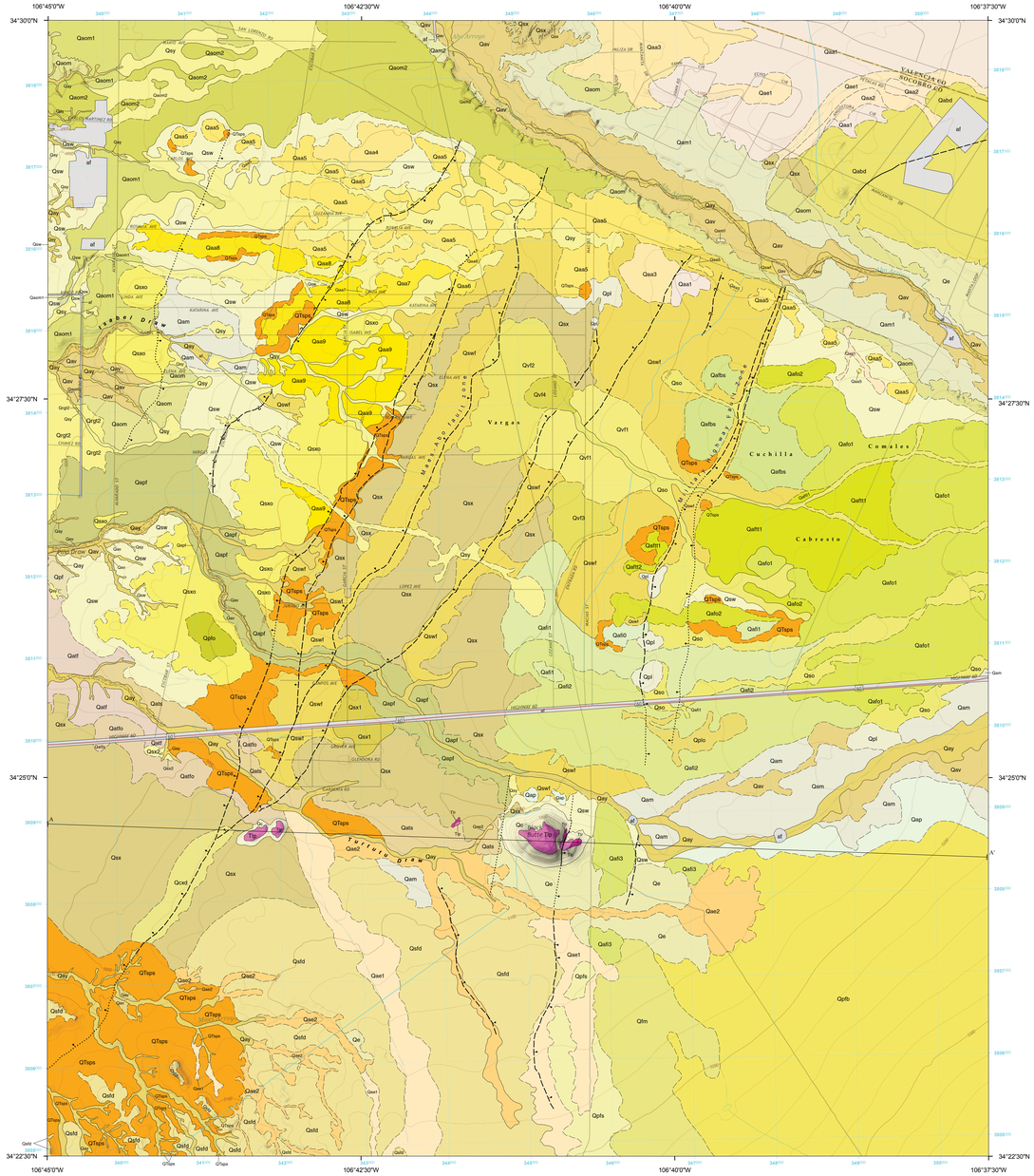



Base map from U.S. Geological Survey 1952, from photographs taken 1947. Map edited 1979.
1927 North American datum. Polyconic projection. Reprojected to UTM projection NAD 27 zone 13.
1000-meter Universal Transverse Mercator grid, zone 13, shown in red.

1:24,000

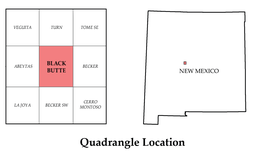
1 0.5 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 0.5 0 1 KILOMETER

CONTOUR INTERVAL 20 FEET

NATIONAL GEODETIC VERTICAL DATUM OF 1929




**Quadrangle Location**

Magnetic Declination
July, 2012
9.0385° East
At Map Center

New Mexico Bureau of Geology and Mineral Resources
Open-file Geologic Map 235

Mapping of this quadrangle was funded by a matching-funds grant from the STATEMAP program of the National Cooperative Geologic Mapping Act (Award Number: G13AC00186), administered by the U. S. Geological Survey, and by the New Mexico Bureau of Geology and Mineral Resources, (L. Greer Price, *Director and State Geologist*, Dr. J. Michael Timmons, *Geologic Mapping Program Manager*).

# Geologic Map of the Black Butte 7.5-Minute Quadrangle, Socorro and Valencia Counties, New Mexico

**June, 2014**

**by**

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This and other STATEMAP quadrangles are available for free download in both PDF and ArcGIS formats at:

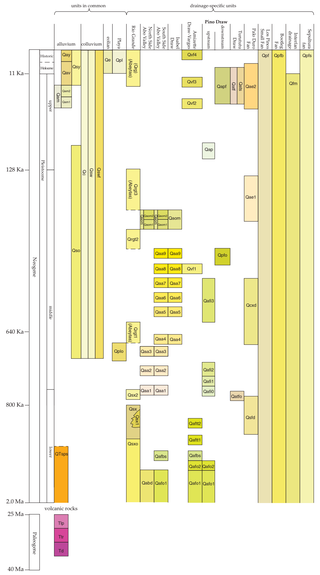
*http://geoinfo.nmt.edu*

## Explanation Of Map Symbols

- Former shoreline—Identity and existance certain location accurate
- Cross section line
- Contact—Identity and existance certain, location accurate
- Contact—Identity and existance certain, location approximate
- Fault generic—Identity and existance certain, location accurate
- Fault generic—Identity and existance certain, location approximate
- Fault generic—Identity and existance certain, location concealed
- Normal Fault—Identity and existance certain, location accurate
- Normal Fault—Identity and existance certain, location approximate
- Normal Fault—Identity and existance questionable, location approximate
- Normal Fault—Identity and existance certain, location concealed

Figure 1 - View southwest across Black Butte quadrangle from high Abo fan surface (Qafd) across Abo valley, inset Abo terraces, faulted plains of old Abo fans, to Black Butte, Magdalena Mountains on skyline, Socorro and Lemitar mountains in far middle distance.

## Correlation Of Map Units




This draft geologic map is preliminary and will undergo revision. It was produced from either scans of hand-drafted originals or from digitally drafted original maps and figures using a wide variety of software, and is currently in cartographic production. It is being distributed in this draft form as part of the bureau's Open-file map series (OFGM), due to high demand for current geologic map data in these areas where STATEMAP quadrangles are located, and it is the bureau's policy to disseminate geologic data to the public as soon as possible.

After this map has undergone scientific peer review, editing, and final cartographic production adhering to bureau map standards, it will be released in our Geologic Map (GM) series. This final version will receive a new GM number and will supercede this preliminary open-file geologic map.

**DRAFT**

## Comments To Map Users

A geologic map displays information on the distribution, nature, orientation, and age relationships of rock and deposits and the occurrence of structural features. Geologic and fault contacts are irregular surfaces that form boundaries between different types or ages of units. Data depicted on this geologic quadrangle map may be based on any of the following: reconnaissance field geologic mapping, compilation of published and unpublished work, and photogeologic interpretation. Locations of contacts are not surveyed, but are plotted by interpretation of the position of a given contact onto a topographic base map; therefore, the accuracy of contact locations depends on the scale of mapping and the interpretation of the geologist(s). Any enlargement of this map could cause misunderstanding in the detail of mapping and may result in erroneous interpretations. Site-specific conditions should be verified by detailed surface mapping or subsurface exploration. Topographic and cultural changes associated with recent development may not be shown.

Cross sections are constructed based upon the interpretations of the author made from geologic mapping, and available geophysical, and subsurface (drillhole) data. Cross-sections should be used as an aid to understanding the general geologic framework of the map area, and not be the sole source of information for use in locating or designing wells, buildings, roads, or other man-made structures.

The map has not been reviewed according to New Mexico Bureau of Geology and Mineral Resources standards. The contents of the report and map should not be considered final and complete until reviewed and published by the New Mexico Bureau of Geology and Mineral Resources. The views and conclusions contained 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 State of New Mexico, or the U.S. Government.

## Map Unit Descriptions

### Quaternary And Neogene

**Post-Santa-Fe-Group units common to whole map**

**Alluvium of stream valleys**

**Qsy**

**Channels and floodplains of major arroyo floors (Historic and Holocene)**—Poorly to moderately sorted, unconsolidated pebble- to cobble-alluvium and fine- to coarse-grained sand with local accumulations of cobbles and small boulders in channels, and silt and clay in backwaters and floodplains. Sand colors generally range from 5YR light values to 10 YR light values. Underlies narrow to broad streams; channels are inset against low terrace and floodplain deposits. Includes active alluvium of Abo, Isabel, Pino, Turututu, and Maes drainages. Deposits are generally thin and range from less than 1 m to more than 4 m thick.

**Qasv**

**Abandoned and active valley bottom alluvium recently incised by modern channels (Holocene and upper Pleistocene)**—Poorly to moderately sorted, unconsolidated fine- to coarse-grained sand with local accumulations of cobbles and small boulders in channels, and silt and clay in backwaters and former floodplains. Sand colors generally range from 5YR light values to 10 YR light values. Soils, where developed, are thin and barely achieve even Stage I pedogenic carbonate horizons. Near Scholle, in Abo Canyon 19 km east of the quadrangle, Hall et al. (2012) obtained radiocarbon ages of 11,100 and 12,300 cal yr BP in a wet-meadow deposit at depths between 5.77 and 6.67 m in similar alluvium. Deposits are generally more than 2 m exposed and locally form bluffs several meters high.

**Qam** **Qamt** **Qam2**

**Alluvium, undivided deposits at intermediate valley-border levels along tributaries (upper to middle Pleistocene)**—Weakly consolidated sand and gravel associated with modern drainages. Inset against older alluvium of large fans and is, where possible, divided locally into two subunits, **Qamt1** and **Qamt2**. Pedogenic carbonate horizons reach Stage II. Colors are from 5YR to10YR light values. Thicknesses are between 5 m to 10 m.

**Qsy**

**Swale bottom alluvium without inset channels or preserved eolian deposits, undivided (Holocene and upper Pleistocene)**—Poorly to moderately sorted, unconsolidated fine- to coarse-grained sand and silt with rare local accumulations of pebbles. Colors are similar to **Qasv**. Swales are inset below other alluvial terrace deposits, but have indistinct boundaries with flanking slope deposits. Deposits are generally thin and range from less than 1 m to more than 2 m thick.

**Qso**

**Alluvium with secondary eolian sediment in broad (50 m to 100 m) shallow (less than 10 m) swales (Holocene to middle Pleistocene)**—Poorly to moderately sorted, unconsolidated fine- to coarse-grained sand and silt with rare local accumulations of pebbles, without inset channels or mappable eolian deposits of the Abo/Pino fan complex. Swales are inset below older alluvial deposits, but have indistinct boundaries with flanking slope deposits. Matrix is generally slightly reddish with a mixture of less than 5 cm diameter subangular clasts of Precambrian quartzite, granite, chert, and uncommon schist and gneisses (50-60%), sub-angular to sub-rounded limestone (30-40%), and blocky sub-angular red fine-grained laminated sandstone (10-20%). Channels are visible and nominally active. Eolian accumulations are thin without identifiable deposits of sand sheets, dunes or wind ripples. Soils are similar to surrounding units, but generally are Stage III-IV. Thicknesses range from 1 m to 3 m.

**Anthropogenic deposits**

**af**

**Artificial fill (historic)**—Dumped fill and areas affected by human disturbances. Mapped where disturbances are extensive; areas commonly include levees and small earth-fill dams, paved raised roads, and dairies.

**Eolian deposits**

**Qe**

**Eolian deposits, undivided (Holocene to upper Pleistocene)**—Unconsolidated, well-sorted and locally stratified eolian sand in thin sheets and coppice dunes draped across pre-existing topographic features such as intermediate inset terraces, inactive stream channels, and colluvial wedges. Colors are generally 10 YR light values. Thickness varies from less than 1 m to 5 m.

**Playa deposits**

**Qpl**

**Playa deposits with secondary eolian sediment in broad (50 m to 100 m) shallow (less than 5 m) closed basins (historic to middle Pleistocene)**—Unconsolidated, fine-grained sand, silt, and clay. Playas are inset below older alluvial deposits, but have indistinct boundaries with flanking slope deposits and swales. Many developed in grabens or low hanging-wall settings. **Qplo** deposits are in depressions developed on lower Pleistocene abandoned fan surfaces. Colors similar to surrounding slopes. Thickness ranges from 0 to 2 m.

**Qplo** Deposits are in depressions developed on lower Pleistocene abandoned fan surfaces.

**Colluvial and slope deposits**

**Qc**

**Colluvium undivided (Holocene to middle Pleistocene)**—Poorly consolidated, poorly sorted, and poorly stratified, fine- to coarse-grained, clast- and matrix-supported deposits derived from a variety of mass-movement hillslope processes, including raveling of single clasts, debris flows, shallow slumps, and creep, overlying and interfingering with tributary alluvium at intermediate inset terrace levels. Clasts are typically rounded to subangular pebbles and cobbles reworked from units **Tlp, Tlr, Qaslp, Qpf, Qsx** and **Qsfd**. Colluvium is common on hillslopes and grades downslope to alluvium. Both are dissected. Thickens downslope from less than 1 m to 5 m.

**Qsw**

**Colluvium and slope-wash deposits on gentle slopes (historic to middle Pleistocene)**—Poorly consolidated, poorly sorted, and poorly stratified, primarily sand- to clay-sized clasts, with matrix-supported larger pebbles derived from adjacent deposits via local hillslope processes and eolian contributions. Overlies and interfingers with tributary alluvium and swales. Locally dissected by rills and small gullies. Locally stable enough to develop Stage I-II pedogenic carbonate horizons. Thickens downslope from less than 1 m to 5 m.

**Qswf**

**Colluvium and slope-wash deposits on slopes related to fault scarps (historic to middle Pleistocene)**—Poorly consolidated, poorly sorted, and poorly stratified, primarily sand- to clay-sized clasts, with matrix-supported larger pebbles and cobbles derived from adjacent deposits uphill on fault scarps. Mass-movement hillslope processes, eolian contributions, and bioturbation cause poor sorting. Locally dissected by rills and small gullies. Thickens downslope from less than 1 m to 5 m.

**Qcxd**

**Colluvium and slope-wash deposits on slopes related to fault scarps (historic to middle Pleistocene)**—Includes poorly-exposed outcrops of coarse-grained cobbly alluvium from the Palo Duro fan interpreted to be interfingering with ancestral Rio Grande deposits (**Qsx**) along the fault scarp east of the pipeline along the northern boundary of Sevilleta National Wildlife Refuge. Overlies and interfingers with tributary valley alluvium at inset levels and in swales. Locally dissected by rills and small gullies. Thickens downslope from less than 1 m to 5 m

**Post-Santa-Fe-Group alluvium of young piedmont aprons and alluvial fans from west face of Los Pinos Mountains**

**Qpf**

**Alluvium in fans and aprons along the west flank of the Los Pinos Mountains (Holocene and upper Pleistocene)**—Poorly to moderately sorted, unconsolidated fine- to coarse- grained sand with local accumulations of cobbles and small boulders in channels and in inter-channel bars, and silt and minor clay in backwaters; grain sizes decrease down slope to distal run-out zones. These fans are graded to modern inset drainages, but commonly bury older fan deposits and soils which probably extend hundreds of meters below the modern surfaces. Rounded "whalebacks" of Pleistocene alluvial deposits stick up 2-5 m above active channels, particularly along distal portions of the fans, but are too small in area to be mapped at 1:24,000. Fan-shaped alluvium from two major canyon drainages are mapped individually as **Qpfs** (Sepultura fan) and **Qpfb** (Bootleg fan) based on extent of active distributary channels.

**Qpfs** **Sepultura fan**

**Qpfb** **Bootleg fan**

**Qtm**

**Elevated, abandoned remants of alluvium between Sepultura Fan (Qpfs) and Bootleg Fan (Qpfb) (upper Pleistocene)**—Poorly to moderately sorted, unconsolidated fine- to coarse- grained sand with local accumulations of pebbles and cobbles; grain sizes decrease down slope to distal inactive run-out channels. Stable portions of surface have Stage I-II pedogenic carbonate horizons. Thickness is at least 3 m.

**Post-Santa Fe Group alluvium on elevated valley margins**

**Rio Grande terrace deposits after abandonment of highest level of Rio Grande deposit**

**Qrgt2**

**Rio Grande alluvium, intermediate terrace deposits (middle Pleistocene)**—White to pale-brown (10 YR 8/2-8/3; 7.5 YR 5/4), poorly consolidated, pebbly to cobbly sand and clast-supported gravel. On adjacent Abeytas quadrangle, lower (Qrgt3) and higher (Qrgt1) terraces are delineated (McCraw et al., 2007) , but not expressed on the Black Butte quadrangle. Unconformably overlies red sandstone, siltstone and conglomerate of unit QTsp on adjacent Abeytas quadrangle (McCraw et al., 2007). Cross-bedded gravels are generally pebbles smaller than 5 cm in diameter, but a few clasts are up to 20 cm in diameter. Pebbles consist of well-rounded, extrabasinal clasts of igneous and metamorphic rocks, particularly orthoquartzite, and polished chert pebbles and cobbles. Sparse rounded pebbles of Rabbit Mountain (Jemez Mountains; 1.4 Ma) and East Grants Ridge (Grants; 3 Ma) obsidians are also present. Deposits sit between 43 and 50 m above the present Rio Grande floodplain.

**Qrxt2**

**Rio Grande alluvium, oldest terrace deposits (middle Pleistocene)**—White to pale-brown (10 YR 8/2-8/3; 7.5 YR 5/4), poorly exposed, poorly consolidated, pebbly to cobbly sand and clast-supported gravel. Gravels are generally pebbles smaller than 5 cm in diameter, but a few clasts are up to 20 cm in diameter. Pebbles consist of well-rounded, extrabasinal clasts of igneous and metamorphic rocks, particularly orthoquartzite, and polished chert pebbles and cobbles. Sparse rounded pebbles of Rabbit Mountain (Jemez Mountains; 1.4 Ma) and East Grants Ridge (Grants; 3 Ma) obsidians are also present. Deposits sit approximately 70 m above the present Rio Grande floodplain. Bluff line of terrace is along the northern edge of the Sunwell surface of **Qsx** deposits on the western part of U.S. Highway 60. Thickness is probably less than 5 m.

**Alluvium of Abo and Isabel drainages inset after abandonment of highest level of Rio Grande deposits**

**Qaom** **Qaom1** **Qaom2**

**Alluvium, undivided inset terrace and fan deposits (upper middle Pleistocene)**—Unconsolidated sand and gravel associated with valley Abo valley borders (north and south) and inset fans upstream from mouth of Abo Valley that also extend along the western edge of the quadrangle to the southwest. Gravels are subangular to subrounded pebbles and cobbles of limestone, sandstone, granitic, and metamorphic rock types indicating derivation from uplands to the east. The gravel matrix and finer-grained beds of alluvium are typical Abo colors (5YR 7/3). Inset against the Sierra Ladrones formation. Overlies all of the Rio Grande terraces of Machette et al. (2007)

**Qaa1** **Qaa2** **Qaa3** **Qaa4** **Qaa5** **Qaa6** **Qaa7** **Qaa8** **Qaa9**

**Alluvial deposits along discrete paths of the Abo drainage after valley entrenchment began (middle Pleistocene to 0.41 Ma)**—Unconsolidated gravel and sand (colors) associated with valley borders, particularly south of Abo Valley and along Isabel Draw. Gravels are subangular to subrounded pebbles and cobbles of limestone, sandstone, granitic, and metamorphic rock types indicating derivation from uplands to the east. Rare clasts of rounded Rio-Grande-derived pebbles are reworked from older **Qaxc** deposits to the east. Inset against the Sierra Ladrones Formation. Pedogenic carbonate horizons reach Stages II-III. **Qaa1** is highest and easternmost inset level of inset fan deposits on both sides of Abo valley, roughly 30-35 m above the valley floor, and **Qaa2** is locally inset below that. **Qaa3** is slightly inset below that and extends farther west on both sides of the valley. Units **Qaa4** through **Qaa9** occur along the Abo-Isabel drainage divide farther west and extend down Isabel Draw to the southwest. **Qaa6** consists of coarse cobbles of Abo alluvium at an intermediate terrace level near the head of Isabel Draw. **Qaa8** is a lower inset terrace along Isabel Draw and one of its tributaries that contains a mixture of Abo clasts and locally reworked Rio Grande sediments derived from **Qsxo** and **Qsx**. Thicknesses range between 3 and 7 m.

**Alluvium of Amizette Draw and east Vargas fans after abandonment of highest level of Rio Grande deposits**

**Qvf1** **Qvf2** **Qvf3** **Qvf4**

**Alluvium at low and intermediate levels of valley of Amizette Draw and east Vargas fans (upper to middle Pleistocene)**—Unconsolidated sand and gravel associated with paths of Amizette drainage and its fans on easternmost **Qsx**. Inset against older alluvium of large Santa-Fe-age Abo fans such as **Qaff1** as the drainage incised across the Military Highway fault zone. Divided into packages of inset fans from oldest to youngest: **Qvf1, Qvf2, Qvf3,** and **Qvf4**. **Qvf4** connects upstream with **Qay** in the valley of Amizette Draw. Pedogenic carbonate horizons reach Stage II on **Qvf1**. Pebbles consist of a mixture of reworked Abo and Rio Grande gravels. Colors are from 5YR to 10YR light values. Thicknesses are estimated to be between 3 m to 7 m.

**Alluvium of Pino Draw after abandonment of highest level of Rio Grande deposits**

**Alluvium of Pino Draw upstream from Black Butte**

**Qap**

**Alluvium at an intermediate level between Qafi and Qam along the valley of Pino draw (Holocene to upper Pleistocene)**—Unconsolidated sand and gravel associated with the path of Pino Draw and interaction with toes north-trending piedmont from the south (**Qpbs, Qfm,** and **Qpfs**). Sediments are generally slightly reddish, poorly sorted sands with small gravels and a Stage II soil. Gravels are subangular and are dominated by granite, granitic gneiss, schist, chert, and quartzite with uncommon limestone and rare red sandstone clasts. It is between less than 1 m to 2 m above the active channel of Pino Draw with a diffuse upper edge. Sediment thicknesses range from less than 1 m to 2 m.

**Qaf3** **Qaf2** **Qaf1** **Qaf0**

**Alluvium at intermediate levels of upper valley of Pino Draw (upper to middle Pleistocene)**—Unconsolidated sand and gravel associated with inset fans and paths of Pino Draw. Inset below higher Abo fan deposits **Qafo1** and **Qafo2** as the drainage incised across the Military Highway fault zone. The sediment has a matrix of pale-reddish, poorly sorted, fine- to coarse-grained sand with subangular granitic, metamorphic, limestone, fine-grained red sandstone common gravels and uncommon cobbles reflective of upstream terrains and reworking of clasts from the older Abo fan deposits (**Qafo1** and **Qafo2**). Clasts are approximately 60% granitic and metamorphic rocks, 30% limestone and 10% red sandstone. Divided into packages of inset fans from oldest to youngest: **Qafo0, Qaf1, Qaf2,** and **Qaf3**. Inset levels north of Pino Draw may reflect paths of the Abo drainage before Pino Draw was established. Soils range from Stage III in **Qaf2** and **Qaf3**, to Stage III-IV on **Qaf1** to Stage IV-IV+ on **Qafo1**, but the proportions of clast lithologies remain approximately constant.

**Alluvium of Pino Draw downstream from Black Butte**

**Qapf**

**Alluvium along low-level terrace in Pino valley and fan on Rio Grande terrace (upper to middle Pleistocene)**—Unconsolidated, poorly sorted, reddish sand and gravel along terrace of Pino Draw and its fan on westernmost eroded Qoxo and QrgZ. Clasts are a mixture of subangular Proterozoic quartzites and other metamorphic rocks, limestone, red sandstone, and well-rounded pebbles of ancestral Rio Grande gravel. Inset against older alluvium and general Santa-Fe-Group basin-fill QTsps. Elevation of tread above Pino Draw is approximately 5 m. Pedogenic carbonate is Stage II. Thickness ranges from 0 to 7 m.

**Qapfo**

**Alluvium on intermediate terrace of Pino Draw deposited as fan on Rio Grande deposits (upper to middle Pleistocene)**—Unconsolidated sand and gravel of Pino Draw deposited as a valley-mouth fan on **Qsxo**. Clasts are a mixture of subangular Proterozoic quartzites and other metamorphic rocks, limestone, red sandstone, and well-rounded pebbles of ancestral Rio Grande gravel. Inset against **Qsxo** and general Santa-Fe Group basin-fill **QTsps**. Elevation of tread above Pino Draw is approximately 7m to 10 m. Pedogenic carbonate is Stage III. Thickness ranges from 0 to 5 m.

**Alluvium of Turututu Draw**

**Qatf**

**Alluvium along low-level terrace in Turututu valley and fan on Rio Grande terrace (upper to middle Pleistocene)**—Unconsolidated sand and gravel along terrace of Turututu Draw and its fan on westernmost eroded **Qsxo** and **Qrgt2** and on fan of Pino Draw (**Qapf**). Grades upstream and upslope to **Qatb**. Inset against **Qsxo** and general Santa Fe Group basin-fill **QTsps**. Clasts are a mixture of subangular Proterozoic quartzites and other metamorphic rocks, limestone, red sandstone, basalt, basaltic andesite, and well-rounded pebbles of ancestral-Rio Grande gravel. Elevation of tread above Turututu Draw is approximately 5 m. Pedogenic carbonate is Stage II. Thickness ranges from 0 to 7 m.

**Qata**

**Alluvium and colluvium along slopes in Turututu valley derived from adjacent basin-fill deposits (middle to upper Pleistocene)**—Unconsolidated sand and gravel along valley-margin slopes of Turututu Draw below the level of **Qatr** in contact with **QTsps**. Clasts are a combination of well-rounded Rio Grande gravel and subangular Proterozoic quartzites and other metamorphic rocks, limestone, red sandstone, and basaltic andesite. Matrix derived from **QTsps** commonly is pink (7.5YR 7/3), reddish-yellow (5YR 6/6), red (2.5 YR 5/6) and reddish brown (2.5 YR 4/4). Locally forms slight intermediate terrace. Thickness less than 4 m.

**Qatfo**

**Alluvium on high terrace of Turututu Draw deposited on local inset Rio Grande deposits (middle Pleistocene)**—White to pale-brown (10 YR 8/2-8/3), unconsolidated sand and gravel of Turututu Draw perhaps deposited as a valley-mouth fan on **Qsx2**. Clasts are a combination of well-rounded Rio Grande gravel and subangular Proterozoic quartzites and other metamorphic rocks, limestone, red sandstone, basalt, and basaltic andesite. Pedogenic carbonate is Stage III. Thickness ranges from 0 to 5 m.

**Qae1** **Qae2**

**Alluvium and eolian deposits, undivided (Holocene to upper Pleistocene)**—Poorly consolidated, poorly sorted and poorly stratified tributary alluvium and eolian sand and silt sheets in tributary drainages and on intermediate inset terrace levels; thickness varies from less than 1 m to 5 m. Locally, **Qae1** fills older swales closer to sediment source terranes than **Qsy** and **Qso**, and has accumulated more calcium carbonate and iron-oxides in the B horizon and has more reworked pebbles at the surface than **Qae2**. **Qae1** is traceable down drainages to the same level as **Qay**, although in some reaches **Qae1** grades down to **Qav, Qas,** or **Qay**. **Qae1** deposits are between 1 m and 5 m thick. **Qae2** is younger and has less pedogenic calcium carbonate and iron oxides, and few pebbles at the surface. **Qae2** is traceable down drainages to the **Qay** or **Qav** level. **Qae2** deposits are generally thin and range from less than 1 m to more than 3 m thick.

**Santa Fe Group**

**Qsx** **Qsx1**

**Sierra Ladrones Formation, axial-fluvial deposits (upper Santa Fe Group, lower Pleistocene)**—White to pale-brown (10 YR 8/2-8/3) pebbly medium-coarse sand. Pebble and cobble gravels consist of well-rounded volcanic rocks (~40%), granite (25%), orthoquartzite (20%), polished multicolored chert (15%), and uncommon subangular clasts of the fan facies reworked into the fluvial deposits. The most distinctive clasts are obsidians from Rabbit Mountain (Jemez Mountains; 1.4 Ma) and East Grants Ridge (Grants, 3 Ma). Associated with the upper part of this unit are rare clasts of ashflow tuff probably derived from floods along the Rio Grande after the upper Bandelier Tuff eruption, documented farther north east of the Rio Grande. **Qsx1** is a coarse cobble unit that locally holds up an elevated remnant of **Qsx** beneath the communications tower along U.S. Highway 60 west of Pino Draw crossing. The unit is poorly exposed. Unit is 0 to 7 m thick.

**Qsxo**

**Sierra Ladrones Formation, mixed axial-fluvial deposits and distal fans (upper Santa Fe Group, lower Pleistocene)**—Interbedded sands and gravels from the Rio Grande and alluvial fans from eastern and southeastern sources. Fluvial gravels contain abundant well-rounded clasts of volcanic rocks (~40%), granite (25%), rounded orthoquartzite (20%) and polished rounded chert (15%) where as local fan alluvium clasts are subangular to subrounded limestone, sandstone, Proterozoic granitic and metamorphic rocks, and basalt. The geochemical fingerprint of pumice clasts as pebbles, granules, and a pumice-raft deposit near the base of exposures is consistent with the Guaje pumice eruption at the base of the Otowi Member of the Lower Bandelier Tuff (1.61 Ma; Kelley et al. 2013). The unit is poorly exposed on hillslopes and in arroyo banks on the western side of the quadrangle. Unit combined with **Qsx** is estimated to be 60 m thick on the west side of the quadrangle, but thins to 0 m at the river's old bluff line to east.

**QTsps**

**Sierra Ladrones Formation, sandstone- and mudstone-dominated generalized piedmont deposits (upper Santa Fe Group, lower Pleistocene to Pliocene)**—Pink (7.5 YR 7/3), reddish-yellow (5YR6/6), red (2.5 YR 5/6) and reddish-brown (2.5 YR 4/4), poorly exposed, unconsolidated to poorly consolidated, uncemented to cemented, mudstones and sandstones with moderately sorted tabular, crossbedded sandstone and scattered, irregular pebbly sandstone and conglomeratic sandstone lenses. Beds commonly form sequences with a basal conglomerate that fines upward into sand and mud that is locally capped by calcic paleosols, thin rhizoconcretionary beds, and cemented tufa-like spring-groundwater-precipitated deposits. Pebbles comprised of subangular Proterozoic granite and metamorphic rocks. Sandstone beds tend to comprise less than 30% of the unit. Mudstone units locally contain concretionary masses of gypsum crystals. Commonly overtopped by fan deposits (e.g. **Qsfd**) and ancestral Rio Grande deposits (**Qsx**). May include tongues of **Qsxo** in west-central part of quadrangle. Exposed thickness in valley walls ranges from 0 to more than 20 m and local water wells penetrate at least 165 m.

**Qabd** **Qafo1** **Qafo2**

**Sierra Ladrones Formation, upper-level coarse-grained fan deposits from Abo drainage (upper Santa Fe Group, lower Pleistocene)**—Pink to reddish-yellow (7.5YR 6/6-7/3), poorly consolidated, uncemented to locally well cemented, poorly to moderately sorted cobble and pebble gravel, and reddish-yellow sandy matrix. Clasts include subangular to subrounded pebbles to boulders of rocks from the Abo Pass area, including red sandstones, brown-to-tan sandstones, limestones, granite gneiss, amphibolite, metarhyolite, and quartzite. Has a scoured basal contact with underlying finer-grained deposits. Locally forms bluff line cut by axial-fluvial deposits of ancestral Rio Grande (**Qsx**). Pedogenic carbonate horizon at top of unit reaches at least Stage IV. **Qabd** underlies high planar surface on north side of Abo valley, with **Qafo1** and **Qafo2** underlie high planar surfaces on the south side of Abo valley, with **Qafo2** slightly inset below **Qafo1**. Exposed thickness of whole unit ranges up to 20 m.

**Qafbs** **Qaff1** **Qaff2**

**Sierra Ladrones Formation, slightly inset upper-level coarse-grained fan deposits from Abo drainage (upper Santa Fe Group, lower Pleistocene)**—Pink to reddish-yellow (7.5YR 6/6-7/3), poorly exposed, poorly consolidated, uncemented to locally cemented, poorly to moderately sorted cobble and pebble gravel, and pebbly sand. These broad inset fan remnants are below the maximum aggradational surfaces of **Qafo1** and **Qafo2**, but their connection to inset Abo-valley pathways farther east remains problematic. Locally some clasts are covered with rock varnish. Bedding follows planar westward slope. Clasts include subangular to subrounded pebbles to cobbles of rocks from the Abo Pass area, including red sandstones, brown-to-tan sandstones, limestones, granite, granite gneiss, amphibolite, metarhyolite, and quartzite. Has a scoured basal contact with underlying finer-grained deposits of **QTsps**. Pedogenic carbonate horizon 1-2 m thick at top of unit reaches Stage III. **Qaffa** underlies high inset planar surface on southern edge of Abo valley and more extensive surface along north side of Amizette Draw. The surface of this deposit shows maximum amount of offset across Military Road fault zone. **Qaff1** underlies a slightly lower planar surface on the south side of Amizette Draw, and **Qaff2** is local and slightly inset below **Qaff1**. Exposed thickness of whole unit ranges up to 5 m.

**Qafd**

**Sierra Ladrones Formation, coarse-grained fan deposits from Palo Duro drainage (upper Santa Fe Group, lower Pleistocene)**—Pink to reddish-yellow (7.5YR 6/6-7/3), poorly consolidated, uncemented to locally well-cemented, poorly to moderately sorted conglomerate and pebbly sand. Bedding follows planar northwestward sloping surfaces with local desert pavement. Clasts include subangular to subrounded pebbles to boulders of rocks from the southern Los Pinos Mountains, including granite, granite gneiss, amphibolite, metarhyolite, quartzite, sandstone, limestone, basalt, basaltic andesite, and rhyolite. Has a scoured basal contact with underlying finer-grained deposits. It overlies top of axial fluvial deposits of ancestral Rio Grande (**Qsx**) and general piedmont deposits (**QTsps**). Medial and proximal parts of the fan(s) on the Becker SW quadrangle show inset elevations and two or more episodes of fan activity not mapped on the Black Butte quadrangle. Thickness ranges up to 15 m.

**Paleogene**

**Tlp**

**La Jara Peak Basaltic Andesite, (probably tongue 5, upper Oligocene)**—Mostly medium-gray to purplish-gray, massive and platy to vesicular basaltic andesite lavas characterized by moderately abundant (5–10%) fine- to medium-grained phenocrysts of olivine, usually altered to reddish brown iddingsite. Phenocrystic plagioclase is typically absent. Thin flows (3–6 m) commonly exhibit vesicular tops and reddish basal breccia zones. Two flows of Tlp at the top of Turututu (Black Butte) rest on Vicks Peak Tuff and have a K-Ar age of 24.3 ±1.5 Ma (Bachman and Mehnert, 1978). This age is probably too young because two-thirds of basaltic andesite eruptions are between 27.2 and 28.7 Ma $^{40}Ar/^{39}Ar$ ages (Chapin et al., 2004). Maximum thickness is 13 m. (Description modified from William McIntosh, written communication, 1 April 2013).

**Tlr**

**Rhyolitic tuffs beneath Tlp on Turututu (Oligocene)**—Vicks Peak Tuff (17-20 m), La Jencia Tuff (13 m), and Hells Mesa Tuff (> 12 m) at 28.4, 28.7, and 32 Ma $^{40}Ar/^{39}Ar$ ages respectively (Chapin et al., 2004). Vicks Peak Tuff: densely welded, brown to light brownish gray and light gray, phenocryst poor, pumiceous, rhyolite ignimbrite. Pervasive well developed compaction foliation, and large "sandy" (vapor phase) pumice lapilli up to 30 cm long. La Jencia Tuff: densely welded light-gray, pale-red and grayish-red, phenocryst poor, rhyolite ignimbrite. Contains sparse (3–5%) phenocrysts of sanidine and quartz with rare plagioclase and biotite. Hells Mesa Tuff: Pale-reddish-gray to light-gray, mostly densely welded, phenocryst-rich (40–50%), quartz-rich, rhyolite ignimbrite. Typically contains abundant medium grained (1–3 mm) phenocrysts of sanidine, plagioclase, quartz and minor biotite. Quartz is minor component (1–2%) in thin basal zone (not exposed here). (Description modified from William McIntosh, written communication, 1 April 2013).

**Td**

**Datil Group, intermediate-composition volcanic and volcaniclastic rocks (Lower Oligocene and Upper Eocene)**—In subsurface in cross section only, beneath rhyolitic tuffs under Black Butte and elsewhere. Spears Formation of Datil Group exposed along Palo Duro Canyon on the Becker SW and the La Joya quadrangles to the south-southwest where it rests on Permian rocks. May be unidentified unit between tuffs and Permian Yeso Formation in local oil well stratigraphic test (B. Black, written communication, 2014).

## Cross Section A—A′