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U.S. GEOLOGICAL SURVEY

Preliminary geologic map of the Silverton 7.5-minute quadrangle, San Juan County Colorado

by

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Introduction

The Silverton 7.5-minute quadrangle, located in the western San Juan Mountains of southwestern Colorado (fig. 1), includes almost 59 square miles (153 km^2) of rugged mountainous terrain at altitudes ranging from about 9,000 ft in the Animas River canyon at the south edge of the map to 13,487 ft on Storm Peak in the northeast part of the map. Steep valley walls below timberline (about 11,500 ft), particularly north-facing slopes, usually are covered with dense timber, underbrush, and soil; geologic features may be obscured by this cover and local rock debris contaminated with transported clayey material and residual products of oxidation.

Silverton, the only commercial center within the quadrangle, became the county seat of San Juan County when the county was formed in 1876 (Henderson, 1926, p. 26). By 1875, Silverton was already a flourishing town with a population of about five hundred. In the ensuing years it has survived the ups and downs of the mining industry, and now, even with mining activity at low ebb, it is still a thriving community. In the summer, Silverton is one terminal of the Silverton-Durango narrow-gauge railroad, a popular tourist attraction.

The geology of the quadrangle was mapped by us in 1962, 1965, 1968-69, 1983-84, and 1991; we were assisted by Mark Bonner, Rene DeHon, Steven Maione, and Gary Galyardt. The earliest geologic studies of the area were made by Cross, Howe, and Ransome in 1905. Our work has modified these and the more recent detailed geologic studies of Varnes (1963) in the Kendall Mountain area southeast of Silverton and Spoelhof (1974) in the southwesternmost part of the map.

Geologic setting

Exposed pre-Tertiary bedrock, consisting of Precambrian igneous and metamorphic rocks and Paleozoic sedimentary rocks, is found mainly in the southern part of the quadrangle. The metamorphic rocks are principally gneisses and amphibolite intruded by small irregular-shaped masses of granite assigned an age of about 1,720 Ma by Barker (1969), and by diabase dikes tentatively assigned a Cambro-Ordivician age by Lipman (1976). The Paleozoic stratigraphic section, ranging in age from Cambrian through Permian, consists mainly of regionally westward-dipping clastic sedimentary rocks except where involved in such local structures as those near Deadwood Gulch south of Sultan Mountain and in the Kendall Gulch-Deer Park Creek area east of the Animas River valley. These older stratified and tilted rocks are beveled by an erosional unconformity that in turn is overlain by a generally flat-lying sequence of Tertiary rocks.

The rocks of Tertiary age, except for the sedimentary

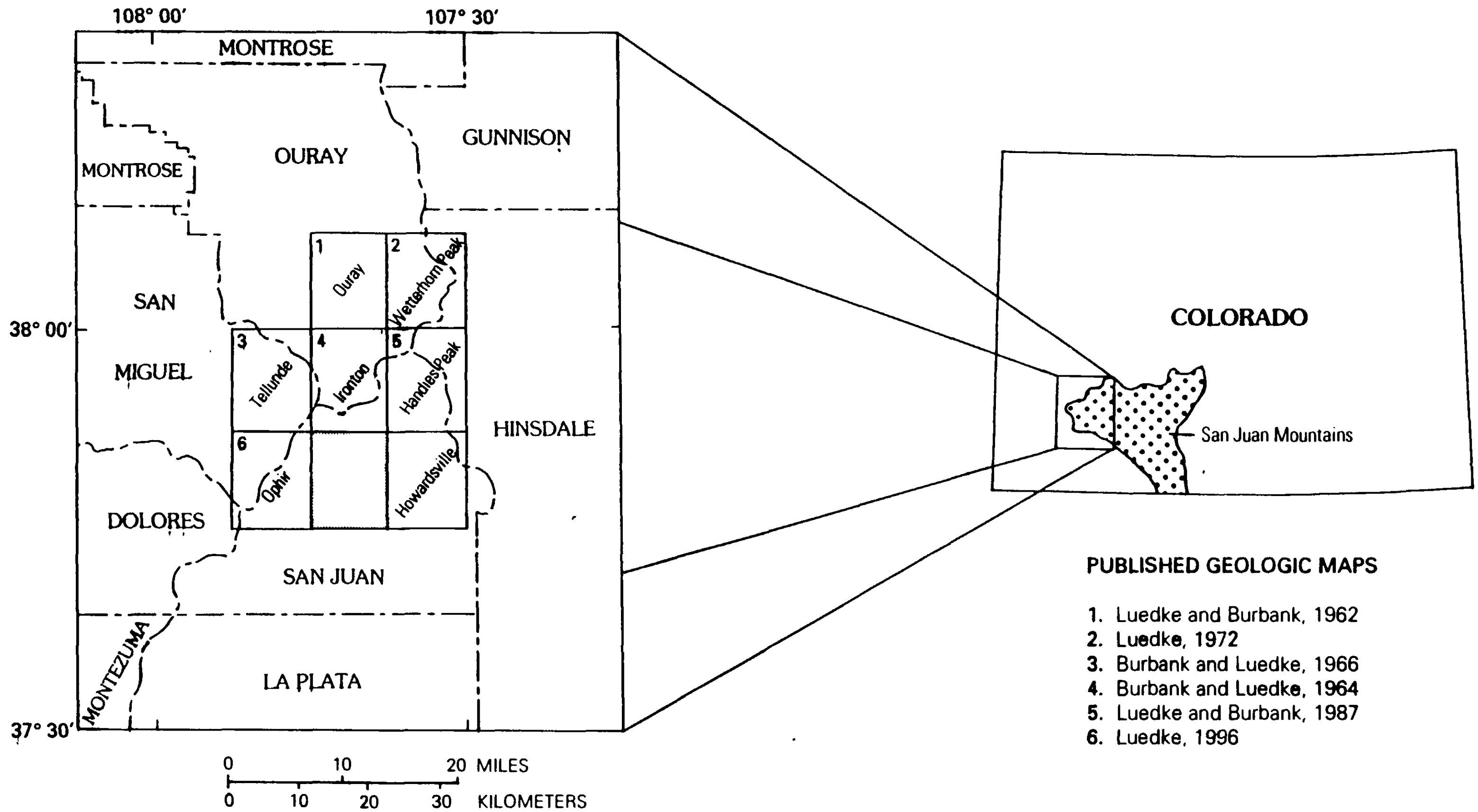

Figure 1.--Index map showing location of the Silverton 7.5-minute quadrangle (shaded) with respect to related quadrangles studied in the western San Juan Mountains of southwestern Colorado. All published geologic maps by the U.S. Geological Survey.

Telluride Conglomerate at the base, consist of a thick volcanic assemblage composed of predominantly volcaniclastic rocks of intermediate composition in the lower part, volcaniclastic rocks, lava flows, and both air-fall and welded ash-flow tuffs of mafic to silicic composition in the middle part, and welded ash-flow tuff of silicic composition in the upper part. Sources for these volcanic rocks were the Silverton caldera (fig. 2) and adjacent areas in the western San Juan Mountains.

Middle to late(?) Tertiary igneous dikes, sills, and small round to irregularly shaped bodies of intermediate to silicic composition have intruded the bedded rocks throughout the quadrangle. In addition, two stocks, the larger Sultan Mountain stock in the central part of the quadrangle (D, fig. 2) and a smaller unnamed stock in the west central part, were emplaced about 26 Ma (McDowell, 1971; Jackson and others, 1980). The Sultan Mountain stock, a composite intrusive mass, is predominantly granodioritic in composition; the unnamed stock is granitic. Contact metamorphism of the country rock adjacent to the stocks varies in extent and intensity and may extend outward locally for several hundred feet, but is more common in the rocks adjacent to the Sultan Mountain stock than either of the smaller stock or the many small intrusive bodies, dikes, and sills.

During Pleistocene time the region was extensively glaciated resulting in typical U-shaped valleys, sharp peaks, narrow ridges, and many steep-walled basins (cirques). This alpine topography is covered locally by a variety of differentiated surficial deposits, but particularly by glacial debris and moderate-sized landslide masses along the major valley walls.

Geologic structural features within the Silverton quadrangle are typical of the western San Juan Mountains region and are characteristic of deformation associated with both mountain building and eruptive volcanic, caldera-related, activity. The map area lies within the region affected by the ancestral San Juan Mountains domal uplift that occurred in Late Paleozoic time (Rocky Mountain orogeny) and again in Late Cretaceous-early Tertiary time (Laramide orogeny). The structural attitudes that reflect these two orogenies, including monoclinal folds, minor synclinal and anticlinal flexures, and local changes in direction of dip within the Paleozoic and Mesozoic strata, are more vividly displayed in adjacent quadrangles to the west and north (Luedke, 1996; Burbank and Luedke, 1966; Luedke and Burbank, 1962).

Within the map area, the principal structural features are those associated with the Silverton caldera and are continuous with similar structures in the Ironton quadrangle to the north and in the Howardsville quadrangle to the east (fig. 1). The caldera outline, although locally shown as a single fault on the geologic map, undoubtedly is a zone consisting of several faults and fault-block segments. Structural control of that part of the

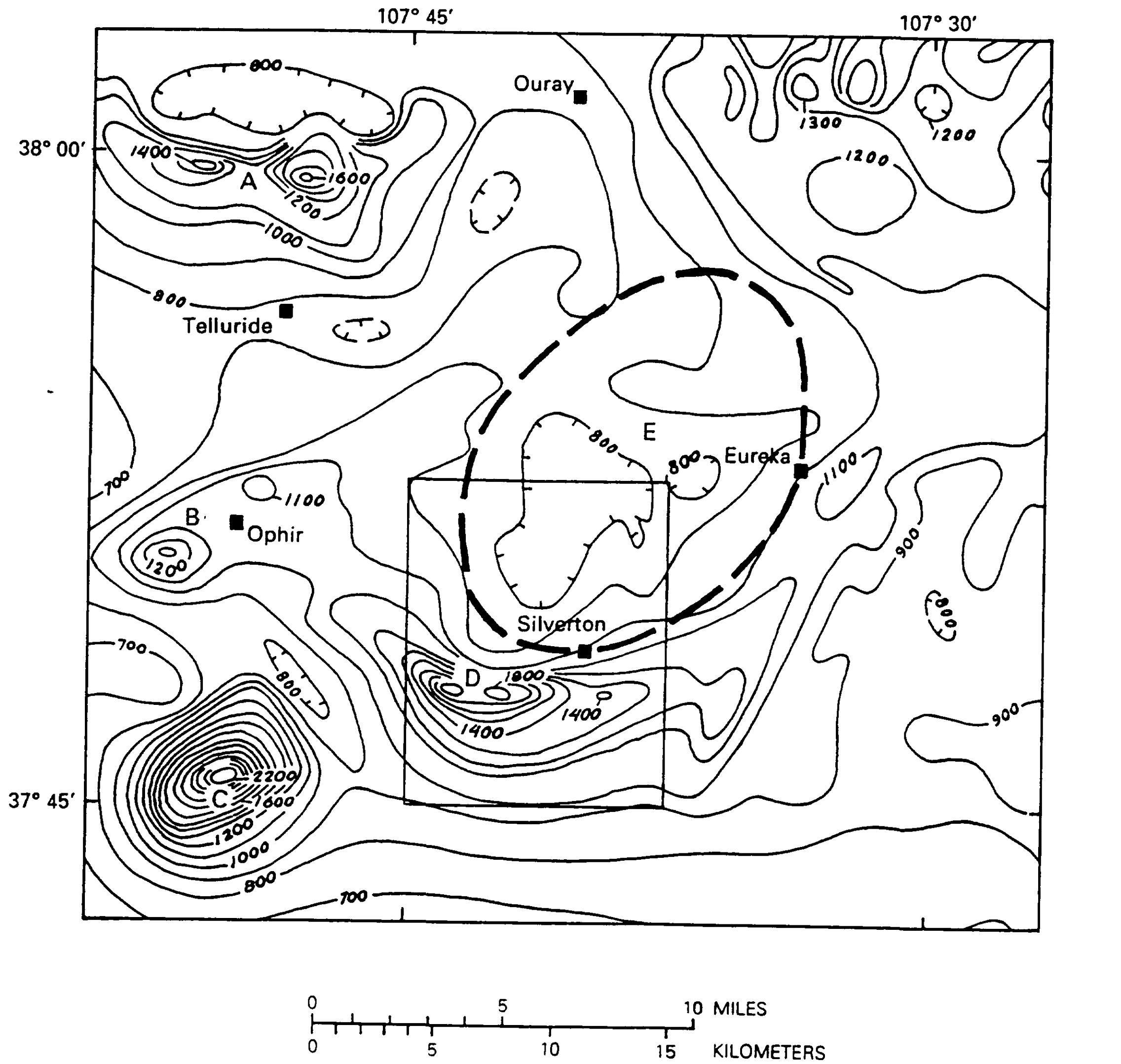

Figure 2.--Aeromagnetic map of part of the western San Juan Mountains region showing location of the Silverton quadrangle in relation to position of major intrusive masses and the Silverton caldera. Contours show total intensity of magnetic field of the earth in gammas relative to an arbitrary datum; hachures indicate closed areas of lower magnetic intensity. Points of reference: A, Mount Sneffels stock; B, Ophir stock; C, Grizzly Peak stock; D, Sultan Mountain stock; E, Silverton caldera (heavy dashed line). Map modified from U.S. Geological Survey (1972).

ring-fault zone along the valley of Mineral Creek is suggested in part by the alignment of several iron-rich spring deposits (bogs). The valley here, also, is believed to contain the structural walls of two calderas, an older one called the San Juan caldera and the younger Silverton caldera. Within the site now occupied by the Sultan Mountain stock the structural walls of the two calderas diverge so that the younger caldera wall trends easterly to northeasterly along the Animas River valley and the older caldera wall trends southeasterly through the south side of Kendall Mountain. The broken and fractured ground within the ring-fault zone provided an easily accessible route for stock to penetrate and locally engulf the country rock. Faults with small displacement and random orientation that occur throughout the quadrangle are presumed to be the result of middle Tertiary deformation related to caldera formation and associated igneous intrusive activity.

The valley trend of Cement Creek, north from the town of Silverton and parallel to the valley of Mineral Creek to the west, may be structurally controlled. This block of ground, the dividing ridge between the two valleys, is extensively silicified and altered; it also is reflected in part by the magnetic low in the southwest half of the caldera (fig. 2). No structures of significance can be seen in the field.

Cutting this same ridge, however, between Anvil Mountain and Ohio Peak, is an east-west trending fault with at least 400 ft (122 m) displacement (north side down) that aligns with the Middle Fork of Mineral Creek. Another east-west fault cutting into this ridge, with less displacement but the south side down, trends along Mill Creek in the northwest corner of the map area. The lopsided graben block defined by these two bounding east-west faults is in general alignment and displacement with and may be coextensive with a major zone of weakness that controls the east-west trend of the valley of Howard Fork described in the adjoining Ophir quadrangle to the west (Luedke, 1996).

Economic geology

The Silverton 7.5-minute quadrangle area has yielded base- and precious-metal ores and has been an integral part of mining activity in the western San Juan Mountains metal-mining region. Prospecting, principally for gold and silver, began here more than a century ago. With the exception of a brief foray by prospecters in 1860 in the Bakers Park area, the present site of Silverton, prospecting did not begin until the early 1870's. Real mining and ore beneficiation started in 1874 when the region was officially declared open by ratification of a treaty between the U.S. Government and the Ute Indians. In 1875, Green and Co.'s Works established the first smelter in Bakers Park (Raymond, 1877, p. 284). Only high-grade ores from the area could be worked because of few mills, the then current milling methods, and high transportation costs to the nearest railhead. Ransome (1901, p. 22) reported ".... ores running less than $100 per ton could seldom be handled with profit...." so that the mining industry here was limited until extension of the Denver & Rio Grande narrow-gauge railroad to Silverton in 1882. With the advent of the railroad, shipping costs were reduced so that lower-grade ores could be handled and more mines could become productive. About 1890 milling methods were successfully developed to permit concentration and amalgamation of lower-grade ores at both the Sunnyside and Silver Lake mines near Silverton (Burbank and Luedke, 1968). Treatment and transportion of the complex low-grade ores of the area gradually improved over the years so that the industry maintained economic viability albeit with the boom-and-bust periods typical of mining regions.

Most mines within the Silverton quadrangle are inaccessible; many were closed and inaccessible even by the turn of the century (Ransome, 1901). Most of the mines are believed to have been small and were explored only to shallow depths. An exception is the North Star mine on Sultan Mountain, west of Silverton, which in the early 1880's was one of the largest and most productive in the area; at the end of 1882 the mine had about 1,700 feet of drifts. The report of the Director of the Mint at the time stated that over 100,000 ounces of silver and 1,500,000 pounds of lead had been extracted (Ransome, 1901, p. 251). The North Star mine workings supposedly now interconnect southeasterly with a number of other mine workings in the direction of the Champion mine in the Animas River. The few mines examined and described in some detail within the map area are discussed in Ransome (1901), Henderson (1926), Varnes (1963), and Musgrave and Thompson (1991); the most up-to-date data available on mining activities for the western part of the quadrangle have been summarized by Neubert (1992).

Most ore produced in the area was from vein deposits within and peripheral to the caldera. Based upon the mineralogy of ore and gangue samples found on the mine dumps, some production from the Anvil Mountain-Ohio Peak area between Cement and Mineral Creeks possibly was from chimney or pipelike deposits. Ransome (1901) and Varnes (1947) described the veins on Sultan Mountain as characteristic of most of the veins elsewhere in the area. The veins consist of lead-silver and/or gold-bearing pyrite and chalcopyrite; the ore minerals occur in a gangue of quartz and barite. Varnes (1947, p. 432) further states that the mineralogy of the Sultan Mountain veins is similar to that of the east-west veins a few miles to the northwest in the Ophir valley. Several veins on Sultan Mountain and in Cement Creek contain hübnerite, and a few of the mines have shipped some tungsten ore (Belser, 1956).

Alteration

Most if not all of the volcanic rocks within the Silverton caldera and peripheral to it have been propylitically altered to varying degrees. This rock alteration (Burbank, 1960), caused by effusions of water and carbon dioxide, intensifies with depth and ranges from weakly carbonatized and chloritized to locally albitized and epidotized; it occurred during and shortly after magmatic resurgence of the caldera and concomitant emplacement of igneous intrusives within and near the caldera ring-fault zone. This alteration preceded vein formation and the general introduction of sulfur and metals.

Typical epithermal quartz-sericite-pyrite alteration is coextensive with the numerous stages of vein-forming solutions that yielded the many siliceous, often compound, sulfide veins in the caldera area and is generally restricted to within a few feet of the veins and ore bodies. This alteration, including some clay products, calcite, and chlorite, was more or less associated with the introduction of certain ores and gangues in the vein deposits.

Several episodes of more intense hydrothermal, near-surface alteration of an advanced argillic or acid-sulfate type were then superimposed upon the earlier propylitic alteration that leached and redistributed the rock bases (Burbank and Luedke, 1961). These highly altered rocks, such as occur in much of the northwest quarter of the Silverton quadrangle, consist of quartz, various clay minerals, alunite, zunyite, and pyrite. The so-called metamorphism of the country rocks and the acid waters issuing from them were discussed at some length by Ransome (1901, p. 113-131). The mineral association of dickite, alunite, and pyrophyllite with enargite and pyrite in the chimney or pipelike ore deposits is characteristic of areas that have undergone acid-sulfate alteration (Burbank, 1941; Burbank and Luedke, 1969; Luedke and Hosterman, 1971). The association of arsenical minerals in leached and oxidized ore deposits, and of arsenic and other metals in acidified mine and surface waters has long been recognized. A geochemical study by Burbank and others (1972) explored the possibility of using arsenic as an indicator element in the search for chimney or pipelike ore deposits in an area where the rocks had been subjected to acid-sulfate alteration and leaching. Preliminary field tests for residual arsenic proved to be a useful geochemical prospecting tool as long as the tests were intended to define specific areas, such as the relatively small pipe localities, and not to show anomalous broad halos. In addition to arsenic residuals, residual values of lead, silver, and mercury generally conform but copper and zinc do not as they are more easily leached by the acid surface waters.

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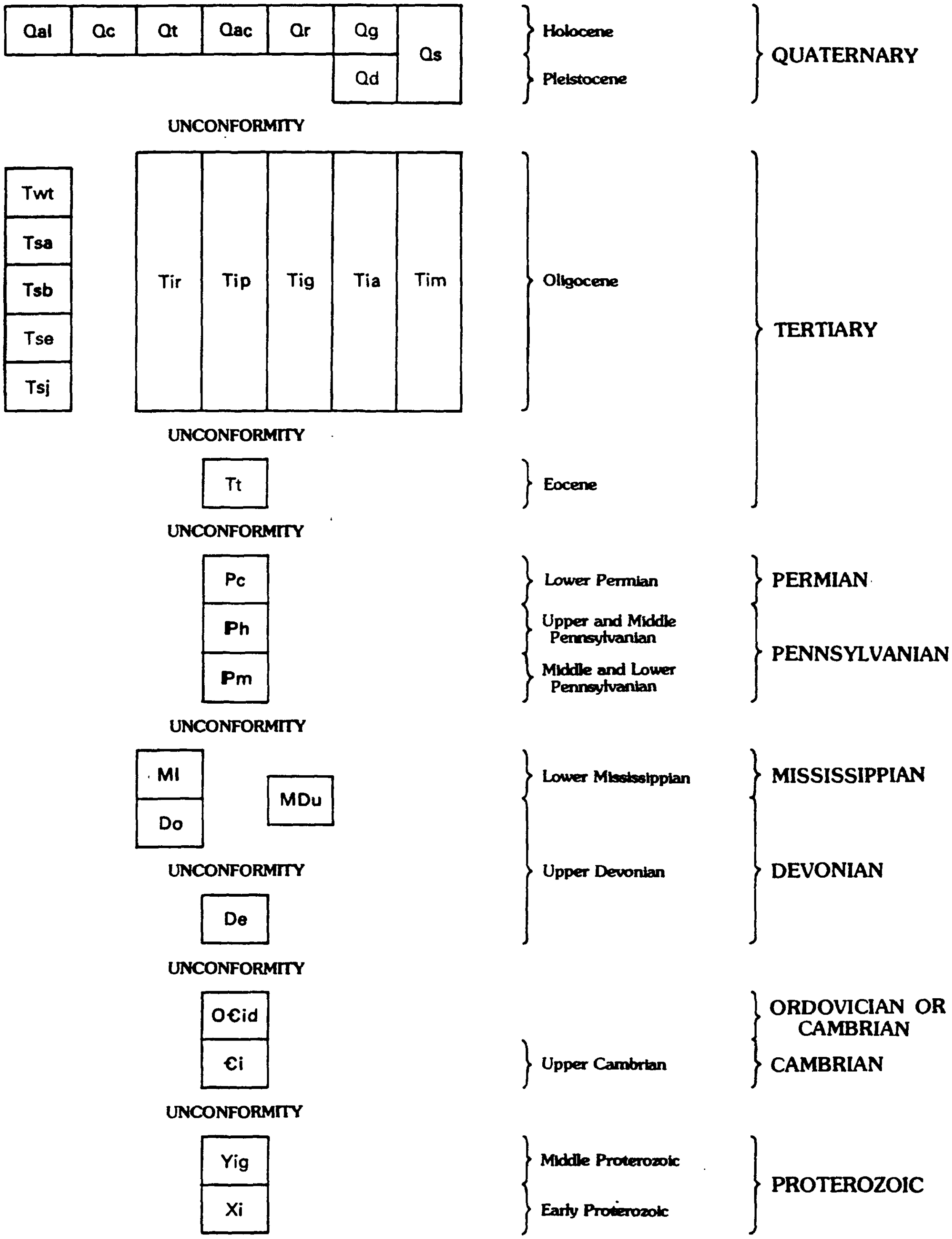
CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

SEDIMENTARY, VOLCANIC, AND INTRUSIVE ROCKS

Surficial Deposits

Qal — Alluvium (Holocene)--Unconsolidated fluvial deposits of silt, sand, gravel, and rounded to subrounded boulders up to 1½ ft (0.5 m) in diameter in valley bottoms

Qc — Colluvium (Holocene)--Unconsolidated and unsorted silt- to boulder-sized rubble comprising in part alluvial fill and in part residual and slope-wash materials on gentle slopes and in upland flats and valley bottoms; often boggy. Locally includes organic-rich material, some talus, alluvial-cone and landslide deposits, and glacial drift

Qt — Talus (Holocene)--Angular rock fragments forming cones, aprons, and slope cover commonly at the base of cliffs and along steep slopes. Locally includes protalus ramparts. Grades into colluvium with increase of silt and sand on less steep slopes

Qac — Alluvial cone deposits (Holocene)--Unconsolidated sand, gravel, cobbles, and subrounded to angular boulders forming lobate masses, with steep slopes, and often coalescing at mouths of tributary streams and gullies; form broader gentler-sloping lobate masses (fans) at mouths of major gulches tributary to Mineral Creek and Animas River valleys

Qr — Rock glacier deposits (Holocene)--Thick tongue-shaped masses of angular rock fragments ranging from sand-size particles to blocks 3 ft (1 m) or more in length, found in many cirques and on high alpine valley walls. Semiactive to actively advancing rock glaciers exhibit flowage by their steep, lichen-free boulder fronts and by the concentric and parallel ridges and troughs on top; many contain interstital ice and some, an interior ice core. Relative ages of rock glaciers are uncertain; only in cirques on Sultan Mountain are there definitely younger rock glaciers (Qr_2) advancing upon and over older ones (Qr_1)

Qg — Gravel (Holocene and Pleistocene)--Cemented gravel consisting of mostly round to subrounded, pebble to cobble-size clasts forming bench or terrace deposits locally in stream courses. Included is a hematitic iron-cemented, 10 to 15 ft (3-5 m) thick gravel deposit consisting mostly of metamorphic and igneous rocks capping Ohio Peak; possibly may be a remnant of a fluvial-gravel deposit on either a post-volcanic/pre-glacial erosional surface or an inter-glacial erosional surface

Qs

Landslide deposits (Holocene and Pleistocene)--Poorly sorted materials derived mostly from bedrock. Exhibit typical hummocky and broken surfaces and flowage features, often including a steep toe and marginal ridges and troughs. Includes small earthflows, larger slumps, and block slides. Several landslide masses throughout the quadrangle exhibit recent scars and scarps of smaller slumps on their upper surfaces

Qd

Glacial drift (Pleistocene)--Unconsolidated to semi-consolidated, unsorted materials consisting mainly of till and ranging in size from clay to boulders; locally may contain some outwash gravels. Lateral and terminal moraines within some drift masses

Intrusive Rocks

Tir

Rhyolite (Miocene? and Oligocene)--White to light-gray, dense to very fine grained with phenocrysts of sanidine, quartz, and sparse plagioclase and biotite. Platy or flow banded. Weakly to extremely altered. Occurs as dikes, sills and plugs

Tip

Quartz monzonite porphyry (Oligocene)--Light gray prophyritic rock with a very fine-grained groundmass composed of feldspar, quartz, and amphibole. Phenocrysts of anhedral to subhedral plagioclase averaging 5 mm in diameter and subhedral to euhedral orthoclase averaging 1 cm in length; some twinning, zoning, and resorption. Occurs as large dike-sill at south edge of Sultan Mountain stock

Tig

Granite (Oligocene)--Light-green to white equigranular to porphyritic rock with abundant phenocrysts or coarser grains of feldspar (plagioclase and orthoclase), quartz, and very little biotite in a very fine granular groundmass of potassic feldspar and quartz. Occurs as dikes, small irregular-shaped masses, and as small stock north of the junction of Mineral Creek and South Fork of Mineral Creek in the west-central part of the quadrangle; this body is extremely hydrothermally altered and silicified

Tia — Andesite (Oligocene)--Dark-greenish gray to dark gray, dense to slightly porphyritic rock with small (1-2 mm) phenocrysts of whitish plagioclase feldspar, pyroxene, and in places hornblende in a dense to very fine-grained groundmass. Weathers generally dark brown to greenish-black and is considerably altered to chlorite, epidote, calcite, sericite, and quartz. Occurs as dikes and sills throughout the quadrangle

Tim — Monzogranite-granodiorite (Oligocene)--Pinkish-white to light-gray, porphyritic rock with phenocrysts of feldspar (plagioclase and orthoclase) to 1 cm in size, quartz, hornblende, and locally biotite in a dense to fine-grained groundmass of feldspar and quartz; rock becomes more coarsely porphyritic near margins and in apophyses. Occurs as dikes, sills, small irregular-shaped plutons, and as the large Sultan Mountain stock. K-Ar ages of the Sultan Mountain stock are 24.7 and 27.6 Ma (McDowell, 1971) and 25.7 Ma (Jackson and others, 1980)

Extrusive and Related Rocks

(Volcanic rock units absent locally in map area due to nondeposition and/or local erosion)

Twt — Ash-flow tuff (Oligocene)--Light- to medium-gray, devitrified, moderately welded rhyolitic to dacitic ash-flow tuff found only in the northwesternmost corner of map and high on the slope east of Chattanooga at the north edge of the quadrangle. Crystal-rich rocks exhibit eutaxitic structure and have mainly feldspar, biotite, and quartz crystals 1-6 mm across in a dense to fine-grained groundmass. Angular, dark, lithic fragments as much as 1 cm across locally abundant. Thickness zero to 50 ft (0-15 m) and rests on an uneven erosion surface. Coextensive with numbered ash-flow tuff units in the Ophir quadrangle to the west (Luedke, 1996) and similarily numbered units of Gilpin Peak Tuff (now abandoned terminology) in the Telluride and Ironton quadrangles to the north and northwest respectively (Burbank and Luedke, 1964 and 1966)

Silverton Volcanics (Oligocene)--Lava flows and related volcaniclastic rocks of predominantly intermediate composition but ranging from andesite to rhyolite

Tsa

Pyroxene andesite member--Brownish weathering, dark-gray, dense to porphyritic high-potassium trachy-andesite, locally two-pyroxene and olivine bearing, in thin to thick, commonly amygdaloidal lava flows and flow breccias mostly found in the northeastern quarter of the quadrangle. Locally contains interbedded gray to black, thin, lenticular, sandy tuff beds; prominent tuff bed occurs at base of member on north and northwest sides of Boulder Mountain. Maximum thickness of member about 1,970 ft (600 m). Outcrop on ridge top north of Ohio Peak is an unaltered dark-gray, fine-grained to slightly porphyritic (feldspar and mafic phenocrysts averaging less than 1 mm in size) andesite or basaltic andesite flow about 65 ft (20 m) thick; possibly may be an erosional remnant equivalent to Hinsdale Formation of Miocene age in the central and eastern San Juan Mountains (Larsen and Cross, 1956). Flow-laminated, thick rhyolitic lava flows, breccias, and tuffs (intensely altered white) tentatively assigned to the base of the pyroxene andesite member on ridge top in vicinity of Ohio Peak; similar to Tsar unit in Handies Peak quadrangle to the northeast (Luedke and Burbank, 1987).

Tsb

Burns Member--Light- to dark-gray massively interbedded flow breccias and tuffs with some thin to thick massive flows and fluidal-banded flows. Consists of predominantly porphyritic high-potassium andesite to trachyandesite with euhedral to subhedral phenocrysts of plagioclase, amphibole, pyroxene, and some biotite averaging 1-5 mm in size in a dense aphanitic groundmass. This unit almost everywhere propylitically altered to chlorite, calcite, and locally to epidote and albite. Base an uneven erosion surface. Probable thickness about 1,800 ft (550 m) outside of and more than 2,300 ft (700 m) thick inside of the Silverton and San Juan calderas

Sapinero Mesa Tuff (Oligocene)

Tse

Eureka Member--Gray to greenish-gray, brown, moderately to densely welded ash-flow tuff with prominent eutaxitic structure and of high-potassium dacitic to low-silica rhyolitic composition. Moderately abundant crystals of feldspar (plagioclase and sanidine), biotite, minor quartz, and locally hornblende in a propylitically altered fine-grained to cryptocrystalline matrix. Locally contains abundant subangular andesitic and dacitic fragments about a centimeter across and very locally, reflecting the underlying basement, rounded amphibolite, gneiss, schist, or granite fragments to 2 cm in diameter. At the base on the north wall of Middle Fork Mineral Creek, and interbedded on the southwest side of Kendall Mountain are slightly altered, dark-gray, thin to thick, moderately porphyritic andesitic lava flows (Varnes, 1963). These may be representative of the underlying Picayune Megabreccia Member. Thickness zero to 40 ft (12 m) on Mill Creek in the northwestern corner of the quadrangle, about 200 ft (60 m) in Middle Fork Mineral Creek, and more than 1,400 ft (425 m) thick on Kendall Mountain

Tsj

San Juan Formation (Oligocene)--Thick-bedded to massive, gray to greenish-gray, locally red or purple, reworked lahar or mudflow breccia with intermixed sandy tuff and tuff conglomerate; consists of finely comminuted matrix and fragments 1½ ft (0.5 m) across of volcanic debris predominantly of intermediate composition. Propylitically altered throughout. The formation here representative of outflow facies in coalescing marginal volcaniclastic aprons of stratovolcanoes centered north to northeast of the quadrangle. Unconformable basal contact. Thickness ranges from zero to more than 1,640 ft (500 m)

Sedimentary Rocks

Tt

Telluride Conglomerate (Eocene)--Gray, brown, and red indurated sandstone and conglomerate with subangular to round clasts in an arkosic and sandy matrix. West of the Animas River valley the pebbles and cobbles of Mesozoic and Paleozoic sedimentary rocks in the lower part grade upwards to Precambrian gneiss, schist, quartzite, and granite (the stratigraphic section upside-down) indicating succession of rocks exposed and eroded in the western ancestral San Juan Mountains region during the Laramide orogeny. Deposited upon an irregular erosion surface that truncates and transgresses Permian and Pennsylvanian beds in the southwestern part of the quadrangle. East of the Animas River valley consists only of clasts of Paleozoic and Precambrian rocks in a silty to sandy matrix; preserved as an isolated erosional remnant in the southeast corner of the quadrangle. Deposition of the formation was both preceded and followed by extensive erosion east of the river, whereas to the west there was an apparent gradation with the overlying volcanic debris of the San Juan Formation. Thickness varies in map area; west of the river it averages about 200 ft (60 m) whereas east of the river the single outcrop is about 40 ft (12 m) thick

PRE-TERTIARY ROCKS

Sedimentary Rocks

Pc

Cutler Formation (Lower Permian)--Reddish-brown thin to thick lenticular beds of micaceous shale, siltstone, fine- to coarse-grained sandstone locally conglomeratic, and arkosic sandstone and conglomerate; locally calcereous. The upper contact everywhere is an erosional angular unconformity. Thickness zero to more than 1,000 ft (300 m)

Ph

Hermosa Formation (Middle and Upper Pennsylvanian)--Thin to thick beds of dark-gray and green interbedded shale, siltstone, fine-grained sandstone, and fossiliferous limestone in the lower part grading upwards into thin to thick beds of gray, brown, and red interbedded shale, siltstone, fine- to coarse-grained or gritty sandstone, arkosic and locally conglomeratic, and minor limestone. Metamorphosed and altered outcrops in Mineral Creek tentatively assigned to unit. Upper contact with overlying Cutler Formation apparently gradational and represented by an unknown thickness of beds tentatively assigned on the basis of contained fossils to the Rico Formation by Cross and others (1905), but not recognized by Spoelhof (1976) nor mapped by us. Thickness more than 1,800 ft

Pm

Molas Formation (Lower and Middle Pennsylvanian)--Brownish-red poorly stratified clayey to silty material with chert pebbles in the lower part grading upwards to thin- to medium-thick lenticular beds of mudstone, shale, fine- to coarse-grained sandstone, locally micaceous and conglomeratic, and locally fossiliferous limestone. Lower part represents ancient soils developed on underlying karst surface; upper part apparently gradational into overlying formation. Maslyn (1977) describes so-called paleokarst towers in vicinity of Molas Lake just south of the quadrangle. Thickness variable but up to about 165 ft (50 m)

Ml

Leadville Limestone (Lower Mississippian)--Medium to dark gray fine-grained limestone, locally dolomitic, in medium-thick to massive beds. Locally coarsely crystalline, brecciated, or with many irregular-shaped pods of black chert. Disconformity at the top represents a long period of erosion and weathering; uppermost part consists of solution weathered limestone fragments intermixed with red shale and mudstone. Thickness about 195 ft (60 m)

MDu

Undivided Leadville (Lower Mississippian) and Ouray (Upper Devonian) Limestones--Poorly exposed east of the Animas River valley north of Kendall Gulch and Deer Park Creek

Do

Ouray Limestone (Upper Devonian)--Irregular thin to medium thick beds of gray to light brown, dense to fine-grained limestone. Locally dolomitic limestone with some thin calcareous shale partings. Fossiliferous with crinoids and brachiopods; occasional mud cracks. Apparently conformable with and gradational into the overlying Leadville Limestone. Thickness 40 to 50 ft (12-15 m)

De

Elbert Formation (Upper Devonian)--Thin-bedded yellow or buff, red, and green calcareous fissile shale and fine-grained sandstone; a few thin sandy, and locally dolomitic, limestone beds. West of the Animas River valley unit is a weak, slope-forming sequence of beds but well exposed; to the east, it is poorly exposed north of Kendall Gulch and on the benches south of Deer Park Creek, and thought to be mostly absent owing to erosion prior to deposition of the overlying formation (Varnes, 1963). Disconformably overlain by the Ouray Limestone. Thickness about 40 ft (12 m)

Ꞓi

Ignacio Quartzite (Upper Cambrian)--Well-bedded dense white quartzite with a few thin yellow and red shaly partings. At base is quartzite-pebble conglomerate about 3 ft (1 m) or less in thickness. Both the basal and upper contacts represent erosional unconformities, the former angular unconformably upon metamorphic and igneous rocks of the Precambrian basement and the latter disconformably with the overlying sedimentary rocks of Devonian age. Exposed on the benches west and east of the Animas River valley, and in and south of Deer Park Creek. Thickness averages about 40 ft (12 m)

Intrusive Rocks

OꞒid Intrusive diabase (Ordovician or Cambrian)--Dark greenish-gray to black, fine- to medium-grained diabase dikes mostly less than 3 ft (1 m) thick. Composed of labradorite and augite in a subophitic texture; locally altered to chlorite and calcite. Some or all of the diabase dikes are suspected to be Precambrian in age

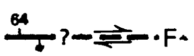
Yig Granite (Middle Proterozoic)--Pink to light gray concordant and crosscutting irregular-shaped intrusive masses and dikes intruded into the Irving Formation. Composed of plagioclase, potassic feldspar, quartz, and biotite; alteration of feldspars to sericite and biotite to chlorite common. Intrusive masses range in size from a few feet to several thousands of feet (most not individually mapped because of limited exposure, accessibility of area, and extremely complex intertonguing nature) in the Animas River canyon and on the benches east and west of the canyon. These granitic rocks, in general, have uranium-lead ages of about 1720 Ga (Barker, 1969), and are tentatively assigned to the Tenmile Granite

Metamorphic Rocks

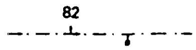
Xi Irving Formation (Early Proterozoic)--Metasedimentary and metavolcanic rocks composed principally of dark gray to greenish-gray, foliated and banded plagioclase-rich geisss interlayered with thin layers of biotite schist, muscovite schist, hornblende schist, and gray-black amphibolite. Amphibolite, with almandine garnet, is the most common rock exposed at the mouth of the Animas River canyon from the railroad bridge to about Kendall Gulch, and is believed to be of volcanic origin. Unit exposed in the southern part of the quadrangle

EXPLANATION OF SYMBOLS

———?——— Contact--Queried where uncertain



Fault--Showing dip. Dashed where approximately located; dotted where concealed; queried where uncertain. Dip not shown where vertical. Bar and ball on downthrown side. Arrows show direction of relative horizontal movement. F, where inferred to be engulfed by intrusive



Vein or mineralized fault or fissure--Showing dip. Dotted where concealed. Dip not shown where vertical or where unmeasured on inclined. Bar and ball on downthrown side

Strike and dip of beds

Inclined

Horizontal

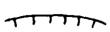
Strike and dip of foliation

Inclined

Vertical

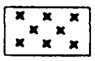
Bearing of plunge of lineation--Combined with foliaticn symbols

Protalus rampart



Slump scar--Hachures indicate direction of slumping

Bog-iron (travertine) deposit--Spring deposit rich in iron oxide minerals



Hydrothermally altered rock--Locally quartz-sericite-clay type commonly associated with ore deposits or structural features related to ore localization; extensive quartz-clay acid-sulfate type in country rocks between South and Middle Forks of Mineral Creek, between valleys of Mineral and Cement Creeks from near north edge map to vicinity of Silverton, and along Animas River valley to east edge of map