Curecanti Pluton, an Unusual Intrusive Body in the Black Canyon of the Gunnison, Colorado

By WALLACE R. HANSEN

CONTRIBUTIONS TO GENERAL GEOLOGY

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Petrographic and spatial relations of a discordant pluton, and an explanation of its origin

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By Wallace R. Hansen

ABSTRACT

The Curecanti pluton is a sublenticular mass of Precambrian quartz monzonite 3½ miles across west to east and 2 miles across north to south. In general shape it is similar to a rather flat laccolith, but it differs fundamentally from a laccolith in being wholly discordant in relation to the intruded rock, which is contorted biotite gneiss. Both the roof and the floor of the pluton are well exposed in the Black Canyon of the Gunnison River and in adjacent tributaries, but the western part of the pluton extends below drainage and appears to be deeply rooted. Physical conformation suggests that the quartz monzonite arose from depth beneath the western part of the pluton, found a set, or sets, of low-angle fractures in the country rock, then spread laterally by forcibly lifting its roof.

INTRODUCTION

The name Curecanti was applied by J. Fred Hunter, in a paper published posthumously (1925, p. 49), to a sublenticular body of Precambrian quartz monzonite centered in the rugged Black Canyon of the Gunnison River at Curecanti Needle, about 4½ miles downstream from Blue Mesa damsite near Sapinero, Colo. (fig. 1). Curecanti Needle is a spirelike monolith nearly 800 feet high and an apt type locality for this rock.

Besides the main body of rock centered at Curecanti Needle, many smaller bodies of similar rock crop out in adjacent parts of the Black Canyon. These bodies are plainly consanguineous with the main body and are regarded as Curecanti Quartz Monzonite also, although they differ slightly in composition and seem to have been intruded somewhat earlier. Some have a weak foliation that is lacking in the main body, but, in general, they are indistinguishable in hand specimen.

The following report concerns primarily the body of rock, hereafter called the Curecanti pluton, centered at Curecanti Needle. Minor bodies of similar rock are mentioned only insofar as they pertain to the discussion of the Curecanti pluton.

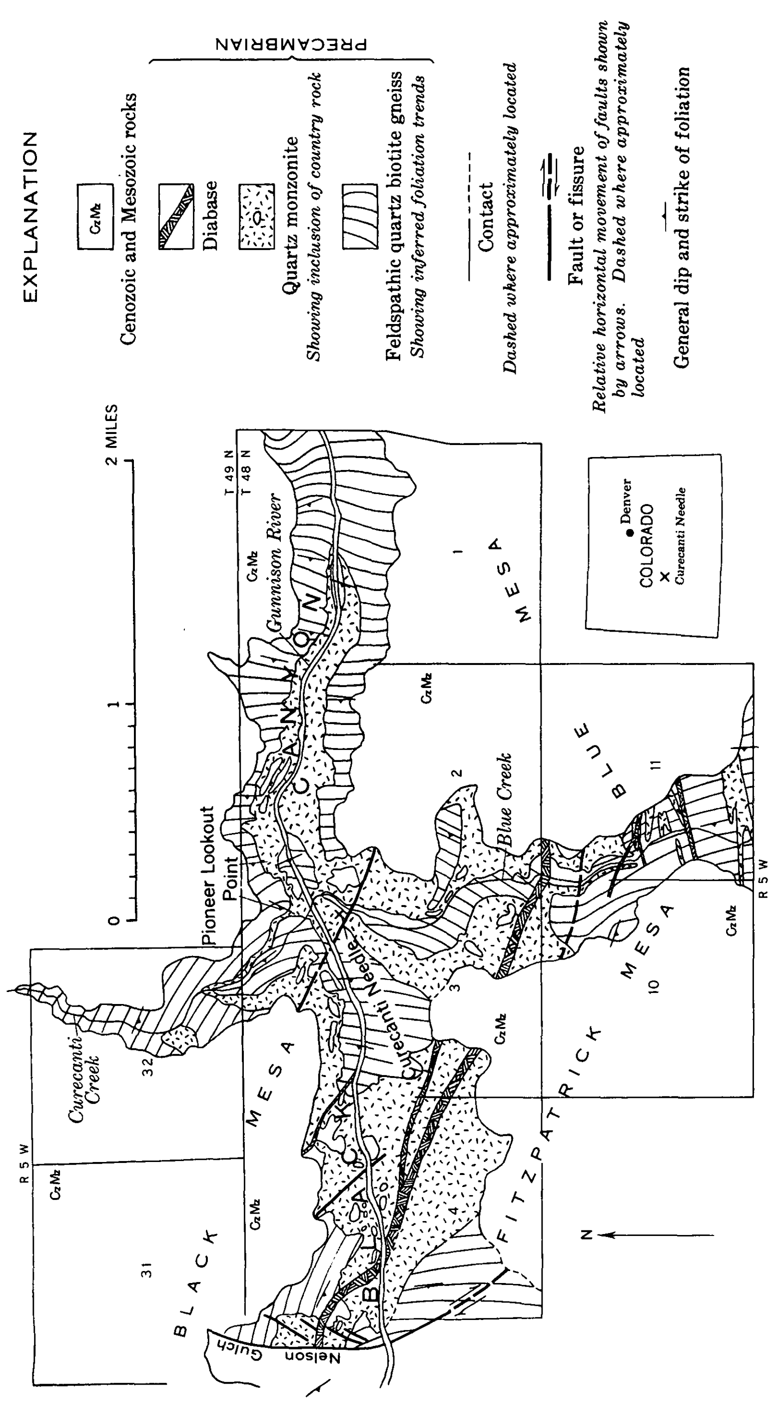

FIGURE 1.—Geologic map of the Curecanti pluton, Gunnison County, Colo.

The Curecanti pluton was studied as a part of an investigation of the geology of the Black Canyon and its vicinity. This report is a byproduct of that study; fieldwork is still (1962) in progress in some parts of the area.

GEOLOGIC SETTING

The Black Canyon of the Gunnison is an outstanding example of superposition (Atwood and Mather, 1932, p. 60; Thornbury, 1954, p. 116). The Gunnison River has entrenched itself through a thick pile of middle to upper Tertiary volcanic and Mesozoic sedimentary rocks into the hard crystalline Precambrian core of the Gunnison uplift. This uplift is a Laramide structure, mainly an upfaulted but partly an arched block, between the West Elk Mountains on the northeast, the San Juan Mountains on the south, and the Montrose trough on the west. The uplift was beveled flat by Tertiary erosion prior to later Tertiary volcanism. Present physiographic expression is due chiefly, if not entirely, to postvolcanic differential erosion.

Crystalline rocks of Precambrian age in the Black Canyon area consist chiefly of gneisses, quartz-mica schists, amphibolites, and quartzites—all of which have been metamorphosed to sillimanite grade and intruded by countless dikes of pegmatite, numerous bodies of quartz monzonite, and a few dikes of diabase and lamprophyre. Granodiorite and quartz diorite are minor variants of the quartz monzonite. The general order of intrusion is pegmatite→lamprophyre→quartz monzonite→most of the pegmatite→Curecanti Quartz Monzonite→pegmatite and minor aplite→and diabase. Country rock intruded by the Curecanti pluton consists chiefly of migmatitic biotite-quartz-microcline-plagioclase-gneiss.

Metasedimentary rocks in the Black Canyon are closely folded on a large scale. They are intricately folded on a small scale also, although the gross structure in the vicinity of the Curecanti pluton is homoclinal. Dips there are chiefly to the west and southwest at moderate to steep angles; the pluton intrudes the west limb of a northward-plunging anticline.

Precambrian rocks in the Black Canyon area are overlain by Upper Jurassic rocks or, locally, by Tertiary volcanic rocks. Lower and middle Paleozoic rocks are preserved in adjacent areas, but they were eroded from the Black Canyon area after Pennslyvanian uplift of the ancestral Uncompahgre highland. This highland was reduced to a peneplain before Jurassic time. The buried peneplain, now seen in the unconformity at the canyon rim where it is partly exhumed by erosion, is one of the more impressive geologic-physiographic features of the area. Below this rim, critical relations of the Curecanti pluton are exposed in the sheer canyon walls.

PETROGRAPHY

The Curecanti pluton consists mainly of sodic quartz monzonite having a silica content close to that of an average granite. Hunter (1925, p. 49), in fact, called the rock granite, although his modal analyses suggest that it should be called quartz monzonite. Silica content is slightly higher in specimens from the Curecanti pluton than in those from the minor quartz monzonite bodies (table 1). The minor bodies, moreover, range more widely in composition. The rock of the pluton ranges from light gray to pink; in texture, general appearance, and composition it is relatively uniform—more so, as Hunter noted (1925, p. 59), than most other intrusive rocks of the Black Canyon area. It has medium grain (seriate grains are commonly 1 to 3 mm in diameter and rarely exceed 5 mm) and has allotriomorphic-granular texture. Modes of selected specimens from both the pluton and the minor related bodies are given in table 2.

TABLE 1.—*Chemical analyses, in percent, of Curecanti Quartz Monzonite*

Sample 1 analyzed by V. C. Smith, by standard method. Samples 2–6 analyzed by Paul Elmore, Ivan Barlow, Gillison Chloe, and Samuel Botts, by rapid method]

	1	2	3	4	5	6
SiO_2	74.99	75.6	75.9	74.8	73.2	73.5
Al_2O_3	13.66	13.9	13.7	13.7	14.3	13.9
Fe_2O_3	.38	.38	.40	.3	.6	.5
FeO	.61	.31	.39	.66	1.0	1.2
MgO	.12	.21	.12	.19	.22	.33
CaO	.80	.60	.60	.64	1.5	1.3
Na_2O	3.58	4.1	3.7	3.3	3.3	3.5
K_2O	4.91	4.4	4.7	5.3	4.7	4.7
H_2O	.28	.32	.24	.33	.44	.36
TiO_2	.06	.03	.06	.06	.20	.19
P_2O_5	.04	.03	.06	.09	.06	.05
MnO	.05	.08	.11	.05	.05	.06
CO_2	.02	$<.05$	$<.05$	$<.05$	$<.05$	$>.16$
	99.50	100.01	100.03	99.47	99.62	99.75

Samples collected from (samples 2 and 6 collected in Curecanti Needle quadrangle outside area shown in fig. 1):
1. Curecanti pluton, canyon bottom just east of Curecanti Creek.
2. Curecanti pluton, east rim above Blue Creek west of U.S. Highway 50.
3. Curecanti pluton, road level in canyon bottom, west end of pluton.
4. Curecanti pluton, canyon floor about 1 mile west of Curecanti Needle.
5. Large dike at adit, SW¼SW¼ sec. 1, T. 48 N., R. 6 W.
6. Small dike with pegmatite core, Black Canyon 1½ miles west of Myers Gulch.

Principal mineral constituents of the Curecanti Quartz Monzonite (samples 1–6, table 2) are in order of descending abundance, sodic oligoclase (about An_{12}), quartz, and microcline. In some of the minor rock bodies, the plagioclase is as calcic as andesine. The rock is predominantly quartz monzonite, although some minor bodies are granodiorite, and border variants of some bodies are as mafic as diorite.

Minor constituents are muscovite and biotite—together comprising about 7 percent of the rock—hornblende (rarely present), and traces of garnet, sphene, apatite, opaque minerals, and zircon. Epidote is a common deuteric mineral. Garnet in euhedral grains as much as 4 mm across is a common minor accessory of the Curecanti pluton, but it is rare or lacking in most of the minor rock bodies.

TABLE 2.—*Modes (volume percent) of Curecanti Quartz Monzonite*

[Other constituents: Apatite, epidote, garnet, opaque minerals, sphene, zircon, and, rarely, hornblende]

Sample	Quartz	Microcline	Oligoclase	Muscovite	Biotite	Other constituents	Total
Samples from Curecanti pluton							
1	28.6	33.5	30.4	4.6	1.0	1.4	99.5
2	33.4	28.8	34.4	1.6	1.6	.4	100.2
3	31.7	28.0	34.3	3.7	2.3	Tr.	100.0
4	25.5	25.5	39.5	4.0	5.5	Tr.	100.0
5	32.7	29.7	30.6	1.8	4.5	.7	100.0
6	32.3	23.3	39.3	3.3	1.0	.6	99.8
Average	30.7	28.1	34.7	3.2	2.6	.5	99.9
Samples from minor bodies of quartz monzonite							
7	42.1	26.5	25.9	<1.0	3.5	<1.0	100.0
8	31.0	26.0	37.0	Tr.	6.0	Tr.	100.0
9	34.6	25.0	29.4	8.8	Tr.	2.2	100.0
10	27.5	27.5	32.5	3.5	9.0	Tr.	100.0
11	39.0	23.5	27.5	2.5	4.5	3.0	100.0
12	36.0	22.3	35.7	1.7	3.7	.6	100.0
13	42.0	21.5	23.5	3.5	9.5	Tr.	100.0
14	34.0	28.5	31.5	1.0	4.0	1.0	100.0

Samples collected from (samples 2, 8, 10, and 11 collected in Curecanti Needle 7½-minute quadrangle, outside area mapped in fig. 1):

1. East rim of Blue Creek near mouth.
2. East rim of Blue Creek west of U.S. Highway 50.
3. Road level at west end of main pluton, floor of Black Canyon.
4. Canyon floor about 1 mile west of Curecanti Needle.
5. Canyon floor 500 feet east of mouth of Curecanti Creek.
6. North rim of Black Canyon 1.1 miles west-northwest of Curecanti Needle.
7. West slope of Fitzpatrick Mesa.
8. Blue Creek at Half Way House.
9. NE¼ sec. 2, T. 48 N., R. 5 W. Grades into pegmatite.
10. Dike-cutting amphibolite 1½ miles east of mouth of Cimarron Creek.
11. North slope of Black Canyon 2 miles east of mouth of Cimarron Creek.
12. Black Canyon floor, NW¼SE¼ sec. 2, T. 48 N., R. 6 W.
13. Black Canyon floor, NW¼SE¼ sec. 2, T. 48 N., R. 6 W.
14. Large dike at adit, SW¼SW¼ sec. 1, T. 48 N., R. 6 W.

A distinctive alaskite variant borders the Curecanti pluton on the northwest at Nelson Gulch. This rock, a moderate reddish-orange medium-grained albite alaskite, occurs nowhere else in the Black Canyon. Under the microscope it is seen to consist of albite (70 percent), quartz (30 percent), and a trace of epidote. Hematite dust diffused through the albite gives the rock its reddish-orange color. The rock has an allotriomorphic-granular texture, but it is deformed internally in that many of the grains are marginally granulated and the albite lamellae are bent and fractured. The alaskite is partly

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separated from the quartz monzonite by a northeastward-trending zone of en echelon fractures.

SHAPE AND CONTACT RELATIONS

The Curecanti pluton differs fundamentally in shape and size from the smaller bodies of similar rock. This difference is stressed here to emphasize the pluton's unusual shape and contact relations. The minor intrusive bodies are irregularly elongate in plan and in vertical section. In general they are 5 to 10 times longer than wide. Their areas of outcrop range from a few tens of acres or less to a few hundreds of acres. Some very small ones are dikelike. Most of the minor bodies are elongate in a westerly direction and cut the foliation of the country rock—which has a general northerly trend—at wide angles. Contacts are steep and sharp.

In contrast, the Curecanti pluton is a sublenticular mass 3½ miles across west to east and 2 miles across north to south (fig. 1). Most of it is concealed by other rocks, but its general three-dimensional form can be inferred from excellent exposures in the walls of the deep canyons of the area. Its overall shape is visualized best with the aid of the stereogram (fig. 2). More detailed features of the contacts and wallrock relations are shown by sketches (fig. 3). The pluton is broadly horizontal and has subparallel lower and upper contacts. Its upper contact is well exposed in many places, particularly between Curecanti Creek and the east end of the pluton in the Black Canyon (figs. 3 and 4*A*). Its lower contact is well exposed locally but is concealed by talus in some places and is below drainage in some others. In the east wall of the canyon of Curecanti Creek, in both walls of the Black Canyon at various points, and in both walls of the canyon of Blue Creek, the roof and floor of the pluton are well exposed (fig. 4*B*). The pluton tapers unevenly to the north, east, and south from those places, and all but wedges out in full view in the exposed canyon walls.

The pluton gradually thickens westward from Curecanti Needle along the Black Canyon. A mile west of Curecanti Needle it reaches from river to rim in one continuous exposure—a vertical distance of about 1,300 feet. The floor passes below river level to an unknown depth, and the roof is partly stripped away by pre-Jurassic erosion, so that quartz monzonite is overlain unconformably by Jurassic rocks. Roof pendants, however, indicate that little of the upper part of the pluton has been removed. Near the west margin the roof is still intact; it dips first gently then steeply outward beneath the overlying gneiss (fig. 3*C*).

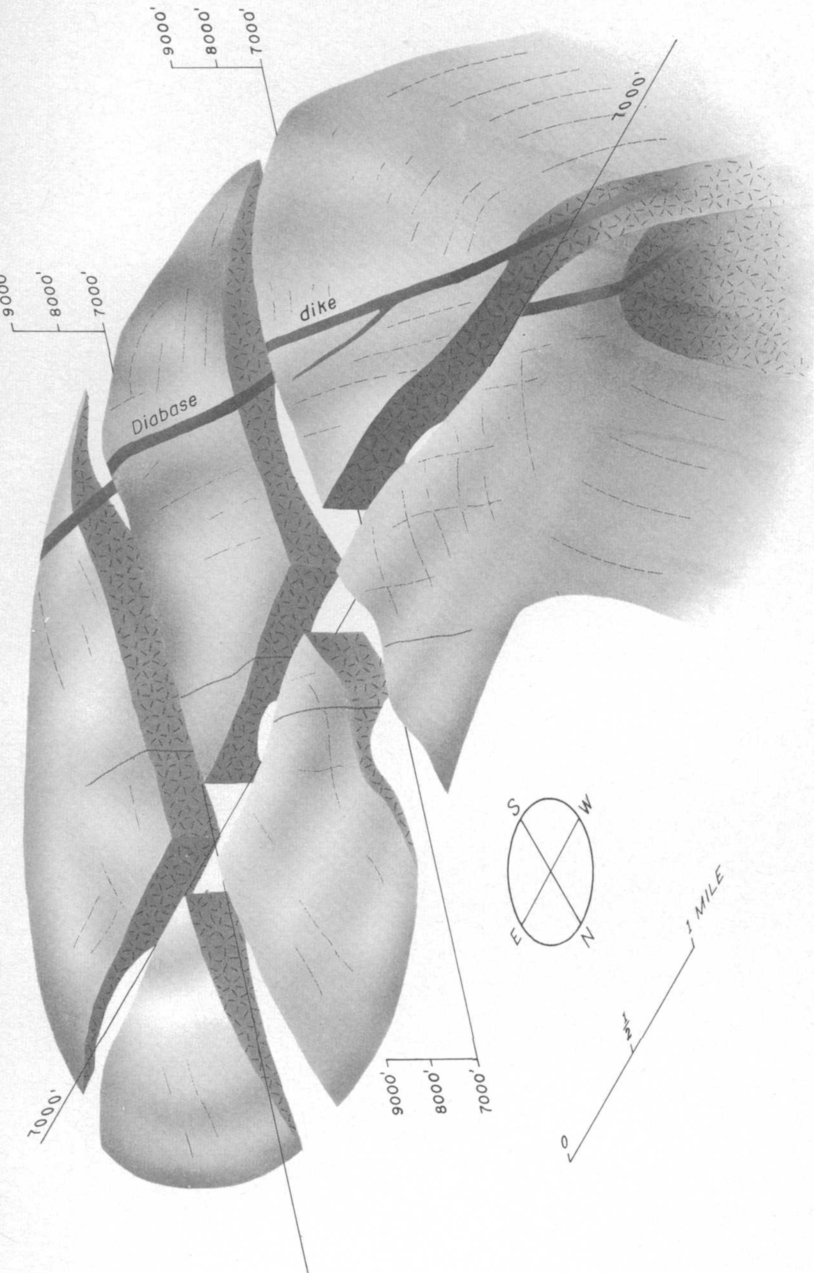

FIGURE 2.—Stereogram of the Curecanti pluton showing generalized restored form of the uneroded body.

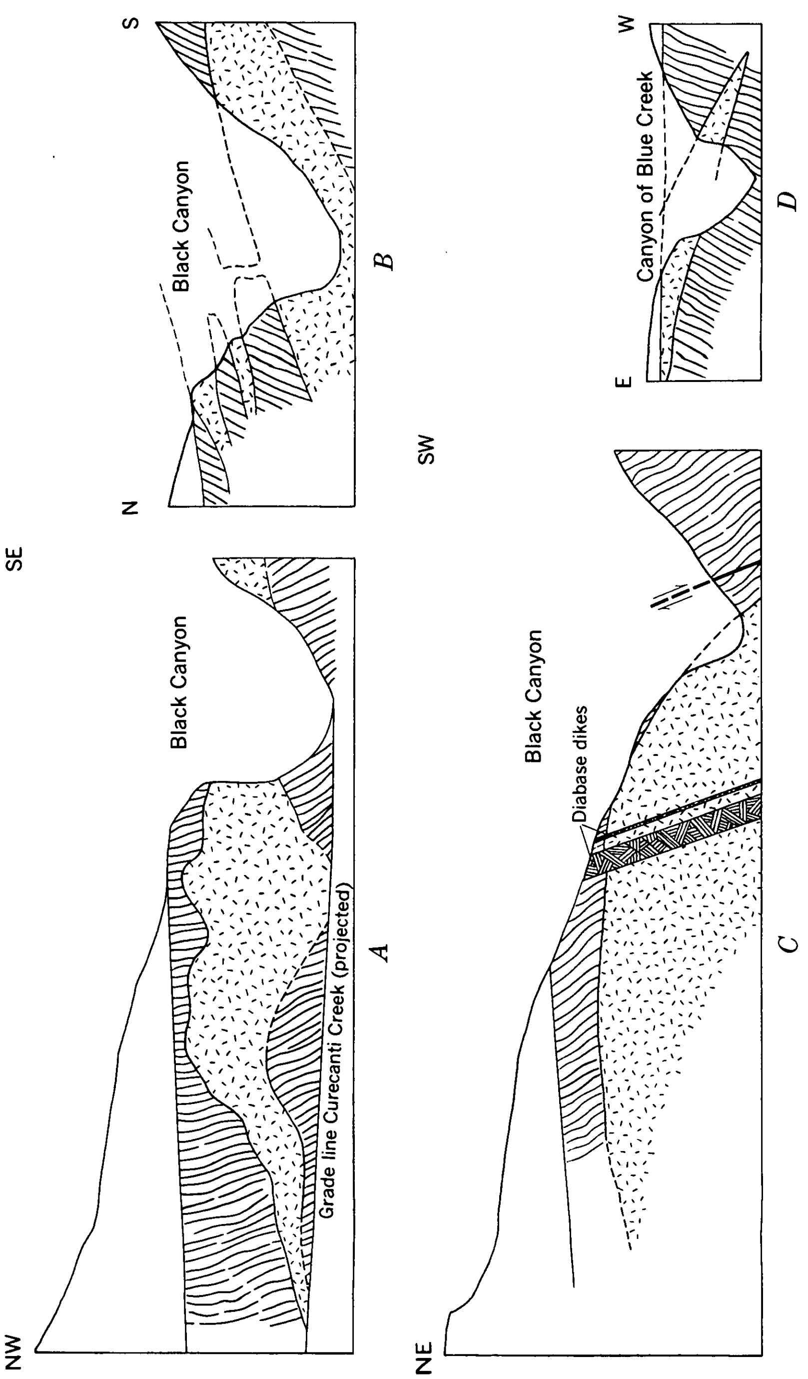

FIGURE 3.—Diagrammatic contact relations of Curecanti pluton, based partly on field sketches. *A*, East wall of Curecanti Creek below Pioneer Lookout Point, viewed from Black Mesa. *B*, Black Canyon, just upstream from Pioneer Lookout Point, looking upstream. *C*, Black Canyon, just upstream from Nelson Gulch, looking upstream. *D*, Blue Creek, 1¼ miles south of Curecanti Needle, looking upstream.

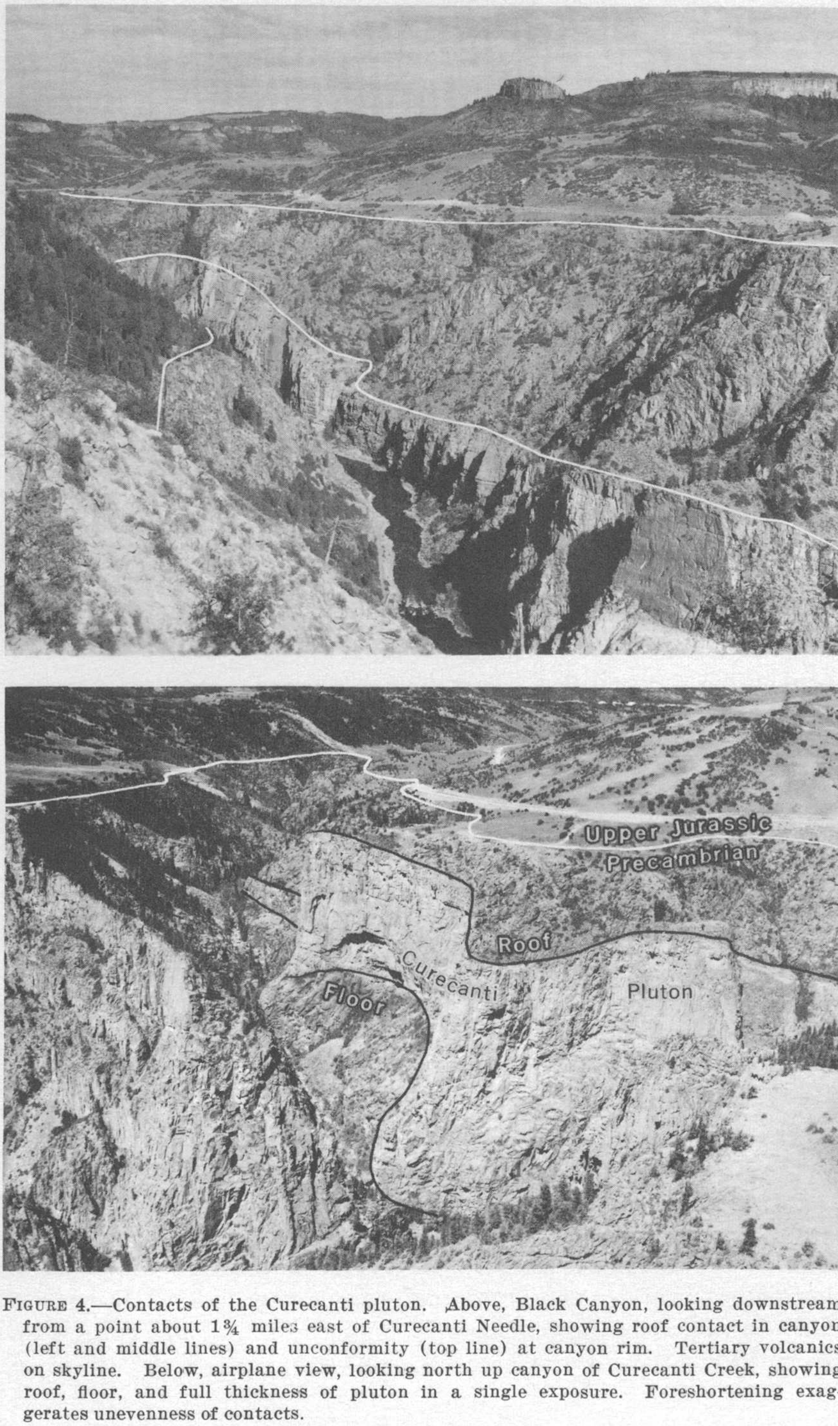

FIGURE 4.—Contacts of the Curecanti pluton. Above, Black Canyon, looking downstream from a point about 1¾ miles east of Curecanti Needle, showing roof contact in canyon (left and middle lines) and unconformity (top line) at canyon rim. Tertiary volcanics on skyline. Below, airplane view, looking north up canyon of Curecanti Creek, showing roof, floor, and full thickness of pluton in a single exposure. Foreshortening exaggerates unevenness of contacts.

Thus it is evident that the general shape of the Curecanti pluton is similar to that of a rather flat laccolith or a very thick tapered sill. The pluton differs from a laccolith or a sill, however, in one important respect—it is wholly discordant in relation to the intruded rock. Its sharp contacts, in both its roof and floor, truncate the foliation of the country rock at wide angles (figs. 3 and 4). The foliation, though highly variable, is generally steep. The contacts, besides being discordant, are expectably less regular than those of typical laccoliths, inasmuch as the intruded rock itself lacks the regularity of the bedded sedimentary rocks into which most laccoliths are injected. To the extent that most laccoliths supposedly are fed by relatively narrow conduits, the Curecanti pluton also is different. It has a well-defined, though uneven, floor under much of its outcrop, but it appears to have broad and deep roots in its western part. This configuration, however, is not distinctive inasmuch as the classic laccoliths of the Henry Mountains exhibit broad tonguelike feeders and other highly varied relationships to sources (Hunt, 1953, p. 141). The chief and most compelling difference is the discordant contact relationship.

INCLUSIONS

Inclusions are sufficiently abundant in some parts of the Curecanti pluton to comprise a distinctive attribute (Hunter, 1925, p. 51), and they indicate that stoping played a significant, though subordinate, part in the intrusion process. These inclusions consist mainly of feldspathic quartz-biotite gneiss similar in all lithologic respects to the country rock in the roof and floor of the pluton. They are angular and sharply bounded, and show little indication of assimilation. They range in size from a fraction of an inch across to hundreds of feet. The largest and most abundant inclusions center around Curecanti Needle, particularly in the north wall of the Black Canyon west of the needle and in the canyon of Blue Creek where they are especially well exposed in the sheer east wall (fig. 5). Very large inclusions can be seen across both canyons from the rims of Fitzpatrick Mesa. The thicker part of the pluton farther west contains fewer inclusions, as do the thin tapered edges of the pluton upstream along Blue and Curecanti Creeks and east along the Black Canyon.

Near Curecanti Needle are a few inclusions of dark-gray quartz monzonite. This rock is similar to dikes and small intrusive masses elsewhere in the Black Canyon. It resembles the Curecanti Quartz Monzonite texturally and petrographically except in its darker color, which is caused by proportionately more biotite. Possibly it is an earlier differentiate of the Curecanti magma.

In the lower mile or two of the canyon of Blue Creek (fig. 5), large tabular inclusions in the quartz monzonite appear to be sundered fragments of wallrock forced apart by the intruding magma, but subjected to minimal settling. In other words, the magma seems to have made its way into preexisting low-angle fractures by forcibly spreading them, rather than by passively occupying space made by foundering blocks.

Relationships similar to those at Blue Creek are shown on the north wall of the Black Canyon about ½ to ¾ mile east of Pioneer Lookout Point where large tabular inclusions separate the quartz monzonite into thick flat dikelike sheets (fig. 3*B*).

Minor irregularities in some places in the contour of the roof are attributed to stoping. At Pioneer Lookout Point, for example, a block-shaped cupola of quartz monzonite stands high above the general level of the pluton and seems to occupy space voided by a sunken block of roof rock.

Just east of Curecanti Needle, a very large mass of dark gneiss extends about a quarter of a mile along the bottom of the canyon and protrudes several hundred feet upward into both canyon walls. This rock mass was believed by Hunter (1925, p. 51) to be a huge

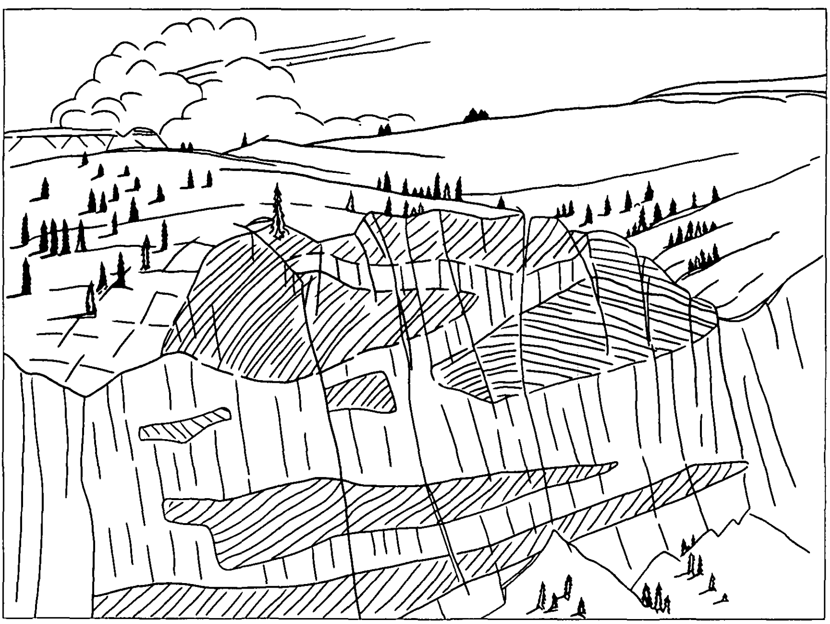

FIGURE 5.—Canyon of Blue Creek, east wall, half a mile south of Curecanti Needle. Large inclusions of feldspathic quartz-biotite gneiss in Curecanti Quartz Monzonite. Cliff is about 600 feet high. From photographs and field sketches.

inclusion, but it is regarded here as part of the irregular floor of the pluton. Its foliation accords with that in the roof of the pluton directly overhead at Pioneer Lookout Point and with the general trend in both the roof and floor in adjacent areas. Moreover, it contains lamprophyric dikes which are truncated by the Curecanti pluton but which crop out in the roof rocks above and have the same attitude and projection in the roof as in the canyon floor. Such a large mass of rock could hardly have settled hundreds of feet from the roof of the pluton without undergoing appreciable rotation; it must be part of the floor.

FRACTURES

Dominant high-angle fracture trends in the Black Canyon area are west-northwest and north-northeast. These trends dominate in the Curecanti pluton also. For reasons that will not be enlarged upon here, these fractures are regarded as a system of shears caused by a left-lateral couple in the earth's crust in the vicinity of the Black Canyon. Some fractures formed long before the Curecanti pluton was emplaced, but many formed afterward. Earlier formed high-angle fractures may have helped guide the Curecanti magma from depth, but they had little influence on its final emplacement. Some of the minor quartz monzonite bodies, however, are clearly controlled by high-angle fractures.

Several major faults of the Black Canyon area are parallel to the west-northwest trend, including the Cimarron fault of Hunter (1925, p. 88) and certain faults or fracture zones that cut the Curecanti pluton, as shown on figure 1. Some of these faults have demonstrable lateral displacements, and some clearly moved more than once after the Curecanti pluton was emplaced. Most diabase dikes of the area also trend west-northwest, some in fractures that cut the Curecanti pluton.

Two sets of steep conjugate joints coincide with the regional system and are the most conspicuous fractures in the pluton. These joint sets are believed to be shear fractures also, and inasmuch as they coincide with the regional fracture system, they probably are unrelated to the intrusion of the Curecanti magma and most probably are significantly younger. They are abundant in the metamorphic country rock and in pegmatite dikes that cut the country rock, but they are most regular in form and most closely spaced in the quartz monzonite. Many joints in the quartz monzonite seem to terminate against the country rock, but some extend the full height of the canyon walls through quartz monzonite and country rock alike. The greater regularity of the joints in the quartz monzonite is attributed to the homogeneity of the rock.

Low-angle joints, though relatively uncommon in the country rock of the Black Canyon, are widely distributed. Despite their infrequency they played a critical part in the emplacement of the Curecanti pluton by providing access for the invading magma.

Low-angle joints are common in the Curecanti pluton, but any seeming relation to the above described fractures probably is spurious. Three sets have been identified. One set of abundant, nearly horizontal joints dips gently northward about parallel to the old unconformity at the top of the Precambrian sequence. These joints may be release fractures formed by removal of a superincumbent load of rock during the pre-Jurassic erosion of the ancestral Uncompahgre highland. Low-angle fractures of primary origin, however, particularly in sheetlike or flat-topped plutons, have been described by Balk (1937, p. 39). Such fractures, as Balk pointed out, may be difficult to distinguish from secondary ones, unless they contain dikes or hydrothermal minerals related to the pluton.

In the thick part of the pluton west of Curecanti Needle, two sets of less-abundant low-angle joints dip westward and eastward at about 30°–40°. These joints, by their symmetry, seem to be shear fractures caused by horizontal movement, perhaps by viscous horizontal flowage of the intruding magma. Postmagmatic compression, however, might achieve identical results.

Sheeting subparallel to the canyon walls is very conspicuous, particularly in the thick western part of the pluton where it adds greatly to the illusion of sheerness in the walls and, hence, to the scenic grandeur of the canyon. Sheet fractures are regarded as superficial release or expansion joints formed by release of confining pressure as the canyon has been enlarged by erosion (Bradley, 1963, p. 522). Sheeting even conforms to the contour of some minor tributaries of the Black Canyon.

INFERRED MODE OF EMPLACEMENT

Very little concrete evidence has been found with which to postulate a mode of emplacement for the Curecanti pluton. The broadly lenticular shape of the body suggests that some subhorizontal structural feature, such as a set of low-angle joints, helped guide the invading magma. Low-angle joints are not plentiful in the adjacent country rock, but neither are they rare.

High-angle fractures clearly existed at the time of intrusion—some had been filled by earlier formed lamprophyre dikes and by minor bodies of quartz monzonite—but for some unknown reason they were very subordinate as channelways for the main Curecanti magma, at least in the depth zone where the pluton finally was emplaced. Perhaps horizontal pressure kept them tight. To a limited extent, they probably helped loosen blocks of rock suspended in the roof, and may have promoted a certain amount of piecemeal stoping as, for example, at Pioneer Lookout Point. But the infrequency of cupolas, steep apophyses, and dikes around and above the pluton points toward the subordination of high-angle fractures as channelways.

In the east wall of Curecanti Creek, approximate parallelism in the outline of the roof and floor of the pluton (fig. 3A) seems to suggest a wedging action on the part of the intruding magma, modified in detail, however, by stoping. Similar action is suggested in the canyon of Blue Creek and in the Black Canyon east of Pioneer Lookout Point, where the magma seems to have invaded preexisting low-angle fractures by forcibly spreading them apart.

Intrusive relations of this sort are best attributed to posttectonic hydrostatic injection under a moderate thickness of cover—not too thick for the magma to lift its own roof and not so thin as to cause extensive fracturing and foundering of the roof. The gentle archlike form of the roof, viewed as a whole, substantiates this supposition. The fact that the roof lacks the steep margins generally associated with laccolithic intrusion (except locally at the western margin of the pluton) suggests a relatively rigid, competent roof. In view of its lithology and structure, the crinkled feldspathic quartz-biotite gneiss of the roof should have behaved as a relatively rigid mass at moderate depths. It should have been much more rigid than the sharply domed roofs of the Tertiary laccoliths of the Colorado Plateau (Cross, 1894; Hunt, 1953, p. 141, 212).

As already noted, the western part of the Curecanti pluton extends below river level in the Black Canyon, and the roof plunges steeply downward (fig. 3C). This part of the pluton may be deeply rooted and may indicate, therefore, the chief source and direction of emanation of the magma. In the absence of even vague flowage features to indicate flow direction, the physical conformation of the pluton alone suggests that the magma arose from depth beneath the western part of the pluton, found a set of low-angle fractures in the country rock, then spread laterally eastward, northward, and southward by forcibly lifting its roof.

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