analyses by J. C. Aubele). * Gravimetric analyses of SiO_2 performed by John Husler; † S.I. (solidification index) = (MgO × 100)/(MgO + FeO_T + Na_2O + K_2O)); ‡ norms calculated with adjusted values of percent Fe_2O_3, such that percent Fe_2O_3 = percent TiO_2 + 1.5 (after Irving and Baragar, 1971).

	1	2	3	4	5	6	7	8	9	10
SiO_2*	60.16	49.11	59.24	60.09	50.18	47.52	56.44	59.73	60.95	48.63
TiO_2	.84	2.07	.70	.78	.93	1.58	1.14	.88	.73	1.92
Al_2O_3	15.93	17.41	15.91	16.92	15.61	16.30	17.03	16.04	15.73	16.29
Fe_2O_3	2.51	4.44	2.53	2.10	3.83	4.47	2.80	3.32	2.58	3.55
FeO	3.59	6.54	2.66	3.53	5.61	5.43	3.82	2.21	2.63	7.41
MgO	3.26	5.40	3.66	2.80	6.58	6.77	3.17	2.64	3.42	6.85
CaO	5.34	8.24	5.75	5.21	8.67	8.44	5.95	5.01	5.43	8.32
Na_2O	3.94	3.95	4.12	4.22	4.10	4.07	4.39	4.14	4.22	3.83
K_2O	2.53	1.69	2.44	2.60	1.72	2.22	2.40	3.17	2.34	1.27
MnO	.10	.16	.09	.09	.14	.16	.09	.09	.09	.15
H_2O^+	.92	.35	1.18	1.08	.004	1.25	.68	1.35	1.04	.04
H_2O^-	.09	.22	.16	.18	.07	.14	.24	.08	.12	.06
P_2O_5	.37	.86	.58	.45	.74	.96	.67	.72	.39	.72
BaO	.07	.05	.08	.08	.05	.08	.08	.09	.07	.04
SrO	.09	.11	.10	.09	.12	.13	.11	.13	.08	.10
Total	99.74	100.60	99.20	100.22	98.35	99.52	99.01	99.6	99.82	99.18
S.I.†	20.6	24.5	23.8	18.4	30.1	29.5	19.1	17.1	22.5	29.9
normative mineralogy‡										
q	10.84	.00	9.35	9.85	.00	.00	5.13	9.76	11.19	.00
or	15.14	9.98	14.65	15.48	10.23	13.22	14.40	19.06	13.95	7.54
ab	35.83	34.42	37.60	38.19	32.40	24.28	40.03	37.83	38.23	34.34
an	18.55	24.78	18.00	19.70	19.24	19.81	19.98	16.10	17.23	23.03
ne	.00	.62	.00	.00	2.80	7.54	.00	.00	.00	.14
di	4.97	8.69	6.05	3.02	15.69	13.26	4.80	3.94	6.19	10.78
hy	10.23	.00	9.89	9.32	.00	.00	9.82	8.00	8.99	.00
fo	.00	8.95	.00	.00	9.70	10.51	.00	.00	.00	11.35
fa	.00	4.15	.00	.00	4.51	3.90	.00	.00	.00	4.43
il	1.18	2.88	.99	1.09	1.30	2.21	1.61	1.24	1.02	2.68
ap	.78	1.79	1.23	.94	1.55	2.02	1.42	1.53	.82	1.51
mt	2.47	3.73	2.33	2.40	2.53	3.24	2.80	2.33	2.35	3.39

Rock type, specimen number and locality

1) Andesite (CD-1), vent 31 (QTa$_1$), south of Cochiti cone
2) Hawaiite (Mel0a), southern hawaiite (QTb$_1$), near Cañada Tetilla
3) Andesite (MuM116), Montoso Peak (QTa$_1$), west of Montoso Peak
4) Andesite (WP305), Ortiz Mountain (QTa$_1$), north of Pankey Peak
5) Hawaiite (WH11L), early northern hawaiite (QTb$_1$), south of vent 48
6) Hawaiite (MH61), Cerro Rito (QTb$_1$), north of vent 5
7) Basaltic andesite (Mc26e), Cerro Micho (QTba$_1$), west of vent 11
8) Andesite (MDP21), Cerrito Portillo (QTa$_1$), west of Tor tuff ring (vent 41)
9) Andesite (MH12c), Colorado Peak (QTa$_1$), south of Colorado Peak
10) Hawaiite (AGF1), Twin Hills vent 7 (QTb$_1$), north of Portales Pond

tion and differentiation (Carmichael, 1974). Extensional fractures would serve as a logical conduit for the rapid rise of alkalic magma from deep sources.

Recently, the Rio Grande rift has been compared to other rifts, many of which are associated with the global tectonics of spreading ridges. Some of these comparisons are instructive; however, an examination of the volcanic petrochemical assemblages leads to the conclusion that the rocks of the Cerros del Rio are not completely analogous to volcanic rocks in other rifts.

In their chemical composition, the hawaiites of the Cerros del Rio strongly resemble the plateau alkali basalts from Ethiopia (Mohr, 1971). No correlation exists, however, between the andesite of the Cerros del Rio and the intermediate lavas of the African rift, which have alkalic rather than calc-alkalic affinities. The northern Mt. Taylor volcanic field, which has been recently mapped by Crumpler (1977, 1978, and work in progress), is the only volcanic field in the Rio Grande area that follows a complete alkalic trend similar to that dominating the African rift. In both Kenya and Ethiopia, basalts become tholeiitic, or at least less alkalic, within the rift (Baker and others, 1972). Lipman (1969) has found a similar correlation in the northern Rio Grande region. However, no tholeiites have been identified in the Cerros del Rio, although the field is located within the rift.

The presence of hawaiite without tholeiite in the Cerros del Rio may be attributed to its location at an extensional fracture zone between two basins. This is not inimical to comparisons between the Rio Grande rift and other tectonic rifts. However, the most appropriate comparison of the petrologic assemblage (hawaiite-basaltic andesite-andesite) of the Cerros del Rio volcanic field is not to the east African rift, but instead to other volcanic fields of the Basin and Range province in the western United States.

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CENOZOIC GEOLOGY OF ESPAÑOLA BASIN

by Kim Manley, *U.S. Geological Survey, Denver, Colorado*

The Española Basin is in a north-south alignment of Cenozoic basins that extends from central Colorado to southern New Mexico (Chapin, 1971; Chapin and Seager, 1975; Manley, 1978), known as the Rio Grande depression or rift. The Española Basin extends 25 mi north to south and 40 mi east to west.

The western half of the basin is filled with the volcanic rocks of the Jemez Mountains (fig. E1); these mountains define the western edge of the topographic basin, which is only 20 mi wide. The topographic basin terminates near mesas capped by basalts of the Servilleta Formation to the north and Cerros del Rio volcanic field to the south. Tertiary sedimentary rocks are preserved in the central basin: Galisteo, El Rito (Smith, 1938), Abiquiu (Smith, 1938), and Picuris (Cabot, 1938) Formations and the Santa Fe Group; several Pliocene and Pleistocene alluvial deposits are also preserved in the central basin, including the Ancha and Puye Formations (Pliocene). The topographic boundary to the east is the Sangre de Cristo range. Structurally, the basin is separated from the Santo Domingo subbasin to the south by the northwest-trending La Bajada fault, downthrown to the southwest. The Española Basin is bounded on the north by the San Luis Valley. This boundary is difficult to pinpoint but is generally assumed to be along the northern flanks of the Picuris range and to extend westward to the Ojo Caliente area via an isolated Precambrian exposure known as Cerro Azul. On the west and east the Española Basin is bounded by Precambrian-cored uplifts—the Nacimiento uplift on the west and the Sangre de Cristo Mountains on the east.

The Tertiary rocks in the basin have been described in part by several authors, and the terminology of these rocks is con-