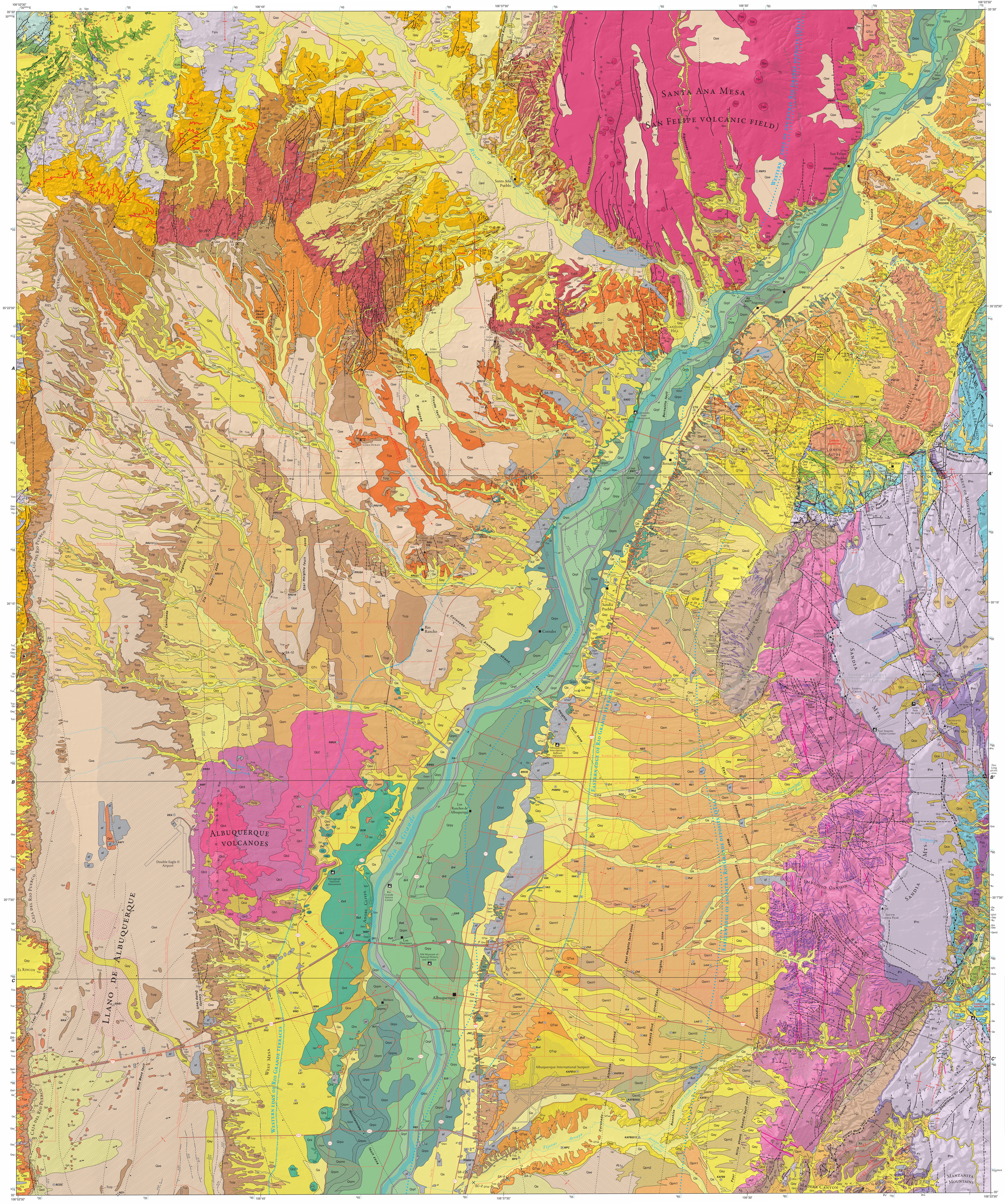

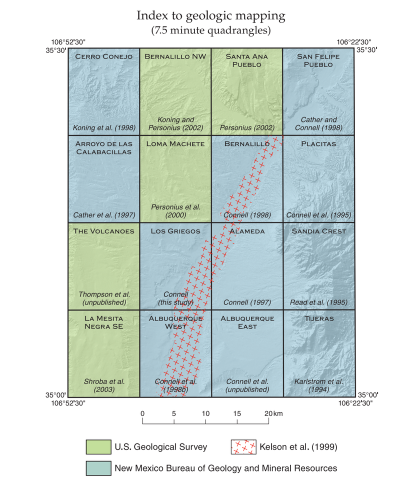

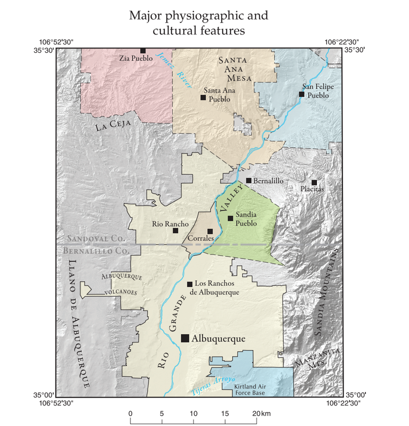

This geologic map graphically displays information on the distribution, character, orientation, and stratigraphic relationships of rock and surficial units and structural features. The geology was compiled by Sean D. Connell at a scale of 1:50,000 from geologic field mapping conducted from 1994 to 2005 at scales of 1:12,000, 1:24,000, and 1:50,000; therefore, significant variations in map detail may be expected. Additional data were derived from many published and unpublished works, from interpretation of available aerial photography and satellite imagery, and from examination and interpretation of available drill-hole data. Locations of geologic unit contacts are not precise; the accuracy depends on the scale of mapping and field conditions. Any enlargement of this map may cause significant 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. Geologic cross sections (Sheet 2) can aid in understanding the general geologic framework of the map area. Construction of geologic cross sections is based on interpretations of geologic mapping, available geophysical data (e.g., aeromagnetic, gravity, gamma ray), and available drill-hole data (published and unpublished well reports, examination of lithologic cuttings, and interpretation of borehole geophysical log data). Geologic cross sections and maps should not be the sole source of information for use in locating wells or other man-made structures. The views and conclusions presented on this map are those of the compiler and should not be interpreted as necessarily representing official policies, either expressed or implied, of the state of New Mexico or the U.S. government.

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Base maps are from the U.S. Geological Survey 7.5-minute topographic series, Polyconic and Universal Transverse Mercator (UTM) projections, North American Datum (NAD) of 1927 and 1983. They have been reprojected to UTM, zone 13, NAD 1983. Grid ticks at 5,000 m, UTM, zone 13, NAD 1983, are shown in blue. Property boundaries on the Major physiographic and cultural features map inset are generalized from data from the New Mexico Earth Data Analysis Center (http://edac.unm.edu). Map editing, digital database construction, and digital cartography for an earlier online version of this map was done by Mark M. Mansell and Sean D. Connell using ArcGIS (ArcInfo) versions 8.2 and 9.1. The earlier online version of this map and digital database data are available in ArcInfo and portable document format at: http://geoinfo.nmt.edu/publications/openfile/496.

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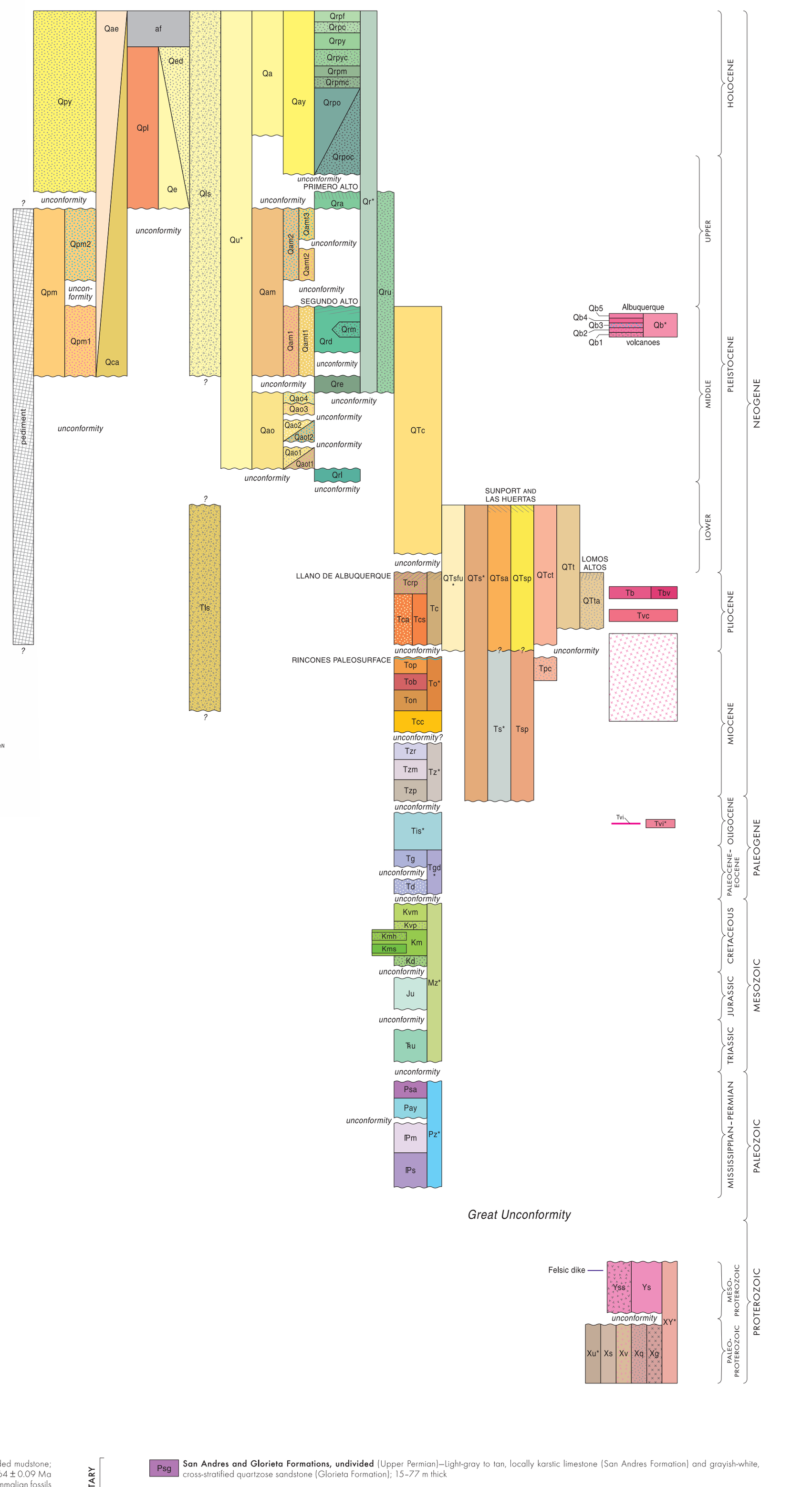
Map Symbols

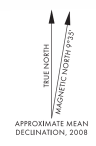
- Contact
- **Normal fault**—Showing dip; bar and ball on downthrown side; dashed where approximately located; dotted where concealed; queried where inferred
- **Aeromagnetically defined fault**—Interpreted from data of Kucks et al. (2001); bar and ball on inferred downthrown side; linear anomalies mark probable locations of faults (Grauch et al. 2001)
- **Reverse fault**—Dashed where approximately located; dotted where concealed
- **Thrust fault**—Dashed where approximately located; dotted where concealed
- **Strike-slip fault**—Showing relative horizontal separation; dashed where approximately located; dotted where concealed
- **Anticline**—Showing direction of plunge; dashed where approximately located; dotted where concealed
- **Syncline**—Showing direction of plunge; dashed where approximately located; dotted where concealed
- **Overturned anticline**—Dashed where approximately located; dotted where concealed
- **Overturned syncline**—Dashed where approximately located; dotted where concealed
- **Monocline**—Dashed where approximately located; dotted where concealed; queried where inferred
- **Tephra bed**
- **Petrocalcic soils of Rincones surface**—Stage* III+, V carbonate morphology; shown beside geologic contact
- **Petrocalcic soils of Sunport and Las Huertas surfaces**—Stage* III+ carbonate morphology; shown beside geologic contact
- **Petrocalcic soils of Llano de Albuquerque surface**—Stage* III + to locally weak stage IV carbonate morphology; shown beside geologic contact
- **Approximate lateral (buried) limit of axial-fluvial deposits of the Sierra Ladrones Formation (QTsa)**
- **Approximate extent of inset ancestral Rio Grande terrace deposits (alluvium of Rio Grande), hachures toward valley**
- **Active Rio Grande channel**
- A–A′ Geologic cross section (Sheet 2)
- County line
- Interstate highway
- Federal highway
- State highway
- City street
- Trail
- Horizontal bedding
- Strike and dip of inclined and overturned bedding
- Strike and dip of inclined foliation
- Strike and dip of inclined joint
- NO2 Oil well
- Wa1 Water supply well
- SCS Monitoring well
- MPC Geotechnical boring
- SA-2 Geochronologic sample site (Table 1 on Sheet 2)
- Azimuth of paleocurrent vector (imbrications and cross stratification); includes data from Lambert (1974) (stream, wind)
- Volcanic vent in Albuquerque volcanoes (Qb2–Qb5) and San Felipe volcanic field (Tb)
- Peak
- Cave

*Pedogenic carbonate morphologic stage (see Machette 1985)

Correlation of Geologic Map and Cross Section Units

Asterisk (*) denotes units shown on Sheet 2 only





1 .5 0 1 2 3 4 5 miles

1 .5 0 1 2 3 4 5 kilometers

1:50,000

(1 inch equals approximately .8 miles)

National geodetic vertical datum of 1929

Geologic map of the Albuquerque–Rio Rancho metropolitan area and vicinity

Bernalillo and Sandoval Counties, New Mexico

Sean D. Connell

New Mexico Bureau of Geology and Mineral Resources

A DIVISION OF NEW MEXICO INSTITUTE OF MINING AND TECHNOLOGY

Peter A. Scholle, *State Geologist*

2008

Description of Map Units

GEOMORPHIC SURFACES

Depositional

Primero Alto terrace surface (upper Pleistocene)—Depositional top of Arenal Formation (*Qra*); weakly developed calcic soils with stage I to II+ pedogenic carbonate morphology on gravel; originally named by Lambert (1968) for his Edith Formation on west side of Rio Grande; 15–21 m above Rio Grande

Segundo Alto terrace surface (middle Pleistocene)—Depositional top of Los Duranes Formation (*Qrd*) and intermediate stream-valley alluvium (*Qam*); weakly developed calcic soils with stage I to II pedogenic carbonate morphology on sand; named by Lambert (1968); 42–48 m above Rio Grande

Sunport and Las Huertas geomorphic surfaces (lower Pleistocene)—Depositional top of Sierra Ladrones Formation (*QTsp* and *QTsa*); strongly developed petrocalcic soils with stage III+ pedogenic carbonate morphology on sand and gravel; Sunport surface named by Lambert (1968) for Albuquerque International Sunport near Tijeras Arroyo; Las Huertas surface named by Connell and Wells (1999) for a surface near Las Huertas Creek; projects 92–122 m above Rio Grande

Llano de Albuquerque geomorphic surface complex (lower Pleistocene or upper Pliocene)—Depositional top of Ceja Formation (*Tc, Tcrp*); strongly developed petrocalcic soils with stage III+ to locally weak stage IV pedogenic carbonate morphology on sand; dashed hachures denote inferred relict surfaces; modified after Machette (1985); 110–215 m above Rio Grande

Lomos Altos geomorphic surface (upper Pliocene)—Local depositional top of Tuerto Formation (*QTta*); strongly developed petrocalcic soils with stage IV pedogenic carbonate morphology; named by Connell and Wells (1999); 21–92 m above local base level

Erosional

Pediment surface (Pleistocene–upper Pliocene?)—Erosion surface in Tijeras and Juan Tabo Canyons and along southwestern flank of Sandia Mountains and Manzanita Mountains; mostly cut on Sandia granite (*Ys*)

SURFICIAL DEPOSITS

af — **Disturbed land and artificial fill** (modern–historic)—Excavations and areas of artificially deposited fill and debris; delineated where areally extensive; includes deposits associated with floor of Jemez Reservoir

Qpl — **Playa-lake deposits** (Holocene–upper Pleistocene)—Silt, mud, and sand in local depressions (eolian blowouts) on low-relief surfaces (*Qe, Qae*); generally less than 2 m thick

Qe — **Eolian sand, undivided** (Holocene–upper Pleistocene)—Pink to light-yellowish-brown, well-sorted sand recognized as laterally extensive, sparsely vegetated, active and inactive sand sheets and discontinuous low-relief dunes; soils are nonexistent or weakly developed with stage I to II+ pedogenic carbonate morphology; northeast-trending dune-crest orientations; 1–3 m thick

Qed — **Eolian sand dune** (Holocene–upper Pleistocene)—Pink to light-yellowish-brown, well-sorted sand primarily recognized as moderate-relief narrow dunes that are common along Ceja del Rio Puerco; weakly developed soils with stage I to II pedogenic carbonate morphology; northeast-trending dune-crest orientations; 1–33 m thick

Qls / Tls — **Landslide debris** (Pleistocene) **and landslide megablock** (Pliocene or Miocene?)—Massive to chaotically bedded sand, gravel, and mud derived from steep hillslopes; includes large Toreva blocks along margin of Santa Ana Mesa; older landslide megablocks (*Tls*) are large allochthonous blocks of Madera Group limestone resting on sheared Sandia granite (*Ys*) along southwestern base of Sandia Mountains east of Lomas Boulevard; 6–30 m estimated thickness

Qca — **Colluvium and alluvium, undivided** (Holocene–Pleistocene)—Sand and gravel from hillslopes and along margins of mesa-capping lavas; weakly to strongly developed calcic soils with stage I to III+ pedogenic carbonate morphology; 5 m estimated thickness

Qae — **Eolian sand and alluvium, undivided** (Holocene–upper Pleistocene)—Pale-brown to light-reddish-brown, moderately sorted sand and silt with scattered pebbles; weakly to moderately developed soils with stage I to II pedogenic carbonate morphology and thin clay films; 1–3 m thick

QTc — **Fault-scarp colluvium and eolian deposits** (Pleistocene–upper Pliocene?)—Pale-brown to yellowish-brown sand with interbedded pebbly sand, mud, and multiple buried calcic paleosols with stage I to III+ pedogenic carbonate morphology; associated with hanging walls of intrabasinal faults, such as the San Ysidro fault, where deposits extend approximately 3 km east of the fault trace and overlie the Llano de Albuquerque geomorphic surface complex; generally poorly exposed; 0–30 m thick

PIEDMONT-SLOPE

Qpy — **Younger piedmont-slope alluvium** (Holocene–upper Pleistocene)—Light-brown sand, muddy sand, and pebble to cobble gravel associated with drainages that are not graded to the Rio Grande; boulders locally present along western flank of the Sandia Mountains; weakly developed soils with stage I pedogenic carbonate morphology; as much as 12 m thick

Qpm (Qpm2, Qpm1) — **Intermediate piedmont-slope alluvium** (middle Pleistocene)—Pale- to strong-brown silty sand, clayey sand, and gravel associated with drainages that are not graded to the Rio Grande; weakly to moderately developed soils with stage II and III+ pedogenic carbonate morphology; divided into younger (*Qpm2*) and older (*Qpm1*) subunits based on soil morphology and inset relationships; 9 m thick

RIO GRANDE VALLEY DEPOSITS

Los Padillas Formation (historic–uppermost Pleistocene)—Pinkish-gray to grayish-brown sand and pebbly sand with lenses of reddish-brown silt and clay; contains paleochannel, point-bar, and overbank levee deposits; underlies modern (inner) valley of the Rio Grande; very weak to no soil development; base not exposed; 15–24 m thick in wells; named by Connell et al. (2007); divided into eight units based largely on surface morphology and inset relationships (modified from Kelson et al. 1999):

Qrpc — **Modern channel deposits** (historic)—Active channel and floodplain of Rio Grande since 1951

Qrpf — **Modern floodplain deposits** (historic)—Channel and floodplain of Rio Grande before 1930s

Qrpy / Qrpyc — **Younger channel and floodplain** (*Qrpy*) **and younger channel** (*Qrpyc*) **deposits** (historic–upper Holocene)—Sand, silt, and clay with gravelly sand interbeds

Qrpm / Qrpmc — **Intermediate channel and floodplain** (*Qrpm*) **and intermediate channel** (*Qrpmc*) **deposits** (upper Holocene) —Sand, silt, and clay with gravelly sand interbeds

Qrpo / Qrpoc — **Older channel and floodplain** (*Qrpo*) **and older channel** (*Qrpoc*) **deposits** (Holocene–uppermost Pleistocene)—Sand, silt, and clay with gravelly sand interbeds

Fluvial (terrace) deposits of the Rio Grande

Qra — **Arenal Formation** (upper Pleistocene)—Pale- to yellowish-brown pebbly to cobbly sand; inset against Los Duranes Formation (*Qrd*); Primero Alto terrace surface marks top; named by Connell et al. (2007); originally part of Lambert's (1968) Edith Formation west of Rio Grande; approximately 15 m above Rio Grande; 3–6 m thick

Qrd — **Los Duranes Formation** (middle Pleistocene)—Pale-brown to light-reddish-brown sand, sandy gravel, and sandy clay mostly exposed west of Rio Grande; Segundo Alto terrace surface marks top; inset against Lomatas Negras Formation (*Qrl*); locally subdivided into the Menaul Member (*Qrm*); named by Lambert (1968) and revised by Connell et al. (2007); contains basaltic lavas of Albuquerque volcanoes (*Qb2*); 44–48 m above Rio Grande; 52 m thick

Qrm — **Menaul Member** (middle Pleistocene)—Yellowish-brown pebble gravel and pebbly sand; probably a coarse-grained lens of Los Duranes Formation east of Rio Grande; soils exhibit stage II+ pedogenic carbonate morphology; overlies intermediate stream-valley deposits (*Qam1*); typically overlain by intermediate stream-valley deposits of subunit *Qam2*; named by Lambert (1968) and redefined by Connell et al. (2007); 26–36 m above Rio Grande floodplain; less than 3 m thick

Qre — **Edith Formation** (middle Pleistocene)—Pale-brown to yellowish-brown pebble and cobble gravel, sand, and sandy clay typically exhibiting an upward-fining succession; locally contains thin, white diatomite between Sandia Wash and Cañon del Agua; disconformably overlain by intermediate stream-valley alluvium (*Qam, Qam2, Qamt2, Qam1*) and Menaul Member of the Los Duranes Formation (*Qrm*); named by Lambert (1968) and redefined by Connell et al. (2007);12–24 m above Rio Grande; 3–12 m thick

Qrl — **Lomatas Negras Formation** (middle Pleistocene)—Pale-brown to pink sandy pebble to cobble gravel; soils exhibit stage III pedogenic carbonate morphology on gravel; unconformably overlies a low-relief strath cut on the Ceja Formation (*Tc, Tcrp, Tcs*) west of Rio Grande; disconformably overlain by older stream-valley alluvium (*Qao*) and commonly buried by intermediate stream-valley alluvium (*Qam*); correlative deposits (~5 km south of map area) contain Lava Creek B tephra (~640 ka; Connell et al. 2007); named by Connell et al. (2007); 46–75 m above Rio Grande; 5–20 m thick

Qru — **Undivided ancestral Rio Grande deposits** (upper–middle Pleistocene)—Poorly exposed rounded orthoquartzite-bearing gravel associated with the ancestral Rio Grande near San Felipe Pueblo; correlative to the Los Duranes or Edith Formations (*Qrd, Qre*)

Tributary stream-valley alluvium

Qa — **Active stream-valley alluvium** (historic–Holocene)—Light-grayish- to yellowish-brown sand, silty to clayey sand, and gravel; boulders are common along western flank of Sandia Mountains; associated with active stream valleys that are graded to the Rio Grande; nonexistent to very weakly developed soils with stage I pedogenic carbonate morphology; 1–12 m thick

Qay — **Younger stream-valley alluvium** (Holocene–upper Pleistocene)—Pale- to light-brown sand, muddy sand, and pebble to cobble gravel associated with streams that are graded to the Rio Grande; boulders locally present along western flank of Sandia Mountains; weakly developed soils with stage I and II pedogenic carbonate morphology; locally contains active stream-valley alluvium (*Qa*); detrital charcoal in Tijeras Canyon yielded radiocarbon ages of 1,790 ± 90 and 4,550 ± 140 radiocarbon years (SC-1 and SC-2 , Table 1); 0–3 m above local base level; as much as 24 m thick beneath major tributary valleys

Qam (Qam2, Qam1) — **Intermediate stream-valley alluvium** (upper–middle Pleistocene)—Yellowish-brown to reddish-yellow sand, silty clay, and gravel associated with abandoned tributary streams; pink Sandia granite and limestone gravel common east of Rio Grande; variable lithology dominated by chert, volcanic, and red granitic gravel to west; surface is commonly mantled by eolian sand west of Rio Grande; variable soil development; divided into two subunits based on surface morphology, soil development, and inset relationships: **younger subunit** (*Qam2*) exhibits soils with stage II+ pedogenic carbonate morphology; **older subunit** (*Qam1*) contains soils with stage III+ pedogenic carbonate morphology; 8–65 m above local base level; 5–51 m thick

Qamt3, Qamt2, Qamt1 — **Intermediate stream-valley alluvium of Tijeras Canyon** (middle Pleistocene)—Sand and gravel associated with former drainage courses of Tijeras Canyon; contains greenstone and sandstone; interfingers with intermediate stream-valley alluvium (*Qam*); divided into three subunits based on inset relationships and soil morphology: **younger subunit** (*Qamt3*), **intermediate subunit** (*Qamt2*), and **older subunit** (*Qamt1*); 5–43 m thick

Qao (Qao4, Qao3, Qao2, Qao1) — **Older stream-valley alluvium** (middle Pleistocene)—Light-reddish-brown sand and gravel associated with abandoned tributary streams; composition similar to intermediate stream-valley alluvium; soils are typically degraded and exhibit variable morphologic development with maximum stage IV pedogenic carbonate morphology; divided into four subunits based on surface morphology, soil morphology, and inset relationships (from youngest to oldest): **subunit 4** (*Qao4*), **subunit 3** (*Qao3*), **subunit 2** (*Qao2*), and **subunit 1** (*Qao1*); 0–100 m above local base level; 2–14 m thick, but locally as much as 30 m thick

Qaot2, Qaot1 — **Older stream-valley alluvium of Tijeras Canyon** (middle Pleistocene)—Sand and gravel derived from former drainage courses of Tijeras Canyon; composition similar to intermediate stream-valley alluvium of Tijeras Canyon; divided into two subunits: **younger subunit** (*Qaot2*) and **older subunit** (*Qaot1*); 0–15 m thick

SANTA FE GROUP

upper

QTt / QTta — **Tuerto Formation** (lower Pleistocene–upper Pliocene)—Pale-brown pebbly to cobbly sand and sandstone; predominantly limestone gravel; unconformably overlies units *QTsp, Tsp,* and older rocks along northern and eastern flanks of Sandia Mountains; locally capped by petrocalcic soils with stage III+ (*QTt*) to IV+ (*QTta*) pedogenic carbonate morphology; Tuerto gravels of Stearns (1953); used as a formation based on mappability northeast of map area; includes the **gravel of Lomos Altos** (*QTta*) of Connell and Wells (1999) west of the San Francisco fault, where the basal contact is 80–100 m above local base level; probable Tuerto correlatives include high-level cobble and boulder gravel along southeastern dip slope of Sandia Mountains (*QTt?*); 4–18 m thick

Sierra Ladrones Formation (lower Pleistocene–Pliocene or Miocene?)—Sandstone, conglomeratic sandstone, and mudstone named by Machette (1978) for deposits associated with through-flowing axial-river system (ancestral Rio Grande); informally divided into piedmont and axial-river members:

QTsp — **Piedmont member** (lower Pleistocene–Pliocene)—Reddish- to yellowish-brown, calcium-carbonate cemented conglomerate, sandstone, and minor mudstone; contains weakly developed paleosols and upward-fining sequences of gravel, sand, and mudstone derived from eastern margin of Albuquerque Basin; gravel contains subrounded to subangular limestone, sandstone, and pink Sandia granite; sparse hypabyssal intrusive gravel on the Cuchilla de Escala; moderately well exposed; interfingers with axial-fluvial member (*QTsa*); generally fines toward Rio Grande valley and coarsens upward; 0–800? m thick

QTsa — **Axial-fluvial member** (lower Pleistocene–Pliocene or Miocene?)— Light-gray to yellowish-brown sand, pebbly to cobbly sand, and sparse interbedded mud of the ancestral Rio Grande; upper ~70 m contains abundant rhyolitic pumice-bearing sand and pumiceous gravel derived from lower Pleistocene Jemez volcanic field; gravel dominated by rounded orthoquartzite and volcanic rocks; weakly consolidated and poorly exposed; distinguished from Ceja Formation by low chert/orthoquartzite gravel ratio (Brandes 2002); interfingers with piedmont member (*QTsp*); contains early Irvingtonian mammalian fossils (SB-1, Table 1); older axial-river deposits ~17 km north of map area contain 6.96-Ma tephra (Peralta Tuff, Smith and Kuhle 1998); poorly exposed; base not exposed; estimated thickness 300–800 m (Connell 2004)

Tc — **Ceja Formation** (lower Pleistocene?–Pliocene)—Pale-brown to yellowish-brown and reddish-brown sand, gravel, and mud derived from southeastern Colorado Plateau, San Juan Basin, Sierra Nacimiento, and southern Jemez Mountains; gravel dominated by rounded chert, subrounded volcanic, and red granitic and gneissic pebbles and cobbles; contains scattered cobbles and small boulders of basalt, sandstone, and rounded chalcedony and chert (Pedernal Member of Abiquiu Formation, see Connell 2004); base is sharp and disconformable with Arroyo Ojito Formation (*Ton* and *Top*); sparse remnants unconformably overlie Cerro Conejo Formation west of Sand Hill fault; base is dominated by mudstone and sandstone (Santa Ana Mesa and Atrisco Members); commonly coarsens upward into mesa-capping sand and gravel of Rio Puerco Member and Llano de Albuquerque geomorphic surface complex; interfingers with axial-fluvial member of Sierra Ladrones Formation (*QTsa*); distinguished from Sierra Ladrones Formation by high chert/orthoquartzite gravel ratio (Brandes 2002); named by Kelley (1977) and redefined by Connell (2008); contains Blancan mammalian fossils (SB-2, Table 1); exposed thickness ranges from 20 to 40 m along western margin of map area (Ceja del Rio Puerco) and may reach 700 m thick in wells east of the Rio Grande valley; divided into three members:

Tcrp — **Rio Puerco Member** (lower Pleistocene?–Pliocene)—Pale-brown to yellowish-brown cobbly sand and gravel with scattered boulders; overlies Santa Ana Mesa and Atrisco Members; Llano de Albuquerque geomorphic surface complex defines top; 20–260? m thick; generally less than 100 m thick west of Rio Grande valley and thickens to east

Tcs — **Santa Ana Mesa Member** (Pliocene)— Reddish-brown to yellowish-red sandstone, conglomerate, and minor mudstone; named for exposures beneath Santa Ana Mesa (Connell 2008); commonly gradational and interfingering contact with Rio Puerco Member (*Tcrp*); occupies similar stratigraphic position to Atrisco Member (*Tca*); inferred using aerial imagery along western flank of Santa Ana Mesa; contains thin fallout ash in Jemez Dam spillway yielding a single-crystal $^{40}Ar/^{39}Ar$ age on hornblende of 3.81 ± 0.29 Ma (SA-15, Table 1); 100–600? m thick

Tca — **Atrisco Member** (Pliocene)— Pink to yellowish-brown and reddish-yellow sandstone, mudstone, and minor pebbly sandstone; disconformably overlies Arroyo Ojito Formation (*Ton*) along western edge of map; locally erosional contact with overlying Rio Puerco Member (*Tcrp*) to northwest; upper contact with Rio Puerco Member gradational to south and southeast; named by Connell et al. (1998a) and revised by Connell (2008); 20–120 m thick

QTct — **Cochiti Formation** (lower Pleistocene–upper Miocene)—Light-brown sandstone and pebbly and cobbly sandstone derived from southeastern Jemez Mountains; exposed near northeastern flank of Santa Ana Mesa; gravels are predominantly mafic and intermediate volcanic; interfingers with basaltic lavas of Santa Ana Mesa (*Tb*) and axial-fluvial member of the Sierra Ladrones Formation (*QTsa*); usage after Smith and Kuhle (1998); base not observed but at least 50 m thick

middle

Tpc — **Cochiti Formation and Peralta Tuff Member of the Bearhead Rhyolite, undivided** (upper Miocene)—Pale-brown, tuffaceous conglomerate and sandstone exposed near northwestern flank of Santa Ana Mesa; contains pumice-bearing intervals, Apache tear obsidian, and lapilli and ash of the Peralta Tuff; pumice bed yielded single-crystal $^{40}Ar/^{39}Ar$ age on sanidine of 7.05 ± 0.06 Ma (SA-24, Table 1); 0–200 m thick

Arroyo Ojito Formation (upper Miocene)—Gravel-bearing fluvial deposits derived from southeastern Colorado Plateau, San Juan Basin, Sierra Nacimiento, and southern Jemez Mountains; named after Arroyo Ojito in northwestern part of map area (Connell et al. 1999; Connell 2008); exposures are 437–456 m thick at type area; divided into three members:

Top — **Picuda Peak Member**—Pinkish-gray to reddish-yellow cobbly sandstone and conglomerate exposed near north-central part of map area; contains abundant red granitic and gneissic, volcanic, and sandstone gravel; locally angular contact with underlying Loma Barbon Member; locally capped by petrocalcic soil with stage V pedogenic carbonate morphology (Rincones paleosurface, Connell 2008); 10–50 m thick

Tob — **Loma Barbon Member**—Pink to reddish-yellow sandstone, mudstone, and pebble to cobble conglomerate; contains abundant red granitic and gneissic gravel and scattered sandstone boulders; comformably overlies Navajo Draw Member; queried where inferred beneath Ceja Formation (*Tcs*) along the western flank of Santa Ana Mesa and east of the Tanaya fault (near Loma Barbon); contains fallout lapilli of the Peralta Tuff Member of the Bearhead Rhyolite (single-crystal $^{40}Ar/^{39}Ar$ ages on sanidine range from 6.85 to 7.14 Ma, SA-20 through SA-23, Table 1); 200 m thick

Ton — **Navajo Draw Member**—Yellowish-brown to pale-brown pebbly sandstone and yellow to reddish-yellow mudstone; contains abundant rounded chert and gray Oligocene tuff pebbles and cobbles; generally poorly exposed; basal contact is disconformable west of Zia fault; gradational and interfingering contact with Cerro Conejo Formation to east; 230 m thick

Tcc — **Cerro Conejo Formation** (upper–middle Miocene)—Pink to very pale brown, tabular and cross-stratified sandstone with thin- to medium-bedded mudstone; contains sandstone concretions and many volcanic fallout ashes (e.g., 11.3–10.8 Ma, SA-25 through SA-28, Table 1); K-Ar date on biotite of 13.64 ± 0.09 Ma immediately west of map area (Tedford and Barghoorn 1999); deposits also contain late Barstovian (SB-3, SB-4, Table 1) and Clarendonian mammalian fossils (Tedford et al. 2004); overlain by ~9.2–9.8 Ma basaltic lava flows of the Paliza Canyon Formation north of Jemez River (cf. Connell 2008); base is disconformable with the Zia Formation (*Tzr, Tzm*, Tedford and Barghoorn 1999); top may be disconformable with Arroyo Ojito Formation west of the Zia fault but interfingers with Navajo Draw Member (*Ton*) to east; originally proposed as a member of the Zia Formation but elevated to formation rank (Connell 2008); 245–316 m thick

lower

Zia Formation (lower Miocene)—Cross-stratified sandstone and mudstone; unconformably overlies Galisteo Formation (*Tg*) and Menefee Formation (*Kvm*) and unit of Isleta well #2 (*Tis*, geologic cross section, see Sheet 2); named by Galusha (1966) and Gawne (1981); contains late Arikareean through Hemingfordian mammalian fossils (SB-5, Table 1) indicating deposition from ~19.5 to 16 Ma (Tedford et al. 2004); divided into three members:

Tzr — **Cañada Pilares Member** (lower Miocene)—Red mudstone and sandstone; fluvial and lacustrine in origin; discontinuously exposed along western edge of map; conformably overlies Chamisa Mesa Member; named by Gawne (1981); 8–75 m thick

Tzm — **Chamisa Mesa Member** (lower Miocene)—Pale-brown to light-reddish-brown cross-stratified fluvial and eolian sandstone and mudstone; disconformably overlies Piedra Parada Member; 30 m thick west of Sand Hill fault; 200 m thick to east

Tzp — **Piedra Parada Member** (lower Miocene)—Whitish-gray to pinkish-gray cross-stratified sandstone; eolian in origin and deposited by prevailing westerly winds (Gawne 1981); base locally contains 0–1 m of chert-bearing pebbly sandstone with scattered cobble ventifacts of gray Oligocene andesitic tuff (Connell 2004); 70 m thick west of Sand Hill fault; 122 m thick to east

Tsp — **Older eastern basin-margin piedmont deposits, undivided** (Miocene–upper Oligocene?)—Pale-brown to reddish-brown conglomerate and sandstone with minor mudstone; contains abundant limestone and sandstone gravel derived from northern Sandia Mountains; dark-gray hornfels and hypabyssal intrusive clasts derived from the Ortiz Mountains (~15 km east of map area) increase in abundance to north on the Cuchilla de Escala; Ortiz-derived gravels not recognized on Lomos Altos; contact with overlying Sierra Ladrones Formation piedmont member (*QTsp*) in Arroyo de San Francisco is indistinct and inferred; correlative to (Miocene–upper Oligocene) Tanos and Blackshare Formations of Connell et al. 2002;150–800 m thick

PALEOGENE SEDIMENTARY

Tg — **Galisteo Formation** (Eocene)—Variegated red, green, purple, and gray mudstone with intercalated thin beds of yellowish-brown, crossbedded, arkosic sandstone and conglomerate deposited by east-flowing streams; exposed in northwestern corner of map; named by Stearns (1943) and restricted by Lucas et al. (1997); unconformably overlies Menefee Formation (*Kvm*); upper contact gradational with Oligocene Espinaso Formation (exposed ~5 km east of map); contains Duchesnean (Eocene) fossils (Lucas 1982); exposed thickness is 133 m in northwest corner of map; regional thickness increases to east and ranges from 22 to 979 m

Td — **Diamond Tail Formation** (Eocene–Paleocene?)—Dark-red and gray variegated sandstone and mudstone with scattered pebbly sandstone; named by Lucas et al. (1997); unconformably overlain by Galisteo Formation; contains Wasatchian (early Eocene–late Paleocene) mammalian fossils; unconformably overlies Menefee Formation (*Kvm*); exposed thickness is 133 m at Lomos Altos; regional thickness increases to east and ranges from 100 to 442 m

MESOZOIC SEDIMENTARY

Mesaverde Group

Kvp — **Mesaverde Group, Point Lookout Sandstone** (Upper Cretaceous)—Grayish-tan to light-yellow, very fine to fine-grained, massive quartzose sandstone with limonitic sandstone lenses and interbedded thin gray shale; 73 m thick

Kvm — **Mesaverde Group, Menefee Formation** (Upper Cretaceous)—White to light-yellow, fine- to medium-grained, well-sorted, lenticular, cross-stratified quartzose sandstone with interbeds of dark-gray to black siltstone and carbonaceous shale and coal; 205–365 m thick

Mancos Shale

Km — **Mancos Shale, undivided** (Upper Cretaceous)—Medium- to dark-gray and olive-gray shale, silty shale, and calcareous shale; divided into lower and upper Mancos Shale by Hosta–Dalton Sandstone (*Kmh*); upper shale includes thin, regionally recognizable marker beds such as the Greenhorn Limestone and Juana Lopez Member; upper shale is correlative to the Graneros–Niobrara interval of the southern High Plains and San Juan Basin; total thickness ranges from 330 to 675 m

Kms — **Mancos Shale, Semilla Sandstone** (Upper Cretaceous)—Dark-gray shale and tan to yellow, planar-laminated siltstone overlain by well-sorted, well-rounded, fine-grained and horizontally bedded sandstone; in lower part of Mancos Shale; 20 m thick

Kmh — **Mancos Shale, Hosta–Dalton Sandstone** (Upper Cretaceous)—Yellowish-gray to yellowish-tan, very fine to medium-grained, weakly cemented, fossiliferous sandstone with olive-brown sandstone lenses; includes Hosta and Dalton tongues of the Mancos Shale; separates upper and lower Mancos Shale; 64–112 m thick

Kd — **Dakota Formation** (Upper Cretaceous)—Light- to yellowish-gray and brown, silica-cemented quartzose sandstone; overlain by and interbedded with dark-gray to olive-gray shale of the Mancos Shale; unconformably overlies Morrison Formation (*Ju*); 8–40 m thick

Ju — **Jurassic sedimentary rocks, undivided** (Upper–Middle Jurassic)—Light-brown to pale-orange, cross-stratified sandstone; dark-gray, thinly laminated limestone; gray gypsum; brown silty sandstone; and pale-orange to grayish-red, variegated, feldspathic, cross-stratified sandstone, conglomerate, and mudstone; includes deposits of the San Rafael Group (Entrada, Todilto, and Summerville Formations) and Morrison Formation; unconformably overlies Chinle Group (*Ŧu*); 310 m thick

Ŧu — **Triassic sedimentary rocks, undivided** (Upper–Middle Triassic)—Red mudstone, trough crossbedded sandstone, and chert-bearing conglomerate with petrified wood and pale-orange, mica-bearing fluvial sandstone; includes deposits of the Chinle Group and Moenkopi Formation; unconformably overlies San Andres Formation (*Psg*); 400–500 m thick

PALEOZOIC SEDIMENTARY

Psg — **San Andres and Glorieta Formations, undivided** (Upper Permian)—Light-gray to tan, locally karstic limestone (San Andres Formation) and grayish-white, cross-stratified quartzose sandstone (Glorieta Formation); 15–77 m thick

Pay — **Abo and Yeso Formations, undivided** (Lower Permian)—Pale-red and grayish-red mudstone and grayish-white to light-orange, lenticular, cross-stratified arkosic sandstone, siltstone, claystone, and beds of gypsum and gypsiferous sandstone; unconformably overlies Madera Group (*IPm*); 500 m thick

IPm — **Madera Group, undivided** (Pennsylvanian)—Gray, ledge-forming, cherty limestone with interbedded argillaceous limestone of the Gray Mesa Formation; overlain by fossiliferous limestone with interbedded sandstone and mudstone of the Atrasado Formation; uppermost part of unit includes mixed marine carbonate and nonmarine clastic sediments; 385–402 m thick

IPs — **Sandia Formation and Arroyo Peñasco Group, undivided** (Pennsylvanian–Mississippian)—Locally preserved quartz-pebble conglomerate, sandstone, and dolostone (Arroyo Peñasco Group, Mississippian); disconformably overlain by interbedded brown clastic sandstone and gray limestone (Sandia Formation, Pennsylvanian); nonconformably overlies Proterozoic crystalline rocks; 37–81 m thick

CENOZOIC IGNEOUS

Qb5, Qb4, Qb3, Qb2, Qb1 — **Basaltic lavas of Albuquerque volcanoes** (middle Pleistocene)—Vesicular olivine tholeiite lava flows; named by Kelley and Kudo (1978); locally divided into five flows (*Qb1–Qb5*) based on surface morphology and stratigraphic position (modified from Kelley and Kudo1978); vents denoted by asterisk (*); whole-rock $^{238}U/^{230}Th$ age of 0.156 ± 0.02 Ma (Peate et al. 1996); generally less than 15 m thick

Tb / Tbv — **Basaltic lavas of Santa Ana Mesa** (upper Pliocene)—Tholeiitic flood basalts and vents (*Tbv*) of San Felipe volcanic field (Kelley and Kudo 1978); smaller vents denoted by asterisk (*); locally contains basal 0–2 m of stratified basaltic tuff; whole-rock $^{40}Ar/^{39}Ar$ ages of 1.78 ± 0.21 and 2.60 ± 0.11 Ma (SA-7 and SA-8, Table 1)

Tvc — **Tuff of Canjilon Hill** (upper Pliocene)—Oval-shaped tuff-breccia diatreme south of Santa Ana Mesa; intrudes Santa Ana Mesa Member (*Tcs*); includes undivided olivine basalt lavas, dikes, and brecciated lava flows; whole-rock $^{40}Ar/^{39}Ar$ age on dike of 2.54 ± 0.43 Ma (SA-9, Table 1)

Buried igneous rocks inferred from aeromagnetic anomalies (Pliocene or Miocene)—Probable buried intrusive or volcanic rocks recognized by areas of higher relative value (>180 nanoTesla) on high-resolution aeromagnetic anomaly maps (Kucks et al. 2001); encountered 360 and 452 m below land surface in drill holes CC1 and SWB1; igneous rocks also encountered beyond lateral limit of unit (454 and 692 m below land surface in drill holes SAF1 and BRTH)

Tvi — **Mafic dike** (Oligocene)—Dark-gray dike of mafic to intermediate composition; whole-rock $^{40}Ar/^{39}Ar$ age of 31.1 ± 0.5 Ma (SA-29, Table 1) for steeply dipping dike that is unconformably overlain by older eastern basin-margin piedmont deposits (*Tsp*) at southern end of Cuchilla de Escala; as much as 8 m thick

PROTEROZOIC IGNEOUS AND METAMORPHIC

Ys / Yss — **Sandia granite** (Mesoproterozoic)—Pink megacrystic biotite monzogranite and granodiorite; intrudes older granite (*Xg*) and schist (*Xs*); includes zones of sheared megacrystic biotite monzogranite and granodiorite of the Seven Springs shear zone (*Yss*) just north of trace of Tijeras fault zone; U-Pb dating on zircon indicates age of crystallization between 1,455 ± 12 Ma and 1,446 ± 26 Ma (Read et al. 1995)

Felsic dike (Mesoproterozoic)—Pegmatite and aplite dikes, pods, and lenses; coeval with emplacement of Sandia granite (*Ys*); thickness ranges from 30 cm to more than 15 m; as much as 1,600 m in length

Xg — **Older granite, undivided** (Paleoproterozoic)—Isolated screens and xenoliths of banded, biotite-rich granitic gneiss intruded by the Sandia granite (*Ys*); also contains leucocratic and aplitic granite and biotite-poor granite; includes Manzanita granite and Cibola granite (gneiss) (Karlstrom et al.1994); U-Pb dating on zircon indicates age of crystallization between 1,645 ± 16 Ma and 1,653 ± 21 Ma (Karlstrom et al. 2004)

Xv — **Metavolcanic rocks, undivided** (Paleoproterozoic)—Metarhyolite, felsic metavolcanic, mafic metavolcanic, and metamorphosed dacitic tuff; intruded by older granite (*Xg*); not dated in map area, but U-Pb dating on zircon from the nearby Monte Largo Hills (~11 km east of map area) metarhyolite indicates an age of crystallization of 1,700 ± 20 Ma (Karlstrom et al. 2004)

Xs — **Schist, undivided** (Paleoproterozoic)—Pelitic schist and phyllite; locally quartz bearing; commonly crenulated; zones of phyllite- to andalusite-bearing schist, to biotite and sillimanite schist characterize metamorphic aureole with Sandia granite (*Ys*) on Rincon Ridge; whole-rock Rb–Sr age of metamorphism is 1,640 ± 40 Ma (Brookins and Majumdar 1983, cited in Kirby et al. 1995)

Xq — **Metasedimentary rocks, undivided** (Paleoproterozoic)—Gray to white, thick-bedded to massive, cross-stratified quartzite with pelitic partings and interbeds; includes Isleta metasediments and Cerro Pelon, Coyote, and Cibola quartzite (Karlstrom et al. 1994); U–Pb age on zircon of metasedimentary rock is 1,423 ± 2 Ma