Geologic Map of the Safford 30' x 60' Quadrangle, Graham and Greenlee Counties, Arizona, Grant and Hidalgo Counties, New Mexico

by

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Arizona Geological Survey
Digital Geologic Map DGM-295

December 2025

Arizona Geological Survey

University of Arizona

1955 East Sixth Street, Tucson, Arizona 85721

Includes 31 pages of text and one 1:100,000-scale geologic map

This geologic map was funded in part by the U.S. Geological Survey National Cooperative Geological Mapping Program under STATEMAP award G23AC00556. The views and conclusion obtained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government.

INTRODUCTION

The Safford 1:100,000-scale quadrangle encompasses a broad swath of diverse geology in the Mexican Highland subsection of the Arizona Basin and Range Province in southeastern Arizona. The geology within the quadrangle is diverse, including Paleoproterozoic and Mesoproterozoic metamorphic and igneous rocks, Cretaceous to Paleogene (Laramide) intrusive and volcanic rocks, Neogene volcanic rocks, intrusive rocks and basin deposits, and extensive Quaternary surficial deposits cover much of the map area.

The quadrangle includes the growing community of Safford (about 10,000 people) and numerous smaller communities. The Safford Mine in the northern part of the quadrangle is an open-pit mine operated by Freeport-McMoran, extracting primarily copper from the San Juan, Dos Pobres, and Lone Star ore bodies. Deposits of the Gila River supply abundant, high-quality aggregate for the region.

A variety of published map data was utilized to construct this Safford 1:100,000-scale quadrangle. Substantial portions of the quadrangle had been mapped previously at 1:24,000 or 1:48,000 scale by geologists with the Arizona Geological Survey or the U.S. Geological Survey. In these areas, the large-scale mapping was generalized and modestly reinterpreted. Other parts of the quadrangle had been mapped at smaller scale by U.S. Geological Survey geologists. This mapping was used for the bedrock compilation, but surficial and basin deposits were remapped as the current map was developed.

GEOLOGIC SUMMARY

Bedrock and Economic Geology

The oldest rocks within the map area are exposed in the Pinaleño Mountains and consist primarily of Mesoproterozoic plutonic rocks and older Paleoproterozoic gneisses with igneous and sedimentary protoliths (Thorman, 1981; Thorman and Naruk, 1987). Several Cenozoic intrusive centers are also exposed in the Pinaleño Mountains. These include the Relleno suite (PEr) on the northern side of the range, and the Gillespie granite (Ng) on the south end of the range. The Relleno suite is a weakly peraluminous suite of biotite (± muscovite)-bearing granitoids intruded between 58-52 Ma along the northeastern margin of the Pinaleño Mountains (Long et al., 1995; Chapman et al., 2021; Scoggin et al., 2022).

The Gillespie granite is an undeformed Neogene pluton with a likely unreliable K-Ar age of 35.6±0.7 Ma (Swan, 1976). The Gillespie granite is juxtaposed against likely similar aged volcanic rocks by a south-dipping low-angle normal fault (Thorman, 1981). Proterozoic rocks on the east side of the Pinaleños experienced Cenozoic mylonitization related to the development of the Pinaleño-Jackson Mountain core complex (Long et al., 1995; Chapman et al., 2024). The low-angle NE-dipping detachment fault is not exposed within the map area, but has been imaged seismically below the Safford basin (Kruger and Johnson 1994; Kruger et al., 1995). The timing of motion on the core complex detachment fault is 29-19 Ma based on $^{40}Ar/^{39}Ar$ ages of biotite and muscovite (Long et al., 1995).

The Safford mining district represents a remarkable porphyry cluster with at least five distinct porphyry systems: Dos Pobres, San Juan, Lone Star, Sanchez, and Sol (Figure 1). The district (inclusive of a mineral inventory for the subeconomic Sol prospect from Yarter, 1981) contains an endowment of ~49.7 billion pounds (24.5 million tons) of copper between total production and mineral resources and reserves (Briggs, 2025). The district geology is dominated by the Safford volcanic rocks, a >1,300 m sequence of generally andesitic volcanic rocks that erupted between ~67-73 Ma (Houser et al., 1985; Russin, 2008). The Safford volcanic rocks were intruded by a diverse assemblage of plutonic to hypabyssal rocks that can be largely divided into early parental granodioritic to quartz dioritic plutons and later mineralizing quartz monzonitic, tonalitic, and granodioritic porphyries (Langton and Williams, 1982). U-Pb ages for the plutonic to hypabyssal rocks range from ~66-54 Ma (Russin, 2008; Stegen and Parker, 2020). The district was later covered by post-mineral volcanic rocks (Houser et al., 1985). The district is principally exposed in the footwall of the Butte fault, a generally poorly exposed, southwest-dipping, range-bounding fault along the flanks of the Gila Mountains. The Sol prospect, the most southeastern of the Safford porphyries, may lie along strike of the Butte fault. Additionally, at the Sol prospect, the Safford volcanic rocks overly Cretaceous(?) sedimentary rocks that have been correlated with the Cretaceous Pinkard Formation at Morenci (Yarter, 1981).

The Safford deposits have so far principally exploited for their supergene ores, with copper oxide and chalcocite hosted in andesite and felsic dikes at Dos Pobres (and derived from bornite-chalcopyrite protore), copper oxide hosted in quartz monzonite at San Juan, and hematitic leached capping, chrysacolla and copper oxide, and a chalcocite enrichment blanket above a chalcopyrite protore at Lone Star (Stegen and Parker, 2020). The unmined Sanchez deposit consists of chrysacolla and minor neotocite, tenorite, native copper, and atacamite above a chalcopyrite protore (Dreier, 1994). Yarter (1981) reports supergene mineralization at Sol, but only describes the hypogene alteration-mineralization. Recently announced results of exploration in the Safford district include the discovery of Una Rica, the faulted piece of Dos Pobres across the Butte fault, and Horseshoe Hill, a low-grade porphyry system situated between Sanchez and Lone Star (Wetzel et al., 2025).

Detailed studies of most of the porphyry deposits have been conducted: Dos Pobres (Langton and Williams, 1982; Russin, 2008); San Juan (Blake, 1971); Lone Star [formerly called Safford] (Cook and Robinson, 1962; Robinson and Cook, 1966; Selck, 2017; Stegen and Parker, 2020); Sanchez (Dreier, 1994); Sol (Yarter, 1981). Additional studies of the district include district-scale structural analysis (Dunn, 1978) and interpretation of spectra data for alteration zonation (Lepley, 1982).

Spencer (2024) proposed the Safford porphyry copper deposits as the high-level expressions of the Relleno suite (referred to as the Pinaleño pluton in Spencer, 2024) and dismembered by the concealed Black Rock-Eagle Pass detachment fault now across the Safford Basin. The largest stock in the Safford district, the Lone Star stock, has a U-Pb zircon age of 66.0 ± 1.4 Ma (Stegen and Parker, 2020). Porphyry dikes associated with porphyry copper mineralization intruded at Dos Pobres ~57 Ma (Russin, 2008). Mineralization at Lone Star is bracketed between 58-56 Ma based on geochronology and cross-cutting relations (Stegen and Parker, 2020). While there is some compositional overlap between the two igneous suites, the Relleno suite is generally more felsic (65-75 wt% SiO_2; Scoggin et al., 2022) while least altered intrusive rocks from the Safford district are more intermediate (59-66 wt% SiO_2; Langton and Williams, 1982; Sharp, 1991; Lang and Titley, 1998; Russin, 2008). The Relleno suite ranges in alkalinity from borderline metaluminous-peraluminous to moderately peraluminous, while the least-altered Safford rocks range from metaluminous to weakly peraluminous (Richardson, unpub. data from above sources). No copper

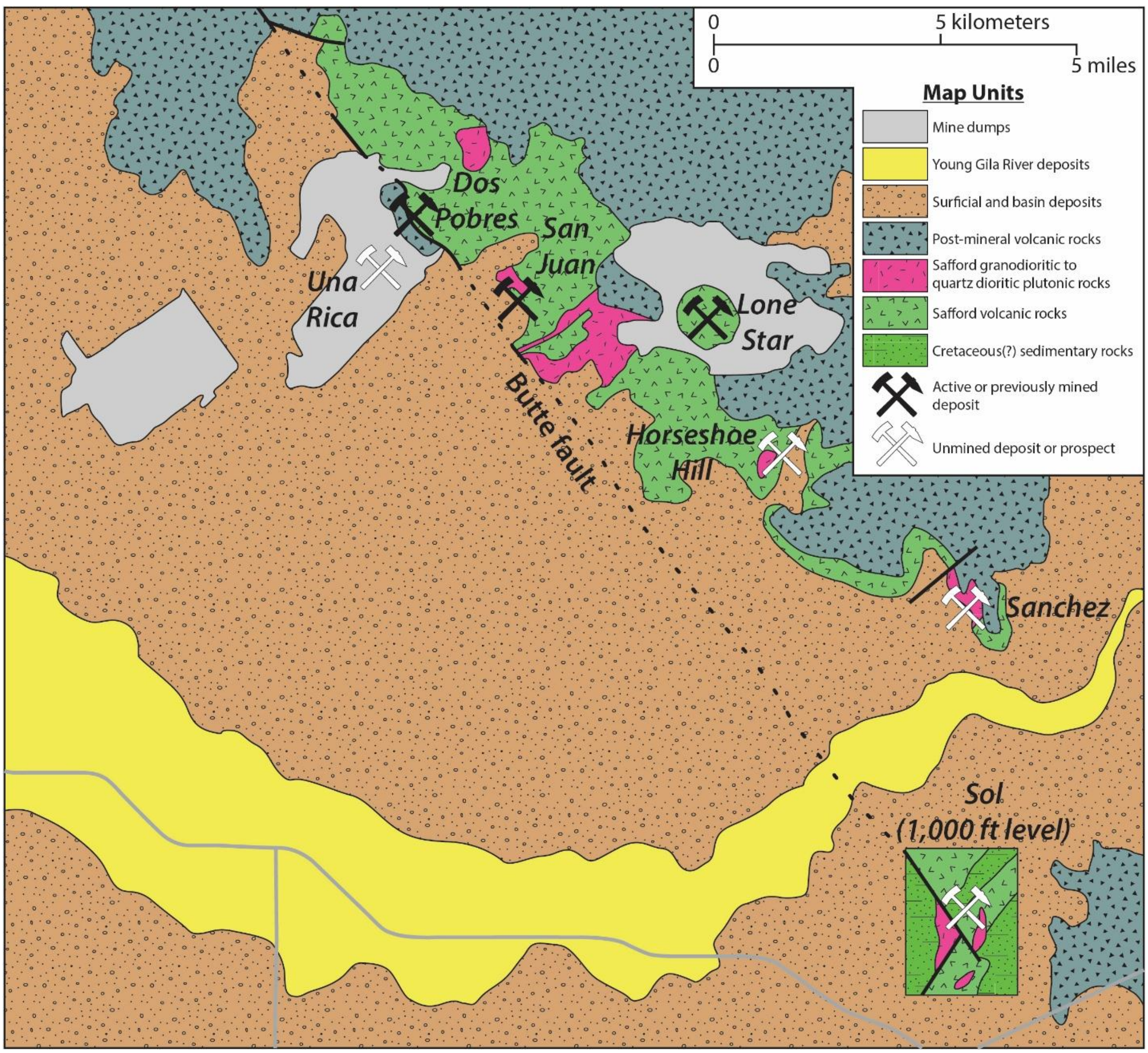

Figure 1. Simplified geologic map of the Safford district showing the locations of the known porphyry deposits and systems. The geology of the Sol prospect is projected from 1,000-feet elevation plan map by Yarter (1981, Figure 3b). Locations of Una Rica and Horseshoe Hill approximated from information presented by Wetzel et al. (2025).

values from whole-rock geochemical analyses have been reported for the Relleno suite for mass balance considerations.

The map area hosts an intricate pile of felsic to intermediate volcanic rocks with many eruptive ages straddling the Miocene-Oligocene (Neogene-Paleogene) boundary (Richter et al., 1981, 1983; Houser et al., 1985). The major felsic eruptive centers include the Ash Peak-Rhyolite Peak complex (Richter et al., 1981; Walker, 1990), the eruptive center of Tollgate Wash (Richter et al., 1983), and the Volcano of Bear Spring (Houser et al., 1985), along with many smaller eruptive centers, volcanic plugs, and flows with unknown source locations. Many of the volcanic units on the eastern edge of the map are laterally extensive and sourced from eruptive centers in New Mexico (Hedlund, 1990; 1993; Ratté et al., 1984). The most laterally extensive volcanic units are the Upper basaltic andesite of Guthrie Peak (Nau) and the Lower basaltic andesite flows (Pal). Previously geochronology (mostly K-Ar) gives inconsistent ages for most of the units, potentially either related to the geochronology method or the long eruption durations, with many crossing the Neogene-Paleogene boundary. Neogene ("N") and Paleogene ("P") designations are thus assigned to map units more to honor the apparent regional stratigraphy than the previously published ages. This avoids the awkwardness of giving a Neogene-Paleogene ("NP") designation to many of the units, which might obscure the relatively clear stratigraphic relationships. Much more could be done to precisely determine the chronology of the volcanic pile and clarify the timing and duration of eruptive processes.

Basin deposits- River integration

Basin deposits record the history and development of major fluvial systems in this region. Safford basin is primarily filled with Neogene fine-grained siliciclastic deposits, with locally sourced tributary alluvial fan deposits confined to the basin margins. The fine-grained basin deposits were likely supplied by the proto-San Francisco River, which fed water and sediment into from the Clifton area into Safford basin for much of the Neogene (Gootee et al., 2021). Water supplied by this system sustained marshes or shallow lakes farther downstream in the San Carlos area.

Latest Neogene to Quaternary basin deposits in the Duncan area record the arrival of the upper Gila River into this region.

Surficial deposits

The map encompasses a wide range of surficial deposits and associated landforms, including alluvial fans, terraces, tributary and distributary channel networks and overbank areas, and colluvium and regolith. The Gila River is the dominant fluvial system; it enters the southeastern corner of the quadrangle near Duncan, Arizona, then snakes through the Duncan B before exiting the northwest corner of the quadrangle toward San Carlos, Arizona. The Gila River is joined by large tributaries, including the San Francisco River, Eagle Creek, and Bonito Creek from the north, and San Simon River from the south. With exception of the southwestern corner of the map, smaller tributaries drain to these larger systems or directly to the Gila River.

Fluvial terrace sequences in the Safford and Duncan areas record the long-term Quaternary incision of the Gila River. The highest terrace deposits (Qors) found 100+m higher than the modern river in both these areas are the earliest record of a through-flowing river. Subsequent river downcutting has resulted in formation of extensive fluvial terraces along the river and its major tributaries, and widespread and deep dissection of sedimentary basins along and near the river. Thus, river incision has driven the erosion that has produced the spectacular erosional landscapes of the Safford, Duncan, and northern San Simon Valleys. Two areas are minimally dissected – the northern part of Sulphur Springs Valley in the southwestern corner of the map and Whitlock Valley in the southeastern part of the map. The former area is not connected to the Gila River system, rather it drains south to the closed basin of Willcox Play. Whitlock Valley is evidently far enough away from the Gila River that significant base-level fall has not propagated upstream into it.

Piedmonts that drain to the Gila River and its major tributaries are covered by Quaternary surficial deposits ranging widely in age, and eroded Neogene to Quaternary basin deposits. Upper piedmont areas typically are covered primarily by intermediate alluvial fan and terrace deposits, with extensive areas of eroded basin deposits and some remnants of high, old alluvial fan deposits. Middle piedmonts typically are a mix of intermediate terraces and relict fans, and extensive young alluvial fans and strips of younger deposits along washes. Lower piedmonts commonly have extensive areas of eroded basin deposits; the extent of intermediate and young deposits in these areas varies dramatically. Thin hillslope colluvium, weathered bedrock regolith, and small alluvial fans cover most lower slopes of bedrock hills and mountains.

AR-AR GEOCHRONOLOGY

Five samples from the Hot Well and Whitlock Peak quadrangles were sent to the University of Nevada, Las Vegas for $^{40}Ar/^{39}Ar$ geochronology. These analyses were conducted with funds for a STATEMAP project by the Arizona Geological Survey in 2022-2024, but unfortunately the analyses were not complete in time for publication with that project. Of the five samples analyzed, three yield meaningful and consistent ages. In each case, the laboratory-determined “preferred age” is an inverse isochron age.

Sample	Map Unit	UTM Northing	UTM Easting	Material	Preferred Age
051223-1115	Nau	3621422	670923	Groundmass	19.12±0.80 Ma
CM015	Nabr	3622819	664580	Biotite	No Age
CM034	Nau	3602116	666326	Groundmass	No Age
CM067	Nar	3621736	667380	Groundmass	22.92±0.96 Ma
CM085	Nau	3625218	672138	Groundmass	21.62±0.91 Ma

DESCRIPTIONS OF MAP UNITS

GILA RIVER DEPOSITS

Qyrg – Gila River deposits (Late Holocene) – Channel, floodplain and low terrace deposits of the Gila River. Deposits consist of moderately to well-bedded sand, silt, clay, pebbles, and cobbles. Soil development is minimal to weak.

Qi3rg – Younger intermediate Gila River deposits – Low intermediate Gila River deposits consisting of at least two terraces that are grouped into Qi3rg, including the older middle-Pleistocene Lava Creek B tephra (630 ka).

Qi2rg – Intermediate Gila River deposits (Middle to Late Pleistocene) – TBD

Qi1rg – Older intermediate Gila River deposits (Early to Middle Pleistocene) – High, intermediate Gila River terrace deposits elevated about 60 m above the modern river. Unconsolidated to weakly consolidated silt, sand, gravel and boulders, with minor clay. Unit Qi1rg exhibits a prominent, broad and planar terrace landform morphology exposed north of Safford along the north flank of the Gila River. Deposits are generally light orange-brown.

Qorg – Older Gila River deposits (Early Pleistocene) – Qorg deposits represent the oldest, highest standing preserved Gila River deposits in the map area. These deposits are located 90 to 130 m (300 to 430 ft) above the modern Gila River channel. Qor deposits are composed of well-rounded to subangular indurated pebble to cobble river gravels and fine-grained river deposits. Locally, planar terrace surfaces are preserved, but more commonly terrace deposits are highly eroded, sloping remnants. Qor deposits are poorly sorted, exhibiting alternating sand and pebble dominated beds with coarse cobble to boulder interbeds. Soil development is strong where surfaces are well preserved, with substantial clay and calcium carbonate accumulation (stage IV+). More commonly, however, terrace deposits are substantially eroded, and soil development is weak to moderate. Vegetation on Qor surfaces consists of creosote, low grasses, shrubby mesquite, and ocotillo especially on eroded slopes exposing the cemented carbonate horizon. Locally, Qor deposits are subdivided into two members with similar morphology that occupy different positions in the landscape.

DEPOSITS OF LARGE TRIBUTARY DRAINAGES

Qyr – Young stream deposits (Holocene) – Gravel, sand, and silt deposits of large tributary washes, including San Simon River, Eagle and Bonita Creeks, and Railroad Wash. This unit includes deposits in modern channels, low bars and terraces, broader floodplain areas and abandoned channels. Deposits characteristics vary between tributaries. Along Railroad Wash deposits are extensive and consist primarily of sand, silt, and clay, with minor gravel. Qyr deposits along San Simon River form a narrow strip of gravelly and sandy deposits within very fine-grained Qys deposit. Young deposits along Eagle and Bonita Creeks are gravelly and sandy. Lithologic diversity varies between tributaries but is generally much less than for the larger rivers, creeks, and washes.

Qir – Older stream deposits (Middle to Late Pleistocene) – Older deposits associated with terraces along larger tributaries. Terrace surfaces are ~5-20 m above adjacent floodplains. They are smooth and flat to broadly rounded, with moderate pebble to cobble lags that have weak to moderate rock varnish. Deposits typically contain substantial percentages of pebbles and cobbles, which contributes to the preservation of these deposits in relatively high landscape positions that are subject to erosion. Soil development and surface color varies substantially due to variable preservation, but well-preserved terrace surfaces are orange to reddish brown and have moderate to strong clay argillic horizons and Stage II-III calcium carbonate soil development in the upper few meters.

PIEDMONT DEPOSITS

Qy – Alluvium undivided (Holocene) – Young deposits found in channels and low terraces along active washes and locally forming extensive alluvial fans. Deposits vary greatly in grain-size distribution, ranging from cobble-boulder dominated deposit in and near mountains to sand, silt and clay with minor gravel in middle and lower piedmont areas. Drainages within Qy deposits are unincised to weakly incised and sheetflow across surfaces between channels appears common based on observation of abundant piled flood debris on the upslope side of vegetation and vegetation mounds throughout the mapped area.

Qys – Young fine-grained deposits, typically reworked from fine basin fill deposits (Holocene) – Laterally extensive, unconsolidated fine-grained alluvium mostly found in valley bottoms and along the margins of larger drainages. These sediments are light brown to white in color and consist of sand, silt, clay, and minor gravel, commonly found as discontinuous surface lags. In valley axes, weakly developed buried soils are common. Gravel makes up a small percentage of these deposits and typically gravel beds are thin and discontinuous. Along a few larger washes, thicker and more extensive gravel beds were observed. Qys deposits locally mantle the toes of slopes formed on eroded fine-grained basin fill (Ns or QNs) deposits. In these areas, Qys deposits are commonly more gravel-rich and sandy to pebbly calcium carbonate aggregate nodules litter slopes. Occasionally weakly channelized flow occurs but minor gradient changes or vegetation cause aggradation that leads again to sheetflow or infiltration. Surface soil development is weak.

Qe – Young eolian deposits mantling alluvial deposits of various ages (Holocene) – Thin eolian sand and silt deposits mantling alluvial deposits of various ages. Eolian landforms typically are extensive, low-relief sand sheets and low, small dunes. The most common are coppice dunes formed around clumps of vegetation. Underlying tributary and river deposits range in age from Holocene to middle Pleistocene.

Qi3 – Younger intermediate tributary alluvium (Late Pleistocene) – Unconsolidated gravelly and sandy deposits forming relict alluvial fans and extensive terrace deposits. Deposits consist of pebbles, sand, cobbles, silt, and clay, with minor boulders. Fans and terraces typically are planar with moderately incised drainages and slightly rounded margins. Fan and terrace surfaces are generally less than 10 m higher than nearby active washes. Deposits consist of pebbles, sand, cobbles, silt, and clay, with minor boulders. Soils are distinctly reddened, with moderately developed argillic horizons.

Qi2 – Intermediate tributary alluvium (Middle to Late Pleistocene) – Unconsolidated gravelly and sandy deposits forming higher relict alluvial fans and extensive terrace deposits. Deposits consist of pebbles, sand, cobbles, silt, and clay, with minor boulders. Fans and terraces are planar with moderately to deeply incised drainages and broadly rounded margins. Fan and terrace surfaces are generally less than 20 m higher than nearby active washes. Deposits consist of pebbles, sand, cobbles, silt, and clay, with minor boulders. Soils are distinctly reddened, with moderately to strongly developed argillic horizons.

Qi1 – Older intermediate tributary alluvium (Middle Pleistocene) – Unconsolidated to moderately consolidated coarse gravel to silt high relict fan deposits. Deposits consist of cobbles, sand, boulders, and minor silt and clay. They are deeply incised and typically form well-rounded ridges, but in some areas extensive planar relict fan remnants are preserved with well-rounded margins. Qi1 deposits typically exhibit moderate to strong calcic soil development, stage III to IV+. Well-preserved planar surfaces typically are dark reddish brown and have very clay-rich argillic horizons.

Qi –Intermediate alluvium undifferentiated (Middle to Late Pleistocene) – Unconsolidated to weakly consolidated deposits of silt, sand, and gravel with rare boulders. Deposits include terraces and alluvial fan remnants of Pleistocene age formed on bedrock, basin fill and older river deposits. Soil development is variable, including moderate to strong reddish argillic horizons and carbonate development up to stage II-III.

Qo – Old alluvial fan deposits (Early Pleistocene) – Weakly to moderately consolidated, relatively coarse alluvial fan deposits associated with the highest preserved alluvial surfaces. Planar alluvial fan remnants are found in upper piedmont areas and rest upon gravelly, but finer-grained basin fill. Qo surfaces typically are of limited extent and their margins are rounded and deeply eroded. Frye Mesa in Safford basin is the most extensively preserved Qo surface. It is planar with fairly sharp, eroded edges, but most other remnant Qo surfaces are much more rounded. Where well preserved, Qo deposits exhibit deeply incised mature tributary drainage networks and very clay rich, reddish brown soils. Coarse cobble to boulder lag derived from erosion of the Qo cap also covers the flanks of underlying Ns and QNs deposits, protecting them from erosion.

OTHER SURFICIAL DEPOSITS

d – Disturbed (recent) – Surface areas that have been substantially modified by human activities. Includes mines and mine tailings, and related operations, landfills, recharge ponds, and large retention basins.

da– Aggregate pits and quarries – Surface areas that have been substantially modified by aggregate pits and quarries.

Qtc – Talus and colluvium (Pleistocene to Holocene) – Unconsolidated to weakly consolidated, very poorly sorted, massive to weakly bedded, angular rock debris deposited at the base of bedrock slopes.

BASIN FILL DEPOSITS

QNs – Basin fill deposits, undivided (Neogene) – TBD

QNc – Coarse-grained basin fill deposits (Pliocene to Pleistocene) – Poorly to moderately consolidated, rounded to well-rounded, clast-supported pebble- and cobble-conglomerate with a coarse sand matrix and minor clay component. Includes Unit of Smuggler Canyon (Ferguson and Enders, 2000; Richter et al., 1983).

QNf – Fine-grained basin fill deposits (Pliocene to Pleistocene) – Unconsolidated to moderately consolidated clay, silt and fine sand, with interbeds of limestone, diatomite, and pebble-gravel. Bedding is horizontal to subhorizontal, massive, medium to thick, with moderately-well defined tops and bottoms. Sand interbeds are medium to thick, increasing in thickness and frequency up-section, with flat-scoured bases and gradational tops. Sand beds exhibit wavy, trough and planar cross-bedding and locally carbonate-cemented into nodules, slabs and irregular flutes. Interbeds of coarse pea and pebble gravel increase up section, grading into the QNdc lithofacies. Carbonate beds are continuous in QNdf, between 30 and 100 cm thick, and consist of sandy calcarenite,

QNl – Basin fill deposits, mudstone and diatomite facies (Pliocene to Pleistocene) – Moderately consolidated to crystalline, white, light gray, light olive brown, and tan diatomite and carbonate with interbeds of mud and fine sand. More extensive at higher elevations around ~1250 m-amsl.

Nsc – Coarse-grained basin fill deposits (Neogene) – Unit Nsc includes other major map units in the mapping area, including fluviatile deposits of Buzzards Roost Canyon (Richter et al, 1983; Ferguson and Enders, 2000), Rail End, Sanchez, One-Eleven.

Nsf – Fine-grained basin fill deposits (Neogene) – Fine-grained basin fill deposits correlative to 111-Ranch beds (Houser, 1990).

Nmc – Conglomerate of Midnight Canyon (Miocene) – Volcanic conglomerate containing clasts derived chiefly from the andesite of Guthrie Peak-Turtle Mountain (Nau). Mapped as Tertiary volcanic conglomerate by Heindl (1960), who included the underlying conglomerate of

Bonita Creek (Nbc) in the unit. Bedding and sorting are poor to moderately poor; individual beds are 1–3 m thick and lenticular. Unit consists chiefly of framework-supported, angular to rounded pebbles to large boulders (as much as 1 m in diameter) in a matrix of zeolite-cemented silt and sand. Some clasts exhibit weathering rinds as much as 2 cm thick. Lower two-thirds of unit forms nearly vertical cliffs; upper part is finer grained, better sorted, and less indurated. In Bonita Creek basin, bedding, sorting, and rounding improve to the south and southwest, and clast imbrication indicates currents flowed southwest. Maximum thickness more than 100 m. (Richter et al., 1983).

Nbc - Conglomerate of Bonito Creek (Miocene) – Volcanic conglomerate, locally interbedded with pyroclastic air-fall and ash-flow deposits (Nv) and andesite flows (Nau), probably deposited in part as debris flows. Bedding is crude to poor with local large-scale crossbeds. Unit consists chiefly of matrix-supported, angular to subrounded coarse sand to large boulders (as much as 1 m in diameter) in a matrix of zeolite-cemented silt and fine sand. Most clasts exhibit weathering rinds more than 2 cm thick; rock breaks across clasts. Clasts are chiefly derived from the andesite of Guthrie Peak-Turtle Mountain, but in the Bonita Creek area felsic volcanic rock clasts from a source northwest of the quadrangle predominate. Unit forms cliffs as much as 100 m high, and box canyons are common. Maximum thickness about 120 m; individual conglomerate layers as much as 45 m thick. (Richter et al., 1983).

MIOCENE VOLCANIC ROCKS

Nb – Porphyritic basalt flows (Miocene) – "Dark-gray to medium dark-gray, massive (up to 10 m thick) flows with vesicular tops and bottoms. Rocks contain conspicuous phenocrysts (about 20 percent) of plagioclase (An50-60) as much as 1 cm long in a fine-grained (up to 2 mm) intergranular to locally intersertal groundmass of 30-50 percent plagioclase (An45) laths, 10-15 percent olivine (locally altered to iddingsite), 10 percent clinopyroxene, 2-4 percent opaque minerals, and a trace of apatite. Intersertal varieties contain as much as 10 percent interstitial cryptocrystalline material. Flows cap higher elevations and are locally separated from underlying basaltic andesite flows by a thin (<1 m) paleosol. K-Ar dates from plagioclase and groundmass yield ages of 16.6 m.y. and 16.2 m.y. respectively. Source unknown, but probably local." (Richter et al., 1981).

Ngbp – Andesite Breccia Plug of Gila Box (Miocene) – "Reddish-gray breccias and pale-brown irregular intrusive masses in crater of cone. Breccia consists chiefly of densely welded grayish-red and dark-gray glassy fragments as much as 1m in diameter. Intrusive rocks are fine-grained containing amber-colored clinopyroxene, plagioclase, and minor dark-red amphibole, shreds of bleached biotite, and opaque minerals in an intersertal to intergranular groundmass." (Richter et al., 1983).

Ngba – Andesite cinder core and flows of Gila Box (Miocene) – Chiefly dark gray, locally unconsolidated glassy and scoriaceous lapilli and coarse-grained ash. Intercalated thin, dark-grey flows contain microlites of plagioclase and occasional microphenocrysts of hypersthene and clinopyroxene in a pilotaxitic matrix. Beds in ashes have quaquaversal dip away from andesite plug breccia. (Modified after Richter et al., 1983).

Nv – Volcanoclastic rocks, undivided (Miocene) – Volcanoclastic rocks including tuffs, breccias, cinder cones, pyroclastic, vent, ash flow, and air-fall deposits. This unit includes all the previously mapped Neogene volcanoclastic units that are mapped above and below lava flows and surrounding volcanic centers throughout the central part of the Safford quadrangle. These rocks commonly contain pumice clasts altered to clinoptilolite, poorly sorted clasts of surrounding volcanic rocks (up to 2m in diameter), and broken glass and crystal fragments. Exposures range from massive to relatively thinly bedded deposits, with bedding at chaotic, overly-steep orientations or dipping away from eruptive centers (Richter et al., 1981, 1983; Mako et al., 2024).

Ngf – Dacite and andesite flows of Guthrie Peak (Miocene) – "Grayish-red to moderate-red, medium to thick flows (5-20 m), generally having scoriaceous tops and bottoms, and locally interbedded with pale-greenish-yellow to very light gray zeolitized breccias. Rocks are typically fine grained and sparsely porphyritic or microporphyritic containing phenocrysts (as large as 4 mm) of plagioclase (An_{45-50}) and subordinate and varying microphenocrysts (as large as 0.5 mm) of hypersthene, clinopyroxene, and opaque minerals in a pilotaxitic to trachytic groundmass of plagioclase microlites and reddish cryptocrystalline material. Quartz and altered olivine are present locally. Flows locally contain spheroidal nodules, as much as 5 cm in diameter, consisting of microphenocrysts of green actinolite, after hypersthene, and plagioclase in a cryptocrystalline groundmass and having thin (<0.1mm) chalcedonic rinds. Flows are apparently variants of the [Upper basaltic andesite flows of Guthrie Peak (Nau)] but are distinguished from them on the basis of their reddish color, restricted distribution in Slick Rock basin, and general lack of olivine." Richter et al. (1983).

Nau – Upper basaltic andesite flows of Guthrie Peak (Miocene) – Extensive flows covering almost 2000 km^2 within the map area, informally named after significant exposures at Guthrie Peak (Richter et al., 1983). The composition is commonly described as andesite or basaltic andesite (Richter et al., 1981, 1983; Houser et al., 1985), with recent geochemical analyses from the Hot Well and Whitlock Peak quadrangles falling in the trachy-andesite and basaltic trachyandesite fields of the TAS diagram, or latite and shoshonite when classified by relative Na_2O and K_2O contents (Mako et al., 2024). Flows are typically flat-lying and no more than a few degrees from horizontal. Exposures 5km NW of Duncan are a notable exception, with dips of 15-30º toward the NE, perhaps related to a buried fault beneath the York Valley. Nearly 800m of relief in this unit is exposed within the Whitlock Valley and about 900m of relief within this unit is exposed surrounding Guthrie Peak. Flows are apparently concurrent with silicic volcanism throughout the area including the eruptive centers of Tollgate Wash, Ash Peak, Bear Spring (Richter et al., 1981, 1983; Houser et al., 1985). The upper flows of this unit are intercalated with the conglomerate of Bonita Creek (Richter et al., 1983). K-Ar dates range from 19-27 Ma (Richter et al., 1981, 1983; Houser et al., 1985). A recent $^{40}Ar/^{39}Ar$ inverse isochron age from this study is 19.12±0.80 Ma from very low in the volcanic stratigraphy in the Hot Well quadrangle. Thus, the andesites of Guthrie Peak represent a long-lived and voluminous eruption.

Outcrops are typically dark- to medium-gray, brownish-gray, and locally grayish-red, generally vesicular flows 2-25 m thick that have conspicuous scoriaceous tops and bottoms. Occasional volcanoclastic or pyroclastic interbeds are common, as are bedded cinder and scoria deposits indicating vents (Richter et al., 1981; Houser et al., 1985; Mako et al., 2024). A representative description from Richter et al. (1983) is as follows. "Rocks are fine grained, generally porphyritic or microporphyritic, containing widely varying amounts (1-30 percent) of phenocrysts, dominantly plagioclase, but-including olivine, clinopyroxene, hypersthene, and opaque minerals in pilotaxitic, intergranular, and intersertal groundmasses. Chiefly olivine-clinopyroxene andesites, but includes subordinate olivine andesites and basaltic andesites and two-pyroxene andesites and dacites. Typical olivine-pyroxene andesite consists of scattered phenocrysts (as large as 5 mm) of plagioclase (An_{45-55}), olivine altered to iddingsite and locally exhibiting hypersthene reaction rims, and opaque minerals in a pilotaxitic groundmass of small plagioclase laths, stubby clinopyroxene prisms, and opaque minerals and interstitial dark cryptocrystalline material. Vesicles [are] generally empty but may be lined with chalcedony, calcite, or clay minerals." Plagioclase groundmass microphenocrysts are often crudely align (Richter et al., 1981; Mako et al., 2024). Latite or andesitic dikes (Nda) throughout the map area are likely related to this unit (Richter et al., 1981; Mako et al., 2024). Previously used designations for this map unit include Tba (Richter et al., 1981), Tau (Richter et al., 1983; Houser et al., 1985), and NPbu (Mako et al., 2024).

Nr – Rhyolite vent plugs, isolated intrusions, and dikes (Miocene) – Crystal-poor high-silica rhyolites and related rocks, in addition to other minor young dikes and sub-volcanic intrusives. This unit includes more than a dozen previously distinguished units on more detailed maps, but is chief comprised of Trp (Rhyolite vent plugs, Richter et al., 1983). The combined units include the following: Trp, Trpb, Trd, Tad (Richter et al., 1981); Trr, Trp, Trb, Trrd, Trd, Tard, Tsd (Richter et al. 1983); Tr, Ttr, Trd (Hedlund, 1990, 1993). The occurrences are described as vents, plugs, dikes, and breccias, usually including the immediately sub-jacent volcanoclastic breccias (Trb). Rocks are described as aphanitic to slightly porphyritic, or crystal-poor, with phenocrysts of sanidine, quartz and plagioclase usually less than 5%. Flow laminations, spherulites, vitrophyre, and clasts of exotic volcanics (frequently basaltic andesite) are commonly described.

Nrp – Rhyolite porphyry intrusive bodies and dikes (Miocene) – The following description is from Hedlund (1993). "Pinkish-gray to moderate reddish-orange porphyry with locally abundant vug fillings of quartz and variable silicification of the groundmass. Irregular-shaped intrusions contain 10-15 percent phenocrysts as much as 6 mm across. Phenocrysts include 5-8 percent sanidine and 2-4 percent bipyramidal quartz. Accessory minerals are biotite, oxyhornblende, and iron oxides. The groundmass is spherulitic to cryptocrystalline." Dikes of similar minerology, up to 120 ft thick, are included with this unit, but are noted to have larger feldspar phenocrysts (up to 2 cm) and locally up to 2 percent biotite (Hedlund, 1993).

Nda – Andesite and latite dikes (Miocene) – Medium-gray, fine-grained or aphanitic to sparsely porphyritic dikes. Porphyritic varieties contain small (1-3 mm) phenocrysts of plagioclase, olivine, and locally clinopyroxene. They are typically short (<500m), discontinuous dikes mineralogically similar to andesite flows (Nau) (Richter et al., 1981, 1983; Houser et al., 1985; Hedlund, 1993). Dikes previously designated as Tbad (Richter et al. 1981), Tad (Richter et al., 1983; Houser et al., 1985), and Tl (Hedlund, 1993) are included in this unit. A porphyritic andesite dike associated with Tpa (now Npf), which is potentially a few m.y. older than other andesitic dikes, is also included in this unit (Richter et al., 1983).

Eruptive Center of Tolgate Wash

Ntd – High-silica rhyolite domes, flows and breccias (Miocene) – The following description is modified from Richter et al. (1983). Pinkish-gray to light-brownish-gray, flow-laminated rhyolite forming central core of the Tollgate Wash eruptive center (originally Ttd). Rocks are crystal-poor to moderately crystal-rich containing small (1-2 mm) phenocrysts of quartz (1-7 percent), sanidine (<1-4 percent), and traces of fayalite and opaque minerals in a variable groundmass consisting of laminae of fine-grained anhedral quartz and alkali feldspar, spherulites, and cryptocrystalline material. A K-Ar date on sanidine yields age of 17.3±0.4 Ma. Also included in this are grayish-red, densely welded monolithologic breccias containing fragments and blocks of flow-laminated, crystal-poor rhyolite (originally Ttb). These breccias probably represents hot avalanche deposits from the central rhyolite dome-flow complex.

Ntr – Low-silica porphyritic rhyolite flows (Miocene) – "Light-gray to light-brownish-gray massive flows, as much as 180 m thick; have locally well-developed columnar joints. Rock is coarsely porphyritic containing 21 to 27 percent large (as much as 1 cm) euhedral to subhedral phenocrysts and glomerocrystic clots (as large as 5 cm) of alkali feldspar (probably a high-albite-sanidine cryptoperthite) minor (1 percent or less) microphenocrysts of fayalite, clinopyroxene, amphibole, and opaque minerals, and traces of zircon, sphene, and apatite in a felty aggregate of feldspar, and irregular patches of quartz dusted with microlites of opaque minerals. Rocks southeast of main eruptive center are, in part, intrusive. [A] K-Ar whole-rock date… yields [an] age of 21.2±0.4 m.y." (Richter et al., 1983)

Npf – Porphyritic Dacite and Andesite Flows (Miocene) – Grayish-red to dusky-red, conspicuously porphyritic, medium to thick (3-15 m) flows with highly vesicular and scoriaceous tops and bottoms (Richter et et al. 1983). In addition to more extensive exposures in the Slick Rock basin (Tpa- Richter et al., 1983), the rock occurs locally at the base, or low in the section, of Nau in Sexton Canyon north of Sheldon Mountain (Tpaf- Richter et al., 1983) and adjacent to the Safford Mine (Taup- Houser et al., 1985). Sub-map scale occurrences are found in the Hot Well quadrangle at 109.203142°W 32.696626°N and 109.161915°W 32.751199°N (Mako et al., 2024). While Richter et al. (1983) originally divided Tpa and Tpaf, the rock descriptions are very similar, so they are combined on this map. The rock is described as containing 20-25 percent 1-3cm plagioclase phenocrysts (An35-50) with alkali feldspar rims, typical "turkey-track" glomerocrysts up to 5cm, trace-5 percent clinopyroxene. Altered, resorbed hypersthene, embayed quartz, olivine altered to iddingsite, ragged alkali feldspars and opaque minerals are all noted, hosted within a pilotaxitic matrix of plagioclase, clinopyroxene, hypersthene, and cryptocrystalline material (Richter et al., 1983; Houser et al., 1985). A K-Ar of 20.4±0.4 Ma is reported by Richter et al. (1983) for this unit, which is consistent with a new $^{40}Ar/^{39}Ar$ inverse isochron age of 21.62±0.91 Ma on groundmass in the study from the Hot Well quadrangle.

Ash Peak Eruptive Complex

Nai – Intrusive rhyolites of the Ash Peak Complex (Miocene) – Intrusive rhyolite and vent plug at two principle volcanic centers, one to the north near Rhyolite Peak and one to the south near Ash Peak. The Rhyolite Peak center was the source of late porphyritic low-silica rhyolite dome and flows (Nap). This intrusive rhyolite (previously designated Tapi) is described as follows (Richter et al., 1983). "Pinkish-gray, massive, holocrystalline porphyritic rock containing xenoliths of grayish-red andesite or basaltic andesite. Rock contains about 20 percent large (as large as 8 mm) phenocrysts of alkali feldspar, probably a high-albite-sanidine cryptoperthite, having cores of plagioclase (An_{15}), 5 percent small (1 mm or less) phenocrysts of altered clinopyroxene, and traces of biotite, opaque minerals, zircon, and sphene in a fine-grained, subhedral, granular groundmass of alkali feldspar and quartz." The intrusive bodies near Ash Peak (previously Tap and Tai) overlie and cross-cut (Richter et al. 1981) the surrounding volcanoclastic rocks (Nv) and rhyolitic flows (Nar), and thus apparently do not have an eruptive equivalent exposed in the area. Similar to the Rhyolite Peak center, the Ash Peak center intrusives are described as "pale-red to pinkish-gray, flow-laminated and brecciated, moderately crystal rich intrusive rhyolite. Rock contains about 10-15 percent crystals (as large as 3 mm in diameter) including 6-11 percent sanidine as euhedral crystals and crystal clots, 3-6 percent sodic plagioclase (An20-25), and between a trace and 1 percent each of quartz, biotite, basaltic hornblende generally replaced by black iron oxides, fayalite, and opaque minerals in a cryptofelsitic-spherulitic groundmass." (Richter et al., 1981).

Nap – Porphyritic low-silica rhyolite domes and flows (Miocene) – Massive to flow-laminated porphyritic rhyolite and dacite, locally containing lenses of dark-gray vitrophyre and breccia. The rock is described as containing "17-25 percent large (2-5 mm), conspicuous phenocrysts of alkali feldspar, probably a high-albite-sanidine cryptoperthite, and smaller (1 mm or less) phenocrysts of clinopyroxene (2-5 percent), hypersthene locally altered to fibrous amphibole (0-5 percent), opaque minerals (1 percent), and a trace of olivine in a cryptofelsitic to felty (feldspar and quartz) groundmass. Plagioclase ($An_{15\text{-}20}$) commonly cores the large alkali feldspar phenocrysts and locally occurs as small single crystals" Additionally, the dome rhyolites are described as containing "conspicuous xenoliths, as much as 2 cm in diameter, chiefly of grayish-red andesite or basaltic andesite." This units is separated from Npf and Nau above by a "prominent erosional surface marked by thin, silicic, pyroclastic air-fall and reddish volcaniclastic deposits and locally steep paleotalus breccias." This description is modified from Richter et al. (1983) who originally distinguished two units (Tap and Tapd).

Nar – Crystal-poor rhyolite domes and flows (Miocene) – Pinkish-gray, light-gray, and light brownish-gray, flow-laminated crystal-poor rhyolite generally with coarse brecciated bases consisting of rhyolite blocks cemented by similar rhyolite (autobreccia), and locally including lenses and masses of black to gray vitrophyre and conspicuously spherulitic phases. Spherulites are typically 1-3 cm, but as large as 25 cm. Isolated 1-20 cm xenoliths of Pal are also common (Richter et al., 1983; Mako et al., 2024). "Rhyolite typically contains a few (<1 percent total) small (<1 mm) crystals of quartz, sanidine, clinopyroxene, and opaque minerals in a matrix composed of laminae, as thin as 0.5 mm, of spherulites and microspherulites alternating with laminae of cryptocrystalline aggregates of quartz and feldspar and irregular lenses of tridymite and tridymite-quartz all dusted with fine opaque minerals and locally with fine red hematite" (Richter et al. 1981). In the Hot Well quadrangle (Mako et al., 2024), four successive flows of this unit were distinguished based on the presence of layers of volcanoclastic rocks, usually a pumiceous block-lapilli tuff containing clasts of Pal and Nar. New $^{40}Ar/^{39}Ar$ geochronology on groundmass from a sample in the Hot Well quadrangle yields an inverse isochron age of 22.92±0.96 Ma, consistent with a previous K-Ar age on "biotite and sanidine" of 23.1±0.5 Ma (Richter et al., 1983) for the underlying biotite rhyolite (Nabr). With the new dates being just younger than the Miocene-Oligocene boundary, the Ash Peak volcanics are designated as Miocene or Neogene. See also the thesis by Walker (1990) on the geochemistry of the Ash Peak eruptive complex.

Nabr – Biotite rhyolite flow (Miocene) – Biotite rhyolite flow. Pale-red to light-olive-gray, moderately crystal-rich flow-laminated rhyolite with dark gray vitrophyric base. Rock contains crystals (0.5-3 mm) of sodic plagioclase (An_{15-25}) (0-9 percent), sanidine (3-10 percent), oxidized biotite (1-2 percent), rounded and embayed quartz (0-2 percent), and traces of clinopyroxene, opaque minerals, and sphene in a cryptofelsitic-spherulitic groundmass with tridymite locally filling interstices between spherulites (Richter et al., 1981, 1983; Mako et al., 2024). Elongate, black, rusty, or bronze biotite phenocrysts (1-2mm) are particularly distinctive and diagnostic in this unit. This single lava flow represents the earliest unit in the Ash Peak complex and is locally overlain by flows of Pal. While flow foliations in the biotite rhyolite can be near vertical and bedding in volcanoclastic rocks is locally as steep as 45 degrees, flows in Nar and Nabr are nearly flat-lying or dipping only a few degrees to the east (Mako et al., 2024).

Greasewood Mountain Eruptive Center

PNgm – Volcanic rocks of Greasewood Mountain (Oligocene to Miocene) – Dacitic porphyry flows and breccias as much as 10 to 15 m thick. Rocks are plagioclase-biotite-hornblende porphyries with a pilotaxitic matrix of plagioclase, biotite, hornblende, and opaque minerals. Locally contains minor quartz, clinopyroxene, and hypersthene. Zircon fission-track ages of 25.4 ± 1.3 Ma and 26.1 ± 1.6 Ma were obtained from two flows (Thorman, 1981).

PNdl – Diorite of Little Cottonwood Canyon (Oligocene? to Miocene) – Medium-grained, hypidomorphic to panidomorphic granular clinopyroxene-biotite diorite to quartz diorite with myrmekitic and graphic interstitial intergrowths (Thorman, 1981).

PNah – Andesite of Hog Spring (Oligocene? to Miocene) – Plagioclase-pyroxene andesite porphyry flows as much as 8 to 10 meters thick. Contains medium- to coarse-grained plagioclase (labradorite) and clinopyroxene in a pioltaxitic to felty matrix. Rocks are weakly to moderately chloritized and epidotized. Rocks resemble turkey-track andesite of Cooper (1960). Local thin channel deposits of granitic clasts derived from Proterozoic rocks occur within the unit (Thorman, 1981).

PNfs – Volcanic rocks of Frog Spring (Oligocene? to Miocene) – Interbedded andesitic flows, breccias, and volcaniclastic beds. Flows have felty to pilotaxitic texture with fine- to medium-grained phenocrysts of saussuritized plagioclase and altered pyroxene and hornblende. Volcaniclastic beds are intraformational sandstones, conglomerates, and breccias. A single zircon-fission track age of 26.8 ± 1.2 Ma was obtained from an andesite flow (Thorman, 1981).

NPa – Andesite of the Gila River (Miocene) – "Medium-gray, brownish-gray, and dusky-blue massive flows, as much as 30 m thick interlayered with thick flow breccias. Rocks are predominantly olivine-free, two-pyroxene andesites containing sparse phenocrysts (as large as 2 mm) and microphenocrysts of clinopyroxene, hypersthene generally altered to a fibrous amphibole, and opaque minerals in a pilotaxitic groundmass of plagioclase microlites, minute clinopyroxene and hypersthene prisms, and cryptocrystalline material. Intergranular textures characterize some flows. Unit may include flows of overlying andesites of Guthrie Peak-Turtle Mountain [Nau]. Source and age unknown, and position in volcanostratigraphic column is uncertain." (Richter et al., 1983).

NPc – Conglomerate (Oligocene-Miocene) – Grey-tan, well-indurated conglomerate, with 10-150cm thick gently dipping bedding. It is generally matrix-supported with angular to sub-angular clasts, typically 2-10cm, commonly up to 20cm with at least one rhyolite-dacite clast measuring >2m. Clasts are mostly felsic volcanic lithologies with minimal basaltic andesite clasts. A 40m thickness of this unit is exposed on Round Mountain, the southeast corner of the mapping area, beneath the upper basaltic andesite (Nau), with only a few other exposures observed (Gootee et al., 2024).

OLIGOCENE VOLCANIC ROCKS

West of York Valley

Pv – Oligocene volcanoclastic rocks, undivided (Oligocene) – Undivided volcanoclastic rocks including primarily pyroclastic deposits and dome related breccias. These deposits are distinguished from the Neogene volcanoclastic rocks (Nv) only on the basis of age. The primary exposures of this unit are in the Volcano of Bear Spring (originally Tbp, Tbdb, Tbdp, Tbbc) (Houser et al., 1985), the Whitlock Mountains (originally Tpb and Tlb) (Richter et al. 1981), and Coyote Wash area (originally Tvc) (Houser et al., 1985).

Ppp – Rhyodacite, dacite, andesite dome-flow-cone complex of Powerline Pass (Oligocene) – Primarily hornblende andesite flows and a hornblende-biotite rhyodacite dome complex with a remnant of a pyroclastic breccia cone, as well as an overlying porphyritic dacite flow of more silicic composition (Richter et al., 1981). The hornblende andesite flows are described as "typically microporphyritic containing microphenocrysts (<1 mm) of plagioclase (An_{30-50}) (10-20 percent), hornblende (3-4 percent) largely replaced by black iron oxides, stubby clinopyroxene (1-2 percent), and rare embayed quartz with clinopyroxene reaction rims, in a pilotaxitic groundmass of plagioclase microlites, minute clinopyroxene grains, opaque minerals, and cryptocrystalline material. Some phases are porphyritic with plagioclase phenocrysts as much as 5 mm in diameter." The rhyodacite dome is described as "microporphyritic to locally porphyritic with sparse phenocrysts (<5 mm) and microphenocrysts (<0.5 mm) of sodic plagioclase (2-10 percent), hornblende replaced by black iron oxides (1-3 percent), dark ragged biotite (0-2 percent), and opaque minerals (1-3 percent) in a cryptofelsitic or microtrachytic groundmass." Richter et al. (1981) reports a biotite K-Ar date of 24.9 Ma.

Pdr – High-silica rhyolite dome-flow complex of Dry Mountain (Oligocene) – "Massive quartz-eye rhyolite flow(s) with basal vitrophyre and vitrophyre breccia. Rocks are very light gray to light gray to pale brown, flow-laminated, and moderately crystal-rich containing small (1-3 mm) but conspicuous, round to euhedral quartz phenocrysts (3-5 percent) together with small phenocrysts of sanidine (2 percent), plagioclase (An_{15-25}) (1 percent), and a trace of ragged biotite, in a groundmass consisting of laminae of felty quartz and alkali feldspar, spherulites, and locally quartz, all with a dusting of fine opaque mineral grains. The bases of flows are gradational downward into dark-gray to black vitrophyre and coarse vitrophyre breccia through a transitional zone of rhyolite flow breccia and light-pinkish-gray spherulitic-rich rock." Richter et al. (1981). Previously distinguished breccia cone deposits, a vent breccia, and a possible vent plug are included with this unit, all containing quartz-eye phenocrysts.

Pwq – Quartz latite flows of Whitlock Mountains (Oligocene) – "Grayish-red to brownish-gray, flow-laminated, thick (20-80 m) quartz latite flows with basal dark-gray vitrophyres and flow breccias as much as 10 m thick. Individual flows generally separated by grayish-orange, pyroclastic and epiclastic breccias as much as 15 m thick. Flows are porphyritic containing (1) 20 percent zoned sodic plagioclase (An_{10-40}) as phenocrysts, up to 5 mm long, and in glomerocrysts, up to 1 cm in diameter, with (2) smaller (<3 mm) phenocrysts of clinopyroxene (<2 percent) dusted with opaque minerals and locally replaced by fibrous amphibole, and (3) opaque minerals (<2 percent) and rare embayed quartz, apatite needles, and fluorite in a cryptofelsitic groundmass of feldspar, mafic minerals, and opaque dust. Small (<1 mm) crystals of biotite locally associated with clinopyroxene in some glomerocrysts." (Richter et al., 1981).

Pjr – Rhyolite flow of Javelina Peak (Oligocene) – "Massive rhyolite flow with basal vitrophyre and vitrophyre breccia. Rocks are light gray to medium light gray, flow-laminated, and moderately crystal-rich containing 6-10 percent sanidine crystals (up to 5 mm) and about 1 percent each of smaller (<2 mm) crystals of plagioclase, biotite, and opaque minerals in a microspherulitic groundmass of alkali feldspar and quartz with patches of micromyrmekite and irregular quartz veinlets. Masses of black vitrophyre occur locally along upper contact. Basal vitrophyre consists of dark-gray to black glass, locally perlitic, that grades downward into a glass breccia which is commonly intensely distorted." (Richter et al., 1981).

Pta – Porphyritic andesite flows (Oligocene) – "Grayish-red, conspicuously porphyritic, medium-thick (3-8 m) flows with highly vesicular and scoriaceous tops and bottoms. Rock contains (1) 20 to 25 percent plagioclase, commonly poikilitic, as euhedral tabular crystals up to 3 cm long and typical turkey track glomerocrysts up to 5cm in diameter, and (2) about 2 percent small (<1 mm) stubby prisms of clinopyroxene in an intergranular to pilotaxitic groundmass of plagioclase microlites, clinopyroxene, and opaque minerals with varying amounts of interstitial, turbid, cryptocrystalline material. Microprobe analysis indicates plagioclase crystals zoned An_{50} to An_{40} with extremely thin (30μm) outer rims of Or_{55}-Ab_{40}-An_5." Richter et al. (1981) reports K-Ar dates on whole rock groundmass and plagioclase phenocrysts of 26.7 and 28.7 Ma, respectively.

Pbcd – Dacite of Bonita Creek (Oligocene) – "Light-brownish-gray, locally flow-laminated and brecciated, massive flow or top of dome exposed in Bonita Creek canyon. Brecciated units weather cavernously. Rock has a trachytic texture and contains small (1 mm) phenocrysts of rounded plagioclase (An_{47}) rimmed by alkali feldspar (3 percent), clinopyroxene (2 percent), oxyhornblende (3 percent) with magnetite rims, and biotite (3 percent) in a groundmass of plagioclase, biotite, and hornblende microlites and cryptocrystalline material." (Houser et al., 1985).

Ptu – Andesite-Dacite Flow (Oligocene) – "Flow-banded andesite lava flow. Phenocrysts include 1-4 mm twinned plagioclase (5%), rare chalky white potassium feldspar, and <1% biotite and other mafic minerals. This unit is only observed in a small exposure on the southern edge of the Whitlock Peak Quad, but it is contiguous with the widespread Ttu (andesite and dacite flow, undivided) of Richter et al. (1990)." (Ben Horin et al., 2024).

Pcr – Rhyolite flows of Coyote Wash (Oligocene) – "Light-brownish-gray to pale-brown, flow-laminated microporphyritic flows containing microphenocrysts of oligoclase (2-7 percent), oxyhornblende (1-5 percent), biotite (1 percent), and opaque minerals (1 percent) in a felty to trachytic matrix of feldspar and opaque minerals." (Houser et al., 1985).

Volcano of Bear Spring

Pbr – Rhyolite dome, flows, and agglutinates (Oligocene) – Rhyolite flows, pyroclastic rocks, agglutinates, and a dome that likely fills a central eruptive crater of the volcano of Bear Spring, which was active between 24-26.5 Ma. The volcano is stratigraphically between the voluminous upper andesite flows (Nau) and lower andesite flows (Pal) (Houser et al. 1985). Flows (formerly Tbd) are described as "Very light gray to light-brownish-gray, crystal-poor, low-silica rhyolite. Generally massive, but locally exhibits highly contorted flow laminae with lithophysae. Rock contains sparse (about 1 percent), small (0.5-2 mm) phenocrysts of oligoclase locally mantled by alkali feldspar, biotite, and opaque minerals." The agglutinates (formerly Tba), which occupy positions further from the volcanic center are similarly described as containing "1-3 percent small (0.3-1 mm) phenocrysts of oligoclase and about 1 percent each of clinopyroxene, altered biotite, and opaque minerals in a trachytic to microtrachytic matrix of feldspar and opaque minerals" (Houser et al., 1985).

Pbd – Porphyritic and non-porphyritic dacite flows (Oligocene) – Laterally extensive dacite flows apparently intruded by the central volcano of Bear Spring. Non-porphyritic flows (formerly an upper and lower flow; Tbud and Tbld) are described as medium-gray to brown with 1-2 percent small phenocrysts of plagioclase, minor oxyhornblende and altered biotite in a trachytic groundmass (Houser et al., 1985). Porphyritic flows (formerly an upper and lower flow exposed on the western side of Turtle Mountain; Tbuf and Tblf) are described as containing 5-20 percent plagioclase phenocrysts, 1-15 percent oxyhornblende, with minor clinopyroxene, biotite, and trace olivine. The upper flow is reported to have larger and high proportion plagioclase. A K-Ar date on hornblende from one of the non-porphyritic flows yielded an age of 25.9±0.6 Ma (Houser et al., 1985).

Pca – Andesite and dacite flows of Coyote Wash (Oligocene) – "Light-brownish-gray to medium-gray massive flows, as thick as 15 m, with scoriaceous tops and bottoms. Rocks are dominantly porphyritic two-pyroxene andesites containing 10-29 percent phenocrysts and glomerocrysts (2-10 mm) of plagioclase (An_{35-52}) (10-22 percent), clinopyroxene (1-6 percent), hypersthene (1-4 percent) generally altered to fibrous amphibole, and local oxyhornblende (0-6 percent), biotite (0-3 percent), and olivine (0-2 percent) altered to iddingsite in a pilotaxitic, intersertal, or cryptocrystalline groundmass. Opaque minerals and sphene are common accessory minerals." Additionally, "flows and intercalated volcanoclastic and pyroclastic rocks that may represent biotite- and hornblende-bearing variants of the andesite of Guthrie Peak [Nau].” (Houser et al., 1985)

Pal – Lower andesite flows (Oligocene) – Brown to rusty orange-weathering vesicular basaltic trachyandesite to trachyandesite. Almost always with large amygdules (Mako et al., 2024) filled with quartz, chalcedony, chlorite, zeolite minerals (probably clinoptilolite and heulandite) and clay minerals (celadonite?) (Richter et al., 1981). Usually intensely oxidized and weathered, forming low, rounded, recessive outcrops. Flows are thin, usually 2-10m (Richer et al., 1981). The rock is described as “sparsely porphyritic containing small (<1 mm) phenocrysts of olivine, altered to iddingsite, and(or) microphenocrysts (<0.5 mm) of plagioclase (An_{40-50}) in a pilotaxitic to intergranular groundmass of feldspar microlites, abundant (10 percent) euhedral to blotchy opaque minerals, and rare clinopyroxene. Films of red iron oxide are locally very abundant coating plagioclase microlites, and calcite is commonly present in veinlets and as interstitial masses.” (Richter et al., 1981). Plagioclase phenocrysts are densely packed and weakly to moderately aligned (Mako et al., 2024). Equivalent to Tal of Richter et al. (1983) and Houser et al. (1985), and Toa of Richter et al. (1981) and Morrison (1965).

Houser et al. (1985) reports a K-Ar age of 26.6±0.6 Ma and Richter et al. (1983) gives K-Ar ages of 21.8-22.6 Ma, while Richter et al. (1981) places this unit below a 26-28 Ma andesite. While the reported ages overlap with that of the Ash Peak complex, there is reason to at least suspect that the eruptions are not contemporaneous. The lower basaltic andesite is almost everywhere deeply weather and altered in appearance, giving the impression of a longer near-surface history than rhyolitic volcanics or overlying basaltic andesites of the same composition. Indeed, Richter et al. (1983) suggest the rocks were “covered by water or were below the water table for a significant period of time.” However, field relationships seem to suggest that there is at least some overlap in the timing of eruption between the Ash Peak complex and the lower andesite flows (Richter et al., 1983).

East of York Valley

Ptai – Intrusive andesite of Tillie Hall Canyon (Oligocene?) – “Medium-gray, porphyritic andesite containing 30-50 percent andesine-labradorite (An_{38-50}) phenocrysts as much as 2 cm long in a “turkey track” arrangement. Forms small stock of about 4 mi^2 (10 km^2) just north of Tillie Hall Peak. Aplitic to granitic segregations are locally present. In places the andesite has numerous miarolitic cavities lined with coarse euhedral quartz crystals. Clinopyroxene grains as much as 1 mm across make up about 2-3 percent of the rock, and apatite is a common accessory. Intrusion is of uncertain correlation but shows intrusive contacts with the andesite flows of Pine Cienega Creek [Ppca] and with the Rhyolite of Hells Hole [Phr] [sic]. A plagioclase concentrate has yielded a K-Ar age of 24.5±0.8 Ma (Marvin and others, 1987; Ratté and Hedlund, 1981).” (Hedlund, 1993).

Plpc – Rhyodacitic to dacitic lava flows of Crookson Peak (Oligocene) – "Brownish-gray, grayish-red-purple to grayish-red porphyritic rock containing 8-25 percent phenocrysts 1-4 mm across. Flows are commonly flow-laminated and display a platy weathering habit. Phenocrysts include 4-10 percent oligoclase-andesine (An_{27-35}), 0-2 percent sanidine, and 1-2 percent biotite. Outcrops on and near Yellowjacket Peak are a small part of a more extensive flow complex that is as much as 1,500 ft (460 m) thick in the Crookson Peak quadrangle to the east." (Hedlund, 1993).

Phr – Rhyolite of Hells Hole (Oligocene) – "Large (30 mi^2; 75 km^2) intrusive-extrusive rhyolite dome complex that extends northwest from Tillie Hall Peak for about 10 mi (16 km) to New Mexico State Highway 78 in the Big Lue quadrangle. The rhyolite is very light gray, aphyric, and highly flow laminated. The lower flows are commonly reddish brown, especially where they are intercalated with sandstone [Ths of Hedlund, 1993]. Dome-flow complex is at least 1,200 ft (370 m) thick. A biotite concentrate has yielded a K-Ar age for the Rhyolite of Hells Hole in the adjacent Big Lue Mountains quadrangle of 27.1±1.0 Ma (Marvin et al., 1987, table 4)." (Hedlund, 1993). Sandstones intercalated with the rhyolite are as much as 15 m thick, poorly sorted with angular clasts of rhyolite up to 5 cm (Hedlund, 1993).

Pbca – Andesitic Dome of Bitter Creek (Oligocene) – "Brownish-gray, weathers light-brown, porphyritic andesite that has locally strong, steeply dipping flow layering. Phenocrysts include sodic andesine (An_{33-35}), oxyhornblende, traces of clinopyroxene, and xenocrystic(?) quartz. The groundmass is finely pilotaxitic. Locally has gradational contact with basaltic rocks of Dark Thunder Canyon (Tbd) and contact is locally difficult to determine." (Hedlund, 1993).

Ppca – Andesitic lava flows of Pine Cienega Creek (Oligocene) – "Medium-gray, amygdaloidal, aphyric, pilotaxitic lava flows intruded by the rhyolite of Hells Hole [Phr] and intrusive andesite of Tillie Hall Canyon [Ptai]. Flows are locally propylitized, marginally to these intrusions. Dark-greenish-gray celadonitic amygdules as much as 4 mm across are abundant. The andesite typically contains about 30 percent sodic andesine (An_{30-32}) microlites in a cryptocrystalline matrix through which iron ore granules are dispersed. Patchy calcite replaces some of the plagioclase." (Hedlund, 1993).

Prf – Rhyolitic and dacitic flows (Oligocene) – Rhyolite and dacite flows exposed in a relatively small area on the Arizona-New Mexico border in the Tillie Hall Peak quadrangle (Hedlund, 1993). The rhyolite (originally Trf) is described as flow-laminated and aphanitic to slightly porphyritic. The dacite flows (originally Tdf) are flow-laminated and "highly convoluted… locally grad[ing] into autobrecciated units (Hedlund, 1993)". The rhyolite and dacite units are each approximately 200 ft thick and overly the basaltic rocks of Dark Thunder Canyon (Pdb).

Pdb – Basaltic and andesitic rocks of Dark Thunder Canyon (Oligocene) – "Dark-gray to medium-olive-gray, grayish-red, aphanitic to porphyritic andesite and basalt flows. Commonly amygdaloidal with celadonitic alteration locally common. Flows generally contain 5-10 percent phenocrysts of andesine (An_{33-45}) and as much as 5 percent clinopyroxene set in a pilotaxitic groundmass of aligned andesine microlites. Accessory minerals are oxyhornblende, disseminated magnetite-ilmenite granules, and iddingsite after altered pyroxene." (Hedlund, 1993). Intercalated tuffaceous sandstones, most abundant near the Fraser mine, are very thinly bedded and poorly sorted (Hedlund, 1993).

Pwr – Rhyolite and Rhyodacite porphyry of Willow Creek (Oligocene) – "Light-brownish-gray to pale-red, platy-weathering, porphyritic flows containing 15-20 percent phenocrysts up to 5 mm across in a finely pilotaxitic groundmass. Phenocrysts are 2-3 percent sanidine, 10 percent sodic andesine (An_{30-32}), and as much as 5 percent quartz. Accessory minerals are biotite, oxyhornblende, iron oxides, white mica, and calcite" (Hedlund, 1990). The adjacent rhyolite flows are described as aphanitic and intensely flow-laminated with vitrophyric bases (Hedlund, 1990).

Pkrd – Rhyodacite, rhyolite, and basaltic breccia of K-6 Mountain (Oligocene) – Primarily dacite flows with very minor flow-laminated rhyolite, and basalt bomb breccia with rhyolite and dacite matrix. The dacites (originally Tkrd) are described as "less than 10 percent phenocrysts including 2-5 percent zoned and highly resorbed laths of calcic oligoclase-sodic andesine (An_{28-36}) and as much as 2 percent dusky-brown biotite plates as much as 2 mm across. Accessory minerals are oxyhornblende, highly resorbed sanidine, iron oxides, and quartz. The pilotaxitic groundmass contains iron ore granules and some patchy aggregates of quartz" (Hedlund, 1993). The rhyolite flows (originally Tkr), exposed in a relatively small area near Mule Mountain and Linden Creek, are spherulitic with "as much as 8 percent bipyramidal quartz, 7 percent sanidine, and 3-5 percent sericitized plagioclase phenocrysts. Accessory minerals are biotite and iron oxides" (Hedlund, 1993). The thin, heterolithic, basalt breccia unit (originally Tkb), is exposed on K 6 Mountain (Hedlund, 1993).

Pcba – Andesitic rocks of Copper Basin (Oligocene) – "Dark gray, scoriaceous, slightly amygdaloidal, andesite flows that are locally autobrecciated and propylitized. Pilotaxitic groundmass contains generally less than 5 percent phenocrysts of calcic andesine (An_{45-48}). Propylitized andesite locally contains abundant epidote and calcite along northwest-striking faults near the Copper Basin mines." (Hedlund, 1993).

Pbg – Bloodgood Canyon Tuff (Oligocene) – "Light-gray to light brownish-gray, densely welded, devitrified, ash flow tuff containing about 15 percent phenocrysts as much as 3 mm across. Upper part of ash flow is nearly white and less welded. Phenocrysts include 8-12 percent satiny chatoyant sanidine, and 2-5 percent resorbed bipyramidal quartz. Accessory minerals are sphene, biotite, oxyhornblende, and iron oxides. Mapped as "Noeh Mesa Tuff' in unpublished thesis by Wahl (1980). $^{40}Ar/^{39}Ar$ determinations from other quadrangles indicate a 28.05±0.04 Ma age (William C. McIntosh, written commun., 1989). Eruptive source, the Bursum caldera (Ratte and others, 1984)." (Hedlund, 1993).

Paa – Basaltic andesite of Apache Creek (Oligocene) – "Dark gray, aphanitic to slightly porphyritic flows that are locally altered yellowish gray. Outcrops commonly covered by debris from ash-flow tuff [Pbg]." (Hedlund, 1993).

Psdp – Dacite porphyry of Summit Mountain (Oligocene) – The following description is modified from Hedlund (1990, 1993). Medium-gray to grayish-red-purple to pale-red, porphyritic dacite flows with intercalated air-fall tuff, sandstone, and rhyolite. Dacitic flows contain 15-40 percent phenocrysts as much as 4-5 mm across. Phenocrysts included plagioclase, variably reported as 10-15 percent calcic oligoclase-sodic andesine (An_{28-37}) (Hedlund, 1993) or 10-33 percent andesine (An_{38-45}) (Hedlund, 1990), 0-3 percent biotite, and 0-5 percent oxyhornblende. Accessory minerals are clinopyroxene, allanite, calcite, white mica, quartz, and iron oxides. The groundmass is felted cryptocrystalline and contains disseminated granules of iron oxides. Intercalated sandstones, up to 60 m thick, are thin-bedded, fine- to medium-grained and well-sorted. Sandstones are locally sericitized, silicified, or alunitized, with Liesegang banding. In the vicinity of Goat Camp Springs, the dacite flows are locally argillized and sericitized; gypsum is associated with some of the clay minerals; traces of alunite are present in the more silicified dacite. A hornblende concentrate yielded a K-Ar age of 31.3±2.2 Ma (M. Shafiqullah, written commun., 1980). (It is uncertain whether the hornblende age is for the altered dacite). A sample of alunite-quartz rock at the west end of Saddleback Mountain yielded a K-Ar age of 31.3±1.1 Ma (Marvin and others, 1987; sample collected by R.B. Hall).

OLIGOCENE TO NEOGENE INTRUSIVE ROCKS

PNql – Quartz latite dike (Oligocene to Miocene) – Quartz latite dikes with a very fine-grained quartz-feldspar-mica matrix with fine- to medium-grained quartz and feldspar phenocrysts. Two dikes have zircon fission-track ages of 22.8 ± 1.4 Ma and 22.9 ± 1.0 Ma (Thorman, 1981).

Ngl – Gillespie Granite (Oligocene) – The Gillespie granite is a high-silica (~71-77 % SiO_2; Sharp, 1991) granite with variable textural varities that range from aphanitic to porphyritic and range from medium- to coarse-grained equigranular texture (Swan, 1976).

LATE CRETACEOUS TO PALEOGENE VOLCANIC AND INTRUSIVE ROCKS

PErm – Mylonitized Relleno suite (Paleocene to Eocene) – Mylonitized rocks of map unit PEr (Relleno suite).

PEr – Relleno suite (Paleocene to Eocene) – The Relleno suite was originally mapped by Thorman and Naruk (1987) as the Middle Proterozoic Granodiorite of White Streaks Canyon.

Recent U-Pb zircon geochronology by Chapman et al. (2021) and Scoggin et al. (2022) constrains the age of the intrusive suite between ~57-52 Ma, renamed the exposures as the Relleno suite. The Relleno suite is principally comprised of a metaluminous to weakly peraluminous biotite granodiorite (phase 1) that is cut by two generations of more felsic leucogranitic dikes (phases 2 and 3).

KPg – Safford granodioritic to quartz dioritic plutonic rocks (Late Cretaceous to Paleocene) – The Safford district intrusive and hypabyssal rocks have broadly been previously divided into two types: 1) parental granodioritic to quartz dioritic plutons, and 2) productive (mineralizing) quartz monzonitic, tonalitic, and granodioritic porphyries (Langton and Williams, 1982). The Lone Star pluton, the largest of the stocks in the district, has several textural phases, but is principally a quartz diorite porphyry with phenocrysts of plagioclase, hornblende, and rare quartz (Stegen and Parker, 2020). Intruding the Lone Star stock are at least four compositionally and/or texturally distinct sets of dikes (Stegen and Parker, 2020). Dikes from the Dos Pobres porphyry copper deposits are east- to northeast-trending plagioclase- and biotite-bearing quartz monzodioritic to low-silica granodioritic dikes ranging from 15-100 m in width and 150-300 m in length (Russin, 2008).

Kv – Safford volcanic rocks (Late Cretaceous) – The Safford district is dominantly comprised of the "Safford Volcanics" or "Safford Metavolcanics" (also described as the "older volcanics" by Robinson and Cook, 1996) which consist of >1,300 m of Late Cretaceous and younger hornblende and pyroxene andesite flows, breccias, agglomerates, wackes, and mud flows (Langton and Williams, 1982). Near the Dos Pobres and San Juan porphyry copper deposits, the rocks are dominantly basaltic (trachy)andesites (Russin, 2008), while least-altered samples near the Lone Star porphyry copper deposit are described as a dark-grey porphyritic and aphanitic andesite intercalated with breccias and tuffs (Stegen and Parker, 2020). Selck (2017) suggests the original compositions of the volcanic rocks near Lone Star were andesitic to dacitic. The basaltic (trachy)andesite at Dos Pobres has been dated at 73.3 ± 1.0 Ma, which a stratigraphically higher andesite near San Juan has a K-Ar age of 67.6 ± 1.4 Ma (Houser et al., 1985; Russin, 2008). Langton and Williams (1982) also describe a younger, less altered volcanic suite called the "Baboon Volcanics," consisting of andesitic agglomerates, flow breccias, and lithic tuffs. William Stavast (pers. comm., in Russin, 2008) reports that Freeport geologists interpret the "Baboon Volcanics" to be part of the "Safford Volcanics" as they interfinger with one another and only differ in degree of hydrothermal alteration.

PROTEROZOIC METAMORPHIC AND INTRUSIVE ROCKS

Yd – Diabase (Mesoproterozoic) – Diabase dikes and irregularly shaped bodies. Rocks are comprised of fine- to coarse-grained plagioclase (labradorite), clinopyroxene, and opaque minerals; clinopyroxene altered to chlorite, biotite, and hornblende (Thorman and Naruk, 1987).

Ygsm – Mylonitized Granite of Slick Rock (Mesoproterozoic) – Mylonitized rocks of map unit Ygs – Granite of Slick Rock.

Ygs – Granite of Slick Rock (Mesoproterozoic) – Two-mica granite that cuts the foliation of the Gneiss of Pinaleno Mountains (Xpm). Medium-grained rock with hypidiomorphic-granular texture, typically containing quartz (31%), microcline (27%), plagioclase An_{30} (35%), biotite (2%), muscovite (2%), epidote (2-3%), sphene (<0.5%), and trace amounts of zircon, apatite, and opaque minerals. Mafic minerals occur chiefly in clots (Thorman and Naruk, 1987).

Ygt – Granite of Treasure Park (Mesoproterozoic) – Massive to weakly foliated, medium-grained, porphyritic two-mica granite with hypidiomorphic-granular texture. Typical mineral assemblage is quartz-microcline-saussuritized plagioclase-chloritized biotite-muscovite-epidote with trace amounts of zircon, sphene, apatite, and opaque minerals. Rock is typically moderately to deeply weathered in contrast to adjacent, fresh country rocks (Thorman and Naruk, 1987).

Ygl – Granite of Ladybug Saddle (Mesoproterozoic) – Massive to weakly foliated, medium- to coarse-grained porphyritic biotite granite with hypidiomorphic-granular texture that cuts the foliation of the Gneiss of Pinaleno Mountains (Xpm). The crystalloblastic foliation in the pluton is subparallel to foliation in the Gneiss of Pinaleno Mountains (Xpm). Typical mineral assemblage includes quartz (27-35%), microcline (24-26%), plagioclase An30-34 (35%), biotite (4-12%), sphene (1-1.5%), epidote (1-2%, and trace zircon, apatite, allanite, and opaque minerals. Mafic minerals occur primarily in clots. Xenoliths and schlieren present mainly along margin, where they are oriented parallel to foliation in country rock (Thorman and Naruk, 1987).

Ygsp – Granite of Stockton Pass (Mesoproterozoic) – Medium- to coarse-grained porphyritic two-mica granite with hypidiomorphic-granular texture with distinct finer and coarser phases in a complex intrusive relations. Typical mineral assemblage includes quartz, microcline, plagioclase, biotite, muscovite, sphene, and trace zircon, apatite, and trace minerals. Mafic minerals occur both as disseminations and in clots. Graphic and myrmekitic intergrowths are common. Pegmatitic phases commonly occur near the contact with the Gillespie granite (Ng) and have megascopic graphic intergrowths. Mafic minerals commonly absent on weathered surfaces giving outcrops a leucocratic appearance (Thorman, 1981).

Ygv – Granite of Veach Ridge (Mesoproterozoic) – Massive to weakly foliated, medium- to coarse-grained biotite granite with a hypidiomorphic-granular texture that cuts foliation of the Gneiss of Pinaleno Mountains (Xpm). The crystalloblastic foliation in the pluton is subparallel to foliation in the Gneiss of Pinaleno Mountains (Xpm). Mineral assemblage includes quartz, microcline, plagioclase, biotite (1-15%), and epidote, with trace sphene, allanite, zircon, apatite, and opaque minerals. Xenoliths of the Gneiss of Pinaleno Mountains (Xpm) range in size from 05-100 m across and 1 to 300 m in length and are aligned paralle to foliation of the country rock (Thorman and Naruk, 1987).

YXjm – Mylonitized Gneiss of Johns Dam (Paleoproterozoic to Mesoproterozoic) – Mylonitized rocks of map unit YXjm (Gneiss of Johns Dam).

YXj – Gneiss of Johns Dam (Paleoproterozoic to Mesoproterozoic) – Intercalated granitic gneiss and Gneiss of Pinaleno Mountains (Xpm). Granitic gneiss is medium-grained biotite-rich rock with coarse- to very coarse-grained microcline phenocrysts, having augen texture where rock is foliated. This unit is finer-grained than the Gneiss of Pinaleno Mountains (Xpm), with individual layer up to 50 m in thickness given a pronounced banded appearance on aerial imagery. Typical granitic gneiss mineral assemblage is quartz, microcline, plagioclase (An20-50), biotite, epidote, and sphene (Thorman and Naruk, 1987).

Xpmm – Mylonitized Gneiss of Pinaleno Mountains (Paleoproterozoic) – Mylonitized rocks of map unit Xpm – Gneiss of Pinaleno Mountains.

Xpm – Gneiss of Pinaleno Mountains (Paleoproterozoic) – Compositionally layered felsic, leucocratic gneiss and minor amphibolite that underlies most of the Pinaleno Mountains and is the oldest unit in the range. The rocks are fine- to medium-grained and include the following mineral assemblages: quartz-microcline-plagioclase-biotite granite; quartz-plagioclase-biotite gneiss; quartz-plagioclase-microcline-muscovite gneiss; quartz-two mica-plagioclase-microcline gneiss; plagioclase-hornblende gneiss; and muscovite-bearing quartzite. Foliation defined by compositional banding or layering, aligned disseminated mafic minerals, and elongation of normally equant or stubby minerals (Thorman and Naruk, 1985).

Xm – Metamorphic rocks of Bar X Canyon (Paleoproterozoic) – Intercalated gneiss and quartzite. Fine- to medium-grained, moderately foliated rocks. Rock units include a muscovite-bearing quartzite, quartz-two mica-plagioclase gneiss, and rare beds of quartzitic metaconglomerate. Rocks locally strongly weathered to purplish red to brown hues. Rocks likely are metamorphosed sandstones and/or felsic volcanic rocks (Thorman, 1981).

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