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STRUCTURE AND PETROLOGY OF COCHETOPA PLUTON AND ITS METAMORPHIC WALLROCKS, SAGUACHE COUNTY, COLORADO

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INTRODUCTION

The Cochetopa Granite pluton and its metamorphic wallrocks are exposed in an erosional window that has been cut through the Jurassic Junction Creek Sandstone (fig. 1). The area described in this paper is bisected by northward-flowing Cochetopa Creek and includes approximately 33.7 km^2. Cochetopa Granite pluton includes about 14.5 km^2 and the metamorphic wallrocks the remainder. Nine different lithologically distinct mappable units are present as well as dikes of pegmatite and aplite.

The major lithologic units are granite-gneiss (ggn), porphyroblastic gneiss (Pgn), quartzite (qz), metadiorite (mdi), mixed zones (mz, and mz,), metagabbro (mg), Cochetopa Granite (Cg), and Cochetopa granite-gneiss (Cgn). Figure 2 shows the units in geological cross section.

PETROGRAPHY

Quartzite

The quartzite unit is massive, brownish black (SYR 2/1), very fine grained, and varyingly intimately laced with fine, narrow 1-30 mm subparallel bands that are parallel to relict sedimentary layering.

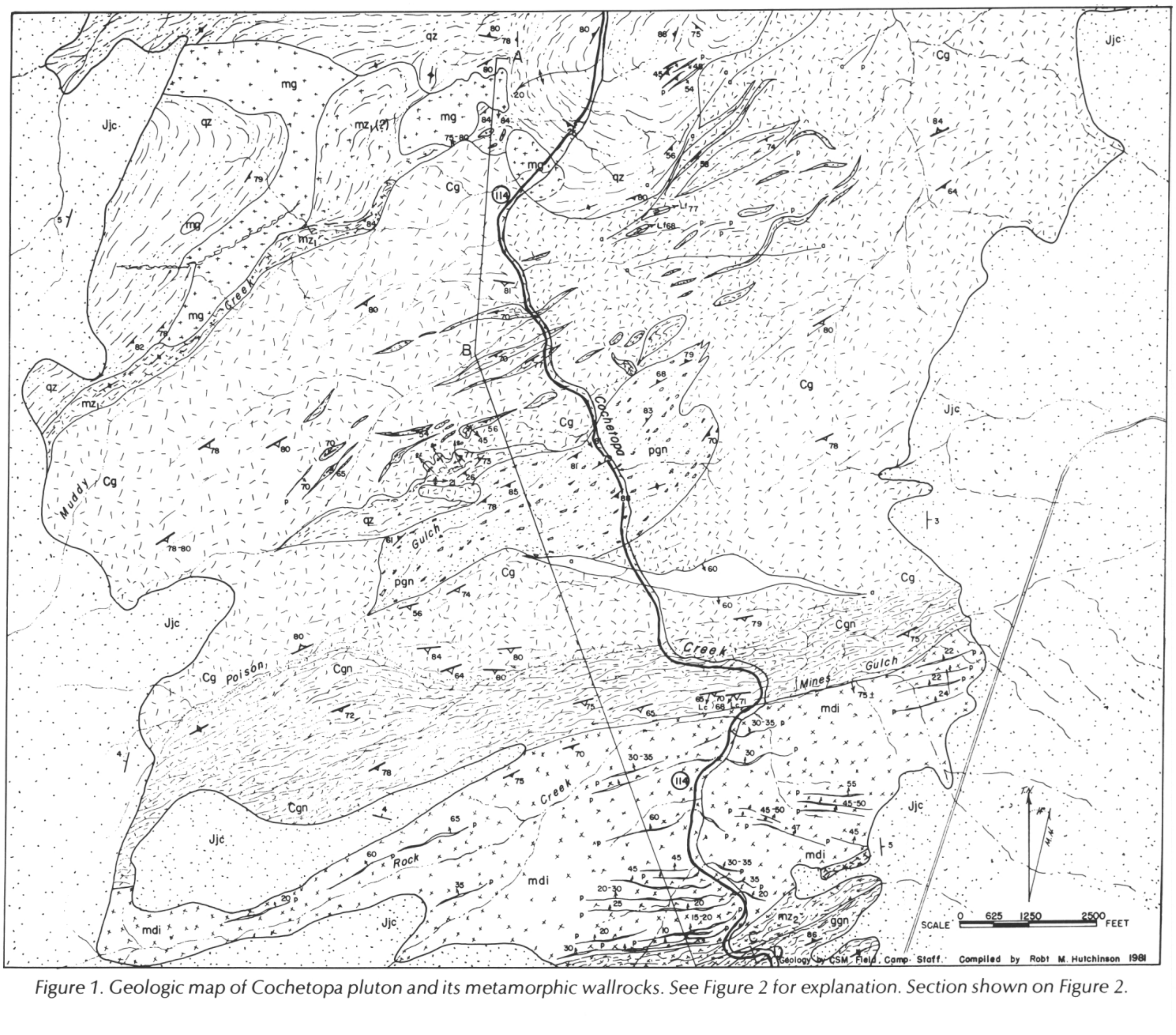


Figure 1. Geologic map of Cochetopa pluton and its metamorphic wallrocks. See Figure 2 for explanation. Section shown on Figure 2.

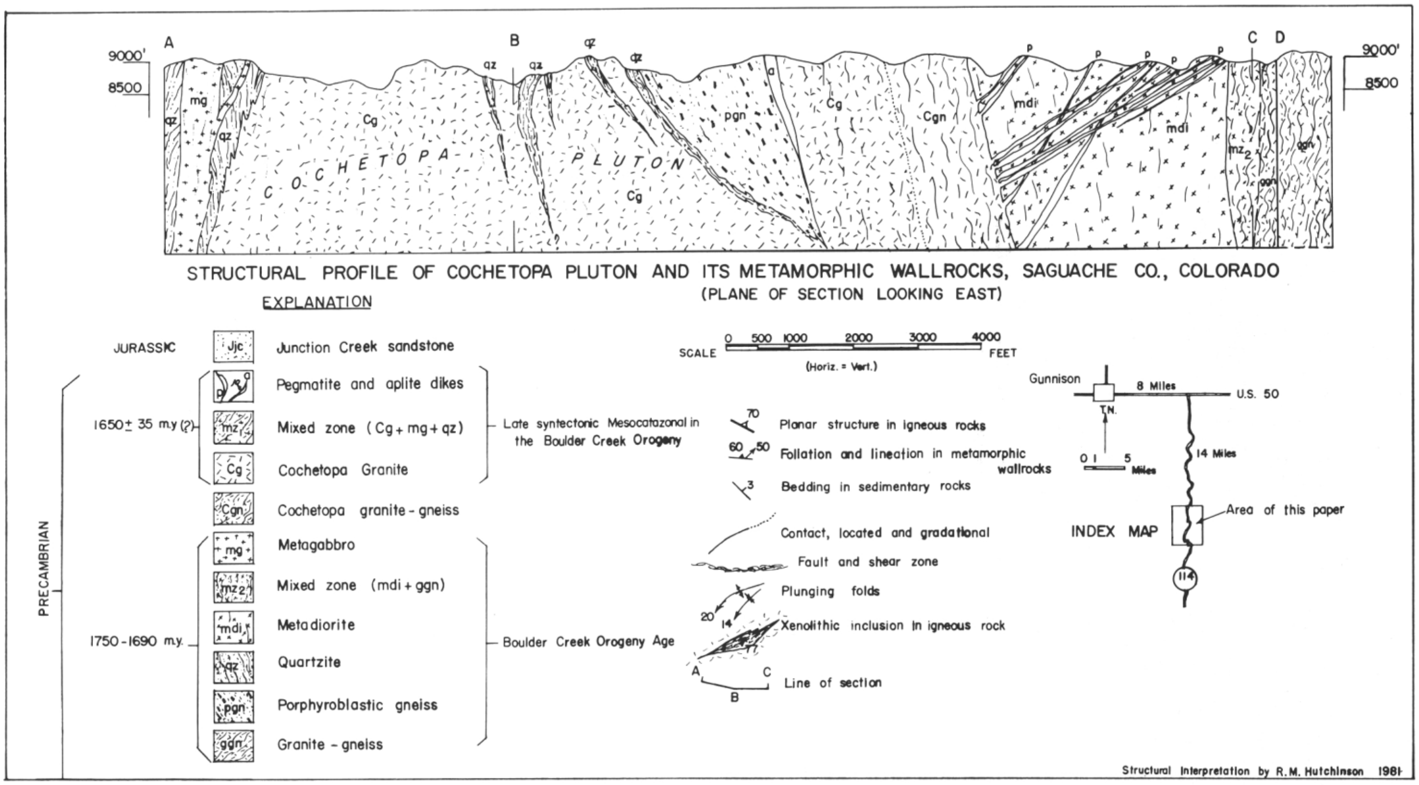


Figure 2. Structure profile of Cochetopa pluton and its metamorphic wallrocks. Line of section shown on Figure 1.

Texture of the quartzite is granoblastic, xenoblastic-granular, weakly lepidoblastic and gneissose. Gneissic layering and migmatizational layering vary in intensity throughout the unit. About two kilometers north of the area of the map shown on Figure 1, the massive quartzite is replete with circular blotchy areas of microclinization. As one approaches the Cochetopa pluton to the south, migmatization develops a banded structure and seems to become more abundant. The migmatization, however, is thought to have formed prior to emplacement of Cochetopa pluton. The quartzite is typically a biotite quartzite but also ranges to a hornblende-microcline-biotite-quartzite (Table 1 and fig. 3, photo 1).

Metagabbro

The texture of metagabbro is granoblastic, medium to coarse grained with blastoporphyritic poikiloblastic hornblende xenoblasts set in a fine- to medium-grained matrix or groundmass. The rock is greenish black (5 G 2/1). Some relict subophitic to ophitic texture is visible (Tables 1, 2 and fig. 3, photo 2). Anorthite content of the plagioclase averages about An„ with rare values up to An_{51}. Rock composition is intermediate between that of gabbro and diorite, leaning more toward diorite, but the rock is probably best classified as metagabbro.

Table 1. Modal composition of Cochetopa pluton and its metamorphic wallrocks. See Table 2 for rock description.

Rock Unit	qz	mgb	Cg	Cgn	pgn	aplite	mdio	mdio	mz_2	ggn
microcline	10	–	50	40–50	35–40	50–55	–	–	45–50	35–40
plagioclase	–	50–60	10	10–12	10–15	10	35–40	35	10–15	10–15
quartz	50–60	–	15–20	20	20–25	20–25	8–10	5–7	10–12	30–35
hornblende	2–3	30–35	–	–	–	–	25–30	50	10–12	–
biotite	25–30	–	8–12	10–15	15–20	5	7–10	5	10–15	10–12
muscovite	–	–	3	3	3	5	–	–	–	5
sphene	1	–	3–5	1	1	–	2	2	2–3	–
magnetite	1	–	trace	tr.	tr.	–	1	tr.	5	2
zircon	–	–	tr.	–	–	–	tr.	–	–	–
apatite	–	–	–	–	–	–	tr.	–	–	–
epidote	–	–	–	–	–	–	tr.	5	5	–
hematite	–	1	–	1	1	–	1	–	–	1
pyrite	–	1	–	tr.	tr.	–	1	–	–	–
fluorite	–	–	tr.	1	1	–	–	–	–	–
An-Content	–	An_{46}–An_{51}	An_{28}	An_{30}	An_{37}	An_{10}	An_{45}	An_{36}	An_{37}	An_{24}

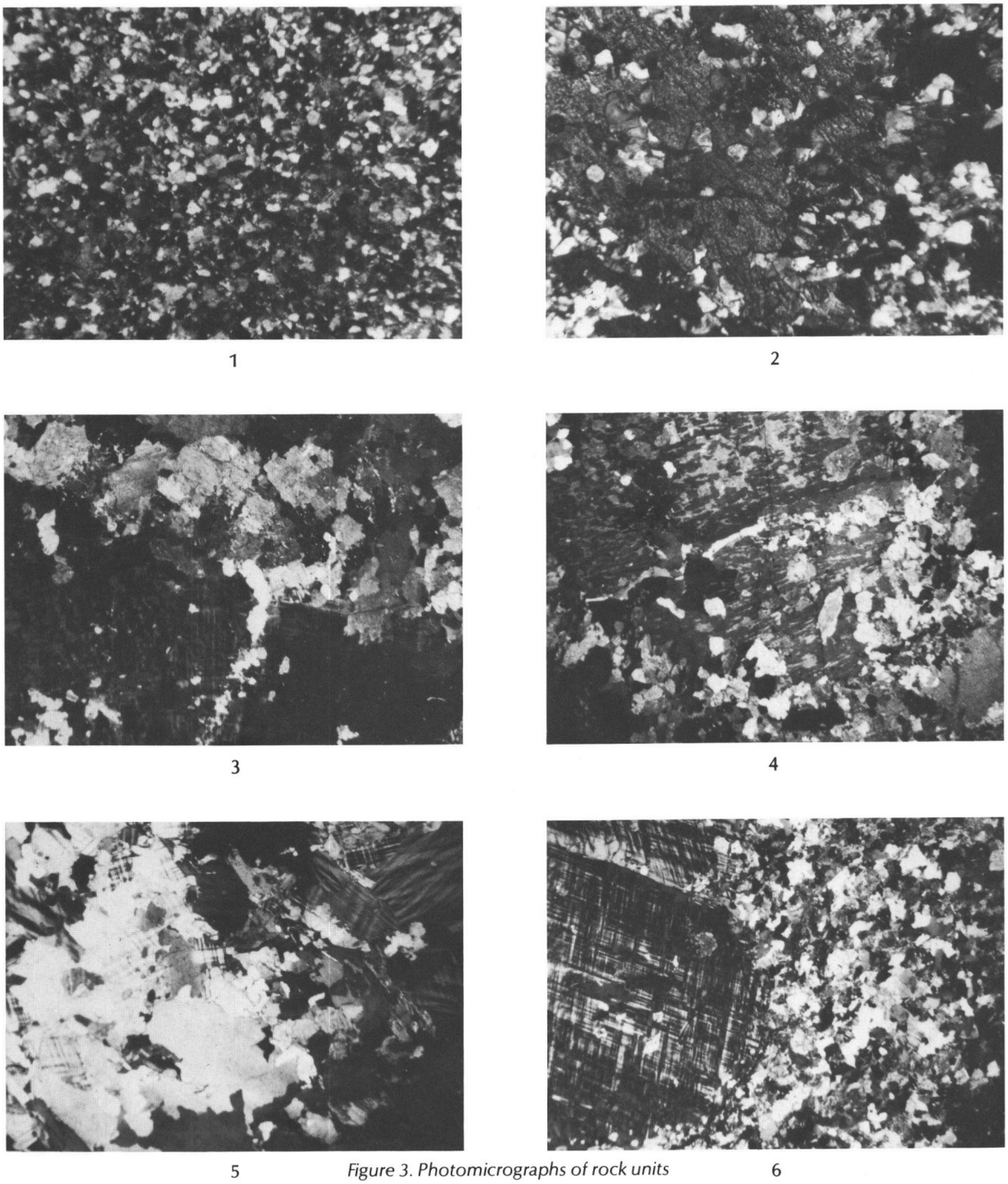


Figure 3. Photomicrographs of rock units

Photo 1—Quartzite from the northern part of the area, very fine grained, granoblastic, xenoblastic-granular. Crossed polars, × 10.

Photo 2—Metagabbro, granoblastic, medium to coarse grained. The field of view is occupied by a poikiloblastic blastoporphyritic xenoblast of hornblende which probably was originally augite. Crossed polars, × 25.

Photo 3—Cochetopa Granite showing granulation and recrystallization effects along grain boundaries of larger microcline grains. Crossed polars, × 25.

Photo 4—Cochetopa Granite showing granulation and recrystallization effects along grain boundaries of microcline-perthite. Crossed polars, × 25.

Photo 5—Cochetopa granite-gneiss showing weak planar foliation of biotite and allotrimorphic-granular texture. Crossed polars, × 25.

Photo 6—Porphyroblastic gneiss showing an idioblastic microcline porphyroblast surrounded by fine-grained granoblastic groundmass. Crossed polars, × 25.

Table 2. Description of rock units mapped in the Cochetopa pluton area.

Rock Unit	Description
qz	biotite quartzite to hornblende-microcline-biotite quartzite
mgb	metagabbro
Cg	peraluminous biotite granite (Cochetopa Granite)
mz_1	Cochetopa Granite with metagabbro and quartzite
Cgn	muscovite-plagioclase-biotite-quartz-microcline gneiss (Cochetopa granite-gneiss)
pgn	porphyroblastic-plagioclase-quartz-biotite-microcline gneiss or blastoporphyrtic meta quartz monzonite.
aplite	granite aplite
mdio	meta diorite to meta quartz diorite
mz_2	quartz-hornblende-biotite-andesine-microcline metasomite or granitized diorite to quartz diorite
ggn	muscovite-biotite-oligoclase-quartz-microcline gneiss or granite-gneiss

Cochetopa Granite

Cochetopa Granite is holocrystalline, hypidiomorphic-granular, medium grained, averaging about 3 x 6 mm, and moderate reddish brown (10R 4/6). The rock has a pleasing uniform appearance and would make an ideal decorative facing stone if it could be quarried in large enough blocks. Euhedral wedge and diamond-shaped sphene crystals are distributed more or less uniformly through the rock and are partly altered to leucoxene. Grain boundaries of the larger microclines are weakly to moderately cataclasized (fig. 3, photos 3 and 4). Narrow, elongate, polycrystalline aggregates of individual 0.2 x 0.3 mm microcline and plagioclase register the microfracturing, granulation, and recrystallization that has occurred. The rock is a peraluminous biotite granite.

Mixed Zone Rock (mz,)

No petrographic analysis was made of rocks from this unit. The Cochetopa Granite intruded and partially reacted with the metagabbro wallrock and to a minor extent with the quartzite. Feldspathization of the metagabbro has taken place, and the relict fine stratigraphic layering of the quartzite has been varyingly intruded concordantly by tongues and layers of Cochetopa Granite. This mixed zone ranges in thickness from 100 to 150 m.

Cochetopa Granite-Gneiss

This unit is considered a moderately cataclasized border facies of the Cochetopa Granite. Contact of Cochetopa Granite with the granite-gneiss is gradational over 180 to 300 m. The rock is holocrystalline, dominantly allotriomorphic-granular, medium grained, and moderate reddish brown (10 R 4/6). Biotite, muscovite, and anhedral, undulose quartz aggregates show increasing planar and linear alignment to the south as one approaches the contact of the metadiorite. Biotite is partly converted to muscovite. The rock is best classified as a biotite peraluminous granite-gneiss or cataclastic peraluminous granite-gneiss (fig. 3, photo 5).

Porphyroblastic Gneiss

Petrographic and fabric features seem to suggest a metamorphic rather than an igneous origin for this rock. Medium to coarse to very coarse porphyroblasts of idioblastic microcline show a weak to moderate planar alignment. They often occur in roughly aligned swarms over more than 100 m or they may be present in very minor amounts. Groundmass material is fine grained, granoblastic, xenoblastic-granular and contains an average of 20 percent biotite. Some locations may have up to 30 percent biotite. Texturally the groundmass might be described as having a salt-and-pepper appearance (fig. 3, photo 6). Except for the scattered pale yellowish brown feldspar phenocrysts the rock is olive black (5Y 2/1). The rock is best classified as porphyroblastic oligoclase-biotite-quartz-microcline salt-and-pepper gneiss. Should an igneous origin be ascribed to the rock then the best name would seem to be blastoporphyritic meta-quartz monzonite.

Granite Aplite

Granite aplite is present mainly as a large dike in the central part of the area (fig. 1). The dike is about 1600 m long, dips 60° SE and reaches a maximum thickness of about 200 m. Texture is holocrystalline, allotriomorphic-granular, very fine to fine grained and color is moderate yellowish brown (10YR 5/4). Muscovite and biotite are both present with the biotite somewhat altered to limonite (fig. 4, photo 1).

Metadiorite

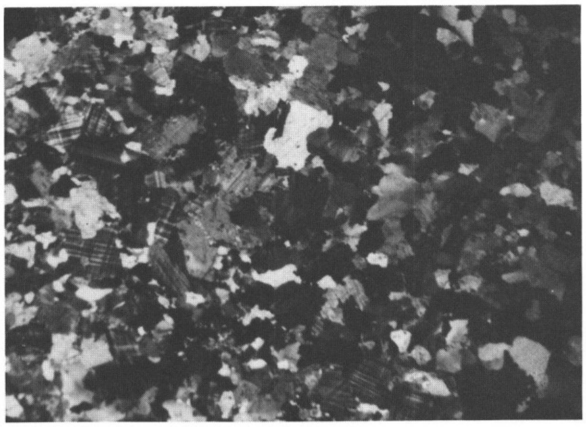
Grain size in the northern part of the metadiorite body is fine to medium grained but is dominantly medium grained in the southern part. Textures are xenoblastic-granular to xenoblastic-inequigranular. Color is grayish black (N2). A weak, barely perceptible fine streaky layering or banding is best seen on some exposures from a distance of 10 m or more. Within a hundred meters of the mixed zone (mz,) to the south, microcline enrichment appears between plagioclase and hornblende grains. The rock is a metadiorite to meta-quartz diorite. Some relict subophitic texture is present (fig. 4, photos 2, 3).

Mixed Zone Rock (mz,)

A mixed rock zone occurs between the metadiorite to the north and the massive granite-gneiss to the south. Textural and compositional variations are large and nonuniform throughout this mixed zone (fig. 4, photo 4). Xenolithic dark ferromagnesian-rich clot-like blocks and smaller fragments are subangular to subrounded to rounded. They are distributed unevenly throughout the mixed rock and range in composition from granodiorite to quartz monzonite to granite. Grain sizes vary from fine to coarse. Biotite and hornblende tend to be finer grained than feldspars which are hypidioblastic; the entire mixture presents a blotchy, indefinite textural appearance. Some parts of the mixed zone rock take on a skialithic appearance where there has been considerable feldspar enrichment. The rock is a quartz-hornblende-biotite-andesine-microcline metasomite or a partially granitized and metasomatized diorite to quartz diorite. There is a possibility of a fault existing between the metadiorite and the granite-gneiss.

Granite-Gneiss

The southern limit of the area is occupied by a dense, massive, streaky granite-gneiss. Texture is granoblastic, xenoblastic-granular, generally on the fine side of medium grained with a moderate gneissic streaking. Color is pale reddish brown (10R 5/4). Ovoidal to elongate streaky groupings of fine-grained black biotite are nonuniformly sparsely distributed along the foliation and gneissic layering (fig. 4, photo 5). Size of the biotite clusters is usually no larger than 2 x 3 cm and more commonly is smaller and considerably more elongate. The rock is a muscovite-biotite-oligoclase-quartz-microcline granite-gneiss.



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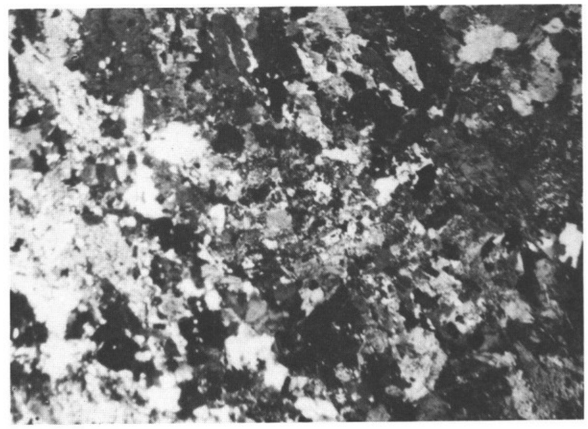

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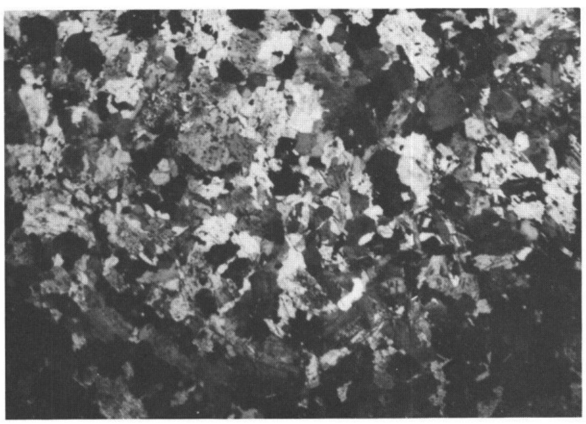

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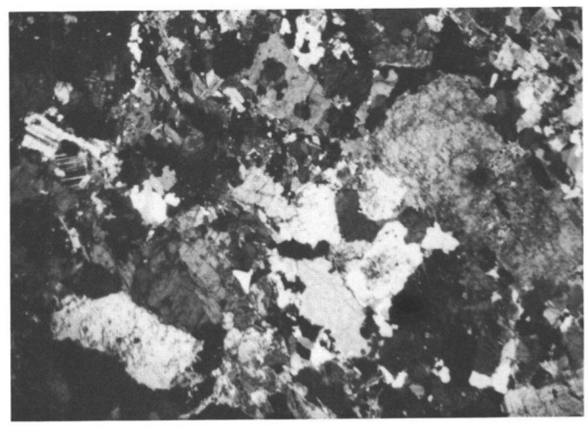

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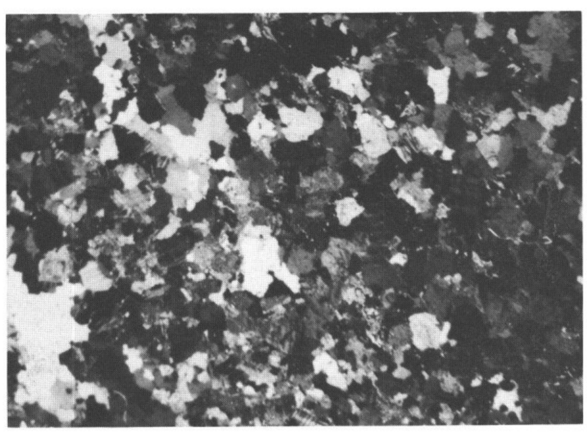

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Figure 4. Photomicrographs of rock units

Photo 1—Granite aplite from the large dike in the central part of the area. Texture is holocrystalline, allotriomorphic-granular, fine grained (aplitic). Crossed polars, × 25.

Photo 2—Metadiorite from the northern part of the rock unit about 200 m south of the contact between Cochetopa granite-gneiss and the metadiorite unit. Hornblende, plagioclase, and quartz are visible. Crossed polars, × 25.

Photo 3—Metadiorite from the southern part of the rock unit about 200 m north of the metadiorite-mixed zone (mz_2) contact. Crossed polars, × 25.

Photo 4—Mixed zone unit (mz_2) from the southern part of the area. Note the variation in grain size present between quartz (clear), hornblende, biotite and the feldspars. Crossed polars, × 25.

Photo 5—Granite-gneiss from the southern end of the area. Note the weak planar orientation of the biotite and the elongate, sutured mosaics of clear quartz. The planar foliation trends northwest in the photograph. Crossed polars, × 25.

STRUCTURE

Lithologic boundaries and foliations in Cochetopa pluton and its metamorphic wallrocks have a dominant trend of N. 50-80° E. and dips generally greater than 70-75° SE. Contact of the pluton with the metamorphic wallrocks on the north is generally concordant but is locally discordant (fig. 1). Prior to emplacement of the pluton the quartzite wallrock was strongly deformed and migmatized. Cochetopa granite also intruded and partially reacted with a metagabbro as well as with the quartzite. A more or less continuous, narrow zone of mixing of Cochetopa Granite with quartzite and metagabbro (mz,) is present.

Trend of the contacts and foliations of Cochetopa pluton and its wallrocks in the southern part of the area range N. 60-80° E. and dip generally steeper than 75° SE. Relatively large, more or less continuous dikes of granite pegmatite cut through the metadiorite and dip 10-50° north towards Cochetopa pluton (fig. 2). Planar foliation within the pluton is weak in its northern and central part but becomes increasingly stronger toward the contact with the metadiorite wallrock to the south.

Joints in Metamorphic Wallrocks

Schmidt equal-area net plots of poles perpendicular to joint sets in Cochetopa pluton and its metamorphic wallrocks show interesting and significant geometric differences. Joints in the metamorphic wallrocks have three dominant trends: (1) a joint set with a girdle maximum at N. 14° W. with dips varying 66° NE to 75° SW; (2) a joint set striking N. 60° E. to N. 76° E. with dips mainly 79-88° SE; and (3) a relatively flat joint set striking close to east and dipping 7-20° N. with a few joints dipping as much as 30° N. Some joint sets also dip 15-28° S. (fig. 5A). These three joint systems have formed in geometric response to the structural attitude of the varying lithologies present in the metamorphic wallrocks. The lithologic layering and formational contacts of the wallrocks have a general trend of N. 55-80° E. and a dip of 70-88° S.

Joints in Cochetopa Pluton

Joints within the Cochetopa pluton display a significant geometric and tectonic difference from those present in the metamorphic wallrocks (fig. 5B). Three sets of joints are present: (1) a major set oriented subperpendicular to perpendicular to the contact of the pluton with the metamorphic wallrocks; this set has a girdle polar maximum with a strike of N. 20° W. and dips ranging from 82° NE to 81° NW; (2) a set striking N. 50-82° E. dipping 30-45° SE; and (3) a set striking N. 42-70° E. and dipping 40-57° NW.

Geometric relation of these three joint sets to the sheetlike mode of emplacement of Cochetopa pluton suggests a genetic relationship between formation of the joint sets and emplacement of the pluton relative to its metamorphic wallrocks. The major joint set (1) is not only normal to the trend of the contact between the pluton and its wallrocks, but is also approximately normal to the general trend of the planar structures within the pluton.

A genetic interpretation of the orientation of joint sets (2) and (3) above would seem to indicate that they are marginal fissure-type joints related to movement of the magma sheet as it intruded upwards between the quartzite and metagabbro wallrocks to the north and the metadiorite to the south. Frictional drag along the solid wallrocks caused the magma to pull away from itself, and when the rock was solid enough to crack it did so in response to the internal stresses that accumulated during emplacement. The marginal fissures dip in the direction from which the magma column rose.

The apparent absence in Cochetopa pluton of the three joint sets present in the metamorphic wallrocks, and vice versa,

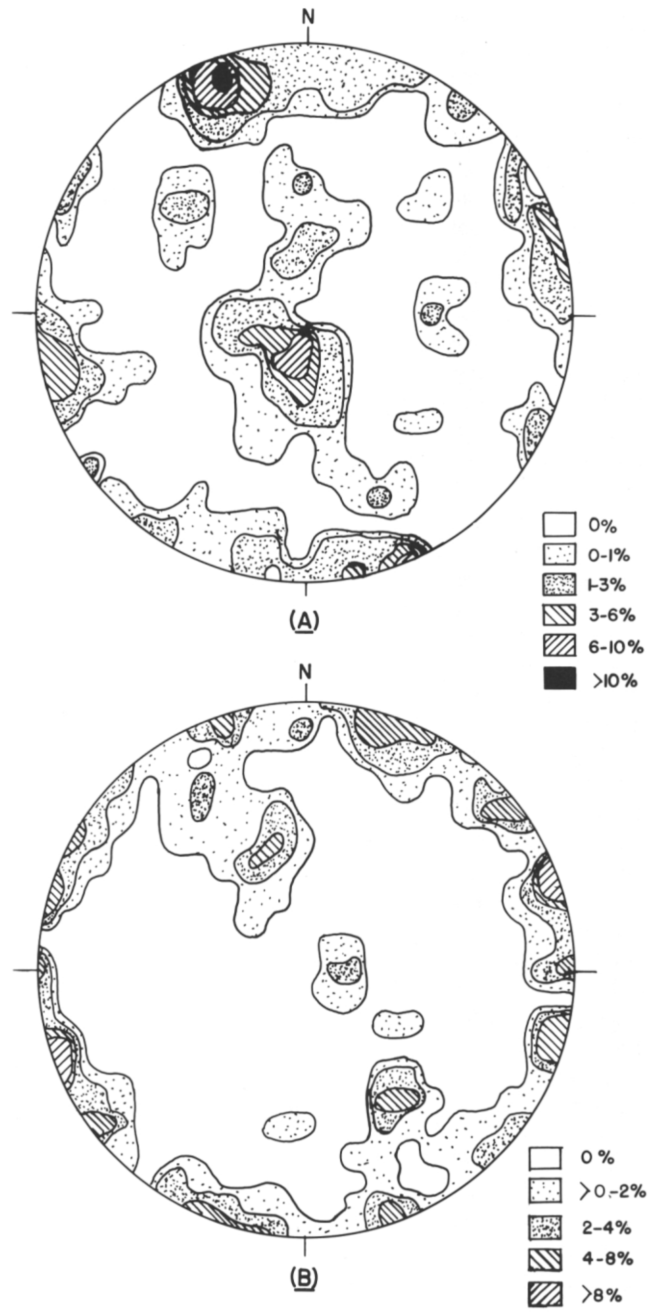

Figure 5. Petrofabric diagrams of joints in the Cochetopa Granite and its metamorphic wallrocks. A. 125 points in metamorphic wallrocks. B. 72 points in Cochetopa Granite.

indicates Cochetopa pluton was emplaced as a late syntectonic to possibly post-tectonic pluton during the waning stages of the Boulder Creek orogeny. Joint sets in the metamorphic wallrocks formed during the Boulder Creek orogeny and prior to emplacement of the pluton. It is believed that Cochetopa pluton then developed its own unique set of joints as it worked its way upward seeking out and following lithologic boundaries and planes of foliation of the metamorphic wallrocks.

EMPLACEMENT OF COCHETOPA PLUTON

Cochetopa pluton appears to be more lower mesozonal than catazonal, i.e., mesocatazonal, in its depth of emplacement. The granite body mainly was intruded concordantly to the structure and attitude of its metamorphic wallrocks and is an elongate, sheet-like body of undetermined length in the northeasterly direction. Thickness shows an increase from 2.2 km in the southwestern part of the pluton to 3.4 km in the northeast before it is covered by the Junction Creek Sandstone. Intense pre-batholithic folding of the quartzite unit on the northern flank of the pluton is responsible for some undulate planar and cross-cutting relationships between the granite and its wallrocks. Contact with the metadiorite on the southern flank is straight-planar and reflects the trend of the foliations in the metamorphic wallrocks.

The question of how the magma made room for itself is best answered by noting the many xenolithic inclusions of quartzite shown on Figures 1 and 2, of which about 70 percent have been mapped. Except for the large disc-shaped body of the porphyroblastic salt-and-pepper gneiss in the central part of the pluton, the xenoliths north of this body are characteristically long, narrow, septa-like inclusions of impure quartzite. These quartzite bodies show very little reaction with and minimum potash metasomatism by the surrounding Cochetopa Granite. The overall structural trend of the quartzite xenoliths is subparallel to that present in the quartzite wallrock on the north side of the pluton.

Emplacement of the magma was by forceful injection and magmatic stoping, although it was passive enough to preserve the general structural positions of the xenoliths relative to their wallrocks. The magma sheet rose slowly between the metadiorite and the quartzite units, passively yet forcefully inserting itself along planes of foliation and relict stratigraphic layering. Not only did the intrusion of granite magma completely engulf and isolate rib-like plates of the quartzite, but the emplacement of the pluton most probably made room for itself by forcefully pushing apart and opening up the many subparallel structural elements it was intruding. Evidence for shoving aside of the country rock for short distances around the pluton is hard to find because the pluton is mainly parallel to the structural trend of its metamorphic wallrocks.

Confirmative evidence that the granite magma was highly viscous and underwent high frictional drag along its wallrocks is shown by the swarm of parallel granite pegmatite dikes in the metadiorite. The dikes are fairly continuous over more than 100 m and dip 10° to 50° toward the pluton. Proximity of the pegmatite dikes to the Cochetopa pluton suggest that frictional drag of the rising magma caused a series of marginal fissure-type fractures to open up in the metadiorite wallrock and that these were readily occupied by late-stage pegmatitic solutions emanating from Cochetopa pluton.

Perhaps the strongest evidence that Cochetopa pluton is late syntectonic to possibly post-tectonic in its time of emplacement is observed in the field relations of the pegmatites to the three joint sets present in the metadiorite wallrock. It is true that the pegmatitic fluids followed the marginal fissures formed in the metadiorite wallrock, but what is more significant is that locally pegmatite dikes have departed at a sharp angle from marginal fissures and followed a pre-existing joint set. The joint set followed, in some places, belongs to that striking N. 14° W. and dipping 66° NE to 75° NW. An excellent example of this can be seen along Highway 114 in the southern part of the area. The structural relations of the granite pegmatites to the joints in the metadiorite are plainly visible in a 120-m high cliff of metadiorite.

In summary, Cochetopa Granite pluton is most probably meso-catazonal in its depth-zone style of emplacement. The evidence supporting this is as follows: (1) general concordance with the country rock structures and occurrence as a conformable sheet-like body, probably considerably attenuated; (2) exposure in a deeply eroded basement terrain of Precambrian basement rocks; (3) moderate granitization and minor migmatization in the country rock; (4) emplacement by forceful injection and magmatic stoping; (5) moderate shoving aside of the country rock for short distances around the pluton; (6) sharp contacts in the sense that aphanitic textures are absent; and (7) marginal fissure-type fracture sets, which though they are more characteristic of upper mesozonal and lower epizonal depths of emplacement, probably developed because the metamorphic country rocks were solid, thereby confirming the late syntectonic or more probably the post-tectonic age of Cochetopa pluton.

GEOCHRONOLOGY

Absolute age determinations of granitic and metamorphic wallrocks outcropping in this area have not been made. Wetherill and Bickford (1965) determined two Rb-Sr whole rock ages on granites similar to the Cochetopa Granite. Their ages were for granites exposed on Highway 50, 9.1 and 3.2 km east of the town of Parlin. Wetherill and Bickford's descriptions of the two granites closely resemble that for granite of Cochetopa pluton.

Another age determination was probably for a granite pegmatite intruding the metadiorite in the south part of the area. The Rb-Sr isochron for the whole rock samples implies emplacement of granitic to granodioritic rocks about 1650 ± 35 million years ago (Wetherill and Bickford, 1965).

Proximity of Cochetopa pluton to Precambrian basement rocks exposed in the Black Canyon of the Gunnison about 30 km northwest and the Needle Mountains area 70 km southwest lends credence to the temporal correlation of the Cochetopa pluton granite and its metamorphic wallrocks to both of these areas (fig. 6). In terms of structural position and proximity to the granite at Parlin, there is a good possibility that Cochetopa Granite pluton is also 1650 ± 35 m.y. old.

In summary, the metasedimentary wallrocks were probably first deposited as early as 1900 m.y. ago, and from 1750-1700 m.y. were involved in regional metamorphism accompanied by orogeny during the Boulder Creek orogeny (Hutchinson, 1972, 1976). Metadiorite and metagabbro are older than 1750 m.y. but younger than the metasediments. Cochetopa pluton is possibly late syntectonic but more probably slightly post-tectonic and was possibly intruded 1650 ± 35 m.y. ago.

ACKNOWLEDGMENTS

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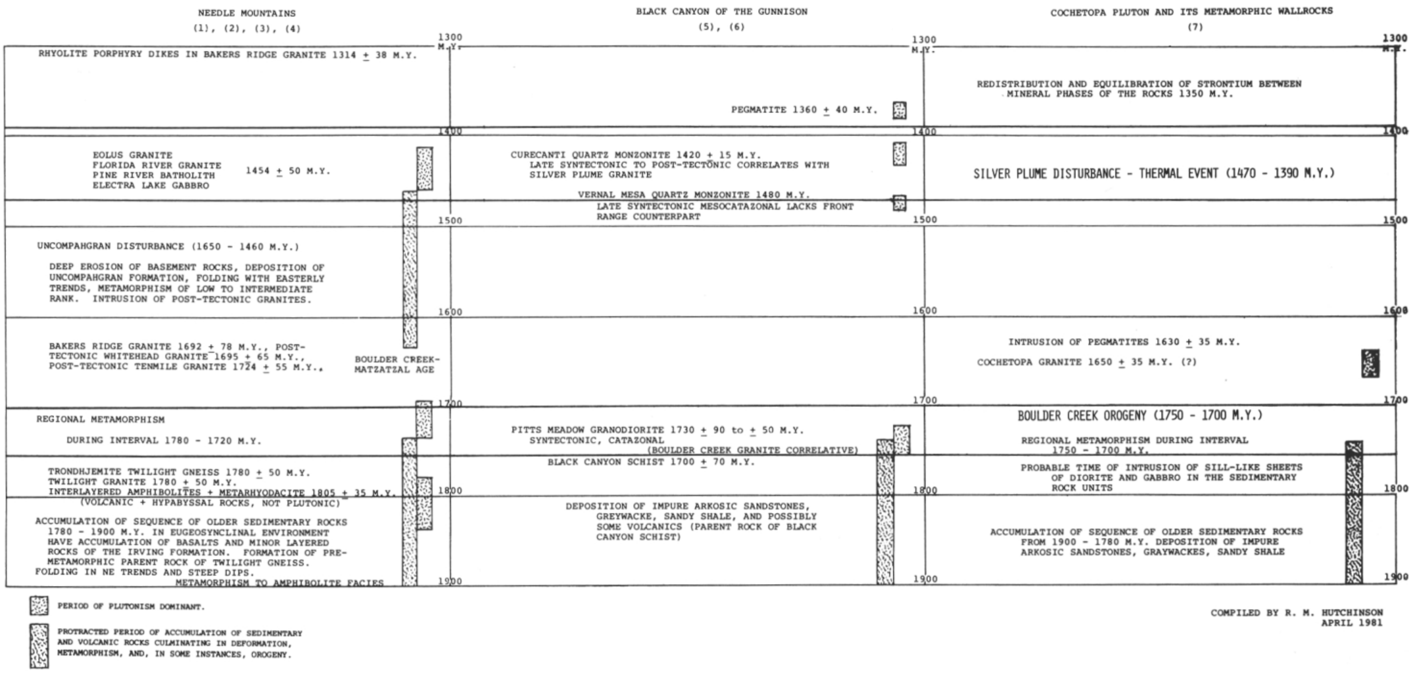

Figure 6. Geochronological correlation of Cochetopa pluton and its metamorphic wallrocks with the Black Canyon of the Gunnison and the Needle Mountains. Numbers under localities refer to references below.

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Note: Numbers refer to Figure 6.