SILVER CITY QUADRANGLE TERTIARY VOLCANICS

Tcm — Circle Mesa Breccia. Matrix red-brown to gray or tan. Clasts of gray volcanics, banded purple and gray and lesser red and gray rhyolites or latites, and dense buff tuff(?). Some banded purple clasts over 6 inches, but most clasts 1 inch or less across.

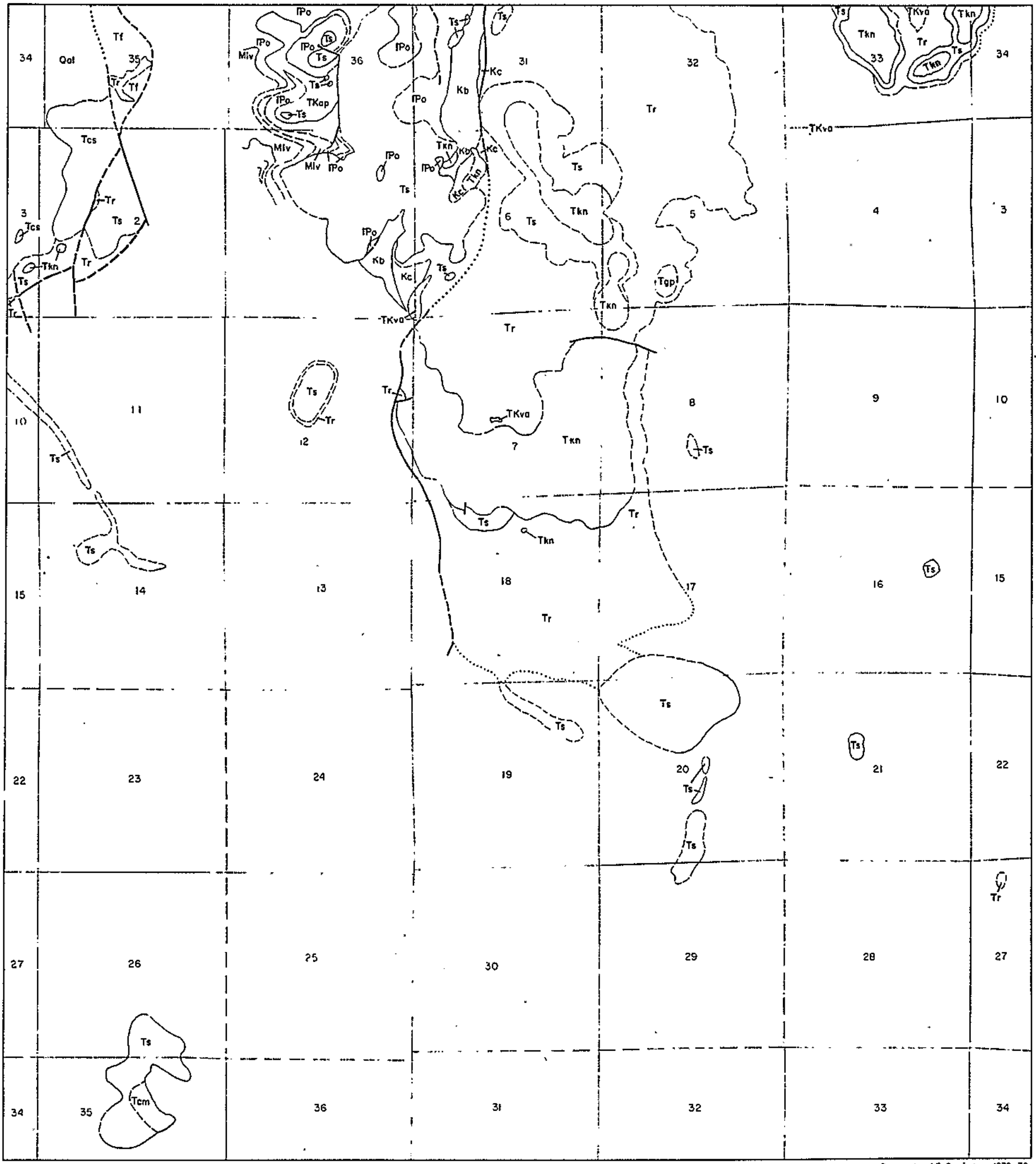
Tf — Felsite. Slabby aphanitic brown-gray rock. Felty mass of feldspar crystallites with sparse small quartz and glass shards. Montronite on many joint surfaces. Relationship with Cane Spring Canyon Latite Porphyry not clear in Silver City Quadrangle, but appears to be later in Circle Mesa Quadrangle, to west.

Tcs — Cane Spring Canyon Latite Porphyry. Dense red-brown to purple matrix with abundant andesine phenocrysts, minor small quartz, biotite, and magnetite.

Tkn — Kneeling Nun (?) Tuff. Gray to purple rhyolitic ash-flow tuff containing conspicuous phenocrysts of quartz, potassium feldspar, plagioclase, minor biotite and magnetite, and sparse glass shards. Some eutaxitic structure. Appears disconformable over Sugarlump Tuff.

Ts — Sugarlump (?) Tuff. Light-colored (white, gray, pink, and red) tuff and ash-flow tuff. Crystals of quartz, sanadine, andesine, biotite, and magnetite. Sparse medium-sized clasts of white tuff, purple, red-brown, and gray volcanics and red-brown feldspar porphyry. Disconformable over Rubio Peak Formation.

Tr — Rubio Peak (?) Formation. Mainly red-brown, brown, and gray sandstones, arkoses, and conglomerates. Conglomerates contain subangular pebble to boulder sized clasts of red-brown, gray, and dark green volcanics, cobbles to boulders of granodiorite porphyry. Cross-bedding and imbrication of cobbles indicate fluvial deposition on surface of considerable relief. Interbedded thin green granulites and shales, and white to cream-colored and gray tuffs. Lowermost unit (basal?) seen is a slabby lavender tuff-breccia. Unconformable on Cretaceous-Tertiary andesites and andesite breccias.

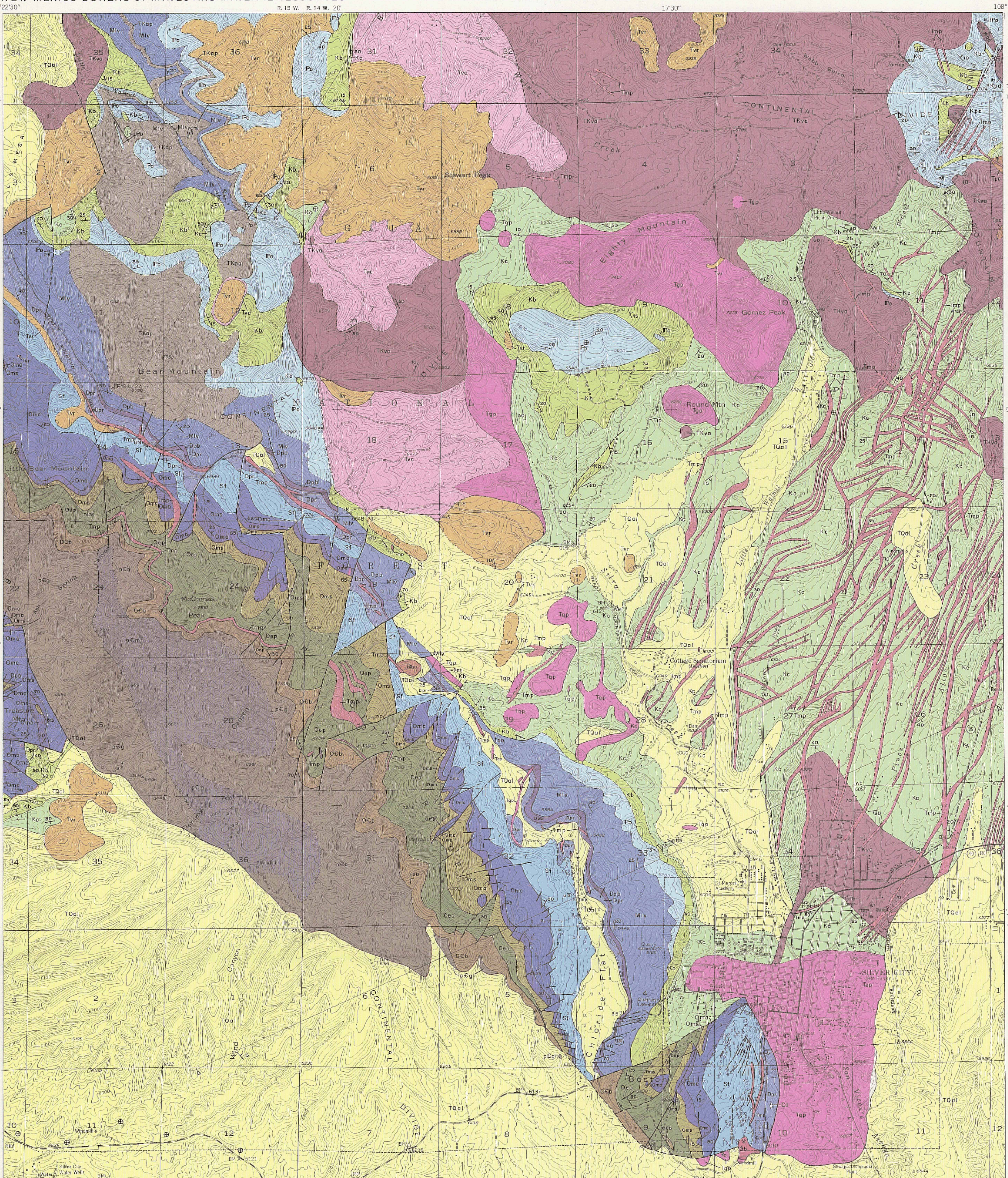


Geology by J.E. Cunningham, 1978–79

Revision of Tertiary Volcanics in Geologic Map 30

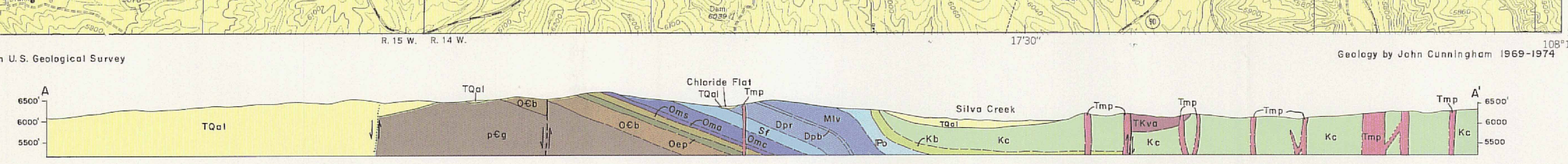
(New Mexico Bureau of Mines & Mineral Resources, 1974)

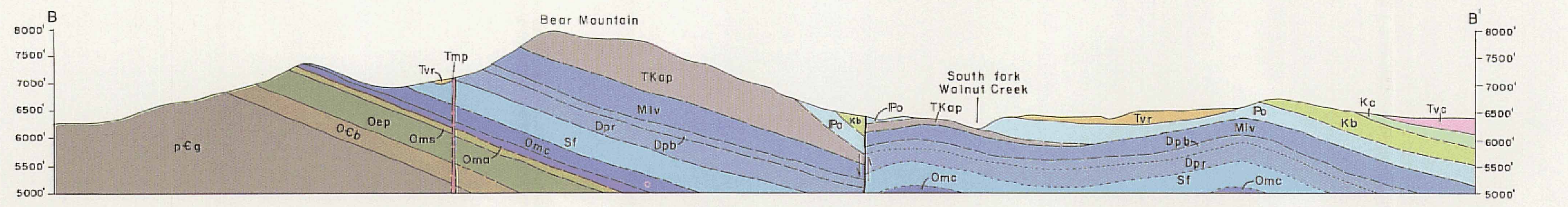
by John E. Cunningham



Base from U.S. Geological Survey

Geology by John Cunningham 1969-1974





GEOLOGIC MAP AND SECTIONS OF SILVER CITY QUADRANGLE, NEW MEXICO

by John E. Cunningham 1974

Scale 1:24,000

0 1 2 Miles

EXPLANATION

Ql — Freshwater limestone; **Qb** — Breccia (QUATERNARY)

Ql: *Dirty white color, east of Boston Hill*

Qb: *Angular to subangular fragments of dolomite, quartz diorite, and manganiferous iron ore, cemented by caliche; found at Boston Hill*

TQal — Alluvium

Sands and gravels with clasts of all older rocks; semiconsolidated

Tvr — Rhyolite, latite, tuff, andesitic breccia; **Tb** — Breccia (TERTIARY)

Tvr: *Phenocrysts of quartz, pink and white feldspar, sanadine, biotite; clasts of white tuff, dark volcanics, Beartooth Quartzite, and glass shards; light colors: white, buff, pink, lavender, light gray, red brown, purple*

Tb: *Breccia. Large to small, angular to rounded fragments of metamorphosed Paleozoic sedimentary rocks, mafic dike, and quartz diorite in a matrix of quartz, feldspar, and hydrothermal minerals.*

Tvc — Sandstone and conglomerate

With clasts of andesitic volcanics, mafic dikes, intermediate stocks; mostly drab colors, but some green, white, purple

Tqp, **Tgp** — Intermediate stocks

Tqp: *Gray matrix with medium to large, euhedral to subhedral white andesine phenocrysts, smaller hornblende, quartz diorite porphyry*

Tgp: *Eighty Mountain-Gomez Peak stock has some large euhedral to subhedral pink orthoclase prophyroblasts, granodiorite porphyry*

Tmp — Mafic porphyry dikes

Gray to green matrix with conspicuous large euhedral hornblende phenocrysts, some with smaller hornblende, medium feldspar; weather yellowish brown

Tpc — Pyroxene porphyry

Gray pyroxene andesite with plagioclase and augite phenocrysts; from Jones and others (1970)

TKva — Andesites, andesite breccias, and dacite

Dark colors: gray, purplish gray, greenish gray, dark gray-green, black; phenocrysts of hornblende and white to gray andesine

TKap — Andesite porphyry, Bear Mountain laccolith

Dense purplish gray matrix with hornblende and white andesine phenocrysts

Kpd — Hornblende andesite porphyry (UPPER CRETACEOUS)

Medium-grained black hornblende and white plagioclase phenocrysts in fine-grained greenish-gray matrix of quartz and potassic feldspar; from Jones and others (1970).

Kc — Colorado Formation

Mixed lithologies of impure sediments: arkose, sandstone, shale, limestone; light to dark, but generally drab colors; thickness not determined due to spotty nature of outcrops, but must exceed 1000 ft

Kb — Beartooth quartzite

Thick-bedded white to gray sandstone with minor interspersed conglomerate beds; iron stain; 155 ft

IPo — Oswaldo Formation (MIDDLE & UPPER PENNSYLVANIAN)

Medium-gray crinoidal limestone and mudstone with brown chert bands; surface often mottled; to 175 ft

Mlv — Lake Valley Limestone (LOWER MISSISSIPPIAN)

Gray crinoidal limestone consisting of four members; lowest 40 ft is alternating massive limestone and slabby shaly partings (Andrecito); Alamogordo has 20 ft of massive light-gray cliff-forming cherty limestone overlain by 270 ft of similar but thinner-bedded limestone; Nunn is darker, coarsely crystalline, 50 ft; Tierra Blanca is light gray, crinoidal; 105 ft

Dpb, **Dpr** — Percha Shale (DEVONIAN)

Dpb, Box Member: *Light-gray to buff, containing gray limestone nodules and lenses, 135 ft thick, grades into Dpr*

Dpr, Ready Pay Member: *Gray to black fissile shale, 290 ft thick*

Sf — Fusselman Dolomite (SILURIAN)

Dark brownish-gray, slabby to massive dolomite; pitted surface and vugs common; mottled color in southern portion due to manganese stain; 100 ft

Montoya Group (UPPER ORDOVICIAN):

Omc — Cutter Dolomite

Light to medium brownish-gray sublithographic dolomite; 40 ft

Oma — Aleman Formation

Alternating bands (1 to 3") of medium-gray, fine-grained dolomite and pink to gray chert; 60 ft

Oms — Second Value Dolomite

Medium-gray, fine-grained, silty or sandy dolomite (Upham Dolomite Member); lowermost 3 to 20 ft is brown coarse dolomitic sandstone Cable Canyon member; 105 ft

Oep — El Paso Dolomite (LOWER ORDOVICIAN)

Medium-gray to gray-brown, often mottled, fine to coarsely crystalline dolomite, sandy dolomite, and mudstone; lower third is fuccoidal; upper two-thirds has lenses and nodules of pink to gray chert; contains intraformational breccias, channel and mound structures, and, in lower beds, scattered glauconite; 330 ft

O€b — Bliss Sandstone (UPPER CAMBRIAN, LOWER ORDOVICIAN)

Red-brown and gray sandstone with interstitial hematite; basal conglomerate grades to arkosic sandstone; beds of oolitic hematite, dolomite; upper dolomite bed represents Cambrian-Ordovician boundary; glauconite may mask hematite in some beds; 225 ft

p€g — Precambrian granite (PRECAMBRIAN)

Variable in grain size and color, but most is medium- and even-grained, pink, with quartz, orthoclase, and muscovite; some is coarse, gray, porphyritic, with biotite; contains pods and dikes of aplite and pegmatite

p€m — Precambrian metamorphic rocks

Metaquartzite, meta-arkose, quartz-mica schist, and quartz-mica gneiss; found as inclusions in Precambrian granite, and in one large area in southwestern quarter of map

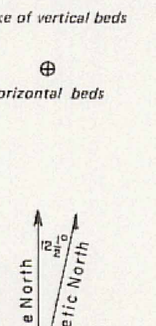
Contact, dashed where approximately located, dotted where concealed

Fault, showing dip, dashed where approximately located, dotted where concealed

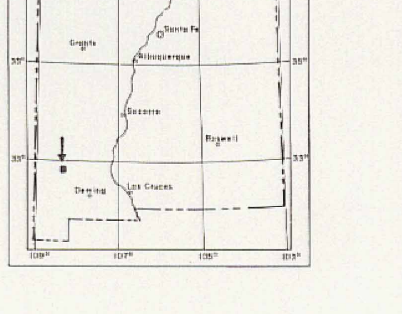
Strike and dip of beds

Strike of vertical beds

Horizontal beds



Approximate mean Declination 1970



INTRODUCTION

Although Paige's Silver City Folio has stood the test of time in most respects, subsequent refinement of rock unit descriptions and more detailed maps now permit more precise mapping. The present study was carried out during the summers of 1969 through 1972 under the auspices of the New Mexico Bureau of Mines and Mineral Resources, augmented during the 1969 season by a research grant from Western New Mexico University. Measured sections and stratigraphic studies of the Bliss, El Paso, Second Value, and Oswaldo formations were made by David V. LeMone of the University of Texas at El Paso. Thanks are also due Jacques R. Renault of the New Mexico Bureau of Mines and Mineral Resources for his petrographic studies of several thin sections of the breccia in the northeast corner of sec. 30, T. 17 S., R. 14 W.

REGIONAL SETTING

The Silver City quadrangle is located in the transition zone between the Colorado Plateau and the Basin and Range provinces, and is part of the Gila block (Trauger, 1965), an elevated area diverging from the Texas lineament. Although the structure in the Silver City quadrangle appears relatively simple, a complex tectonic history is recorded, including long, essentially uninterrupted, subsidence and sedimentation, followed by several episodes of uplift, warping, and igneous activity.

STRUCTURE

The Silver City quadrangle is on the west limb of a synclinorium, the westernmost extension of which is seen in the Big Burro Mountains, while its eastern limb is bounded by the Pinos Altos and Cobre Mountains. This trough has been broken by a number of faults, some of which result in repetition of the rocks units. One such fault occurs in the southwest portion of the quadrangle, bordering the western flank of the Silver City Range.

The dominant structural feature of the quadrangle is, therefore, a monocline, the erosion of which has resulted in the exposure of a complete sequence of rocks from Precambrian to Tertiary. The nonconformity between Precambrian granite and metamorphics and the Bliss Sandstone (Cambrian and Ordovician) flanks the Silver City Range to the southwest, and wherever seen is a flat regular surface. Successive Paleozoic formations crop out in sequence to the northeast, although numerous faults undoubtedly cause apparent thickening and thinning of some units as well as the more conspicuous offsetting of contacts. Bedding attitudes in the Paleozoic sequence are essentially parallel, with all the strata tilted 20° to 30° NE, although disconformities are present between the El Paso and Montoya, the Montoya and Fusselman, and the Lake Valley and Oswaldo formations. The usual hiatus between Paleozoic and Cretaceous sedimentation is present, and the Beartooth Quartzite lies with an angular unconformity on all units from Permian to Precambrian in the general area, although only from Pennsylvanian to Ordovician (Montoya) within the quadrangle. The Beartooth-Colorado contact appears to be gradational and conformable.

The Paleozoic and Mesozoic sediments have been folded, offset by a large number of faults, and intruded by dikes, sills, stocks, and at least one laccolith. The dikes increase in number and complexity of pattern to the east to form the conspicuous swarm in the Fort Bayard quadrangle. Mapping all the dikes in the eastern portion of the Silver City quadrangle is not feasible: the larger or more easily traced ones have been mapped, as opposed to the overlay scheme employed on the Fort Bayard quadrangle map, to illustrate their trends and the divergent-convergent pattern.

Cretaceous and Tertiary volcanics present an unconformable cover over much of the northern third of the quadrangle; scattered remnants to the south indicate that this cover was once more extensive.

HISTORICAL GEOLOGY

Precambrian granite and metamorphic rocks in the Silver City quadrangle suggest a picture similar to, although less complete than, that which Hewitt (1959) interpreted in the Big Burro Mountains to the west. The metamorphics include meta-quartzite, meta-arkose, quartz-mica schist, and quartz-mica gneiss, which correspond to Hewitt's Bullard Peak series: rocks analogous to the later Ash Creek series were not seen. The Precambrian scene, then, is one of nearshore sediments incorporated within a granite batholith, and subsequently subjected to prolonged erosion to produce a maturely weathered surface of low relief.

The seas encroached upon the area in Upper Cambrian time, reworking the sands left on the Precambrian granite surface to produce the Bliss Sandstone, probably as a shore and nearshore deposit, as suggested by the hematite content, crossbedding, brachiopod molds, and glauconite. As the seas continued to advance, clastic deposition gave way to the nonclastic sequence from Ordovician through Pennsylvanian, with the El Paso-Montoya, Montoya-Fusselman, and Lake Valley-Oswaldo disconformities, and the Cable Canyon Sandstone representing short-lived fluctuations and withdrawals. The Percha Shale may indicate instability nearby, with uplift and erosion of a deeply weathered surface.

A thin deposit of red breccia on north flank of Bear Mountain contains fossils of both Pennsylvanian and Permian aspect, suggesting uplift at the close of the Pennsylvanian, stripping of Paleozoic strata, and exposure of Precambrian basement. This uplift appears to have been centered on the Big Burro Mountains where erosion was deepest, with Cretaceous rocks now lying on Precambrian granite; in the Silver City area the Beartooth Quartzite (Upper Cretaceous) lies on Upper Ordovician dolomite through Pennsylvanian limestone.

Renewed subsidence in the Upper Cretaceous resulted in deposition of the Beartooth Quartzite: crossbedding and plant remains in the Beartooth indicate a nearshore environment. The seas continued to advance, depositing the varied lithology of the Colorado Formation. Occasional ripple mark in Colorado beds indicate that the seas remained shallow.

Uplift of the area and igneous activity at the close of the Cretaceous heralded the Laramide orogeny. In the Silver City region this resulted in tilting, faulting, and a variety of igneous activity, both extrusive and intrusive. The sequence of igneous activity is not immediately apparent from the map patterns, but can be worked out in conjunction with the results of the Fort Bayard study. The first upwelling of magma apparently resulted in the intrusion of intermediate concordant plutons—the andesite porphyry laccolith at Bear Mountain and the quartz diorite sill which underlies the Cleveland mine (unpublished report by Harrison Schmitt and Olaf Rove, 1931, entitled Final Report Cleveland Unit Examination and Exploration of 1928-1931).

These plutons inflated and bowed up the sedimentary section, resulting in structurally controlled hills from which the uppermost sedimentary rocks were stripped by erosion. Thus, when the andesites and andesite breccias were deposited, they rested on the Colorado Formation in topographic lows, but covered the Beartooth Quartzite and Oswaldo Formation on topographic highs as the Cleveland mine area. The andesites may be fairly coarse grained in places (for example, the Cleveland mine), and thus appear plutonic, but field relations indicate that flows having diverse texture and a resistance to erosion are resting on the older sedimentary rocks. On the northeast flank of Bear Mountain, conglomerate with andesitic clasts rests on the Beartooth, the Oswaldo, and the laccolith, suggesting that the andesites once blanketed that area as well. Additional evidence of a formerly more extensive andesitic cover is supplied by the andesite breccia in Silver City; and the andesitic mass south of the Little Walnut picnic area (sections 1 and 10, northeast corner) probably represents one of the conduits for the volcanics, because the sedimentary rocks are steeply uptilted around the east side. The small plugs in the northeast corner, labelled Kpd and Tpc from the Fort Bayard quadrangle map, could also be conduits, because Jones and others (1970) note that although the plugs intrude andesite breccia, similar rocks are found as fragments within the breccia.

Following the extrusion of the andesite, regional extension resulted in extensive fractures along which the mafic porphyry dikes (and minor sills) were emplaced (Jones and others, 1970). Most of the dikes are shown within the Colorado Formation, probably due to two factors: 1) greater ease of fracture of the Colorado, with the igneous rocks acting as resistant bastions, and 2) the difficulty of tracing dikes in volcanic terrane.

The last phase of intrusive activity within the Silver City quadrangle was the emplacement of the intermediate stocks—the Eighty Mountain, Silver City, and Cottage San stocks (this latter appearing as isolated cupolas within the Colorado Formation in sections 20, 21, 28, 29, and 33, T. 17 S., R. 14 W.). Similarity of these bodies with nearby stocks (Santa Rita and Pinos Altos stocks) suggest they were emplaced about 53 m.y. ago (Jones and others, 1970). Subsequent to their emplacement extensive erosion in an area of considerable relief stripped off much of the volcanic cover, especially where it was thinner over the old sedimentary hills, and deposited volcanic clastics ranging from coarse sandstone to boulder conglomerate. Renewed igneous activity produced the rhyolitic flows and pyroclastics now found as isolated remnants on topographic highs appearing to cap everything else. Although radioactive age determinations have not been made, these flows and pyroclastics correspond fairly well in appearance to nearby Oligocene volcanics (Jones and others, 1970).

Following the Oligocene volcanism, erosion was the dominant force in the Silver City area, and apparently a westward-flowing drainage pattern was established, possibly emptying into lakes in the present-day Mangas and Gila valleys: boulders of Colorado Formation are present in ridge-top gravels in the Silver City Range, considerably west of any present Colorado exposures. A late Tertiary age is postulated for this drainage system on the basis of Pliocene horse teeth found in a welded tuff intercallated with pediment gravels near Cliff (two species of *Pliohippus*, William S. Strain, personal communication, 1973). If the westward drainage hypothesis is correct, then Pleistocene (or even Recent) uplift and eastward tilting disrupted that drainage to create the present southward-flowing drainage in the southern two-thirds of the Silver City quadrangle.

ECONOMIC GEOLOGY

Although the Silver City area has been the scene of considerable mining activity in the past, only one mine is operating today within the quadrangle—the Boston Hill, which has been producing manganiferous iron ore since 1916. The ore includes a number of both hypogene and supergene minerals of iron, manganese, copper, lead, and zinc, with the iron and manganese oxides being of greatest economic importance. The mineralization was localized by fractures and brecciation in the Paleozoic dolomites in combination with a damming effect as the fractures were absorbed by the incompetent Percha Shale. Primary deposits were lean, therefore, economic importance is due to secondary enrichment.

The Chloride Flat subdistrict, which gave rise to Silver City's name and much of its early growth, is in reality a continuation of the same mineralization and structures found at Boston Hill. The basic difference between the two is the presence of argentiferous galena, the primary source of the silver, at Chloride Flat. This difference probably reflects mineral zonation inasmuch as Entwistle (1944) concluded that the ore solutions were derived from the Silver City stock. From the first discovery of silver at Chloride Flat in 1870 until 1937, $3,293,000 of ore was produced, mostly in cerargyrite but with some native silver and argentite. Since 1937 production has not been significant.

Fleming Camp, at Treasure Mountain on the southwestern edge of the map, was worked during the 1880's and 1890's, and produced an estimated $300,000 of ore similar to that of Chloride Flat, the main difference being localization in pockets in the Beartooth Quartzite. Lindgren and others (1910) noted that stopes were related to the bedding, therefore, stratigraphic control may be a factor here as well, with some beds fracturing more readily than others.

Other workings with manganiferous mineralization were seen, such as those in sections 16, 17, and 18, T. 17 S., R. 14 W., but information was not available on them.

The Cleveland mine, in the northeast corner of the map, contained ore of a considerably different nature. The deposit was a metasomatic replacement of lead and zinc lodes in Paleozoic limestone. This difference could be due either to zoning or to a relationship with the Pinos Altos stock to the north rather than to the stocks found within the Silver City quadrangle.

Future discoveries of silver in the quadrangle seem rather unlikely. Certainly hidden bodies similar to those described do exist, but the small, sporadic nature of the known deposits suggests that exploration for blind ore bodies of this type would be a high risk venture at best.

Probably the greatest potential for future discoveries in the Silver City area is in a search for hidden base metal deposits. The quadrangle is situated between the ore bodies of Santa Rita and Tyrone, both associated with intermediate plutons similar to those of the Silver City quadrangle. In addition, the presence of minor copper, lead, and zinc with the Boston Hill-Chloride Flat deposits suggests the possibility of base metal concentrations related to the same solutions but deposited with a different relationship to the stock. Hints of mineralization are found in the stocks themselves: the Silver City stock has been subjected to chloritization, epidotization, and sericitization; the Cottage San stock outcrops have also undergone some chloritization and epidotization, and in places contain considerable magnetite and a bit of pyrite; and the Eighty Mountain-Gomez Peak stock has considerable amounts of potash feldspar porphyroblasts on its eastern and western flanks, suggesting potash introduction, and in places has undergone some sericitization and silicification. Away from the known ore bodies, the sedimentary rocks do not exhibit conspicuous alteration or mineralization, except for hematite stain along faults, and abundant alteration minerals with minor chalcopyrite in and around the breccia in the NE¼ sec. 30, T. 17 S., R. 14 W. Some exploration of these stocks and the surrounding areas has been carried on by mining companies. Although the results are obviously not available, the potential of the Silver City quadrangle does not seem exhausted.

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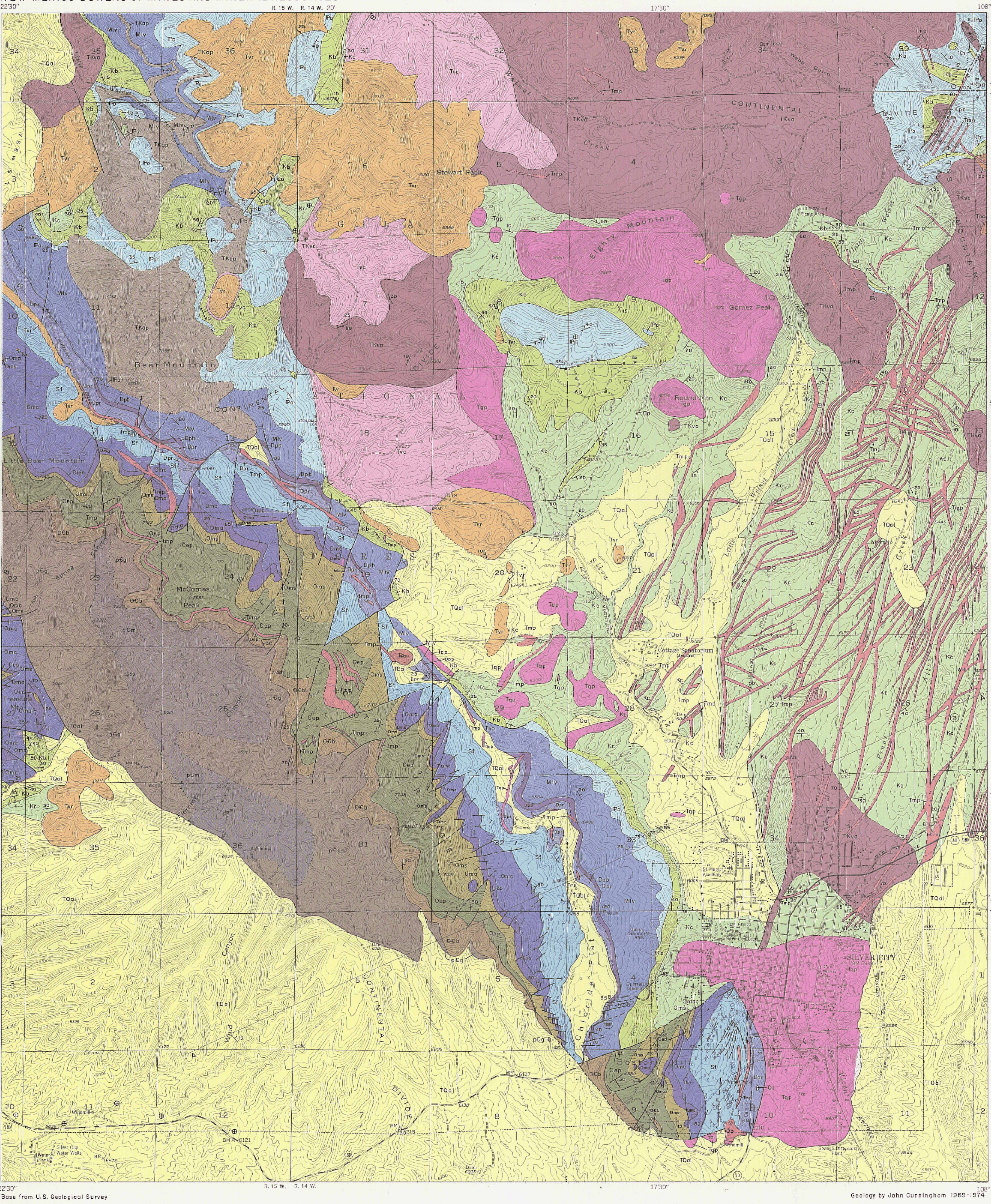
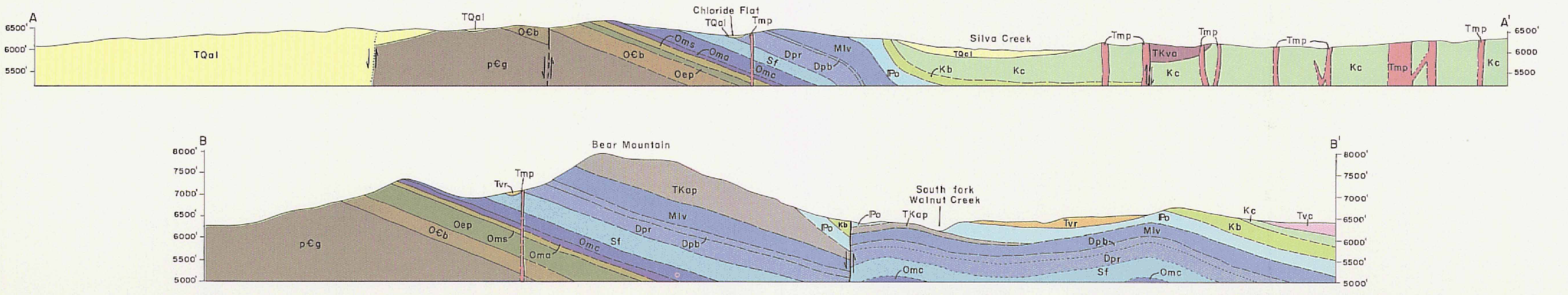


Base from U.S. Geological Survey

Geology by John Cunningham 1969-1974



GEOLOGIC MAP AND SECTIONS OF SILVER CITY QUADRANGLE, NEW MEXICO

by John E. Cunningham 1974

Scale 1:24,000

0 — 2 Miles

EXPLANATION

Ql — **Freshwater limestone** — **Qb** — **Breccia** (QUATERNARY)

Ql: Dirty white color, east of Boston Hill
Qb: Angular to subangular fragments of dolomite, quartz diorite, and manganiferous iron ore, cemented by caliche; found at Boston Hill

TQal — **Alluvium**
Sands and gravels with clasts of all older rocks; semiconsolidated

Tvr — **Tb** — **Rhyolite, latite, tuff, andesitic breccia** — **Breccia** (TERTIARY)
Tvr: Phenocrysts of quartz, pink and white feldspar, sanadine, biotite; clasts of white tuff, dark volcanics, Beartooth Quartzite, and glass shards; light colors: white, buff, pink, lavender, light gray, red brown, purple
Tb: Breccia. Large to small, angular to rounded fragments of metamorphosed Paleozoic sedimentary rocks, mafic dike, and quartz diorite in a matrix of quartz, feldspar, and hydrothermal minerals.

Tvc — **Sandstone and conglomerate**
With clasts of andesitic volcanics, mafic dikes, intermediate stocks; mostly drab colors, but some green, white, purple

Tqp — **Tgp** — **Intermediate stocks**
Tqp: Gray matrix with medium to large, euhedral to subhedral white andesine phenocrysts, smaller hornblende, quartz diorite porphyry
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Tmp — **Mafic porphyry dikes**
Gray to green matrix with conspicuous large euhedral hornblende phenocrysts, some with smaller hornblende, medium feldspar; weather yellowish brown

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Gray pyroxene andesite with plagioclase and augite phenocrysts; from Jones and others (1970)

TKva — **Andesites, andesite breccias, and dacite**
Dark colors: gray, purplish gray, greenish gray, dark gray-green, black; phenocrysts of hornblende and white to gray andesine

TKap — **Andesite porphyry, Bear Mountain laccolith**
Dense purplish gray matrix with hornblende and white andesine phenocrysts

Kpd — **Hornblende andesite porphyry**
Medium-grained black hornblende and white plagioclase phenocrysts in fine-grained greenish-gray matrix of quartz and potassic feldspar; from Jones and others (1970).

Kc — **Colorado Formation** (UPPER CRETACEOUS)
Mixed lithologies of impure sediments: arkose, sandstone, shale, limestone; light to dark, but generally drab colors; thickness not determined due to spotty nature of outcrops, but must exceed 1000 ft

Kb — **Beartooth quartzite**
Thick-bedded white to gray sandstone with minor interspersed conglomerate beds; iron stain; 155 ft

IPo — **Oswaldo Formation** (MIDDLE & UPPER PENNSYLVANIAN)
Medium-gray crinoidal limestone and mudstone with brown chert bands; surface often mottled; to 175 ft

Mlv — **Lake Valley Limestone** (LOWER MISSISSIPPIAN)
Gray crinoidal limestone consisting of four members; lowest 40 ft is alternating massive limestone and slabby shaly partings (Andrecito); Alamogordo has 20 ft of massive light-gray cliff-forming cherty limestone overlain by 270 ft of similar but thinner-bedded limestone; Nunn is darker, coarsely crystalline, 50 ft; Tierra Blanca is light gray, crinoidal; 105 ft

Dpb / **Dpr** — **Percha Shale** (DEVONIAN)
Dpb, Box Member: *Light-gray to buff, containing gray limestone nodules and lenses, 135 ft thick, grades into Dpr*
Dpr, Ready Pay Member: *Gray to black fissile shale, 290 ft thick*

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Dark brownish-gray, slabby to massive dolomite; pitted surface and vugs common; mottled color in southern portion due to manganese stain; 100 ft

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Light to medium brownish-gray sublithographic dolomite; 40 ft

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Alternating bands (1 to 3") of medium-gray, fine-grained dolomite and pink to gray chert; 60 ft

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Medium-gray, fine-grained, silty or sandy dolomite (Upham Dolomite Member); lowermost 3 to 20 ft is brown coarse dolomitic sandstone Cable Canyon member; 105 ft

Oep — **El Paso Dolomite** (LOWER ORDOVICIAN)
Medium-gray to gray-brown, often mottled, fine to coarsely crystalline dolomite, sandy dolomite, and mudstone; lower third is fuccoidal; upper two-thirds has lenses and nodules of pink to gray chert; contains intraformational breccias, channel and mound structures, and, in lower beds, scattered glauconite; 330 ft

O€b — **Bliss Sandstone** (UPPER CAMBRIAN LOWER ORDOVICIAN)
Red-brown and gray sandstone with interstitial hematite; basal conglomerate grades to arkosic sandstone; beds of oolitic hematite, dolomite; upper dolomite bed represents Cambrian-Ordovician boundary; glauconite may mask hematite in some beds; 225 ft

p€g — **Precambrian granite** (PRECAMBRIAN)
Variable in grain size and color, but most is medium- and even-grained, pink, with quartz, orthoclase, and muscovite; some is coarse, gray, porphyritic, with biotite; contains pods and dikes of aplite and pegmatite

p€m — **Precambrian metamorphic rocks**
Metaquartzite, meta-arkose, quartz-mica schist, and quartz-mica gneiss; found as inclusions in Precambrian granite, and in one large area in southwestern quarter of map

Contact, dashed where approximately located, dotted where concealed

Fault, showing dip, dashed where approximately located, dotted where concealed

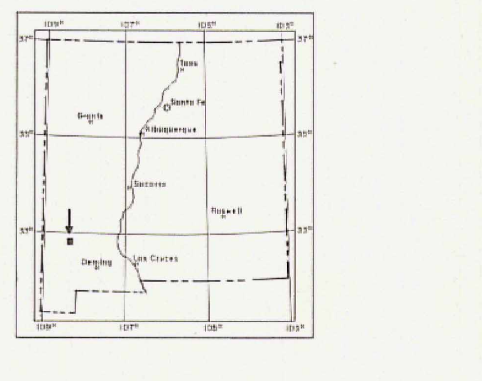
Strike and dip of beds

Strike of vertical beds

Horizontal beds

True North — Magnetic North

Approximate mean Declination 1970



INTRODUCTION

Although Paige's Silver City Folio has stood the test of time in most respects, subsequent refinement of rock unit descriptions and more detailed maps now permit more precise mapping. The present study was carried out during the summers of 1969 through 1972 under the auspices of the New Mexico Bureau of Mines and Mineral Resources, augmented during the 1969 season by a research grant from Western New Mexico University. Measured sections and stratigraphic studies of the Bliss, El Paso, Second Value, and Oswaldo formations were made by David V. LeMone of the University of Texas at El Paso. Thanks are also due Jacques R. Renault of the New Mexico Bureau of Mines and Mineral Resources for his petrographic studies of several thin sections of the breccia in the northeast corner of sec. 30, T. 17 S., R. 14 W.

REGIONAL SETTING

The Silver City quadrangle is located in the transition zone between the Colorado Plateau and the Basin and Range provinces, and is part of the Gila block (Trauger, 1965), an elevated area diverging from the Texas lineament. Although the structure in the Silver City quadrangle appears relatively simple, a complex tectonic history is recorded, including long, essentially uninterrupted, subsidence and sedimentation, followed by several episodes of uplift, warping, and igneous activity.

STRUCTURE

The Silver City quadrangle is on the west limb of a synclinorium, the westernmost extension of which is seen in the Big Burro Mountains, while its eastern limb is bounded by the Pinos Altos and Cobre Mountains. This trough has been broken by a number of faults, some of which result in repetition of the rocks units. One such fault occurs in the southwest portion of the quadrangle, bordering the western flank of the Silver City Range.

The dominant structural feature of the quadrangle is, therefore, a monocline, the erosion of which has resulted in the exposure of a complete sequence of rocks from Precambrian to Tertiary. The nonconformity between Precambrian granite and metamorphics and the Bliss Sandstone (Cambrian and Ordovician) flanks the Silver City Range to the southwest, and wherever seen is a flat regular surface. Successive Paleozoic formations crop out in sequence to the northeast, although numerous faults undoubtedly cause apparent thickening and thinning of some units as well as the more conspicuous offsetting of contacts. Bedding attitudes in the Paleozoic sequence are essentially parallel, with all the strata tilted 20° to 30° NE, although disconformities are present between the El Paso and Montoya, the Montoya and Fusselman, and the Lake Valley and Oswaldo formations. The usual hiatus between Paleozoic and Cretaceous sedimentation is present, and the Beartooth Quartzite lies with an angular unconformity on all units from Permian to Precambrian in the general area, although only from Pennsylvanian to Ordovician (Montoya) within the quadrangle. The Beartooth-Colorado contact appears to be gradational and conformable.

The Paleozoic and Mesozoic sediments have been folded, offset by a large number of faults, and intruded by dikes, sills, stocks, and at least one laccolith. The dikes increase in number and complexity of pattern to the east to form the conspicuous swarm in the Fort Bayard quadrangle. Mapping all the dikes in the eastern portion of the Silver City quadrangle is not feasible: the larger or more easily traced ones have been mapped, as opposed to the overlay scheme employed on the Fort Bayard quadrangle map, to illustrate their trends and the divergent-convergent pattern.

Cretaceous and Tertiary volcanics present an unconformable cover over much of the northern third of the quadrangle; scattered remnants to the south indicate that this cover was once more extensive.

HISTORICAL GEOLOGY

Precambrian granite and metamorphic rocks in the Silver City quadrangle suggest a picture similar to, although less complete than, that which Hewitt (1959) interpreted in the Big Burro Mountains to the west. The metamorphics include meta-quartzite, meta-arkose, quartz-mica schist, and quartz-mica gneiss, which correspond to Hewitt's Bullard Peak series: rocks analogous to the later Ash Creek series were not seen. The Precambrian scene, then, is one of nearshore sediments incorporated within a granite batholith, and subsequently subjected to prolonged erosion to produce a maturely weathered surface of low relief.

The seas encroached upon the area in Upper Cambrian time, reworking the sands left on the Precambrian granite surface to produce the Bliss Sandstone, probably as a shore and nearshore deposit, as suggested by the hematite content, crossbedding, brachiopod molds, and glauconite. As the seas continued to advance, clastic deposition gave way to the nonclastic sequence from Ordovician through Pennsylvanian, with the El Paso-Montoya, Montoya-Fusselman, and Lake Valley-Oswaldo disconformities, and the Cable Canyon Sandstone representing short-lived fluctuations and withdrawals. The Percha Shale may indicate instability nearby, with uplift and erosion of a deeply weathered surface.

A thin deposit of red breccia on north flank of Bear Mountain contains fossils of both Pennsylvanian and Permian aspect, suggesting uplift at the close of the Pennsylvanian, stripping of Paleozoic strata, and exposure of Precambrian basement. This uplift appears to have been centered on the Big Burro Mountains where erosion was deepest, with Cretaceous rocks now lying on Precambrian granite; in the Silver City area the Beartooth Quartzite (Upper Cretaceous) lies on Upper Ordovician dolomite through Pennsylvanian limestone.

Renewed subsidence in the Upper Cretaceous resulted in deposition of the Beartooth Quartzite: crossbedding and plant remains in the Beartooth indicate a nearshore environment. The seas continued to advance, depositing the varied lithology of the Colorado Formation. Occasional ripple mark in Colorado beds indicate that the seas remained shallow.

Uplift of the area and igneous activity at the close of the Cretaceous heralded the Laramide orogeny. In the Silver City region this resulted in tilting, faulting, and a variety of igneous activity, both extrusive and intrusive. The sequence of igneous activity is not immediately apparent from the map patterns, but can be worked out in conjunction with the results of the Fort Bayard study. The first upwelling of magma apparently resulted in the intrusion of intermediate concordant plutons—the andesite porphyry laccolith at Bear Mountain and the quartz diorite sill which underlies the Cleveland mine (unpublished report by Harrison Schmitt and Olaf Rove, 1931, entitled Final Report Cleveland Unit Examination and Exploration of 1928-1931).

These plutons inflated and bowed up the sedimentary section, resulting in structurally controlled hills from which the uppermost sedimentary rocks were stripped by erosion. Thus, when the andesites and andesite breccias were deposited, they rested on the Colorado Formation in topographic lows, but covered the Beartooth Quartzite and Oswaldo Formation on topographic highs as the Cleveland mine area. The andesites may be fairly coarse grained in places (for example, the Cleveland mine), and thus appear plutonic, but field relations indicate that flows having diverse texture and a resistance to erosion are resting on the older sedimentary rocks. On the northeast flank of Bear Mountain, conglomerate with andesitic clasts rests on the Beartooth, the Oswaldo, and the laccolith, suggesting that the andesites once blanketed that area as well. Additional evidence of a formerly more extensive andesitic cover is supplied by the andesite breccia in Silver City; and the andesitic mass south of the Little Walnut picnic area (sections 1 and 10, northeast corner) probably represents one of the conduits for the volcanics, because the sedimentary rocks are steeply uptilted around the east side. The small plugs in the northeast corner, labelled Kpd and Tpc from the Fort Bayard quadrangle map, could also be conduits, because Jones and others (1970) note that although the plugs intrude andesite breccia, similar rocks are found as fragments within the breccia.

Following the extrusion of the andesite, regional extension resulted in extensive fractures along which the mafic porphyry dikes (and minor sills) were emplaced (Jones and others, 1970). Most of the dikes are shown within the Colorado Formation, probably due to two factors: 1) greater ease of fracture of the Colorado, with the igneous rocks acting as resistant bastions, and 2) the difficulty of tracing dikes in volcanic terrane.

The last phase of intrusive activity within the Silver City quadrangle was the emplacement of the intermediate stocks—the Eighty Mountain, Silver City, and Cottage San stocks (this latter appearing as isolated cupolas within the Colorado Formation in sections 20, 21, 28, 29, and 33, T. 17 S., R. 14 W.). Similarity of these bodies with nearby stocks (Santa Rita and Pinos Altos stocks) suggest they were emplaced about 53 m.y. ago (Jones and others, 1970). Subsequent to their emplacement extensive erosion in an area of considerable relief stripped off much of the volcanic cover, especially where it was thinner over the old sedimentary hills, and deposited volcanic clastics ranging from coarse sandstone to boulder conglomerate. Renewed igneous activity produced the rhyolitic flows and pyroclastics now found as isolated remnants on topographic highs appearing to cap everything else. Although radioactive age determinations have not been made, these flows and pyroclastics correspond fairly well in appearance to nearby Oligocene volcanics (Jones and others, 1970).

Following the Oligocene volcanism, erosion was the dominant force in the Silver City area, and apparently a westward-flowing drainage pattern was established, possibly emptying into lakes in the present-day Mangas and Gila valleys: boulders of Colorado Formation are present in ridge-top gravels in the Silver City Range, considerably west of any present Colorado exposures. A late Tertiary age is postulated for this drainage system on the basis of Pliocene horse teeth found in a welded tuff intercalated with pediment gravels near Cliff (two species of *Pliohippus*, William S. Strain, personal communication, 1973). If the westward drainage hypothesis is correct, then Pleistocene (or even Recent) uplift and eastward tilting disrupted that drainage to create the present southward-flowing drainage in the southern two-thirds of the Silver City quadrangle.

ECONOMIC GEOLOGY

Although the Silver City area has been the scene of considerable mining activity in the past, only one mine is operating today within the quadrangle—the Boston Hill, which has been producing manganiferous iron ore since 1916. The ore includes a number of both hypogene and supergene minerals of iron, manganese, copper, lead, and zinc, with the iron and manganese oxides being of greatest economic importance. The mineralization was localized by fractures and brecciation in the Paleozoic dolomites in combination with a damming effect as the fractures were absorbed by the incompetent Percha Shale. Primary deposits were lean, therefore, economic importance is due to secondary enrichment.

The Chloride Flat subdistrict, which gave rise to Silver City's name and much of its early growth, is in reality a continuation of the same mineralization and structures found at Boston Hill. The basic difference between the two is the presence of argentiferous galena, the primary source of the silver, at Chloride Flat. This difference probably reflects mineral zonation inasmuch as Entwistle (1944) concluded that the ore solutions were derived from the Silver City stock. From the first discovery of silver at Chloride Flat in 1870 until 1937, $3,293,000 of ore was produced, mostly in cerargyrite but with some native silver and argentite. Since 1937 production has not been significant.

Fleming Camp, at Treasure Mountain on the southwestern edge of the map, was worked during the 1880's and 1890's, and produced an estimated $300,000 of ore similar to that of Chloride Flat, the main difference being localization in pockets in the Beartooth Quartzite. Lindgren and others (1910) noted that stopes were related to the bedding, therefore, stratigraphic control may be a factor here as well, with some beds fracturing more readily than others.

Other workings with manganiferous mineralization were seen, such as those in sections 16, 17, and 18, T. 17 S., R. 14 W., but information was not available on them.

The Cleveland mine, in the northeast corner of the map, contained ore of a considerably different nature. The deposit was a metasomatic replacement of lead and zinc lodes in Paleozoic limestone. This difference could be due either to zoning or to a relationship with the Pinos Altos stock to the north rather than to the stocks found within the Silver City quadrangle.

Future discoveries of silver in the quadrangle seem rather unlikely. Certainly hidden bodies similar to those described do exist, but the small, sporadic nature of the known deposits suggests that exploration for blind ore bodies of this type would be a high risk venture at best.

Probably the greatest potential for future discoveries in the Silver City area is in a search for hidden base metal deposits. The quadrangle is situated between the ore bodies of Santa Rita and Tyrone, both associated with intermediate plutons similar to those of the Silver City quadrangle. In addition, the presence of minor copper, lead, and zinc with the Boston Hill-Chloride Flat deposits suggests the possibility of base metal concentrations related to the same solutions but deposited with a different relationship to the stock. Hints of mineralization are found in the stocks themselves: the Silver City stock has been subjected to chloritization, epidotization, and sericitization; the Cottage San stock outcrops have also undergone some chloritization and epidotization, and in places contain considerable magnetite and a bit of pyrite; and the Eighty Mountain-Gomez Peak stock has considerable amounts of potash feldspar porphyroblasts on its eastern and western flanks, suggesting potash introduction, and in places has undergone some sericitization and silicification. Away from the known ore bodies, the sedimentary rocks do not exhibit conspicuous alteration or mineralization, except for hematite stain along faults, and abundant alteration minerals with minor chalcopyrite in and around the breccia in the NE¼ sec. 30, T. 17 S., R. 14 W. Some exploration of these stocks and the surrounding areas has been carried on by mining companies. Although the results are obviously not available, the potential of the Silver City quadrangle does not seem exhausted.

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