Geologic Map of the Tularosa Mountains 30′ × 60′ Quadrangle, Catron County, New Mexico

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INTRODUCTION

The Tularosa Mountains 30' × 60' quadrangle is in southwestern New Mexico just east of the Arizona state line (fig. 1). U.S. Highway 180 provides access along the western side of the quadrangle, and New Mexico Highway 12, which enters the quadrangle in its northeastern corner, joins U.S. Highway 180 near Reserve, the seat of Catron County and the largest community in the quadrangle (fig. 2). U.S. Highway 180, New Mexico Highway 12, and part of New Mexico Highway 32 are the only paved highways in the quadrangle, but most parts of the area can be reached from National Forest gravel roads and trails. Other settlements include Luna, along U.S. Highway 180, and Apache Creek, Aragon, and Old Horse Springs, along New Mexico Highway 12.

The Continental Divide (fig. 2) enters the Tularosa Mountains quadrangle about midway along its northern border and continues irregularly southward to within about 6 km of the southern border, where it turns eastward and leaves the quadrangle a little south of center of the eastern border (fig. 2). Streams in most of the east half of the quadrangle, north of the Continental Divide, drain into the closed San Agustin basin. West of the Continental Divide, streams drain mainly westward to the San Francisco River, a major tributary of the Gila River, and south of the Continental Divide streams drain into the Middle and East Forks of the Gila River.

The Tularosa 30' × 60' quadrangle is covered by thirty-two 7a-minute topographic quadrangles, and all but three of the quadrangles have been geologically mapped at a scale of 1:24,000 by the U.S. Geological Survey (fig. 2). In addition, a number of older, mainly reconnaissance, geologic maps from other sources have been used in this compilation and these are shown in figure 3.

The Tularosa Mountains quadrangle is bordered on the north by the Quemado 30' × 60' quadrangle, which was mapped by Chamberlin and others (1994), and on the south by the Mogollon Mountains 30' × 60' quadrangle, which is covered by geologic maps at various scales, but mainly by a reconnaissance geologic map of the Gila Wilderness (Ratté and Gaskill, 1975).

STRATIGRAPHY AND CORRELATION OF MAP UNITS

With the exception of a small, isolated fault block of Permian strata on the northern edge of the Plains of San Agustin, the rocks in the Tularosa Mountains quadrangle are entirely Eocene to Quaternary volcanic rocks, with interlayered volcaniclastic sedimentary rocks, and Quaternary surficial deposits. The Tertiary volcanic rocks comprise the Datil and Mogollon Groups (Cather and others, 1994), and the volcaniclastic sedimentary rocks are separated into the Spears Group, and the Gila and equivalent Santa Fe Groups. The Gila Group has a number of intercalated basaltic lava flows and andesitic to rhyolitic eruptive centers.

Datil Group (35–32 Ma)

Datil Group volcanic rocks in the Tularosa Mountains quadrangle are represented by multiple, thin ignimbrite outflow sheets and a much greater volume of andesitic lava flows. The ignimbrites occur mainly in scattered outcrops around the margins of the Plains of San Agustin in the northeastern part of the quadrangle, where they commonly are separated by a few meters of volcaniclastic sedimentary rocks. Individual tuff units range from about 0 to 30 m thick. In the western part of the quadrangle, the ignimbrites are thinner (0–2 m thick), are largely uncorrelated, and consist chiefly of discontinuous layers in the upper Pueblo Creek Formation, above the andesite of Dry Leggett Canyon.

Andesitic lava flows of Dry Leggett Canyon (unit Tla) are the only non-ignimbrite units in the Datil Group in the quadrangle. They have an aggregate thickness of as much as 300 m and cover large areas of the western part of the quadrangle, north and west of the San Francisco Mountains fault zone (fig. 4).

The dacitic to rhyolitic Datil Group ignimbrites represent the thin, distal, outflow sheets of regional ash-flow tuffs, although only two of the eight ignimbrites that have been mapped in this quadrangle have known sources. The 32-Ma Hells Mesa Tuff (unit Thmt) is from the Socorro caldera, east of the Tularosa Mountains quadrangle (Osburn and Chapin, 1983), and the 34.9-Ma Kneeling Nun Tuff (unit Tkt) is from the Emory caldera in the Black Range, to the south (Elston and others, 1975). The 31.6-Ma Caballo Blanco Tuff (unit Tcbt) probably was erupted from an unidentified source cauldron near the southern end of the Black Range, west of Truth or Consequences (fig. 1). The source(s) for the other Datil Group ignimbrites are most likely buried beneath the Plains of San Agustin. A proposed genetic relationship between the Horse Springs dacite (unit Thsd) and the Blue Canyon Tuff (Tbct) (Ratté, Modreski, and others, 1994, p. 198) is possible evidence for a buried Blue Canyon Tuff caldera beneath the plains. This is an alternative to the proposed Crosby Mountains caldera, or volcano-tectonic depression, of Bornhorst (1976) and Elston (1984, 1989). The evidence aganist a Crosby Mountains caldera was summarized by Chamberlin (1994, p. 16-18).

Mogollon Group (32–28 Ma)

The Mogollon Group volcanic rocks comprise all of the ignimbrites and associated lava flows that are younger than Caballo Blanco Tuff but older than the volcaniclastic Gila Group and its interlayered rhyolitic to basaltic rocks (Cather and others, 1994). Ignimbrites of the Mogollon Group in the Tularosa Mountains quadrangle are mainly outflow facies of regional tuffs (as opposed to intracaldera facies) and include La Jencia Tuff (unit Tlt), from the Magdalena-Sawmill caldera west of Socorro; Vicks Peak Tuff (unit Tvt), from the Nogal Canyon caldera at the southern end of the San Mateo Mountains, southwest of Socorro; and Davis Canyon Tuff (unit Tdt), Shelley Peak

Tuff (unit Tst), Bloodgood Canyon Tuff (unit Tbt), and Tuff of Triangle C Ranch (unit Tct), all from the Bursum caldera complex in the Mogollon Mountains to the south. These tuffs range between 29.0 Ma (Davis Canyon) and 28.0 Ma (Bloodgood Canyon and Triangle C Ranch).

Lava flows, ranging from andesite and basalt to rhyolite, make up the greater volume of the volcanic rocks of the Mogollon Group in the Tularosa Mountains quadrangle. They occur throughout the Mogollon Group, whereas lava flows in the Datil Group are confined to its central part. Major lava flows in the Mogollon Group comprise the andesitic Telephone Canyon volcano; the high-silica Taylor Creek Rhyolite dome field; the rhyolites of Gwynn Canyon, Bat Cave Wells, Stallings Tank, and Hay Canyon; the Squirrel Springs Canyon Andesite; and the several Bearwallow Mountain Andesite volcanoes that are alined along the southeast side of the Plains of San Agustin and elsewhere.

Spears Group (Eocene to Miocene)

The Spears Group (Cather and others, 1994) includes all of the epiclastic and other volcaniclastic rocks that are interlayered with the volcanic rocks of the Datil and Mogollon Groups and that overlie the Eocene Baca Formation in the Quemado 30' × 60' quadrangle (fig.1) and elsewhere. Lower, middle, and upper Spears Group, and constituent formations, were defined and mapped in the Quemado quadrangle (Chamberlin and others, 1994) but have not been carried south yet into the Tularosa Mountains quadrangle. Here the Spears Group is divided into lower and upper units (units Tsl and Tsu) where the sedimentary units are below or above the andesite of Dry Leggett Canyon, respectively. The lower Spears is locally called Pueblo Creek Formation, which is subdivided locally into upper and lower Pueblo Creek Formation, where it is above or below Andesite of Dry Leggett Canyon (Ratté, 1989).

In the southwestern part of the Tularosa Mountains quadrangle, the volcaniclastic rocks of the Spears Group grade into mudflows and lahars that contain an increasingly greater component of lava flows, eventually attaining the characteristics of vent facies volcanic rocks rather than volcaniclastic sedimentary rocks. Thus, the Spears Group nomenclature of Cather and others (1994) is probably best restricted to the northwestern part of the Mogollon-Datil volcanic field, where fluvial processes clearly predominate over volcanic processes in the origin of the volcaniclastic rocks.

Gila and Santa Fe Groups (Miocene to Pleistocene)

The Gila and Santa Fe Groups are equivalent names for the volcaniclastic sedimentary rocks and interlayered volcanic rocks that were deposited during the culminating and waning stages of regional extension (basin and range tectonism) in the Mogollon-Datil region. These rocks are included in the Gila Group if they occur west and south of the Continental Divide and in the Santa Fe Group if they occur east and north of the divide.

Volcanic rocks that are interlayered with the volcaniclastic rocks are commonly associated with specific volcanoes or volcanic centers. They range from andesites and rhyolites of middle Miocene age, to predominantly basaltic, small-volume lava flows and cinder cones of Miocene to Pleistocene age.

STRUCTURE

The pattern of dominant northeast-trending and subordinate northwest, east-west, and northerly trending normal faults (fig. 4) represents the prevalence of regional extensional forces in the Tularosa Mountains quadrangle during Neogene time. Although horizontal to moderately plunging slickensides are present on some faults in the San Francisco Mountains fault zone, they are rare and weak, and they probably represent only minor strike-slip and oblique movement on these predominantly dip-slip, normal faults. Consistent with this extensional structural setting are the several volcanic centers along or adjacent to the major fault systems.

The fault patterns in this quadrangle further define a number of complex, en echelon grabens and half-grabens, including the Reserve, Luna, Sand Flats, and San Augustin grabens (fig. 4). The Reserve half-graben (Crews, 1990, 1994), which typifies the development of extensional structures in this area, is filled with Gila Group basin-fill of Miocene to Pleistocene(?) age. The San Agustin graben, on the other hand, is still an aggrading, closed basin, with fill of Pliocene(?) and Pleistocene age (Markgraf and others, 1984), but there is no evidence of current subsidence of the graben.

The buried northern margin of the 28-Ma Bursum caldera of the Mogollon Mountains caldera complex is interpreted to be near the central southern border of the quadrangle, where it is identified by the juxtaposition of phenocryst-poor, post-caldera rhyolite lava flows inside the caldera and presumed pre-caldera, older, phenocryst-rich, coarsely porphyritic rhyolite flows on Elk Mountain (28 Ma, Taylor Creek–type) in the caldera wall. Confirmation of the relative ages of the two rhyolites is pending the results of $^{40}Ar/^{39}Ar$ dating. The “New Mexico Geologic Highway Map” (New Mexico Geological Society, 1982) also shows the northern margin of the Bursum caldera in this area, but **older** rhyolite is shown **inside** the caldera and **younger** rhyolite in the **wall**, and thus the geologic units are incompatible with the interpretation presented here.

Smith and Rhodes (1974) proposed a buried cauldron at the southwest end of the San Agustin graben, which they called the Squirrel Springs volcano-tectonic depression, and attributed its collapse to eruption of their Tularosa Canyon Tuff. They cited a shallow structural basin in which the Bearwallow Mountain Andesite presumably ponded and an arcuate pattern of ring faults as the evidence for this buried cauldron. Because the 25- to 26-Ma Bearwallow Mountain is much younger than the 31-Ma Tularosa Canyon Tuff, and the arcuate faults cut only younger rocks, they proposed that the original ring faults were rejuvenated both before and after the Bearwallow ponded in the rejuvenated collapse.

Although the John Kerr Peak and Squirrel Springs Canyon 7a-minute quadrangles are two of the three that were not remapped in this study (figs. 2 and 3), reconnaissance for this compilation failed to provide evidence to support the presence of a structural basin beneath Bearwallow Mountain Andesite in this area, or a buried caldera. The supposed thickening of the Bearwallow due to ponding in a structural basin by rejuvenation of ring fractures is probably better explained by constructional accumulation of flows around vents and variable erosion of this and other Bearwallow accumulations. The proposed arcuate ring faults are based on faults that can be shown only to have had post-Bearwallow movement, and the arcuate traces are themselves largely buried beneath alluvium and thus may be artifacts of geological speculation. Furthermore, new $^{40}Ar/^{39}Ar$ ages of 31.7 Ma for the Tularosa Canyon Tuff (Smith and Rhodes, 1974) (which should be abandoned) shows that it correlates as a thin, distal outflow of the Caballo Blanco Tuff, which has a center of distribution and probable source far to the south or southeast in the Mogollon Mountains, Pinos Altos Range, or Black Range, near Silver City (McIntosh and others, 1992, p. 864).

MINERAL DEPOSITS

There are no known viable mineral resources in the quadrangle, except sand and gravel, but there has been extensive exploration for oil and gas in Paleozoic sedimentary rocks beneath the volcanic cover rocks. The SWEPI No. 1 oil test well is located in sec. 2, T. 4 S., R. 13 W., in the northeastern part of the Horse Mountain West quadrangle, west of Horse Mountain.

The presence of silicic and altered intrusions at the surface and in the subsurface along the extensional structures of the Morenci Lineament indicates the possibility of hydrothermal mineral deposits in Paleozoic and other sedimentary or volcanic rocks along this structural zone. The most highly mineralized rocks found in the quadrangle have been the jasperoid-related iron- and zinc-rich jasperoid nodules associated with quartz monzonite inclusions at the Cerro Caballo dome, or cone, near Old Horse Springs, volcanic center 2, figure 4 (Ratté, Modreski, and others, 1994).

DESCRIPTION OF MAP UNITS

[Isotopic ages followed by an asterisk (34.7 Ma*) are $^{40}Ar/^{39}Ar$ ages; all others are conventional K-Ar ages]

SURFICIAL DEPOSITS

Qa **Alluvium (Holocene)**—Mainly boulders, gravel, sand, and silt in channels and on floodplains of major perennial and intermittent streams

Qsa **Playa alluvium of the Plains of San Agustin (Holocene)**—Modern playa sediments of gray, silty clay containing minor sand-sized calcite grains. Alluvium is underlain by at least 610 m of lacustrine silt, clay, and alluvial gravels of Holocene to Pliocene(?) age as determined in a drill hole in southern part of plains

Deposits of prehistoric lake San Agustin (B.B. Houser *in* Ratté and others, 1990)

Qsb **Bar and barrier ridge deposits (Holocene and Pleistocene)**—Variously oriented lenses of sand, pebbles, and cobbles deposited by longshore currents and wave action; generally 50–100 m wide and less than 3 m high

Qsfd **Fan delta deposits (Holocene and Pleistocene)**—Vegetated, fan-shaped deposits of undetermined composition beneath modern alluvium at mouths of some streams along shoreline of prehistoric lake San Agustin

Qss **Shoreline deposits (Holocene and Pleistocene)**—Chiefly sand, gravel, and silt deposited along shore of prehistoric lake San Agustin

Qac **Colluvium and alluvium (Holocene and Pleistocene)**—Mainly older alluvium in fan deposits that commonly grade into slope wash and talus. May include younger alluvium, unit Qa, and alluvial terrace gravels

Ql **Landslide deposits (Holocene and Pleistocene)**—Include semicoherent blocks consisting of rocks in stratigraphic sequence as well as slumped masses of mixed lithologies. Some slide blocks within extensive landslide slopes are identified by their own lithologic map unit symbols, as at southwest end of Plains of San Agustin, northeast of John Kerr Peak

Qp **Piedmont slope deposits (Pleistocene)**—Chiefly boulders, sand, and gravel deposits on gently sloping erosion surfaces

VOLCANIC AND VOLCANICLASTIC ROCKS

Volcaniclastic rocks of the Gila Group—Basin-fill deposits eroded from uplifted blocks during extensional breakup of Mogollon-Datil volcanic field to form incipient basin-and-range topography

QTg **Gila Group, undivided (Pleistocene(?) to early Miocene)**—Nonindurated to well-indurated clastic sedimentary rocks, which are readily subdivided only where interlayered with lava flows and tuffs from nearby volcanic eruptive centers. Locally includes beds of basaltic cinders, as along San Francisco River in O Block Canyon quadrangle. Volcanic clasts are predominantly derived from local sources

QTgu **Upper Gila Group (Pleistocene(?) to middle Miocene)**—Nonindurated to poorly indurated, bouldery, volcaniclastic sand and gravel mapped above lava flows of Eagle Peak volcano

QTgl **Lower Gila Group (middle to early Miocene)**—Chiefly well-indurated, coarse-grained, volcaniclastic beds containing clasts of locally derived volcanic rocks; beneath Eagle Peak lava flows and above Bearwallow Mountain Andesite or older rocks

QTs **Volcaniclastic rocks of the Santa Fe Group (Pleistocene to Miocene)**—Volcaniclastic rocks north and east of the Continental Divide are arbitrarily distinguished from the Gila Group south and west of the divide. Santa Fe Group mapped only at head of Shaw Canyon, at east edge of quadrangle

Volcanic rocks interlayered with the Gila Group—Includes thin, tholeiitic and alkali-olivine basalt flows, distinct from older Bearwallow Mountain Andesite volcanoes. Also includes andesitic, dacitic, and rhyolitic volcanoes localized along northeast-trending Morenci-Reserve fault zone (Ratté, 1989), or Morenci lineament (Chapin and others, 1978)

QTb **Basalt (Pleistocene and Pliocene, 0.9–2.5 Ma)**—Includes alkali-olivine basalt and tholeiitic basalt flows at Luna, Spur Lake Basin, Apache Creek, Feathery Hill, and elsewhere. May have diktytaxitic texture

QTd **Basalt dikes (Pleistocene and Pliocene)**—Dikes associated mainly with cinder cones in northwestern part of quadrangle

QTbc **Basalt scoria (Pleistocene and Pliocene)**—Cinders and bombs in cinder cones and around vents

Tb **Basalt, andesite, and dacite, undivided (Miocene)**—Basalt flows commonly characterized by large (0.5–3 cm) plagioclase (labradorite) and pyroxene (augite) phenocrysts; some flows contain granitic crustal xenoliths and quartz xenocrysts

Tbd **Basalt dikes (Miocene)**—Generally short, thin dikes 1–3 m wide and a few meters to a few tens of meters long; commonly resemble Miocene basalt flows, units Tb and Tsb, by having large pyroxene and plagioclase phenocrysts. Mapped mainly in southwestern part of quadrangle

Tbcc **Basaltic scoria, cinders, and bombs (Miocene)**—Generally red, scoriaceous flows and pyroclastic deposits associated mainly with basalt lava flows in south-western corner of quadrangle, along San Francisco River

Tfb **Basalt on Flat Top Mesa (Ratté, Bove, and McIntosh, 1994) (Miocene, 9 Ma*)**—Fine-grained lava flows containing 1- to 3-mm-long clinopyroxene phenocrysts and quartz xenocrysts having pyroxene reaction rims; along Negrito Creek, southwest of Eagle Peak

Rocks of Apache Peak volcano—Intrusive-extrusive, andesite dome complex at an eruptive center along southeastern margin of Morenci-Reserve fault zone in O Block Canyon 7a-minute quadrangle

Taa **Andesite at Apache Peak (Miocene, 10.6 Ma, H.H. Mehnert, oral commun., 1990)**—Fine-grained, seriate-porphyritic to granular, two-pyroxene, plagioclase flows, flow breccia, lahars, and possible intrusive facies

Rocks of Eagle Peak volcano—Multiple eruptive centers comprising a composite dome of andesite and dacite flows around an eccentric, dacite plug dome at Eagle Peak (Bove and others, 1995)

Tedp **Central dacite plug (Miocene, 11.4 Ma*)**—Dacite agglomerate apron, about 0.8 km in diameter, intruded by porphyritic dacite plug, about 0.5 km in diameter; plug contains about 2.3 percent small plagioclase phenocrysts, traces of orthopyroxene and clinopyroxene and rare hornblende

Tedu **Upper dacite flows (Miocene)**—Anhydrous dacite containing about 2.5 percent small phenocrysts, mostly plagioclase and minor orthopyroxene

Tedl **Lower andesite and dacite flows (Miocene, 12 Ma*)**—Hydrous andesite and dacite containing about 9 percent phenocrysts, mainly plagioclase and minor orthopyroxene, hornblende, and biotite, and rare clinopyroxene

Tedw **Wilson Canyon andesite flows (Miocene)**—Anhydrous andesite related to proposed Wilson Canyon satellitic eruptive center, containing about 8 percent phenocrysts and glomerocrysts, mainly plagioclase, minor orthopyroxene, and a trace of clinopyroxene. Also present are hornblende-bearing enclaves of finely porphyritic, hydrous andesite that indicate possible magma mixing

Tedm **Milligan Mountain andesite-dacite flows (Miocene, 12 Ma*)**—Hydrous, borderline andesite-dacite related to Milligan Mountain satellitic eruptive center; flows contain about 12 percent phenocrysts and glomerocrysts, mainly plagioclase and minor hornblende and orthopyroxene, and traces of clinopyroxene

Ted **Andesite dike at Dry Mesa (Miocene)**—Fine-grained dike that is petrographically similar to Milligan Mountain flows and contains sparse plagioclase, hornblende, and orthopyroxene microphenocrysts, indicating that it might have been a feeder for Millgan Mountain flows formerly present on Dry Mesa

Rocks of Horse Mountain volcano—Composite rhyodacitic dome and flows along northwest side of San Agustin graben, in northeast corner of quadrangle (Ratté and others, 1990)

Thv **Predominantly dacitic, rhyolitic to andesitic lava flows (Ratté and others, 1990) (Miocene, 12–14 Ma*)**—Wide range of fine-grained and finely porphyritic platy and flow-banded, red to black and gray lavas and flow breccias

Thd **Northwest-trending, andesitic-dacitic breccia dikes (Miocene**)—Dikes that intrude, and maybe feed, Horse Mountain vent or flow breccia northwest of main eruptive center

Tht **Pyroclastic rocks (Miocene)**—Rare bedded outcrops beneath eastern edge of Horse Mountain lava flows; probably from precursor explosive eruptions of Horse Mountain volcano. Tuffs contain plagioclase, biotite, and hornblende, and are mixed with surge and other volcaniclastic deposits

Thp **Dacite plug (Miocene)**—Very fine grained porphyritic rocks containing sparse phenocrysts and microphenocrysts of plagioclase, clinopyroxene and orthopyroxene, biotite, and hornblende. Light and dark-gray phases are petrographically similar but have sharp contacts, which may be partly the result of color changes and related more to hydrothermal alteration than to differences in composition. Occupies northwest-elongate area near Horse Peak in central part of Horse Mountain volcano

Thdr **Aplite dikes (Miocene)**—Pink, 3- to 5-m thick, northwest-trending dikes adjacent to southeast contact of central intrusive plug. Dikes contain 30–40 percent 0.25- to 0.5-mm microphenocrysts and rare 1-mm phenocrysts of plagioclase, green amphibole, and biotite; matrix is subvitreous and contains patches of granophyre along cracks; resembles rock of central plug

Thb **Vent(?) breccia (Miocene)**—Finely vesicular, light- to dark-gray, very finely brecciated, aphyric, generally glassy, structureless body. Intrusive vent breccia or flow breccia. Extends over elongate area northwest of central plug, unit Thp

Tha **Megacrystic andesite lava flow (Miocene, 12 Ma*)**—Andesite-trachyandesite containing abundant megacrysts of anorthoclase and (or) sanidine and 0.5- to 1-cm augite phenocrysts. Single flow, a few tens of meters thick, has highly oxidized, red spatter locally at base. Occurs only in ledge about 1 km long in lower slopes near northeast corner of Horse Mountain and as a small landslide or fault block north of New Mexico Highway 12 in the same area

Tsb **Basalt of Saliz Hill (Ratté, 1980) (Miocene, 12.2 Ma)**—Fine-grained, commonly flow-layered basalt or basaltic-andesite near southwest corner of quadrangle

Tkb **Basalt at Kiehnes Canyon (Ratté, Bove, and McIntosh, 1994) (Miocene, 13.5 Ma*)**—Small plug, about 100 m in diameter, surrounded by scoriaceous, red cinders and bombs. Two associated basalt flows, each less than 10 m thick; basalt ranges from fine-grained to seriate porphyritic and contains phenocrysts of plagioclase, pyroxene, and olivine altered partly to iddingsite. Restricted to Kiehnes Canyon area southwest of Eagle Peak

Rocks of John Kerr Peak volcano—Complex of dacite and rhyolite domes, flows and breccia surrounded by Bearwallow Mountain Andesite at northeast end of Tularosa Mountains

Tjr **Rhyolite domes and flows (Smith, 1976) (Miocene, ≈13 Ma, Marvin and others, 1987)**—John Kerr Peak quartz-latite of Smith (1976). Coarsely porphyritic rhyolite and rhyodacite contains phenocrysts as much as 2 cm long, including various proportions of sanidine-mantled plagioclase, quartz, sanidine, hornblende, biotite, and both clinopyroxene and orthopyroxene

Tmr **Rhyolite near Maverick Peak (Ratté, 1989) (Miocene, ≈14 Ma)**—Present only along San Francisco Mountains fault zone, west of U.S. Highway 180. Includes small quartz-porphyry rhyolite plug, about 0.7 km northeast of Maverick Peak, and domal rhyolite flows or intrusive rhyolite in hanging wall of San Francisco Mountains fault zone

Tmrd **Rhyolite dike in rhyolite near Maverick Peak (Miocene)**

Tli **Porphyritic quartz-diorite intrusions at Wet Leggett Spring (Ratté, 1989) (Miocene, ≈15 Ma, Marvin and others, 1987)**—Quartz diorite containing about 25 percent phenocrysts and xenocrysts(?), including pale-pink quartz (having corroded margins and pyroxene rims), plagioclase hornblende, and biotite. The intrusion at Wet Leggett Spring, south of Leggett Peak, has abundant coarse and fine-grained, hornblende-rich, cognate(?) inclusions. Along San Francisco fault zone southwest of U.S. Highway 180 in Wet Leggett Canyon (in Bull Basin 7a-minute quadrangle)

Volcaniclastic rocks of the Spears Group (Osburn and Chapin, 1983) (Oligocene and Eocene)

Tsu **Upper Spears Group (Oligocene)**—Volcaniclastic sedimentary rocks above Davis Canyon Tuff and interlayered between volcanic rocks of the Mogollon Group (Cather and others, 1994)

Tsl **Lower Spears Group, undivided (Oligocene and Eocene)**—Volcaniclastic sedimentary rocks equivalent to Pueblo Creek Formation (Ratté, 1989). Mapped only beneath Caballo Blanco Tuff at south end of Plains of San Agustin

Tslw **White sandstone sequence of lower Spears Group (Eocene)**—Upper subdivision of lower Spears Group; mapped only northwest of Spur Lake Basin fault zone in northwestern part of quadrangle

Tslg **Green to gray sandstone sequence of lower Spears Group (Eocene)**—Lower subdivision of lower Spears Group; mapped only northwest of Spur Lake Basin fault zone in northwestern part of quadrangle

Tpu **Upper Pueblo Creek Formation (Oligocene and Eocene)**—Rocks ranging from andesitic lahars and thin lava flows (vent facies) in southwest corner of quadrangle to predominantly mudflows and volcaniclastic conglomerates and sandstones (alluvial facies) elsewhere. Overlies andesite of Dry Leggett Canyon (unit Tla). Units Tt and Tt_{1-4} are discontinuous, thin (0 to about 5 m thick) Datil Group ignimbrites interlayered in upper Pueblo Creek Formation

Tpl **Lower Pueblo Creek Formation (Eocene)**—Volcaniclastic conglomerate and sandstone containing highly rounded boulders and cobbles of Precambrian granitic rocks and fossiliferous Paleozoic limestone, as well as volcanic clasts. Underlies andesite of Dry Leggett Canyon (unit Tla). Tuff of Bishop Peak (unit Tpt) is interlayered near top of lower Pueblo Creek Formation

Volcanic rocks of the Mogollon Group (Cather and others, 1994) (Miocene and Oligocene)—Voluminous caldera-related, dacitic and rhyolitic ignimbrites (ash-flow tuffs) and equally voluminous andesitic to high-silica rhyolite lavas comprise culminating eruptive phase of Mogollon-Datil volcanic field, which includes main pulse 3 of middle-Tertiary ignimbrite flare-up of McIntosh and others (1992)

Tmgu **Mogollon Group, undivided (Miocene and Oligocene)**—Mapped only at southwest edge of Plains of San Agustin (where Squirrel Springs Canyon Andesite, unit Tsa; Shelley Peak Tuff, unit Tst; and Bloodgood Canyon Tuff, unit Tbt, are repeated and jumbled in landslide slopes) and north of Wagontongue Mountain in southwest corner of Tularosa Canyon 7a-minute quadrangle, where Mogollon Group tuff outcrops are too small to subdivide

Tad **Andesite dikes (Miocene and Oligocene)**—Fine-grained to porphyritic dikes; some of uncertain age and correlation, scattered throughout Tularosa Mountains quadrangle

Bearwallow Mountain Andesite (Oligocene, 25–26 Ma, Marvin and others, 1987)—Predominantly calc-alkaline, andesitic lava flows, but ranging from dacite to basalt; erupted from numerous, low-profile shield volcanoes lacking in appreciable pyroclastic components

Tba **Basaltic-andesite to dacite lava flows (Oligocene)**—Typically aphanitic to fine-grained porphyritic flows; commonly are spotted with tiny, rusty-orange, iddingsitic-altered olivine. Major eruptive centers have distinctive compositions, such as Pelona Mountain and O Bar O Mountain, which are predominantly hypersthene andesite. Quartz xenocrysts are common in the flows at many localities

Tbad **Andesitic dike (Oligocene)**—Associated with scoriaceous cinder cone remnants on southwest flank of Pelona Mountain. Some dikes, mapped as unit Tad (undivided), undoubtedly also are of Bearwallow Mountain age, but their geologic relationships are uncertain

Tbap **Andesite plugs (Oligocene)**—Fine-grained, pervasively jointed, hypabyssal intrusive rocks commonly marking major eruptive centers, as at Pelona Mountain and O Bar O Mountain, and minor eruptive centers elsewhere

Tbac **Andesitic cinder and scoria deposits (Oligocene)**—Shown only as remnants of a small cinder cone east of Coyote Peak between O Bar O Mountain and Pelona Mountain

Thr **Rhyolite of Hay Canyon (Oligocene?)**—Light-gray, phenocryst-poor, high-silica rhyolite that covers buried northern margin of Bursum caldera; has sparse, tiny, needle-like amphibole crystals. Underlain by rhyolite of Gwynn Canyon and overlain by Bearwallow Mountain Andesite

Tfr **Rhyolite at Frying Pan Creek (Oligocene?)**—Small, phenocryst-poor rhyolite intrusion between Frying Pan Canyon and San Francisco River in O Block Canyon 7a-minute quadrangle. Intrudes Bloodgood Canyon Tuff and older rocks

Tsr **Rhyolite of Stallings Tank (Oligocene)**—Rhyolite containing about 5 percent phenocrysts, mainly oligoclase and minor biotite, and traces of opaque oxide, clinopyroxene, apatite, zircon and anorthoclase(?). At head of Shaw Canyon, at east edge of Tularosa Mountains quadrangle. Overlies Taylor Creek Rhyolite and Bloodgood Canyon Tuff in Shaw Canyon and underlies Bearwallow Mountain Andesite

Tct **Tuff of Triangle C Ranch (Ratté and others, 1990) (Oligocene, 28.1 Ma*, McIntosh and others, 1992)**—Late high-silica rhyolite ignimbrite from Bursum caldera. Commonly included as part of Bloodgood Canyon Tuff, with which it is virtually identical; locally mapped separately, as along Negrito Creek and east of O Bar O Mountain. Locally separated from Bloodgood Canyon Tuff by a meter or two of pumiceous, volcaniclastic sandstone

Tbt **Bloodgood Canyon Tuff (Elston, 1976) (Oligocene, 28.1 Ma*, McIntosh and others, 1992)**—Phenocryst-rich, rhyolite ignimbrite outflow sheet from the Bursum caldera. Contains abundant sanidine (moonstone) and quartz phenocrysts, rare biotite, and minor tiny, distinctive yellow sphene crystals

Tca **Basaltic-andesite of Cottonwood Canyon (Oligocene)**—Thin, discontinuous, reddish-brown, fine-grained lava flow(s) locally present between Shelley Peak and Bloodgood Canyon Tuffs along Cottonwood Canyon, near southeast corner of Plains of San Agustin in Rail Canyon 7a-minute quadrangle

Tst **Shelley Peak Tuff (Ratté and Gaskill, 1975) (Oligocene, 28.1 Ma*, McIntosh and others, 1992)**—Reddish-brown to light-gray, phenocryst-rich ignimbrite; contains abundant oligoclase and biotite, and minor distinctive green clinopyroxene phenocrysts. Constitutes proximal to distal outflow sheet in Tularosa Mountains quadrangle; derived from caldera complex in Mogollon Mountains, south of Tularosa Mountains quadrangle. May be mapped with Bloodgood Canyon Tuff where too thin to show separately, as in Fullerton and Luna 7a-minute quadrangles

Taylor Creek Rhyolite and associated rocks—Taylor Creek Rhyolite here includes northwestern part of Taylor Creek Rhyolite described by Duffield and Dalrymple (1990) and similar or identical rhyolite domes and flows to the north and west in Shaw Canyon, the Collins Park area, and Elk Mountains, in Tularosa Mountains quadrangle

Tgt **Tuff of Garcia Camp (Lawrence, 1985; Duffield and Dalrymple, 1990) (Oligocene, 28.1 Ma*, McIntosh and others, 1992)**—Precursor, dome-related, rhyolitic pyroclastic flows ranging from poorly indurated to weakly welded ignimbrite; average 20 percent phenocrysts, mainly quartz and sanidine. Here includes local pyroclastic rocks associated with rhyolite flows near head of La Jolla Canyon, east of Collins Park (W.A. Duffield, oral commun., 1994)

Ttr **Taylor Creek Rhyolite (Duffield and Dalrymple, 1990) (Oligocene, 28.1 Ma*, McIntosh and others, 1992)**—Major rhyolite dome complexes; high-silica rhyolite containing moderate abundance of sanidine and quartz phenocrysts, and minor plagioclase and biotite. Wood tin nuggets from Taylor Creek Rhyolite have been prospected in pediment deposits and regolith near Whiskey Canyon and Railroad Canyon, in Indian Peaks West 7a-minute quadrangle (Lawrence and Richter, 1986)

Tsa **Squirrel Springs Canyon Andesite (Rhodes and Smith, 1976) (Oligocene, 28.5 Ma*, McIntosh and Chamberlin, 1994)**—Gray to reddish-gray, mainly very coarsely porphyritic, plagioclase phyric andesite and basaltic andesite flows

Tvt **Vicks Peak Tuff (Osburn and Chapin, 1983) (Oligocene, 28.6 Ma*, McIntosh and others, 1992)**—Light-colored, phenocryst- poor ignimbrite outflow sheet derived from Vicks Peak caldera in San Mateo Mountains, to east of Tularosa Mountains quadrangle. Combined with Davis Canyon Tuff (unit Tdt) locally on north side of Eagle Peak, where too thin to show both separately

Tgr **Rhyolite of Gwynn Canyon (Oligocene, 28.7 Ma*, unpub. age, D.J. Bove, 1993)**—Light-tan rhyolite containing abundant phenocrysts of quartz, sanidine, and biotite, and minor brown oxyhornblende and sphene. Confined to vicinity of Gwynn Canyon along buried north margin of Bursum caldera, in Telephone Canyon 7a-minute quadrangle

Tlt **La Jencia Tuff (Osburn and Chapin, 1983) (Oligocene, 28.9 Ma*, McIntosh and others, 1992)**—Light-gray to reddish-brown, phenocryst-poor, rhyolitic ignimbrite, which crops out in Tularosa Mountains quadrangle only along southern edge of Plains of San Agustin; represents distal outflow sheet from Sawmill Canyon–Magdalena caldera complex near Socorro, east of Tularosa Mountains quadrangle

Tdt **Davis Canyon Tuff (Ratté and Gaskill, 1975) (Oligocene, 29.0 Ma*, McIntosh and others, 1992)**—Light-colored, phenocryst-poor, high-silica, rhyolite ignimbrite, which contains sparse tiny phenocrysts of quartz and sanidine. Tuff outflow sheet probably is derived from Mogollon Mountains caldera complex south of the Tularosa Mountains quadrangle

Ta **Andesite flows (Oligocene)**—Thin, discontinuous, fine-grained to porphyritic flows containing plagioclase and pyroxene phenocrysts. Interlayered with volcaniclastic rocks in upper Pueblo Creek Formation above andesite of Dry Leggett Canyon, mainly north of Saddle Mountain at west edge of Tularosa Mountains quadrangle and south of Monument Mountain in Dillon Mountain quadrangle

Tbr **Rhyolite of Bat Cave Wells (Ratté and others, 1990) (Oligocene)**—Gray to reddish-brown, porphyritic rhyolite flows and domes, containing about 5–15 percent phenocrysts, mainly sanidine and (or) anorthoclase, minor clinopyroxene and opaque oxide, and traces of biotite, apatite, and zircon. Underlies Davis Canyon Tuff on south side Plains of San Agustin and beneath Jack Peak, south of Old Horse Springs, on north side of plains, where it was called rhyolite of Wye Hill by Bornhorst (1976). K-Ar ages range from 27.3 Ma to 32.2 Ma (Marvin and others, 1987, entries 121, 122, and 212)

Rocks of Telephone Canyon volcano—Composite andesite domes at a complex eruptive center along South Fork, Negrito Creek. These are oldest rocks exposed along buried northern margin of Bursum caldera, in south-central part of Tularosa Mountains quadrangle

Tta **Andesite of Telephone Canyon, undivided (Oligocene, 32.9–29.7 Ma*, D.J. Bove, unpub. ages, 1993)**—Numerous andesite to dacite and trachydacite flows and breccias; mainly finely porphyritic and containing small plagioclase, biotite, and hornblende phenocrysts

Volcanic rocks of the Datil Group (Osburn and Chapin, 1983; Cather and others, 1994) (Oligocene and Eocene)—Includes all of the regional ignimbrites and most of the andesitic to rhyolitic lavas erupted prior to the 31.4- to 29.0-Ma hiatus in major volcanic activity defined by McIntosh and others (1991, 1992). Exceptions in Tularosa Mountains quadrangle are rhyolite flows of Bat Cave Wells and Telephone Canyon volcano, both of which may overlap boundary between Datil and Mogollon Groups

Tdgu **Datil Group, undivided (Oligocene and Eocene)**—Mapped only along south flank of Horse Mountain, where Datil Well, Kneeling Nun, and Rock House Canyon Tuffs are jumbled in a slumped and faulted(?) sequence. These outcrops are important in constraining distribution of rocks of Horse Mountain volcano

Tcbt **Caballo Blanco Tuff (Elston, 1957) (Oligocene, 31.6 Ma*, McIntosh and others, 1992)**—Light-colored, coarsely porphyritic, rhyolitic ignimbrite. Contains abundant phenocrysts of quartz, sanidine, oligoclase, and biotite; minor opaque oxides, sphene, and oxyhornblende; and trace apatite, zircon, and clinopyroxene. Source of this distal ignimbrite outflow is unknown, but it is probably from an occult caldera in Mogollon Mountains or southern Black range, or Twin Sisters cauldron complex, northwest of Silver City (McIntosh and others, 1992)

Thmt **Hells Mesa Tuff (Osburn and Chapin, 1983) (Oligocene, 32.1 Ma*, McIntosh and others, 1992)**—Light-colored, rhyolitic ignimbrite containing abundant quartz, sanidine, and plagioclase phenocrysts; minor opaque oxide and biotite; and traces of sphene, zircon, apatite, and hornblende. Thin, distal outflow sheet in Tularosa Mountains quadrangle was derived from Socorro caldera to east. Occurs only near head of South Fork Alamocito Canyon and on east flank of Jack Peak, south of Old Horse Springs

Tt **Distal outflow of regional ignimbrites (Oligocene and Eocene)**—Discontinuous, thin (0–5 m), partly reworked, tuffs. Correlations uncertain; interlayered in upper part of Pueblo Creek Formation, lower Spears Group. Labeled Tt_{1-4}, where present in sequence. Tt_3 (tuff of Luna) is tentatively correlated with Box Canyon Tuff by $^{40}Ar/^{39}Ar$ age of 33.62±0.1 Ma (McIntosh and others, 1991, Appendix 1, p. 62)

Rocks of Saddle Mountain volcano—Andesite dome, or cone, and associated hornblende-rich dikes at west edge of Bull Basin 7a-minute quadrangle (Ratté, 1989). At least half of Saddle Mountain volcano is in adjoining Blue 15-minute quadrangle, New Mexico and Arizona

Tas **Andesite lava flows (earliest Oligocene or latest Eocene, about 33.3 Ma)**—Andesite flows containing 40–50 percent phenocrysts, mostly plagioclase, opaque oxide, and highly oxidized mafic crystals, which include partly to completely altered hornblende, and minor clinopyroxene and orthopyroxene. Also contains minor cognate(?) inclusions having hypautomorphic granular texture and mineralogy similar to that of enclosing flows. Flows crop out only near el. 2495 m in southwest corner of quadrangle on east flanks of Saddle Mountain eruptive center, which lies immediately to the west, in the Blue 15-minute quadrangle

Tasb **Andesite agglomerate (Oligocene or Eocene)**—Rounded clasts of hornblende-rich andesite breccia underlying lava flows around east side of Saddle Mountain eruptive center

Tasd **Andesite dikes (Oligocene or Eocene)**—Hornblende-rich dikes probably related to Saddle Mountain eruptive center; most are only a few meters to 10 m long, but one north-south dike is about 5 km long

Tsca **Andesitic intrusive-extrusive complex of Saliz Canyon (Eocene)**—Fine-grained andesite has microphenocrysts of plagioclase and clinopyroxene and appears to intrude associated vent(?) breccia

Tscb **Andesitic vent(?) breccia (Eocene, 33.6 Ma, Marvin and others, 1987)**—Breccia has abundant plagioclase, clinopyroxene and orthopyroxene, brown hornblende, and biotite phenocrysts. K-Ar biotite age of 33.6±1.1 Ma indicates correlation with Eocene andesitic rocks rather than with a younger intrusive body, as interpreted previously on geologic map of Saliz Pass 7a-minute quadrangle (Ratté, 1980)

Tla **Andesite of Dry Leggett Canyon (Ratté, 1989) (Eocene)**—Widespread thick plagioclase and pyroxene-phyric lava flows, which occur between tuff of Bishop Peak (34.6 Ma*) and andesites of Saddle Mountain volcano (about 33.3 Ma). Flows present mainly northwest of San Francisco Mountains fault zone in northwestern part of quadrangle, and in adjoining Quemado 1:100,000 quadrangle to the north

Tlai **Possible plug or vent for andesite of Dry Leggett Canyon (Eocene)**—Isolated body of columnar-jointed andesite about 300 m in diameter, about 1 km north of Aragon; or may be related to underlying topography

Rocks of Horse Springs volcano or volcanic center—Pyroclastic flows, block and ash flows, and lava flows(?) distributed about an eruptive center or centers west of Old Horse Springs

Thsd **Horse Springs dacite (Ratté and others, 1990; Ratté, Modreski, and others, 1994) (Eocene, 33.7 Ma*, W.C. McIntosh, written commun., 1995)**—Porphyritic dacite containing abundant phenocrysts of oligoclase-andesine and biotite, minor opaque oxides, green clinopyroxene, and trace zircon and apatite. Block and ash flows, which contain 2–3 m cognate quartz monzonite blocks and silicified and mineralized accidental lithic inclusions of Paleozoic rocks, probably mark the main volcanic eruptive center. Referred to elsewhere as “tuff breccia of Horse Springs Canyon” by Bornhorst (1976) and Jones (1980), and as “pumice breccia of Old Horse Springs” by Ratté and Modreski (1989, STOP 3–1, Pumice breccia of Old Horse Springs, p. 70–80)

Thsb **Megabreccia and mesobreccia (Eocene)**—Breccia consisting of slabs, tens of meters long, of older Datil Group ignimbrites, and smaller breccia outcrops that contain block-sized clasts of Squirrel Springs Canyon Andesite and volcaniclastic sedimentary rocks. Outcrops of megabreccia and mesobreccia, mostly too small to be shown at this map scale, are scattered along eastern margin of north-south-trending belt of Horse Springs dacite outcrops, possibly outlining margins of a buried caldera source for Blue Canyon Tuff 6–8 mi in diameter (Ratté, Bove, and others, 1994, p. 109–110) beneath alluvial fans of Alamocito Creek reentrant, north of Plains of San Agustin

Tbct **Blue Canyon Tuff (Lopez and Bornhorst, 1979; Osburn and Chapin, 1983) (Eocene, 33.7 Ma*, McIntosh and others, 1992)**—Gray, densely welded, dacitic ignimbrite containing abundant phenocrysts of glassy sanidine, dull-white plagioclase, minor biotite and opaque oxide, and traces of green clinopyroxene, hornblende, zircon, apatite, and sphene. Petrographically, chemically, and texturally similar to younger Horse Springs dacite. Unit may include Rock House Canyon Tuff locally

Trt **Rock House Canyon Tuff (Osburn and Chapin, 1983) (Eocene, 34.4 Ma*, McIntosh and others, 1992)**—Light-gray, phenocryst-poor, rhyolite ignimbrite; source unknown. May be included locally with Blue Canyon Tuff where outcrops are too small to show separately

Tbrt **Blue Canyon and Rock House Canyon Tuffs, undivided (Eocene)**—Mapped only where outcrops are too small to show tuffs separately

Tlwt **Tuff of Lebya Well (Ratté and others, 1990) (Eocene, 34.7 Ma*, McIntosh and others, 1992)**—Reddish-brown to purplish-gray, densely welded rhyolite ignimbrite containing moderately abundant phenocrysts of sanidine and minor plagioclase, green clinopyroxene, biotite and opaque oxide, and trace apatite and zircon. Occurs locally in Old Horse Springs–New Horse Springs area north of Plains of San Agustin; may correlate with Tuff of Bishop Peak of similar age and composition in Underwood Lake 7a-minute quadrangle, Reserve-Luna area. Source unknown

Tpt **Tuff of Bishop Peak (Ratté, 1989) (Eocene, 34.6 Ma*, McIntosh and others, 1992)**—Thin, reddish-brown, dacitic ignimbrite containing a moderate abundance of plagioclase, sanidine, and biotite phenocrysts. Crops out mainly in northwestern part of Tularosa Mountains quadrangle, north of Luna, but has been tentatively identified elsewhere, as in region south and west of Reserve. Source unknown

Tkt **Kneeling Nun Tuff (Elston and others, 1975) (Eocene, 34.9 Ma*, McIntosh and others, 1992)**—Light-gray, rhyolite ignimbrite containing abundant quartz and sanidine phenocrysts, minor plagioclase and biotite, and accessory opaque oxides, sphene, brown hornblende, apatite, and zircon. Scattered outcrops north of Plains of San Agustin near Old Horse Springs and New Horse Springs and Horse Mountain are remnants of distal outflow sheet from Emory caldera, in Black Range more than 100 km south and east of Plains of San Agustin and Tularosa Mountains quadrangle

Tft **Tuff of Farr Ranch (Ratté and others, 1990) (Eocene, 35.6 Ma*, McIntosh and others, 1992)**—Light-gray to reddish-brown, phenocryst-poor, rhyolitic ignimbrite. Sparse phenocrysts are mostly sanidine, but include minor plagioclase, biotite, clinopyroxene, and opaque oxides, and accessory sphene, apatite, and zircon. Constitutes a thin, discontinuous outflow sheet that is petrographically identical to Datil Well Tuff but commonly separated from it by volcaniclastic sandstone. Source unknown

Twt **Datil Well Tuff (Lopez and Bornhorst, 1979) (Eocene 35.5 Ma*, McIntosh and others, 1992)**—Light-gray to light-pinkish-brown rhyolite ignimbrite containing moderate abundance of sanidine phenocrysts, minor clinopyroxene, plagioclase, biotite, and opaque oxides, accessory brown hornblende or allanite, zircon, and apatite, and rare quartz. Thin, discontinuous outflow sheet, typically accompanied by overlying tuff of Farr Ranch. Source unknown

Twft **Datil Well Tuff and (or) tuff of Farr Ranch, undivided (Eocene)**—Mapped where only one of the tuffs is present and identity is uncertain, or where both tuffs are present but too thin to map separately, as in northeast corner of Tularosa Mountains quadrangle

Tac **Basaltic lava flow of Alamocito Canyon (Eocene)**—Dark-gray, coarsely porphyritic basalt or andesite flow interlayered with volcaniclastic sedimentary rocks of Spears Group and overlain by Datil Well Tuff at Alamocito Spring at Forks of Alamocito Creek. Thickness 0 to about 30 m

OLDER SEDIMENTARY ROCKS

Psgy **Sedimentary rocks, undivided (Permian)**—A measured section (Stearns, 1962) on north side of Plains of San Agustin, in Horse Mountain East quadrangle, includes (ascending order) 201 ft (61 m) of Yeso Formation, 95 ft (29 m) of Glorieta Sandstone, and 417 ft (127 m) of San Andres Limestone, all of Early Permian age. Red sandstone associated with this sequence was originally considered by

Stearns to be possibly Triassic, but is now thought to belong with volcaniclastic sedimentary rocks of Spears Group

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