Geologic Map of the Patagonia Mountains, Santa Cruz County, Arizona

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Abstract

The Patagonia Mountains contain two large porphyry Cu-Mo systems each with separate associated hypogene and supergene zones, two high-grade Cu-Mo breccia pipes, one large epithermal Ag-Pb-Zn-Mn deposit, and numerous additional areas of base- and precious-metal mineralization all zoned around a Laramide-age composite batholith of intermediate composition. Compilations and new work by Vikre and others (2014) have identified as many as eight separate intrusive phases of the batholith and five separate hydrothermal events spanning at least 16 m.y., in addition to a supergene enrichment event of middle Tertiary age. The geologic map presents a spatial context for this important new information that is intended to support further work in this highly mineralized region.

Several spatial databases provide data for the geologic map of the Patagonia Mountains in Arizona. The data can be viewed and queried in ArcGIS 10, a geographic information system; a geologic map is also available in PDF format. All products are available online only at http://dx.doi.org/10.3133/ofr20151023.

Introduction

The Patagonia Mountains are located 90 km south of Tucson, Arizona, and extend 23 km south from the town of Patagonia, Arizona, into Sonora, Mexico (see fig. 1 and map sheet). The geology of the Patagonia Mountains and their deposits of metallic minerals are described in numerous published and unpublished reports with geologic maps at various scales; however, other than Schrader (1915), no detail is available for the U.S. part of the mountain range.

For this publication, the geology of the Patagonia Mountains in Arizona was compiled primarily from a geologic map by Simons (1974) from mapping done in 1960–1966 and 1970; other sources of data included maps by Drewes (1971, 1980), and Graybeal (1973; unpub. data, 1973) and D.L.E. Huckins (unpub. data, 1975, in Quinlan, 1986). The unpublished data were formerly presented as generalized maps in page-size format in Graybeal (1984, 1996) and Quinlan (1986). Very little new mapping was performed after 1975, although minor revisions were made throughout areas of Mesozoic and early Tertiary rocks and are included in this new geologic map. On the basis of limited field checking, we caution that the representation of Tertiary and Quaternary units on the southwest and west sides of Red Mountain may require further revision.

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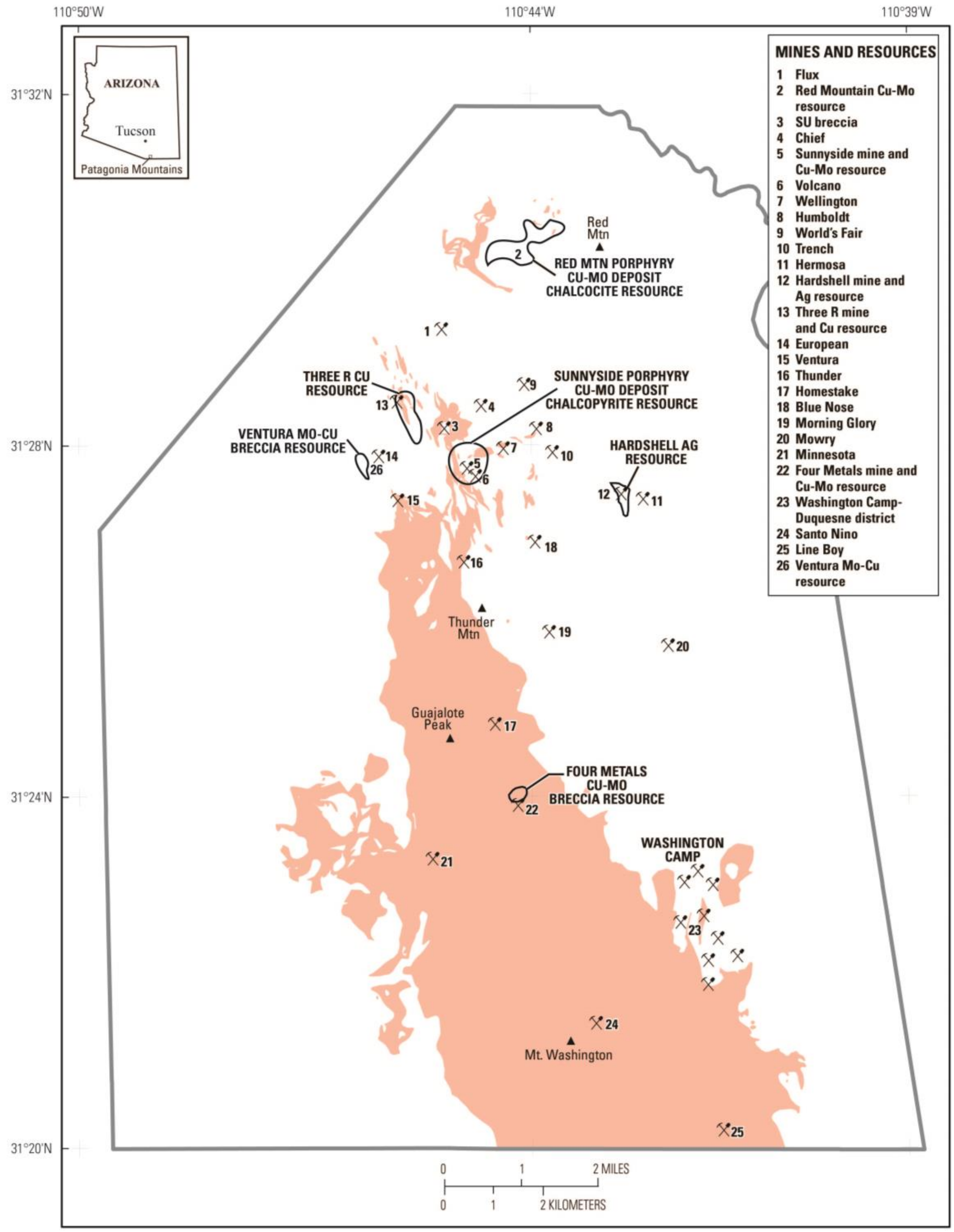

Figure 1. Map of mines and deposits of the Patagonia Mountains, Arizona. Map also shows all Laramide-age intrusions (pale red) that are genetically related to the mineral deposits. These intrusions include units Tqp, quartz feldspar porphyry of middle Alum Gulch; Tqmp, quartz monzonite porphyry; Tg, granodiorite; Tlp, latite porphyry; Tbq, biotite quartz monzonite; Tbg, biotite granodiorite; Tsy, syenodiorite; Tag, biotite augite quartz diorite; Tmp, quartz monzonite porphyry of Red Mountain; and Kpg, porphyritic biotite granodiorite.

Spatially referenced data for geology, and a topographic basemap, are provided for use in version 10 of Esri's ArcGIS software package, a geographic information system (GIS). Geologic data were primarily digitized from the geologic maps; some data were already in a digital format (Drewes and others, 2002). Terminology specific to ArcGIS is used throughout this report; a dictionary is available online at http://support.esri.com/en/knowledgebase/Gisdictionary/browse (accessed March 18, 2014).

Overview of Digital Data Files

The spatial data for the geologic components of the map are provided in vector format in a projected coordinate system (Universal Transverse Mercator, zone 12, North American datum of 1927); the topographic basemap is in raster format in the same map projection. Metadata files describe the geospatial data.

A list of all the digital data files is provided in table 1. The complete suite of Esri-format GIS data is packaged in the compressed archive file GIS_PatagoniaMtns.zip. All files are available on the Internet at http://dx.doi.org/10.3133/ofr20151023.

Table 1. Description of digital data files in the compressed archive file GIS_PatagoniaMtns.zip

File Name	File Description
Adobe Acrobat Portable Document Format (PDF) files	
PatMtns_GeoLines_metadata.pdf	Metadata for geologic lines
PatMtns_GeoUnits_metadata.pdf	Metadata for geologic map units
PatMtns_pyrite_metadata.pdf	Metadata for pyrite zones
PatMtns_shear_metadata.pdf	Metadata for shear zones
PatMtns_StrikeDip_metadata.pdf	Metadata for strike and dip data
PatMtns_TopoMap_metadata.pdf	Metadata for topographic base map
Esri files in the file geodatabase PatagoniaMtns.gdb	
AZ_bndy_UTM	Feature class for political boundary for the state of Arizona.
PatMtns_GeoLines	Feature class (lines) for contacts, faults, dikes, and very thin geologic map units.
PatMtns_GeoUnits	Feature class (polygons) for geologic map units.
PatMtns_pyrite	Feature class (polygons) for pyrite zones.
PatMtns_shear	Feature class (polygons) for shear zones.
PatMtns_StrikeDip	Feature class (points) for strike and dip of planar geologic structures.
TopoMap	Raster dataset of topographic base map derived from 1:62,500-scale topographic maps for Elgin (1958), Lochiel (1948), Mount Wrightson (1958), and Nogales (1958).
Esri map document and symbolization files	
PatagoniaMtns_Arizona.mxd	ArcMap document used for querying and viewing data in a map format and for producing customized maps.
Contacts, faults, folds, and linear units.lyr	Symbolization file for patterned lines for contacts, faults, folds, and very thin geologic map units, in color, in the feature class PatMtns_GeoLines.
Map units.lyr	Symbolization file for map units, listed by age, in color, in the feature class PatMtns_GeoUnits.
Pyrite zones.lyr	Symbolization file for pyrite zones in the feature class PatMtns_pyrite.
Shear zones.lyr	Symbolization file for shear zones in the feature class PatMtns_shear.
Strike and Dip.lyr	Symbolization file for strike and dip of planar geologic structures in the feature class PatMtns_StrikeDip.

Spatial Databases

Several spatial databases are packaged in an Esri file geodatabase (PatagoniaMtns.gdb) and are ready to use in an ArcMap map document (PatagoniaMtns_Arizona.mxd). Five spatial databases for map units (PatMtns_GeoUnits); geologic contacts, faults, folds, and very thin map units (PatMtns_GeoLines); pyrite zones (PatMtns_pyrite); shear zones (PatMtns_shear); and strike and dip data (PatMtns_StrikeDip) are stored as feature classes in a feature dataset (Geology) in the file geodatabase PatagoniaMtns.gdb. A georectified mosaicked image (TopoMap), derived from historical U.S. Geological Survey 1:62,500-scale topographic maps used in part by Drewes (1971) and Simons (1974) as basemaps, is also provided in the file geodatabase. Metadata files provide information about the spatial databases. Embedded metadata can be viewed in ArcGIS 10; metadata are also provided in Portable Document Format files.

Map Document and Symbolization Files

The ArcMap map document PatagoniaMtns_Arizona.mxd provides the ability to view, query, and create a variety of maps with map units symbolized by unit name and age, in addition to geologic contacts, faults, folds, and other very thin map units. Map symbolization files provide predefined map explanations and views associated with each feature class for use within a map document.

DESCRIPTION OF MAP UNITS

Many map units incorporate descriptions from Simons (1974) and include ages provided to him by S.C. Creasey, R.F. Marvin, and T.W. Stern, as noted. Some map unit descriptions include igneous mineral dates from Vikre and others (2014). Locations of mines and deposits referred to in descriptions are on figure 1.

UNCONSOLIDATED DEPOSITS

Qal **Younger alluvium and talus (Quaternary)**

QTal **Older alluvium (Quaternary and Tertiary)**

QTg **Gravel and conglomerate (Quaternary and Tertiary)**—Iron oxide-cemented colluvium on pediments west of Red Mountain

BEDROCK

Tl **Limestone (Miocene and Oligocene)**—Yellowish-gray, fine-grained, wavy-bedded, freshwater limestone; 3–4.5 m (10–15 ft) thick

Tt **Biotite rhyolite tuff (Miocene and Oligocene)**—Light-gray, yellowish-gray, or white, weakly consolidated, distinctly bedded, pumice lapilli tuff in beds as thick as 7.6 m (25 ft); mostly pumice lumps 2.5 cm (1 in) or less across; contains abundant lithic pebbles. At least 45.5 m (150 ft) thick. Unconformably overlies trachyandesite (Ka). Potassium-argon age of biotite 26 ± 2 Ma and 23 ± 2 Ma (two localities) and of hornblende, 27 ± 3 Ma (S.C. Creasey, written commun., 1964); of biotite, 25.3 ± 5.1 Ma (Damon and Bikerman, 1964, p. 71; 1965, p. A1-13)

si **Silicification (Paleocene)**—Alteration. Age about 60 Ma

ROCKS OF MIDDLE ALUM GULCH

Tv **Volcaniclastic rocks of middle Alum Gulch (Paleocene)**—Grayish to white, well consolidated and poorly sorted lapilli tuff and tuff breccia, probable crater-fill material of the Sunnyside porphyry Cu-Mo system. Contains clasts of Mesozoic volcanic and sedimentary rocks and clear quartz xenocrysts in fine-grained, illite-alunite-kaolinite-altered matrix. Numerous silicified zones. Bedded sequences have concentric strike and inward dips

Tib **Intrusive breccia of middle Alum Gulch (Paleocene)**—Grayish, compact rock of the Sunnyside porphyry Cu-Mo system with matrix-supported, angular clasts of Mesozoic volcanic and sedimentary rocks cemented by fine-grained quartz and other minerals

Tqp **Quartz feldspar porphyry of middle Alum Gulch (Paleocene)**—White to gray, pervasively altered, intrusive porphyry of the Sunnyside porphyry Cu-Mo system with 5 percent round, resorbed quartz phenocrysts (up to 2 mm) and relict, euhedral feldspar phenocrysts (up to 4 mm), altered to K-mica, illite, and kaolinite (sanidine preserved in less altered areas), and set in a fine-grained, sericite-altered matrix. Locally well-developed flow banding on northwest side of volcaniclastic rocks of middle Alum Gulch (unit Tv) may mark a remnant flow dome. U-Pb zircon dates of ~60 Ma, and $^{40}Ar/^{39}Ar$ sanidine date of ~59 Ma (Vikre and others, 2014)

Tqpx **Xenolithic quartz feldspar porphyry of middle Alum Gulch (Paleocene)**—White to gray, pervasively altered, quartz feldspar porphyry of the Sunnyside porphyry Cu-Mo system with up to 50 percent angular clasts of Mesozoic volcanic and sedimentary rocks and variably broken, quartz phenocrysts. Rare blocks with flow-banding or eutaxitic textures are preserved along northwest contact with volcaniclastic rocks of middle Alum Gulch (unit Tv)

GRANODIORITE OF THE PATAGONIA MOUNTAINS

Tqmp **Quartz monzonite porphyry (Paleocene)**—Light gray quartz monzonite porphyry, grades from a weakly to extremely porphyritic phase of granodiorite (Tg) with plagioclase phenocrysts 3–6 mm in length. Pervasively altered to quartz-sericite-alunite-kaolinite and other minerals in the Sunnyside porphyry Cu-Mo system. Interpreted U-Pb zircon ages and $^{40}Ar/^{39}Ar$ biotite, hornblende, and plagioclase dates of quartz nonzonite porphyry and granodiorite (below) of ~61–59 Ma (Vikre and others, 2014). Tqmpb indicates brecciated rock

Tg **Granodiorite (Paleocene)**—Light-gray to gray, medium- to coarse-grained, equigranular to weakly porphyritic granodiorite. Contacts with quartz monzonite porphyry (Tqmp) appear to be gradational. Potassium-argon ages of biotite 58 ± 3 Ma (two determinations) and of hornblende, 58 ± 5 Ma (S.C. Creasey, written commun., 1963 and 1964); of biotite, 63.9 ± 2.0 Ma (Mauger and Damon, 1965, p. AII-1-3). Tgb indicates brecciated rock

Tlp **Latite porphyry (Paleocene)**—White, flinty, fine-grained latite porphyry with 1–3 percent rounded quartz phenocrysts

Tbq **Biotite quartz monzonite (Paleocene)**—Light gray facies of granodiorite (Tg). Medium-grained, equigranular to weakly porphyritic biotite quartz monzonite with 3 percent biotite. U-Pb zircon date of ~64 Ma, and $^{40}Ar/^{39}Ar$ biotite dates of ~61–60 Ma (Vikre and others, 2014). Tbqb indicates brecciated rock

Tbg **Biotite granodiorite (Paleocene)**—Medium gray, medium-grained biotite granodiorite, varies to moderately porphyritic with biotite and plagioclase phenocrysts. U-Pb zircon dates of ~64–63 Ma, and $^{40}Ar/^{39}Ar$ biotite date of ~60 Ma (Vikre and others, 2014)

Tibx **Intrusion breccia (Paleocene)**—Brecciated roof pendants of Mount Wrightson Formation (₸m) invaded by biotite granodiorite (Tbg) at north end of exposed granodiorite of the Patagonia Mountains

Tsy **Syenodiorite or mangerite (Paleocene)**—Medium-dark-gray, fine- to medium-grained biotite-hornblende syenodiorite or mangerite; locally coarse grained

Tag **Biotite augite quartz diorite (Paleocene)**—Dark gray, biotite-rich diorite

IGNEOUS ROCKS OF RED MOUNTAIN

Tmp **Quartz monzonite porphyry of Red Mountain (Paleocene)**—Medium-grained, equigranular to porphyritic quartz monzonite, monzonite, and granodiorite of the Red Mountain porphyry Cu-Mo system composed of plagioclase and lesser K-feldspar, biotite and quartz. U-Pb zircon dates of ~62 Ma, and $^{40}Ar/^{39}Ar$ biotite date of ~60 Ma (Vikre and others, 2014)

TKr **Rhyolite of Red Mountain (Paleocene and Upper Cretaceous)**—White, light-gray, yellowish-gray, or pale-red, massive, very fine-grained to sparsely porphyritic rhyolite, locally cliff-forming. Extensively altered to quartz, kaolinite, sericite, and limonite; locally altered to alunite and zunyite. Outcrops stained with iron oxide. Estimated thickness about 457 m (1,500 ft). U-Pb zircon dates of ~70–68 Ma (Vikre and others, 2014)

TKggt **Gringo Gulch Volcanics (Paleocene and Upper Cretaceous)**—Intermediate to silicic tuff, lava, and volcaniclastic rocks. Light- to greenish-gray latitic tuff and biotite-quartz-latitic tuff; some sandy tuff and coarse polymictic conglomerate. Thickness is at least several tens of meters (hundreds of feet). U-Pb zircon date of ~68 Ma (Vikre and others, 2014)

Ka **Trachyandesite (Upper Cretaceous)**—Gray, greenish-gray, or grayish-red, porphyritic to fine-grained, thin to very thick flows of trachyandesite or doreite; contains some rhyodacite or dacite. Maximum thickness about 914 m (3,000 ft). Disconformably overlies silicic volcanics (Kv). Potassium-argon age of biotite from welded tuff at Vaca Ranch, 72.1 ± 3 Ma. (R.F. Marvin, written commun., 1966), and K-Ar whole rock date of ~71 Ma (Vikre and others, 2014)

r **Rhyolite or latite—**Irregular masses and dikes of rhyolite or latite; some may be highly silicified trachyandesite (Ka)

VOLCANIC AND IGNEOUS ROCKS

Km **Pyroxene monzonite (Upper Cretaceous)—**Olive-gray, dark-greenish gray, or light-brown, medium-grained, porphyritic pyroxene monzonite. Mainly intrusive; some thick flows

Kl **Biotite quartz latite(?) (Upper Cretaceous)**—Medium-gray to pale brown, porphyritic biotite quartz latite(?). U-Pb zircon date of ~71 Ma, and K-Ar whole rock date of ~72 Ma (Vikre and others, 2014)

Kv **Silicic volcanics (Upper Cretaceous)**—Light- to dark- or greenish-gray tuff, welded tuff, and volcanic conglomerate and breccia. Locally much altered to quartz, sericite, epidote, and pyrite. Thickness is perhaps as much as 457 m (1,500 ft). Age relations to other Upper Cretaceous rocks in Nogales quadrangle uncertain

la **Biotite latite(?)**

dp **Latitic(?) dike or plug**

Kpg **Porphyritic biotite granodiorite (Upper Cretaceous)**—Light-gray, porphyritic biotite granodiorite; contains large phenocrysts of pale-pink to white potassium feldspar; near Washington Camp. U-Pb zircon date of ~74 Ma (Vikre and others, 2014)

SEDIMENTARY ROCKS

Kb **Bisbee Formation (Lower Cretaceous)**—Mainly dark- to light-gray siltstone and mudstone, and some sandstone, limestone, and conglomerate; weakly to strongly hornfelsed and commonly pyritic. Contains sparse fauna of late Early Cretaceous age. As much as 914 m (3,000 ft) thick; top of sequence absent. Disconformably overlies silicic volcanic rocks (JŦv)

ls **Limestone**—Light- to dark-gray, fine-grained limestone, locally highly fossiliferous

Kbc **Conglomerate**—Pebble-cobble, epiclastic volcanic conglomerate

GRANITE OF CUMERO CANYON

Jtg **Granite of Three R Canyon (Jurassic)**—Light-gray, grayish-orange, or yellowish-gray, coarse-grained granite. Includes pale-red quartz-perthite granite in Flux Canyon area. Average mineral composition 30 percent quartz, 47 percent potassium feldspar (commonly perthitic), 20 percent sodic plagioclase, and 3 percent accessories (mainly biotite, some sphene, zircon, epidote, and allanite). Pervasively sericitized and pyritized in Mary Kane, Three R, and Cumero Canyons and Cox Gulch. Lead-alpha age of zircon, 160 ± 20 Ma (T.W. Stern, written commun., 1965). Jtgb indicates brecciated rock

Jcm **Porphyritic granite (Jurassic)**—Grayish-orange, gray, brownish-gray, or pale-red, fine-grained porphyritic granite. Texture commonly cataclastic. Contains some coarse granite and syenite. Average mineral composition is 20 percent quartz, 41 percent perthitic potassium feldspar, 36 percent highly sodic plagioclase, and 3 percent accessories, mainly biotite. Variably altered to sericite, chlorite, and epidote

Jcs **Equigranular alkali syenite (Jurassic)**—Pale-red, light-gray or grayish-orange, coarse-grained, equigranular alkali syenite. Average mineral composition 51 percent perthitic potassium feldspar, 40 percent highly sodic plagioclase, and 9 percent accessories, mostly chlorite and quartz. Lead-alpha age of zircon, 150 ± 20 Ma (T.W. Stern, written commun., 1965). Jcsb indicates brecciated rock

Jcg **Equigranular granite (Jurassic).** Jcgb indicates brecciated rock

IGNEOUS ROCKS

Jhm **Hornblende monzonite of European Canyon (Jurassic)**—Medium-gray, medium-grained hornblende monzonite in European mine area. Mineral composition 15 percent quartz, 24 percent potassium feldspar, 42 percent sodic plagioclase, 11 percent hornblende, and 8 percent accessories, mainly chlorite. U-Pb zircon date of ~173 Ma (Vikre and others, 2014)

SILICIC VOLCANIC AND SEDIMENTARY ROCKS

JŦv **Volcanic rocks (Jurassic or Triassic)**—Light-colored rhyolitic, alkali rhyolitic, and quartz latitic lava, tuff, and welded tuff; locally much altered to sericite, epidote, carbonate, and chlorite, or strongly hornfelsed. Thickness uncertain but probably more than 1,829 m (6,000 ft)

d **Diorite dike**

ha **Hornblende andesite dike and (or) plug**

tr **Porphyritic trachyte dike**

b **Volcanic breccia**

s **Sedimentary rocks**—Light- to dark-gray sandstone and grit, commonly somewhat feldspathic with sericitic matrix; green to greenish-brown tuffaceous siltstone and shale. Variably replaced by epidote and tourmaline

cg **Limestone conglomerate**

qz **Quartzite**

ls **Exotic blocks of upper Paleozoic limestone**

w **Rhyolitic welded(?) tuff**

lp **Latite(?) porphyry**—May be extrusive in part

J₹vs **Volcanic and sedimentary rocks (Jurassic or Triassic)**—Red volcanic conglomerate, sandstone, and siltstone; red to gray latitic or dacitic tuff and welded tuff; and minor amounts of rhyolitic to dacitic lava. At least 610 m (2,000 ft) thick; base not exposed

VOLCANIC AND SEDIMENTARY ROCKS

₹m **Mount Wrightson Formation (Triassic)**—Mainly light-gray to pale-red rhyolitic to latitic lava and tuff; some tuffaceous sandstone or grit. Locally metamorphosed to hornfels. Commonly highly altered to quartz, sericite, kaolinite, alunite, tourmaline, and pyrophyllite. Unconformably overlies Concha Limestone (Pcn). Thickness is probably 610 m (2,000 ft) or more

q **Quartzite**

a **Biotite(?)-albite andesite lava(?)**

t **Coarse volcaniclastic beds**

₹ms **Sedimentary rocks** —Mostly arkose

Pcn **Concha Limestone (lower Permian)**—Gray to light-gray, fine-grained, medium- to thick-bedded limestone with lenses and nodules of chert. About 155 m (510 ft) thick

Ps **Scherrer Formation (lower Permian)**—Brownish-gray to gray, massive, sandy limestone and white to light-brownish-gray, fine-grained sandstone. About 46 m (150 ft) thick

Pe **Epitaph Dolomite (lower Permian)**—Gray fine-grained, thick-bedded limestone, silty limestone, gray dolomitic limestone, lesser sandstone and conglomerate, and sparse pods of chert and quartz. About 262 m (860 ft) thick

Pc **Colina Limestone (lower Permian)**—Gray to dark-gray, fine-grained, and medium- to thin-bedded limestone and thin beds of dolomite. About 72–104 m (235–340 ft) thick

PIPe **Earp Formation (lower Permian and Upper Pennsylvanian)**—Gray, light-gray, or pink thin-bedded to massive, sandy to silty limestone and dolomitic limestone, and lesser dolomite, chert and limestone conglomerate, and sandstone. About 229 m (750 ft) thick

IPh **Horquilla Limestone (Upper and Middle Pennsylvanian)**—Light-gray, gray, or pinkish-gray, fine- to coarse-grained, medium-bedded limestone and lesser dolomitic limestone and brown to maroon thin-bedded limestone. About 82 m (270 ft) thick. Unconformably overlies Escabrosa Limestone (unit Me)

Me **Escabrosa Limestone (Upper and Lower Mississippian)**—Light-gray, coarse- to fine-grained, thick- to thin-bedded cherty limestone and lesser dolomitic limestone. About 142 m (465 ft) thick. Disconformably overlies Martin Limestone (unit Dm)

Dm **Martin Limestone (Upper Devonian)**—Gray, brownish-gray, or pink, coarse- to fine-grained, thin- to thick-bedded dolomite and dolomitic limestone. About 72 m (235 ft) thick. Disconformably overlies Abrigo Limestone (unit €a)

€a **Abrigo Limestone (Upper and Middle Cambrian)**—Gray, brown, or purple coarse-grained, thick- to thin-bedded limestone, dolomitic limestone, silty limestone, and lesser limestone conglomerate. About 259 m (850 ft) thick

€b **Bolsa Quartzite (Middle Cambrian)**—Brown to light-gray, gritty to pebbly quartzite, and lesser sandstone. About 72–81 m (235–265 ft) thick. Unconformably overlies biotite quartz monzonite (unit p€m), and hornblende diorite (unit p€d)

p€q **Biotite or biotite-hornblende quartz monzonite (Precambrian?)**—Light-gray to pale-red, coarse porphyritic quartz monzonite and lesser granodiorite

p€h **Hornblende-rich metamorphic and igneous rocks (Precambrian?)**—Greenish-gray to dark-gray, fine- to medium-grained, granular to schistose rocks composed of hornblende, labradorite, and lesser biotite and augite with accessory sphene, quartz, apatite, epidote, and opaque minerals

p€m **Biotite quartz monzonite (Precambrian)**—Light- to light-brownish-gray, porphyritic quartz monzonite

p€d **Hornblende diorite (Precambrian)**—Dark greenish-gray, medium-grained, equigranular diorite

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