U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY
MISCELLANEOUS FIELD STUDIES MAP
MF–2377
Version 1.0

GENERALIZED GEOLOGIC MAP OF PART OF THE UPPER ANIMAS RIVER WATERSHED AND VICINITY, SILVERTON, COLORADO

Compiled by
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2002
SCALE 1:48 000
CONTOUR INTERVAL 40 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929SCALE 1:48 000
Base from U.S. Geological Survey, 1955,
Handies Peak, Howardsville, Ironton,
Ophir, Silverton.
Projection: Universal Transverse Mercator, zone 13.
10,000-foot grid based on Colorado
coordinate system, south zone.
1927 North American datum
Geology compiled by Yager and Bove, 1996–1999.
See "Index map" for mapping data sources used in compilation

DESCRIPTION OF MAP UNITS

QUATERNARY SURFICIAL DEPOSITS

Alluvium (Holocene)—Unconsolidated fluvial deposits. Poorly sorted silt, sand, and, locally, cobble- to boulder-size sediment. Includes alluvial fan deposits near mouths of tributary drainages

Undifferentiated surficial deposits (Holocene and Pleistocene)—Consists primarily of alluvium, alluvial fan deposits, talus, and colluvium

Colluvium and landslide deposits (Holocene and Pleistocene)—Poorly sorted silt- to boulder-size sediment. Colluvium is composed of accumulations of rock and soil deposited on gentle slopes, upland flats, and valley bottoms due to slope wash; deposits locally include bogs. Landslide deposits are derived from bedrock, heterogeneous, and poorly sorted; deposits have hummocky surface morphology

Talus, glacial deposits, and rock glaciers (Holocene and Pleistocene)—Talus consists of unconsolidated, angular, cobble- to boulder-size rock fragments near the base of steep slopes and cliffs. Glacial deposits consist of poorly sorted, unconsolidated, clay- to boulder-size material; lateral moraines are locally preserved. Rock glaciers are ice-cored, lobe-shaped masses located near cirque basins; consist of poorly sorted, sand- to boulder-size material. Continuous creep downslope is evidenced by prominent pressure ridges that are both parallel and perpendicular to the direction of flow

Bog deposits (Holocene)—Organic-rich, low-energy fluvial deposits formed in topographic depressions and adjacent to rivers and streams. Well to moderately well sorted; layered or bedded where dry; often iron rich

TERTIARY IGNEOUS AND VOLCANICLASTIC ROCKS

Rhyolite (Miocene)—White to light-gray, aphanitic to porphyritic, flow-foliated rhyolitic dikes and plugs; wall-rock contact margins are commonly brecciated. A fission track date on zircon from a rhyolite dike sampled near Red Mountain Pass summit yielded an age of 11.0±1.2 Ma (Lipman and others, 1976)

Sunshine Peak Tuff (Miocene)—Light-gray to tan, weakly welded, alkalic rhyolitic ash-flow tuff from the Lake City caldera, containing 20–30 percent phenocrysts of quartz, sodic sanidine, and sparse biotite. Quartz phenocrysts are rounded and embayed. 40Ar/39Ar dates on sanidine yielded a mean age of 22.93±0.2 Ma (Bove and others, 1999). Remanent magnetic polarity: reverse. Thickness 0–80 m

Dacite intrusions (Oligocene to Miocene)—Plugs, intrusions, and dikes of gray porphyritic dacite containing 10–30 percent phenocrysts of sanidine, plagioclase, quartz, biotite, and sparse hornblende. Some sanidine crystals are as much as 4 cm across and have oligoclase rims, such as those observed in outcrops near Red Mountain No. 3 above Prospect Gulch. Sanidine and biotite from dacite porphyry intrusions that are spatially associated with mineralized breccias located at the National Belle mine, near Red Mountain Pass, yield slightly discordant K-Ar dates of 21.9±0.6 and 24.0±0.7 Ma, respectively (Hon and Mehnert, 1983). K-Ar ages determined on sanidine and biotite from intrusions of similar composition in the Corkscrew Gulch and Red Mountain No. 3 areas yielded ages of 22.4±0.3 Ma and 23.6±0.4 Ma, respectively (Gilzean, 1984)

Andesite dike (Oligocene)—Dark, aphanitic to porphyritic dikes

Tertiary intrusions (Oligocene to Miocene)—Plugs and intrusions of unknown composition

Sultan Mountain stock (Oligocene)—Light-greenish-gray granitic intrusives. Propylitically to more intensely altered; composed of potassium feldspar, plagioclase, quartz, biotite, hypersthene, augite, magnetite, apatite, and zircon. We use granitic as a general term that denotes intrusive rocks that may be classified as monzodiorite, monzonite, granodiorite, or monzo-granite (Ringrose, 1982). K-Ar dates on biotite separates from several phases of the stock range in age from 25.2±0.6 Ma to 25.9±0.6 Ma (Jackson and others, 1980). Two 40Ar/39Ar dates on biotite samples from the Sultan Mountain stock have a weighted mean age of 26.60±0.04 Ma (Bove and others, 1999)

Crystal Lake Tuff (Oligocene)—Phenocryst-poor, rhyolitic ash-flow tuff and related caldera-collapse breccia. Contains 5 percent phenocrysts of sanidine and plagioclase. Erupted from the Silverton caldera. 40Ar/39Ar age determined from sanidine is 27.62±0.07 Ma (Bove and others, 1999). Remanent magnetic polarity: normal. Thickness 0–70 m

Fish Canyon Tuff (Oligocene)—Nonwelded light-gray to densely welded dark-gray dacitic ash-flow tuff containing about 50 percent phenocrysts (mainly plagioclase, sanidine, biotite, and hornblende). Sparse resorbed quartz, accessory sphene, and hornblende without augite are distincive phenocrysts. 40Ar/39Ar age determined from sanidine is 27.55±0.07 Ma (Lanphere and Baadsgaard,1997). Remanent magnetic polarity: normal. Erupted from La Garita caldera complex east of map area. Thickness 0–200 m

Silverton Volcanics (Oligocene)—Lava flows of intermediate to silicic composition and related volcaniclastic sediments that accumulated within and adjacent to the San Juan and Uncompaghre calderas after their collapse and prior to subsidence of the Silverton caldera. The Silverton Volcanics consist of: (1) pyroxene andesite member, consisting of porphyritic andesitic flows that contain 15–25 percent phenocrysts of plagioclase and augite, which overlies the Burns Member but locally interfingers with it, especially in southeast part of Howardsville 7 1/2' quadrangle; (2) Burns Member, consisting of porphyritic, andesite to rhyolite flows that contain less than 15–30 percent phenocrysts of plagioclase, biotite, augite, and hornblende—ashflows, flow breccias, and reworked volcaniclastic deposits are preserved locally; and (3) Henson Member, consisting of volcaniclastic sedimentary rocks that interfinger with the Burns Member and pyroxene andesite members. Regionally, the Silverton Volcanics is propylitically altered to chlorite, epidote, ±calcite, ±pyrite, and ±magnetite. Calcite and pyrite are often pervasive and disseminated throughout the groundmass and within microveinlets. This unit hosts much of the mineralization in the Silverton mining district. Where not intensely altered, the Silverton Volcanics has the ability to buffer acidic waters (Desborough and Yager, 2000). See Lipman (1976) for detailed description of the Silverton Volcanics. Thickness 1,000 m

Sapinero Mesa Tuff (Oligocene)—Nonwelded gray to densely welded red-brown rhyolitic ash-flow tuff. Contains 2–5 percent phenocrysts of plagioclase, with lesser amounts of sanidine, biotite, and trace augite. Outflow derived from the San Juan and Uncompahgre calderas. Mean 40Ar/39Ar age determined from sanidine is 28.19±0.03 Ma (Bove and others, 1999). Remanent magnetic polarity: reverse. Thickness 0–60 m

Eureka Member and Picayune Megabreccia Member of Sapinero Mesa Tuff (Oligocene)—Eureka Member is partly welded light-gray to densely welded red-brown rhyolitic to dacitic(?) ash-flow tuff containing 5 percent phenocrysts of plagioclase, sanidine, and biotite. Unit is the intracaldera member of the Sapinero Mesa Tuff. Picayune Megabreccia Member consists predominantly of older andesitic to dacitic blocks (often enclosed in a Eureka Member tuff matrix) that caved into the San Juan caldera during caldera collpase. Exposures of the Picayune Megabreccia Member crop out about 2.5 km north of Eureka town site. Remanent magnetic polarity: reverse. Maximum exposed thickness (base not seen) is 800 m

Dillon Mesa Tuff (Oligocene)—Nonwelded gray to densely welded red-brown rhyolitic ash-flow tuff. Mineralogy is similar to that of the Sapinero Mesa Tuff (Ts). The Dillon Mesa Tuff is generally thinner and less densely welded than the Sapinero Mesa Tuff. Mean 40Ar/39Ar age determined from sanidine is 28.40±0.04 Ma (Bove and others, 1999). Probably derived from the Uncompahgre caldera. Remanent magnetic polarity: reverse. Thickness 0–100 m

Blue Mesa Tuff (Oligocene)—Nonwelded gray to densely welded red-brown ash-flow tuff. Contains about 5 percent phenocrysts of plagioclase, sanidine, and biotite. Probably derived from the Lost Lake caldera (Lipman, 1976). Mean 40Ar/39Ar age determined from sanidine is 28.4±0.07 Ma (Bove and others, 1999). Remanent magnetic polarity: reverse. Thickness 0–250 m

Ute Ridge Tuff (Oligocene)—Nonwelded gray to densely welded gray-brown to red-brown dacitic ash-flow tuff. Unit consists of 50 percent phenocrysts of plagioclase, sanidine, biotite, and augite. Derived from the Ute Creek caldera.

Mean 40Ar/39Ar age determined from sanidine is 28.63±0.05 Ma (Bove and others, 1999). Remanent magnetic polarity: reverse. Thickness 0–150 m

San Juan Formation (Lower Oligocene)—Intermediate-composition lava flows and volcaniclastic deposits consisting mostly of mudflow breccias containing dark intermediate-composition volcanic clasts with some conglomerate and sandstone; flows commonly contain hornblende. Volcaniclastic deposits preserved as clastic aprons on the slopes of and between penecontemporaneous stratovolcanoes. Thickness 0–600 m

Tuff of Imogene Pass Member of San Juan Formation (Lower Oligocene)—Dark-brown, andesitic to dacitic ash-flow tuff. Corresponds to unit Tse of Burbank and Luedke (1964). Ash flows formed as a result of stratovolcano collapse near Red Mountain and Imogene Passes. Ash flows are best preserved in the Imogene Pass area but grade laterally into basal lag breccias with blocks as large as 5 m that are enclosed in a pyroclastic matrix. Thickness 0–80 m

Telluride Conglomerate (Eocene)—Gray to brownish-red conglomerate and sandstone. Consists of Precambrian, Paleozoic, and Mesozoic, cobble- to boulder-size clasts in an arkosic, silty to sandy matrix. Thickness 0–60 m

PRE-TERTIARY ROCKS

Granodiorite (Late Cretaceous)—Light-gray, porphyritic granodiorite laccolith restricted to northwest corner of map area

Mancos Shale (Upper Cretaceous)—Mostly dark-gray marine shale. Thickness about 200 m, however unit much thicker to the south

Dakota Sandstone (Upper Cretaceous)—Light-gray to brown sandstone with interbedded siltstone and carbonaceous shale; commonly contains chert-pebble conglomeratic sandstone at base. Thickness about 100 m

Morrison Formation (Upper Jurassic)—Basal part of unit consists of yellowish-white to buff, crossbedded, fine- to medium-grained sandstone with lenses of gray to green variegated mudstone. Upper part of unit consists primarily of variegated calcareous mudstone. Thickness 0–30 m

Wanakah Formation (Middle Jurassic)—Green to red-brown calcareous mudstone and siltstone with thin limestone and sandstone interbeds near top of unit. Thickness 0–30 m

Entrada Sandstone (Middle Jurassic)—Light-tan, fine-grained, crossbedded sandstone. Thickness 0–20 m

Dolores Formation (Upper Triassic)—Brownish-red siltstone and sandstone with interbeds of limestone and quartz-pebble conglomerate. Thickness about 40 m

Cutler Formation (Lower Permian)—Reddish-brown micaceous shale, arkosic sandstone, and conglomerate; locally calcareous. Thickness 0–150 m

Hermosa Formation (Upper and Middle Pennsylvanian)—Red-brown arkosic sandstone, and interbedded fossiliferous greenish-gray shale, sandstone, and conglomerate. Thickness 0–70 m

Hermosa and Molas Formations, undifferentiated (Pennsylvanian)—Reddish-brown shale, sandstone, and conglomerate

Molas Formation (Middle and Lower Pennsylvanian)—Reddish-brown calcareous shale, sandstone, and conglomerate. Thickness 0–25 m

Leadville Limestone (Lower Mississippian)—Gray, dense limestone with a few basal sandy layers; chert and red shale interbeds near top. Thickness 0–60 m

Leadville and Ouray Limestones, undifferentiated (Lower Mississippian and Upper Devonian)—Altered, mineralized, and recrystallized limestone near Ironton Park and in Silverton and Howardsville 7 1/2' quadrangles. Thickness 0–65 m
Ouray Limestone (Upper Devonian)—Light-gray dolomite and limestone. Thickness 0–15 m
Elbert Formation (Upper Devonian)—Tan, thin-bedded dolomitic limestone and interbedded calcareous shale and sandstone. Thickness 0–15 m
Ignacio Quartzite (Upper Cambrian)—Light-gray quartzite, sandstone, and siltstone; locally conglomeratic in lower part; maximum thickness 17 m
Undifferentiated rocks (Precambrian)—Gray and black to brown argillite, slate, quartzite with slate partings, schist with quartz partings, and gneiss

Contact
Fault—Dashed where concealed or inferred. Bar and ball on apparent downthrown block
Mineralized, altered veins and fissures—Location inferred where dashed beneath Quaternary units
San Juan caldera, topographic southern margin—Dashed where approximately located
Strike and dip of bedding
Strike and dip of foliation
Inclined
Vertical

INTRODUCTION

Economic and, later, geologic interest focused on the upper Animas River watershed in the vicinity of Silverton, Colorado, initially because of the discovery of gold in the region in 1870 (Sloan and Skowronski, 1975). Regional and topical geologic investigations in the area have spanned the era from the late 19th century to the present (Ransom, 1901; Cross and others, 1905; Varnes, 1963; Burbank and Luedke, 1964; Steven and others,1974; Luedke and Burbank, 1975; Lipman, 1976; Luedke, 1996). Many of these geologic investigations were concerned with (1) the extensive base- and precious-metal mineral deposits dispersed throughout the region and (2) a remarkable and varied stratigraphic and structural geologic history. The Tertiary volcano-tectonic history and related events of mineralization are not only responsible for the mineral deposits, but also for alteration of the Tertiary volcanic rocks in or near the San Juan and Silverton calderas (Casadevall and Ohmoto, 1977; Bove and others, 1999; Bove and others, 2000; Yager and others, 2000). Weathering of the altered near-surface volcanic rocks produces acidic waters that transport major and trace elements into surface waters.

The purpose of this geologic compilation is to provide the U.S. Geological Survey, Animas River watershed, Abandoned Mine Land (AML) project a geologic map at a suitable scale for geospatial analysis. This map will be used to interpret geochemical, geophysical, hydrologic, and biologic datasets within a geologic framework. Diverse data acquired during the Animas River watershed AML project will also be used by Federal land management agencies in developing effective mined-land remediation strategies (Buxton and others, 1997).

GEOLOGIC SETTING OF THE UPPER ANIMAS RIVER WATERSHED

PHYSIOGRAPHIC SETTING

The map area is located in the rugged and spectacular San Juan Mountains in the western San Juan volcanic field, southwestern Colorado (fig. 1). Topographic relief in the project area exceeds 1,000 m, with elevations reaching over 4,000 m above sea level. The ecoregion is classified as the southern Rocky Mountain Steppe (Bailey, 1995). The watershed receives as much as 88–100 cm of precipitation principally as snow in the winter and early spring months (Daly and others, 1994); brief, but intense, summer thunderstorm activity produces stormwater runoff throughout the summer months. State Highway 550 provides access to the map area from either Montrose or Durango, Colorado. Major streams that are part of the upper Animas River area include Cement and Mineral Creeks, located north and west, respectively, from the town of Silverton and the Animas River in the east and northeast (fig. 1).

GEOLOGIC SETTING

The general stratigraphy of the map area consists of a Precambrian crystalline basement overlain by Paleozoic and Mesozoic sedimentary rocks and by a Tertiary volcanic cover (Luedke and Burbank, 1963; Steven and others, 1974; Lipman, 1976). Tertiary volcanism in the San Juan volcanic field began between 35 and 30 Ma with the eruption of intermediate-composition lava flows, pyroclastic flows, and mudflows. The oldest Tertiary volcanic rocks, the San Juan Formation, consist of mudflows, pyroclastic flows, and lava flows. Caldera-related eruptions commenced in the western San Juan Mountains with formation of the (28.2 Ma) San Juan caldera and the nearly coincident Uncompahgre caldera followed by the nested (27.6 Ma) Silverton caldera (Lipman and others, 1973; Bove and others, 1999).

Caldera-bounding arcuate ring fractures and tangential radial fractures preserved near the periphery of the calderas provided pathways for intrusive magmas and later hydrothermal fluids (fig. 1). These Tertiary volcano-tectonic structures occur as regionally pervasive features that extend for thousands of meters. Secondary caldera-related structures such as apical grabens were also later extensively mineralized and developed as post-caldera collapse magma intruded and domed the central cores of these 15-km-wide calderas (Casadevall and Ohmoto, 1977). Caldera-related structures also provided pathways for eruption of lavas that infilled the calderas. For example, San Juan caldera collapse was followed by ring fracture eruption of post-collapse, intermediate-composition Silverton Volcanics lava flows that infilled the caldera (Lipman and others, 1973). Multiple, intermediate- to silicic-composition, post-caldera-collapse porphyries intrude the San Juan Formation and Silverton Volcanics along the margin of the Silverton caldera (fig. 1). These intrusions usually post-date caldera formation by at least 1 m.y. (Ringrose, 1972). Regional tilting and uplift in the San Juan Mountains during latest Miocene to Pliocene time resulted in significant erosion and downcutting to expose a hydrothermally altered and intensely mineralized terrain (Steven and others, 1995). Extensive Pleistocene glaciation and accompanying erosion throughout the region further exposed the mineralized terrain to weathering processes. Weathering of minerals in hydrothermally altered rocks and in surficial deposits (Bove and others, 2000; Yager and others, 2000) results in acidic and metal-rich streams throughout the Animas River watershed.

MAP COMPILATION APPROACH

Most map data were transferred to stable base materials and scanned or digitized. Digital map data were converted into ARC/INFO and projected to the Universal Transverse Mercator (UTM) geographic projection (zone 13). This is the projection used for other cartographic base information available for the Animas River watershed, AML project. The compilation scale was 1:24,000; sufficient data were generally available from existing geologic maps to maintain continuity in map units and structural features across map boundaries. Parts of the Howardsville and the Silverton 7 1/2' quadrangles were not mapped in as much detail as the remainder of the map area. Thus, certain units and structural features and veins are not displayed in as much detail as is evident in other areas. Units within the Silverton Volcanics, such as the Burns and Henson Members and the pyroxene andesite member (Lipman, 1976), were not mapped separately for this compilation due to the lack of corresponding data for parts of the Howardsville and Silverton 7 1/2' quadrangles. Quaternary units were generalized for the purposes of this compilation. Detailed 1:24,000-scale surficial geology is available for the Animas River from Durango to Silverton and for its major tributaries in the upper Animas River watershed (R.W. Blair, Jr., and D.B. Yager, in progress, DDS–71). Not all veins were compiled from existing maps. Vein orientation and vein density are generalized throughout the map area.

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