

Geologic Map of the Godfrey Peak Quadrangle, Lincoln and Otero Counties, New Mexico

By

**Shari Kelley, Kirt Kempter,
Daniel Koning, Fraser Goff, and Colin Cikoski**

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*Open-file Digital Geologic Map OF-GM 136***

Scale 1:24,000

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**New Mexico Bureau of Geology and Mineral Resources
801 Leroy Place, Socorro, New Mexico, 87801-4796**

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**Preliminary Geologic Map of the Godfrey Peak 7.5-Minute Quadrangle, Lincoln
and Otero Counties**



Shari Kelley
New Mexico Bureau of Geology and Mineral Resources
New Mexico Tech
Socorro, NM 87801

Kirt Kempter
2623 Via Caballero del Norte, Santa Fe, NM 87505

Daniel Koning
New Mexico Bureau of Geology and Mineral Resources
New Mexico Tech
Socorro, NM 87801

Fraser Goff
Earth and Planetary Sciences Dept.
University of New Mexico
Albuquerque, NM 87131

Colin Cikoski
New Mexico Bureau of Geology and Mineral Resources
New Mexico Tech
Socorro, NM 87801

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Introduction

The Godfrey Peak quadrangle is located east of the village of Three Rivers on the eastern margin of the Tularosa Basin in south-central New Mexico. The lava-capped Godfrey Hills on the western edge of the area, the east-striking Barber Ridge in the center of the quadrangle, and the western foothills of intrusion-cored Sierra Blanca along the eastern edge of the area are the prominent topographic features within the quadrangle. Main access to the area is along a paved road to the Three Rivers campground in the east-central part of the area. Southwest-flowing Three Rivers is the only stream that runs year round. The Three Rivers Ranch and the Stephenson Ranch own or manage a mix of private, Bureau of Land Management and State land within the quadrangle. Moore et al. (1988) mapped the northwestern part of the Mescalero Apache Reservation, including the southeastern corner of the Godfrey Peak quadrangle at a 1:24,000 scale. The mapping of Moore et al. (1988) is modified in this report using air photo interpretations to more accurately place some of the contacts on the map.

The quadrangle is located on the western margin of the Sierra Blanca basin, a north-northeast trending Laramide basin that contains sedimentary rocks as young as Eocene in age. The volcanic and plutonic rocks of the Sierra Blanca complex and Lincoln County porphyry belt were erupted onto and intruded into the Sierra Blanca basin ~26 to 38 million years ago. Countless dikes and a few sills associated with Sierra Blanca volcanism criss-cross the older units in the area to the east of the Godfrey Hills. Rio Grande rift extensional faulting has since disrupted the Sierra Blanca basin and the volcanic centers. Rock exposures are generally quite good due to the sparse Chihuahuan desert vegetation and the moderate topography.



View of Sierra Blanca looking east from the Godfrey Hills, Barber Ridge is in the foreground.

Stratigraphic Observations

Thompson (1966, 1972) divided volcanic rocks of the northwestern Sierra Blanca volcanic field into four formations: Walker Andesite Breccia, Nogal Peak Trachyte, Church Mountain Latite, and Godfrey Hills Trachyte. During the course of mapping several quadrangles in this area (Goff et al., 2011; Cikoski et al., 2011, this study), we came to realize that the Walker Andesite Breccia is made up of several compositionally distinct and mappable flow sequences. The Walker Andesite Breccia consists of alkalic basalt, trachyandesite, and trachyte flows, volcanoclastic sediments, and minor welded ash-flow

tuffs preserved on three N-S striking fault blocks on the northwest side of Sierra Blanca. The Walker Andesite Breccia on the eastern fault block, which includes Sierra Blanca, is composed of two sequences. The lower sequence contains the following relatively laterally continuous units (bottom to top): (1) debris flows interbedded with pyroxene-phyric basaltic trachyandesite to trachybasalt flow breccia and lava flows, (2) plagioclase-phyric porphyritic basaltic trachyandesite to trachyandesite, and (3) aphyric to fine-grained trachybasalt to trachyandesite interbedded with maroon volcanoclastic sediment. A rheomorphic tuff that thickens northward caps the lower sequence. The upper sequence contains laterally discontinuous volcanoclastic sediment, trachyandesite, and trachyte of variable thickness. The Walker Andesite Breccia is overlain by Nogal Peak Trachyte on the Sierra Blanca block.

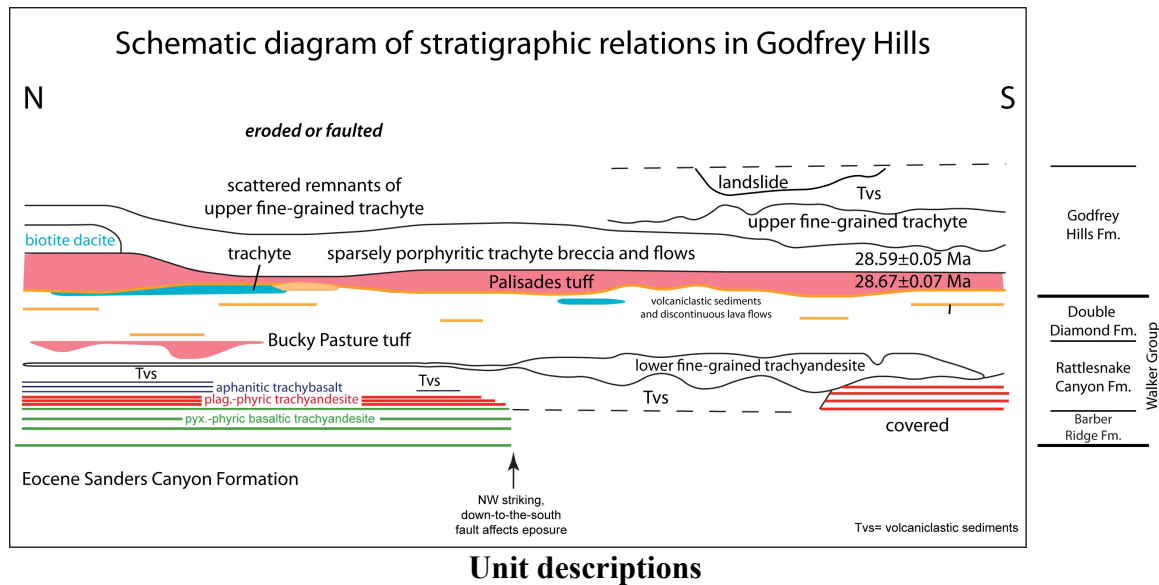
The Walker Andesite Breccia in the middle fault block on Barber Ridge between Sierra Blanca and the Godfrey Hills is composed exclusively of debris flows and pyroxene-phyric basaltic trachyandesite to trachybasalt flow breccia and lava flows. This unit is equivalent to the oldest rocks in the northwestern Sierra Blanca massif.

The western fault block, including the Godfrey Hills, exposes both the older and the younger parts of the volcanic succession of the northwestern Sierra Blanca volcanic field. The oldest units in the Godfrey Hills are distal equivalents of the pyroxene-phyric, the plagioclase-phyric, and the aphyric mafic flows on Sierra Blanca. These older flows are overlain by a lithic-rich tuff with abundant mafic clots (tuff of Buck Pasture); this tuff may correlate with the rheomorphic tuff on Sierra Blanca. A volcanoclastic interval containing a few thin, discontinuous trachyandesite and trachyte flows overlies the tuff of Buck Pasture.

The Walker Andesite Breccia in the Godfrey Hills is overlain by a more felsic sequence that is distinct from the Nogal Peak Trachyte. The Godfrey Hills Trachyte is made up of (from oldest to youngest): (1) a discontinuous thick trachyte with biotite, (2) a welded ash flow tuff (Palisades tuff; 28.67 ± 0.07 Ma), (3) a sparsely porphyritic trachyandesite with zones of breccia (28.59 ± 0.05 Ma), (4) an upper aphyric trachyte, and (5) a volcanoclastic interval. The Palisades tuff thickens to the north.

Here we informally propose raising the Walker Andesite Breccia to group status because the unit clearly contains more than breccia and the volcanic rocks are more alkalic than andesite. The Walker Group is divided into four formations that capture the geochemical evolution of the volcanic field through time. The oldest formation, the Barber Ridge Formation, is made up of debris flows and pyroxene-phyric mafic basaltic andesite to trachybasalt flow breccia and lava flows. The Barber Ridge Formation is overlain by a succession of crystal-rich porphyritic trachyandesite flows with plagioclase as the dominant phenocryst; these flows are intercalated with volcanoclastic sediment. This interval is assigned to the lower part Rattlesnake Canyon Formation. A more mafic unit with thin flows of aphanitic trachybasalt and thick beds of red volcanoclastic sediment overlies the crystal-rich porphyritic lavas. This unit is also included in the Rattlesnake Canyon Formation. A tuff unit that is called the tuff of Argentina Springs on Sierra Blanca and the tuff of Buck Pasture in the Godfrey Hills caps the Rattlesnake Canyon Formation. The volcanoclastic interval with discontinuous and increasingly more felsic lava flows above the tuff is the Double Diamond Formation. The contacts between the formations of the Walker Group are gradational. The Godfrey Peak Trachyte is

renamed the Godfrey Peak Formation and is made up several informal members, including the Palisades tuff.



Quaternary Deposits

Qam Modern alluvium (Holocene): Modern sand and gravel in active stream bottoms that are generally incised at least a meter below adjoining **Qay** or **Qao** surfaces. This unit is characterized by fresh bar and swale topography of 10-100 centimeters. Gravel is generally pebbles and cobbles that are mostly subrounded, poorly sorted, and composed of intermediate-composition volcanic rocks. Sand size ranges from very fine to very coarse, but is mostly medium- to very coarse-grained. Sand is poorly to moderately sorted and subrounded to subangular. 1-3(?) meters thick.

Qamh Modern and historical alluvium (Holocene): sand and gravel that includes modern sediment and historical sediment that are generally incised at least 0.5 meters below adjoining **Qay** or **Qao** surfaces. Historical sediment is present as 0.5-1.5 m-tall terraces, where the sediment is grayish brown, sandy gravel and gravelly sand that are well-bedded; sand is mostly medium- to very coarse-grained, but ranges from very fine- to very coarse-grained, and is typically poorly to moderately sorted and subrounded to subangular; gravel consists of pebbles and cobbles that are mostly subrounded, poorly sorted, and composed of intermediate volcanic rocks. Unit also occurs as small fans at the mouths of gullies. 1-3(?) meters thick.

Qc Undivided colluvium (Holocene): Hillslope colluvial deposits composed of pebble to boulder size clasts from a variety of rock types. Common on north-facing slopes. Varies in thickness from ~ 5 – 50 m.

- Qls** **Landslide deposit (Holocene):** locally derived blocks of trachyte bedrock associated with a head scarp in cliffs along the western escarpment of the Godfrey Hills.
- Qse** **Eolian deposits modified by slope wash (Holocene):** fine-grained tan very fine windblown sand intermixed with granules and pebbles of local rocks. 1-3 m.
- Qtr** **Travertine and carbonate cemented gravel (Holocene):** large deposit of carbonate cemented gravel and banded travertine forms a prominent knickpoint in a small tributary off of Gamble Canyon in the southwestern corner of the area. <5 m thick
- Qay2mh** **Alluvium inset in recent valleys (Late Holocene to modern):** Unit includes three inset units found within a larger valley eroded in the middle to late Holocene. These units include modern, historical, and late Holocene alluvium (as described in units **Qam**, **Qamh**, and **Qay2**).
- Qay** Younger alluvium, undifferentiated (Holocene). Units Qay2 and Qay1 undifferentiated, see individual descriptions for more information. Used where the two units cannot be separated due to the scale used or due to the lack of a surficial expression of their individual distributions. 0.5 to 4 m thick.
- Qay2** **Pre-historical alluvium in relatively narrow valleys (middle(?) to late Holocene):** Pebbly sand with minor sandy pebble beds, locally clayey. Internally massive to well-bedded; sand and pebble beds are commonly laminated to thin and tabular. Estimate 10-25% pebbles and 1-10% cobbles. Pebble beds are clast-supported, subrounded, and moderately sorted. Gravel is composed of intermediate volcanic clasts. Sand is grayish brown to light brownish gray (10YR 5-6/2), very fine- to very coarse-grained (mostly very fine- to coarse-grained), subrounded to subangular, moderately to poorly sorted, and has 5-20 estimated fines. Thin to thick calcium carbonate coats on clasts but no calcium carbonate nodules observed. Soil is marked by a stage I carbonate morphology. Moderately consolidated. Greater than 2 meters thick.
- Qay1** **Alluvium capping older alluvial deposits (early(?) to middle Holocene) –** Poorly bedded to internally massive pebbly sand and clayey sand. Sand is brownish and very fine- to very coarse-grained. Very fine- to fine-grained sand fraction may have abundant gypsum grains; medium- to very coarse-grained sand is composed of volcanic grains. Sand is poorly sorted and angular to subrounded. Pebbles are very fine to very coarse, moderately to poorly sorted, and subangular to subrounded. Topsoil is marked by stage II to I+ carbonate horizon, where there are minor (<10%) soft, calcium carbonate nodules equal or less than 1 cm. Moderately consolidated and 1-3 m-thick.
- Qdct** **Debris flows, colluvium, and talus deposits (middle Pleistocene to Holocene) –** Very poorly sorted pebbles and cobbles, with lesser boulders, in a sand to clayey

sand matrix. Sand is poorly sorted. No bedding. Unit deposited primarily by debris flows, with colluvium and talus found at the base of steep slopes. Gravel is angular to subrounded and consists of intermediate volcanic clasts. Sand is pale brown to light gray (10YR 7/2-6/3), very fine- to very coarse-grained, poorly sorted, and angular to subangular; very fine to fine sand consists of volcanic lithics, quartz, and feldspar; medium to very coarse sand is composed of volcanic lithics. Weakly to moderately consolidated. Commonly several meters thick.

Qao **Older alluvium (middle to late Pleistocene)** – Pebbly sand, sandy gravel, sand, and clayey-silty sand. Sediment is in very thin to medium-bedded, tabular beds. Topsoil generally contains a calcic horizon with stage III carbonate morphology. Generally assigned to either **Qao1**, **Qao2**, or **Qao3** based on the relative height of the surface capping each deposit, but these divisions are entirely allostratigraphic and not based on sediment characteristics.

Qao3 **Older alluvium, youngest subunit (upper? Pleistocene).** Gravel and sand characterized by strongly developed carbonate horizons and buried soils capped by a surface inset upon that of **Qao2**. See descriptions below. 1- 3 m thick.

Qao2 **Older alluvium, younger subunit (upper? Pleistocene).** Gravel and sand characterized by strongly developed carbonate horizons and buried soils capped by a surface inset upon that of **Qao1**. See description of **Qao** for a description of this unit's sediments. As no sedimentary difference could be established between deposits of **Qao1** and **Qao2**, these deposits could be the same with the lower surface being entirely erosional. This problem also precludes confidently determining the deposit's thickness, but it is probably 1 to 3 m thick.

Qao1 **Older alluvium, older subunit (middle? to upper Pleistocene).** Gravel and sand characterized by strongly developed carbonate horizons and buried soils capped by a surface inset upon by **Qao2**. See description of **Qao** for a description of this unit's sediments. As no sedimentary difference could be established between deposits of **Qao1** and **Qao2**, these deposits could be the same with the lower surface being entirely erosional. Thickness is difficult to determine as the basal contact is often poorly exposed, but **Qao1** is 1 to at least 10 m thick.

QTa **High-level sand and gravel deposits (late Pliocene-early Pleistocene?)** – Deposit consists of rounded gravels that are donated by syenite at the base of Sierra Blanca and by trachytic lavas at the base of the Godfrey Hills. The unit is poorly exposed. In general, base of deposit lies above modern surfaces developed on units Qay and Qao. 2-4 m thick.

Neogene Volcanic Rocks

Godfrey Hills Formation

- Tgvsu Upper volcaniclastic sediments (Oligocene):** heterolithic landslide deposit with a white ashy matrix that contains large (1-5 m) angular boulders of porphyritic trachyandesite, Palisades tuff, and trachyandesite breccia. In places the stratigraphy of the debris is in the appropriate order but the units are thoroughly brecciated. 5-15 m thick.
- Tgysl Lower volcaniclastic sediments (Oligocene):** sandy, matrix-supported, carbonate- cemented conglomerate that contains upper trachyte lava as the dominate clast. The clasts are angular and <0.5 m in diameter. The pronounced imbrication in the deposit indicates flow toward 20° to 90°. 30 m thick.
- Tgtu Upper trachyte to trachyandesite (Oligocene):** light to dark gray fine-grained lava with a trachytic texture and contorted platy flow foliation. Microphenocrysts are aligned plagioclase, pyroxene, and magnetite. The unit is composed of a series of thin flows 1-10 m thick with basal scoriaceous breccia and vesicular flow tops with elongated vesicles. Red to yellow alteration of the flow breaks is common. Base fills paleocanyons, top is eroded by modern processes or is cut by Oligocene paleocanyons. 50 m thick.
- Tgbr Trachyandesite breccia (Oligocene):** light gray trachyandesite lava flows with phenocrysts (<5-7%) of sanidine and pyroxene interbedded with monolithologic breccia with subround to angular clasts in a light gray matrix. Other phenocrysts are plagioclase, magnetite, and sparse hornblende. Red fine sandstone often occurs below the basal breccia of the unit and above the Palisades tuff. $^{40}\text{Ar}/^{39}\text{Ar}$ ages of 28.59 ± 0.05 Ma and 28.53 ± 0.03 Ma obtained from sanidine in the unit (Peters, personal communication, 2010). Generally the base is flat and top is eroded; however in two places, one at the north end of the Godfrey Hills and one south of Rose Peak, Tgbr rests on significantly older units and thus must have filled deep paleovalleys. 60-70 m thick.
- Tgbt Biotite trachyte breccia (Oligocene):** trachyte lava flows that are similar to Tgbr flows, but this lava contains biotite in addition to sanidine and pyroxene. Furthermore, the flows are lighter gray in color and are more sugary in texture compared to typical Tgbr flows. This lava is separated from the overlying Tgbr flows by a distinct, mappable flow break. The trachyte breccia is present only on Godfrey Peak and on hills northwest of Godfrey Peak. 60-70 m thick.

Tgpt Palisades tuff (Oligocene): Cliff-forming welded tuff with pronounced eutaxitic foliation and taphony weathering texture. Contains < 2% lithic fragments composed of trachyandesite and trachyte lavas. Phenocrysts include plagioclase, sanidine, pyroxene, magnetite, and sparse biotite and hornblende. A possible feldspathoid was observed in thin section. The tuff is generally crystal-poor (~5-10% phenocrysts), but the more welded intervals are 15-20% phenocrysts. Pumice lapilli in the unwelded tuff are < 2 mm. The tuff is generally strongly welded, with red-brown, knobby-weathering, glassy intervals separated by pinkish gray soft intervals. Occasionally, the tuff has flattened mafic clots near the base. Both the top and bottom of this unit is fairly flat. $^{40}\text{Ar}/^{39}\text{Ar}$ ages of 28.67 ± 0.07 Ma and 28.66 ± 0.08 Ma were obtained from sanidine in the tuff (Peters, personal communication, 2010). Geochemically, this tuff is a trachyte (see appendix). 25-90 m thick.



Tgt Trachyte flows (Oligocene): Cliff-forming succession of light gray flow-banded lava flows and flow breccias of trachyte with ~10% phenocrysts of plagioclase, biotite, and pyroxene. Other phenocrysts include twinned feldspar, magnetite, and apatite. 60-70 m thick.

Walker Group

Published K-Ar and $^{40}\text{Ar}/^{39}\text{Ar}$ ages for the Walker Group lavas and breccias are 29.3-37.3 Ma (Moore et al., 1991).

Double Diamond Formation

Twtdts Intercalated alkaline lava flows and volcanoclastic sediments (Oligocene to Eocene): interval of thin to thick (1-10 m) discontinuous trachyte, porphyritic trachyandesite, biotite trachyte, and trachybasalt flows complexly intercalated with volcanoclastic sediments (**Twds**). The volcanoclastic sediments are sandy conglomerate with subangular to subrounded pebbled, cobbles and boulders of trachytic lava. The deposits are poorly sorted and bedding is not distinct. Exposures of volcanoclastic sediment dominated by biotite-bearing trachyte clasts are designated as **Twdsb**. Some of the flows in this interval are of mappable thickness (**Twdte**=trachyandesite with an equigranular matrix; **Twdt** = trachyte; **Twdta**=trachyandesite; **Twdtb** = trachybasalt,). The trachyte flows are gray platy flows with and very fine-grained matrix and few to no discernible phenocrysts. The trachyandesite is typically porphyritic (5-15% phenocrysts) and contains plagioclase and pyroxene. The lower biotite trachyte is gray, porphyritic (~10%

phenocrysts), and contains plagioclase, pyroxene, and biotite. A thick fine-grained trachyte in the southeastern Godfrey Hills has small phenocrysts of hornblende, pyroxene, and clusters of potassium feldspar. 90 to 100 m.

tuff of Buck Pasture

Twbpt tuff of Buck Pasture (Oligocene to Eocene): Welded to unwelded lithic-rich tuff. The lithic fragments are angular pieces of trachytic lavas. The phenocrysts are sanidine, plagioclase, biotite, and pyroxene. The tuff contains mafic clots that are flattened near the base and that are rounded to embayed, but more equant, upsection. The mafic clots are reddish brown with crystals of plagioclase and pyroxene (5-7%) set in fine-medium grained pinkish tan matrix. In places a thin bed of lithic-bearing tuff similar to the tuff of Buck Pasture (**Twbptl**) is preserved about 15 to 20 m below the main exposures of the tuff of Buck Pasture. In the southeastern Godfrey Hills, the tuff of Buck Pasture is a black to reddish-brown vitric tuff with 35% phenocrysts of sanidine, quartz and sparse biotite with fine-grained reddish tan lithic fragments. This unit likely correlates to the tuff of Argentina Springs on the Sierra Blanca block to the east (Goff et al., 2011; Cikoski et al., 2011). Thickness highly variable 1 – 100 m; fills paleovalleys.



Rattlesnake Canyon Formation

Twrtbu Upper trachybasalt (Eocene): fine-grained, sugary textured lava with platy flow foliation. Phenocrysts include pyroxene. Base rests on **Twrvs** or **Twrtbs**. Top is irregular and in places paleocanyons filled with sediment cut deeply into the unit. This unit thins to the north. 1-5 m.

Twrtbl Intercalated trachybasalt lava flows and volcaniclastic sediments (Eocene): dark gray fine-grained 1-4 m thick lava flows characterized by a silvery sheen and splotches on weathered surfaces. Flows are discontinuous and are intercalated with red, altered volcaniclastic sedimentary rocks. In places, particularly near the Twin Well windmill, a red volcaniclastic succession (**Twrvs**) up to 140 m thick is present at the top of the lower trachybasalt-dominated section. The matrix-supported sandy conglomerate contains rip up clasts of volcaniclastic sandstone, as well as porphyritic and fine-grained trachytic lava. A few tuff clasts also occur. Total unit thickness up to 365 m.

Twrtal Trachyandesite lavas and volcanoclastic sediments (Eocene): Dark gray porphyritic trachyandesite with phenocrysts of plagioclase and pyroxene; plagioclase is the dominant phenocryst. The lavas are variably crystal-poor (5%) to crystal-rich (30%). The basal contact with the underlying Barber Ridge Formation volcanic breccia is gradational. This plagioclase-phyric unit is composed of a thick stack of lava, with modest amounts of volcanoclastic material preserved between the flows on the east side of the quadrangle. In contrast, this unit contains abundant volcanoclastic sediment between flows on the west side of the Godfrey Hills. The uppermost contact of the unit on the west side of the quadrangle is gradational with the overlying interval that is dominated by trachybasaltic lavas. In the area north of Twin Wells windmill, the contact between the plagioclase-phyric trachyandesite and the trachybasalt units is locally marked by a distinctive crystal-rich lava flow with large (1-2 cm) elongate plagioclase laths (**Twrtap**). 150 m thick.



Barber Ridge Formation

Twb/Twbs Barber Ridge Formation

(Eocene): Green to red volcanoclastic to volcanic unit containing flow breccia, debris flows, mudflows, lava flows, and red sandstone to sandy conglomerate. The flow breccia clasts and lava flows are composed primarily of porphyritic basaltic trachyandesite to trachybasalt with phenocrysts of pyroxene and plagioclase; the pyroxene phenocrysts are usually > 5 mm and are noticeable on weathered surfaces. Typical debris flow clasts are 5 to 20 cm in diameter, although some are > 1 m across. The matrix-supported clasts in the debris flows are angular to subrounded and contain a variety of trachyandesite to trachybasalt clasts. Debris flow units are particularly well exposed on Barber Ridge and southeast of Rock House Spring, where blocks 2-7 m in diameter are observed.

The lower contact is transitional. Red fine-grained sandstone and sandy conglomerate (**Twbs**) with scattered pebbles to cobbles of pyroxene-phyric lava are common near the base of the formation on the south side of Barber Ridge in



Winston and Gamble canyons. The red sandstone is similar to the red sandstone in the underlying Sanders Canyon Formation, suggesting that Sanders Canyon deposition continued during the early phases of volcanism at Sierra Blanca and was influenced by local sources. The sand grains are angular, poorly-sorted, and are dominated by pyroxene and feldspar. These sandstones intervals are clearly intercalated with the flow breccia and debris flows of the Barber Ridge Formation. The bedding in the sandstone intervals is tabular, medium to thin bedded, and in places, is finely laminated. Silicified sandstone crops out at 415348 3701814 (NAD27). Petrified wood was found in the sandstone at 415118 3697972 (NAD27).

The upper contact of the Barber Ridge Formation with the overlying crystal-rich, plagioclase-phyric lava flows of the Rattlesnake Formation is also transitional and is marked by intercalation of plagioclase-phyric and pyroxene-phyric lava flows and flow breccias. Transitional greenish flows with subequal amounts of <2-3 mm plagioclase and pyroxene phenocrysts occur near the contact. The top of the Barber Ridge Formation is picked at the top of the highest flow with abundant >5 mm pyroxene phenocrysts.

This unit is cut by many dikes. Some of the dikes appear to be dismembered and may have been emplaced while the lava flow breccia was still hot and moving. 120-180 m.

Neogene Intrusive Rocks

Attempts to date dikes and sills on the Golondrina Draw quadrangle to the south of the Godfrey Peak quadrangle have met with limited success because of the lack of datable minerals and alteration. The ages of dikes and sills associated with Sierra Blanca are likely 37 to 42 Ma, based on $^{40}\text{Ar}/^{39}\text{Ar}$ age determinations for dikes and sills in the Three Rivers area to the west and in the Sacramento Mountains to the southeast (McManus and McMillan, 2002). New dates of poor quality on sills to the south are 36 to 38 Ma.

Mineralization is generally absent along the dikes and sills. The dikes frequently occur in subparallel pairs separated by 5 to 10 m. Dikes generally fill fractures, are 1 to 2 m wide, and commonly strike E-W. Some dikes are up to 7 m wide. Dikes do, on occasion, fill faults, but the dikes generally are not deformed by reactivation of the filled faults. An exception to this observation is the porphyritic trachyte dike SSE of Halfway Windmill, which is brecciated in a N-striking fault zone. E-W dikes clearly cut N-S dikes at UTM coordinates 13 S 417534 3694662 (NAD 27). Near Hall Windmill, the syenite dike with the more E-W strike cuts the syenite dike with the slightly more northeasterly strike.

Ti undifferentiated dikes and sills mapped from air photos.

Tit Porphyritic trachyte (Miocene?-Eocene): dikes and sills of light-gray porphyry with 5 to 15% phenocrysts of plagioclase feldspar, biotite \pm hornblende, and dark green pyroxene that are 1-10 mm across. This unit includes a small hornblende-bearing plug northeast of Coal Mine Tank. $^{40}\text{Ar}/^{39}\text{Ar}$ dating of sanidine from a

dike of this composition cutting the Palisades tuff on the east side of Rose Peak yielded a range of ages between 29 (~ age of the Palisades tuff) and 18 Ma. The older ages are likely xenocrysts incorporated into the dike and the youngest ages of 18 Ma provide a maximum age of the dike.

- Tis/Tisp Syenite (Eocene):** pink, medium-grained equigranular sill composed of potassium feldspar, plagioclase feldspar, pyroxene, and hornblende. Tisp has a similar composition, but contains 5-20 mm phenocrysts of feldspar.
- Titp Porphyritic dikes with aligned plagioclase (Eocene):** Dikes of light gray to dark-gray porphyry with 15 to 25% plagioclase laths 10 to 20 mm long set in an equigranular to fine-grained matrix of dark green pyroxene and feldspar. The plagioclase laths are often distinctly aligned parallel to the margins of the dike. Dikes 1 to 4 m wide.
- Tita Porphyritic trachyandesite (Eocene):** dikes and sills of light-gray porphyry with 5 to 15% phenocrysts of plagioclase feldspar, dark green pyroxene, and potassium feldspar that are 1-10 mm across. These intrusive bodies may grade into more equigranular textures (Tig). Syenitic and sedimentary xenoliths are locally present. This unit includes intrusive bodies to the east of Rose Peak and north of Buck Pasture Spring.
- Titb Fine-grained trachybasalt (Eocene):** Black to dark green, most are aphanitic, but some are fine-grained dikes with barely discernable needles of plagioclase and pyroxene. Dikes 1 to 2 m wide.
- Tig Alkali gabbro-syenogabbro (Eocene):** equigranular, fine- to medium-grained, salt-and-pepper textured dikes and sills with plagioclase feldspar and pyroxene phenocrysts. These intrusive bodies may grade into more porphyritic textures (Tita). Alkali gabbro may contain amphibole and biotite (Moore et al., 1988).
- Tim Megacrystic trachyte porphyry (Eocene):** greenish gray porphyritic sills and dikes with megacrysts of embayed tschermakitic hornblende or green pyroxene that are up to 2 to 4 cm across. Often contains hornblende \pm biotite. These intrusives can contain xenoliths of pink coarse-grained syenite with phenocrysts of orthoclase feldspar and hornblende.

Neogene Sedimentary Rocks

- Tsc Sanders Canyon Formation (Eocene):** Purplish maroon to red siltstone with gray to tan tabular sandstone beds. Sand grains include biotite. Conglomeratic intervals contain mud rip up clasts and volcanic pebbles, including crystal rich-porphyritic hornblende and biotite dacite. Pedogenic carbonate nodules are common. Thin (< 1 m) black micritic limestone beds are exposed in two places near the top of the unit. 260-380 m thick.

Tcm Cub Mountain Formation (Eocene): Yellow cross-bedded sandstone and maroon mudstone. Mud clasts conglomerates occur higher in the section . Sandstone is medium to coarse grained and is poorly- to well-sorted, with angular sand grains of quartz, feldspar (often altered to clay), and black lithic fragments. Bedding is tabular to cross-bedded to ripple-laminated. The base and the top are not exposed. 350-390 m thick.

Mesozoic Sedimentary Rocks

Kcc Crevasse Canyon Formation (Upper Cretaceous): A yellow-tan trough cross-bedded sandstone is present near the upper contact of the Crevasse Canyon Formation. This sandstone generally contains well-rounded pebbles and cobbles of quartz and chert. The troughs indicate flow toward 30 to 60°. The contact between the base of the Cub Mountain and the top of the Crevasse Canyon is well exposed just west of Hide Spring. A mottled red and green paleosol and a strongly cemented sandstone occur at the top of the Crevasse Canyon Formation. The lower part of the formation is characterized by olive brown, tan, and white cross-bedded to tabular bedded sandstone and carbonaceous black shale. The sandstone very fine- to fine-grained and is well-sorted. The sand grains are angular. Wood and leaf fragments are common in the shale. A large leaf fossil is preserved at 410820 3699187 (NAD 27). 550 m thick.

On cross section only

Kgs Gallup Sandstone (Upper Cretaceous): Distinctive white to tan, poorly cemented sandstone with high to low-angle cross stratification. 150 m thick.

Km Mancos Shale (Upper Cretaceous):
Kmd: D-Cross Shale Member 90 m thick
Kmt: Tres Hermanos Member 30 m thick
Kml: lower shale member 105 m thick

Kd Dakota Sandstone (Upper Cretaceous): Medium to thick-bedded to thinly laminated, medium- to coarse-grained, cross bedded white sandstone with lenses of dark gray shale. 90 m thick.

TRm Moenkopi Formation (Upper Triassic): Red-brown, fine-grained, thin bedded, trough cross-bedded to ripple laminated sandstone. 100 m thick.

Pag Grayburg Formation, Artesia Group (Permian): red siltstone with green reduction spots, red mudstone, and massive gypsum. Siltstone is massive to occasionally cross-laminated.

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