Description of Map Units

Map unit descriptions are summarized from descriptions in source maps and modified to reflect general characteristics of the unit across the Albuquerque 30' x 60' quadrangle. Thin deposits of loess are widespread in the region but are not depicted on the map compilation. Carbonate soils are also present on most bedrock and surficial units but are not mapped. Soils are described using the morphogenetic stage classification system of Gile and others (1966) as modified by Birkeland (1984). Color terms are descriptive of fresh rock/sediment material. Grain-sizes of sediment particles are defined using the standard Wentworth size-distribution scale.

NOTE: Several distinctive rock types are present in many fluvial and alluvial deposits within the Rio Grande rift, and the most durable and hardest clasts increase in proportion to others in progressively younger fluvial terrace deposits (due to winnowing). One durable and distinctive clast (vernacular term: "Pedernal chert") consists of dense, banded siliceous concretion-like material that forms irregular lumpy and convolute shapes. It may have been eroded from the Miocene Pedernal Chert Member of the Abiquiu Tuff that was deposited north of the Jemez Mountains. Other durable clasts consist of dense, hard quartzose metamorphic rocks (vernacular term: "quartzite"), which include banded and massive (gray, brown, tan) varieties; few of these rocks are true metaquartzite derived from quartz-cemented quartz arenite.

RIVER ALLUVIUM OF THE RIO GRANDE

Qrc Alluvial deposits in engineered channels (Holocene) – Sand, silt, and gravel beneath the modern channel of the Rio Grande; commonly submerged under flowing stream. Channel is partially confined by artificial levees north of Bernalillo and mostly confined between levees farther south near Albuquerque

Qra Floodplain deposits of the Rio Grande, Rio Puerco, and Jemez River (Holocene) – For Rio Grande and Jemez River, consists of unconsolidated light brown, coarse sand and round pebble to granule gravel with subordinate lenses of fine sand, silt, and clay. For Rio Puerco, consists of grayish-yellow, thin- to thick-bedded silt and interbedded yellowish-gray clay. Locally interlayered with side-stream deposits of units Qa and Qay. Partly equivalent to the informal Los Padillas (allo)formation of Connell and Love (2001). Thickness variable but as great as 40 to 65 feet (12 to 20m) in floodplain borings; rests on Pleistocene cobble gravel in subsurface.

Qry Young river alluvium (upper Pleistocene) – Poorly consolidated deposits of light brown sandy pebble to cobble gravel that underlies lowest terrace of the Rio Grande with upper surface about 20 m above modern floodplain (the Primero Alto surface of Lambert, 1968; deposit partly equivalent to the informal Edith (allo)formation of Lambert, 1968). Uppermost gravel deposit moderately cemented by soil carbonate coatings on clasts. Thickness highly variable but locally as great as 100 feet (30m). Terrace probably formed during enhanced river discharge related to glacial climate of marine oxygen-isotope stage 2

(Stone and others, 2001a, b) at about 10 to 25 ka. Deposits are commercially significant sand and gravel resources in the valley

Qrm Medial-age river alluvium (middle Pleistocene) – Light brown to yellowish brown, poorly to moderately consolidated cobble and pebble gravel, sand, silt, and minor clay. Deposits form multi-storey alluvial fills beneath second fluvial terrace along the Rio Grande with upper surface about 130 feet (40m) above the modern floodplain (the Segundo Alto surface of Lambert, 1968; deposits are largely equivalent to the informal Los Duranes and Menaul (allo)formations of Lambert, 1968). Uppermost gravel deposit moderately cemented by carbonate coatings on clasts. Thickness highly variable but locally as great as 200 feet (60m). Terrace probably formed during enhanced river discharge related to glacial climate of marine oxygen-isotope stage 6 (Stone and others, 2001a, b) at about 130 to 140 ka. Terrace-fill interbedded with distal flows from the Albuquerque volcanoes, erupted at about 156 ka (Peate and others, 1996). Deposits are commercially significant sand and gravel resources in the valley

Qro Old river alluvium (middle to lower Pleistocene) – Moderately consolidated deposits of cobble to pebble gravel and light brown to yellowish-brown, medium- to coarse-grained pebbly sand. Relict calcareous soils display stage III-IV morphology in Bk horizons. Deposits are poorly preserved along the west side of the Rio Grande at altitudes that suggest the fluvial terrace they formed was about 300 feet (90 m) above the modern floodplain (the Tercero Alto surface of Bachman and Machette, 1977). Upper parts of correlated terrace-fill deposits upstream (Smith and Kuhle, 1998) and downstream (Connell and Love, 2001) contain tephra from the Lava Creek B eruption at about 665 ka. Terrace probably formed during enhanced river discharge related to glacial climate of marine oxygen-isotope stage 16 (Stone and others, 2001a, b) at about 620 to 640 ka

Qroc Older river alluvium (lower Pleistocene) – Light grayish-brown coarse, heterolithic bouldery gravel, and light brown to yellowish-gray sand, cobble gravel, pebbly sand, and silt; weakly cemented, moderately sorted; coarse sand deposits typically display conspicuous planar and trough cross-bedding at meter scale. Gravel clasts are highly diverse and include fine-grained quartzose metamorphic rocks, metaquartzite, granite and mylonite gneiss, intermediate and felsic volcanic porphyries, basalt, quartz sandstone, limestone, “Pedernal chert”, and petrified wood as well as conspicuous pebbles and cobbles of Bandelier Tuff pumice. Top of these deposits forms an extensive terrace surface at Albuquerque International Airport (the Cuarto Alto surface of Stone and others, 2001a, b; Sunport surface of Lambert, 1968, and Bachman and Machette, 1977) about 370 feet (110m) above the modern floodplain. North and east of Bernalillo, the uppermost fluvial deposits that contain Bandelier pumice are similarly situated above the local Rio Grande floodplain, although the relict terrace surface is covered by younger piedmont-slope materials (Cather and others, 2000). Relict calcareous soils display stage III-IV morphology in Bk horizons. Vertebrate fossils recovered from this unit are early Irvingtonian (early Pleistocene; Morgan and Lucas, 2000); clasts and tephra of the older and younger Bandelier Tuff eruptions indicate the terrace-fill deposits accumulated over an extended period of early Pleistocene time between about 1.6 Ma and 1.2 Ma. Thickness highly variable, but may exceed 400 feet (120m) in total. Deposits are commercially significant sand and gravel resources in the valley

Qrpo Interlayered fluvial and piedmont-slope deposits (lower Pleistocene) – Shown only where piedmont-slope deposits (unit Qpo) overlie older river alluvium of the Rio Grande (Qroc), east and south of Bernalillo; eastern limit coincides with eastern exposed limit of oldest river alluvium of the Rio Grande

STREAM ALLUVIUM OF TRIBUTARY DRAINAGES

[Soils are similar to those formed in Rio Grande fluvial deposits of similar age; refer to those unit descriptions for details]

Qa Tributary-stream alluvium (Holocene) – Unconsolidated light brown to yellowish-brown sand, silt, and gravel beneath tributary arroyos and small alluvial fans marginal to the Rio Grande floodplain.

Qty Young tributary-stream alluvium (upper Pleistocene) – Poorly consolidated sand, silt, and gravel deposits in low terraces that flank tributary streams. In the Galisteo Creek drainage, unit consists of three strath and fill terraces about 6 to 30 feet (2 to 9m) above creek level. Unit may locally include some Holocene deposits. Thickness variable

Qtm Medial-age tributary-stream alluvium (middle Pleistocene) – Partly consolidated sand, silt, and gravel deposits in intermediate terraces that flank tributary streams. In the Galisteo Creek drainage, unit consists of two terraces about 45 and 63 feet (14 and 19m) above creek level. Thickness variable

Qto Old tributary-stream alluvium (middle to lower Pleistocene) – Partly consolidated sand, silt, and gravel deposits in high terraces that flank tributary streams. In the Galisteo Creek drainage, unit consists of two or more terraces 100 to185 feet (30 to 55m) above creek level. Thickness variable

ALLUVIAL DEPOSITS ON ERODED SLOPES

Qay Young slope alluvium (upper Pleistocene) – Poorly consolidated deposits of light brown to yellowish-brown sand, sandy clay, and local gravel. Deposits form low-gradient alluvial slopes adjacent to floodplains of Rio Grande and major tributary drainages, and form the youngest stream channels and terraces along minor tributary valleys. Calcareous soils weakly developed

Qam Medial-age slope alluvium (middle Pleistocene) – Poorly consolidated deposits of light yellow to brown sand, silt, and local gravel that cover extensive low-gradient alluvial slopes throughout the quadrangle. Calcareous soils moderately developed, display Stage II-III morphology in Bk horizon. Unit may locally include some upper Pleistocene deposits. In the western part of Estancia Basin, geomorphic position allows local subdivision into:

Qam2 Younger medial-age slope alluvium

Qam1 Older medial-age slope alluvium

Qao Old slope alluvium (middle to lower Pleistocene) – Moderately consolidated deposits of light to dark brown sand, silty loam, and boulder to cobble gravel. Calcareous soils strongly developed and display Stage III-IV morphology in Bk horizon

PIEDMONT-SLOPE ALLUVIAL DEPOSITS WEST OF SANDIA CREST

Qpy Young piedmont-slope alluvium (upper Pleistocene) – Poorly consolidated deposits of sand and gravel in low geomorphic positions; contain subangular boulder and cobble gravel near Sandia Mountain front. Calcareous soils weakly developed

Qpm Medial-age piedmont-slope alluvium (middle Pleistocene) – Poorly consolidated deposits of sand and gravel in intermediate geomorphic positions; gravels contain subangular clasts near Sandia Mountain front. Calcareous soils moderately developed, display Stage II-III morphology in Bk horizon. Unit may locally include some upper Pleistocene deposits.

Qpo Old piedmont-slope alluvium (middle to lower Pleistocene) – Moderately consolidated deposits of sand and gravel in high geomorphic positions near the Sandia Mountain front; deposits are chiefly erosional remnants inset by younger piedmont-slope units. Clasts commonly show physical deterioration; calcareous soils strongly developed and display Stage III-IV morphology in Bk horizon

QTp Older piedmont-slope alluvium (lower Pleistocene to upper Pliocene?) – Light brown, red-brown, and yellowish-brown deposits of conglomerate, conglomeratic sandstone, sandstone, and minor siltstone and mudstone eroded from Sandia Mountain uplift. Gravel clasts chiefly consist of subangular limestone, metamorphic rocks, granite, and minor Paleozoic sandstone, with some igneous porphyry and hornfels from Ortiz Mountains in the Hagan Basin area. Age poorly known; base arbitrarily defined north of Placitas but top includes 1.6 Ma tephra of Bandelier Tuff (Smith and Kuhle, 1998; Cather and others, 2000).

QTu Mixed alluvial and eolian material and calcareous soils (lower Pleistocene to upper Pliocene) – Mixed sheetwash, eolian sand, and colluvium. Unit forms extensive geomorphic surface (Llano de Albuquerque) in the southwestern part of the map. Unit forms local composite wedge-shaped deposits on top of down-thrown fault blocks of Santa Fe Group; multiple buried calcareous soils attest to repeated stages of stability following fault displacement (Wright, 1946; Machette, 1978a). Deposits locally as thick as 35 feet (11m); soils typically strongly developed and may include several Bk horizons with stage IV morphology.

FLUVIAL AND LACUSTRINE DEPOSITS OF ESTANCIA BASIN

Qsg Shoreline gravel and sand (upper middle Pleistocene) – Pebble to cobble gravel and light brown to reddish-brown coarse sand. Larger clasts are subangular to subrounded and chiefly consist of porphyry, hornfels, limestone, and sandstone. Current and foreset cross-bedding indicate current and shoreline-wave transport toward the east and northeast. Deposit forms a narrow, north-trending band poorly exposed on gentle slopes west of Moriarty. Interpreted to represent a shoreline (beach) deposit that formed along the edge of a pre-Late Pleistocene stand of pluvial Lake Estancia at approximately 6,340 feet elevation (1,932m) or slightly higher (probably Bull Lake or Illinoian in age, which culminated at 130-140 ka; Cole and others, 2002). Thickness about 20 to 50 feet (6 to16m)

Qfl Fluviolacustrine sand (upper middle Pleistocene) – Light to dark brown and reddish-brown, thick-bedded silty fine sand with scattered thin beds (1-3 feet; less than 1 m) of pebbly sand and sparse scattered pebbles. Interpreted to be deposits of pluvial Lake Estancia formed during a pre-Late Pleistocene stand (Bull Lake or Illinoian in age, which culminated at 130-140 ka; Cole and others, 2002). Thickness about 20-40 feet (6-12 m); deposit covered nearly everywhere by unmapped eolian silt (loess)

MINOR SURFICIAL UNITS

Qe Eolian sand (Holocene to middle Pleistocene) – Wind-blown deposits of sand and minor silt, light yellowish-brown, well sorted; forms sand sheets and minor dune complexes, primarily west of Rio Grande. Locally subdivided as:

Qey Younger eolian sand (Holocene to upper Pleistocene) – Locally active dune fields with complex topography; deposits show minimal soil development

Qem Older eolian sand (middle Pleistocene) – Inactive deposits lacking topographic expression; calcareous soils have Stage I and II morphologies

Qae Eolian sand and slope-wash alluvium, undivided (Holocene to middle? Pleistocene) – Light brown, poorly consolidated sand and silt with scattered pebbles; deposits form discontinuous mantles on upland surfaces throughout the area. Soil development weak to moderate

Qc Colluvium (Holocene to middle? Pleistocene) – Poorly sorted, unconsolidated to partly consolidated, coarse- to fine-grained, weathering debris on steep slopes

Qac Colluvium and alluvium, undivided (Holocene to middle? Pleistocene) – Poorly sorted, poorly consolidated mixture of sand, silt, and angular gravel derived from mass-movement slope processes and rain-wash. Commonly mixed with eolian sand and silt

Qbt Basalt talus (Holocene to middle? Pleistocene) – Chaotic deposits of large, angular blocks of basalt with sand, eolian silt, and basalt rubble that form on slopes immediately below basalt-capped mesas due to slope retreat and mass-wasting

Ql Landslide deposits (upper to lower? Pleistocene) – Poorly consolidated, very poorly sorted fine- to very coarse-grained deposits formed by mass movement processes on steep slopes. Some landslides along the margin of

Santa Ana Mesa are semi-coherent slides capped by slightly rotated basalt flow remnants (Toreva blocks)

SEDIMENTARY UNITS

Santa Fe Group – Pliocene units

[Pliocene units of the Santa Fe Group are largely coeval but differ in clast composition because they were transported from distinct source areas; they are typically interbedded where two occur together and contacts are inherently arbitrary at map scale]

Tc Ceja Formation (Pliocene) – Light gray and light brownish-gray gravel, reddish-yellow sandy gravel and sand, and reddish-brown silt; thin- to medium-bedded, locally cross-bedded; moderately well sorted sands and gravels; weakly to moderately cemented. Maximum gravel-clast size variable, ranging from pebble to boulder (locally as great as 2.5 feet; 0.8m), and clasts tend to be largest and most diverse toward the north and northwest. Paleocurrent indicators show transport direction was chiefly southward in the Rincones de Zia area (Connell and others, 1999) and toward the east and southeast in the El Rincon and Arroyo de los Montoyas areas (Personius and others, 2000; Cole and others, 2001a; Cole and Stone, 2002). Clasts consist of volcanic porphyries, granite, aphanitic quartz-rich metamorphic rocks, Cretaceous sandstone, chert, and minor petrified wood, limestone, and basalt. Base of Ceja is an erosional unconformity, locally an angular unconformity, marked by significant increase in average and maximum grain-size (relative to underlying Santa Fe Group sediments) and by change in paleocurrent directions (Wright, 1946; Cole and others, 2001a). Thickness variable, but as great as about 225 feet (75m) in the quadrangle. Unit redefined here based on Ceja Member of Santa Fe Formation of Kelley (1977); largely equivalent to “Upper buff” member of Bryan and McCann (1937), Wright (1946), and Lambert (1968).

Tt Tuerto Gravel (Pliocene) – Yellowish- to reddish-brown and light red, moderately consolidated pebble to cobble conglomerate and pebbly sandstone with scattered boulders, and some interbedded silty-muddy fine sandstone; matrix of conglomerate is mostly poorly sorted fine- to coarse-grained sandstone. Deposits form large alluvial fans; larger clasts are mostly subangular-subrounded porphyritic intrusive rocks from the nearby Ortiz Mountains, plus hornfels and minor quartzite, chert, sandstone, and limestone. Base of Tuerto is a sub-regional erosion surface (Ortiz pediment surface of Bryan, 1938; lower Ortiz surface of Stearns, 1979) that was cut across Tertiary, Mesozoic, and Paleozoic rocks in and around the Ortiz Mountains. Dense calcrete with stage IV carbonate-soil morphology is conspicuous on upper surface. Thickness variable, but typically 40 to 100 feet (12 to 30m) in little-eroded exposures. Unit is the Tuerto Gravel of Stearns (1953).

Ta Ancha Formation (Pliocene) – Light pink to light yellowish-brown, poorly to moderately consolidated gravel, sandy gravel, pebbly sand, and minor silt that form a complex alluvial fan west of Sangre de Cristo Range. Large clasts are subangular to subrounded and chiefly consist of granite with minor amphibolite, diorite, quartz-rich metamorphic rock, and biotite gneiss eroded from the Sangre de Cristo Mountains. Base of the Ancha is a sub-regional erosion surface (Ortiz pediment surface of Bryan, 1938; lower Ortiz surface of Stearns, 1979) that was cut into Tertiary rift-fill deposits (Tesuque Formation) and older units on the east side of the Espanola basin, mostly north of Galisteo Creek. The Ancha is interfingered with the Tuerto Gravel where the two alluvial-fan deposits mingle in the center of the Pliocene depositional basin. Calcareous soils typically have stage II to III+ Bk morphology (Koning and others, 2001). Thickness variable, but typically about 30 to 130 feet (10 to 40m). Unit is the Ancha Formation of Spiegel and Baldwin (1963)..

Tct Cochiti Formation (Pliocene and(?) upper Miocene) – Very pale brown, coarsely bedded, fine- to coarse grained, volcaniclastic sandstone and sandy pebble-cobble gravel; poorly to moderately sorted. Cross-bedding and imbricated clasts indicate transport toward south and southeast, consistent with abundance of volcanic clasts eroded from Jemez Mountains to the north (Smith and Kuhle, 1998; Personius, 2002). Cochiti Formation is interbedded with sand and pebble gravel of the Ceja formation, which were transported from more diverse source areas farther northwest; Cochiti only compiled in small areas around the margins of Santa Ana Mesa. Unit includes beds with abundant pumice clasts correlated with the 6.8 Ma Peralta Tuff Member of Bearhead Rhyolite (Personius, 2002). Unit is the Cochiti Formation of Smith and Lavine (1996).

Santa Fe Group – Pre-Pliocene units, Albuquerque Basin

Tm "Middle red" formation (upper Miocene) – Varicolored, dominantly fluvial deposits of sandstone, silty sandstone, and mudstone, with thin, discontinuous pebble-gravel lenses near source areas northwest of the quadrangle. Unit is modified in rank from the "Middle red" member of Bryan and McCann (1937). Compiled as undivided unit near Bernalillo and in the drainage of Arroyo de los Montoyas and Arroyo de las Calabacillas where exposure is poor. Subdivided in badlands exposures around the north and west margins of the Llano de Albuquerque, as follows:

Tmb Loma Barbon Member – Reddish-yellow, tan, and yellowish-brown, poorly to moderately well sorted, thin- to thick-bedded, fine- to medium-grained sandstone, pebbly sandstone and siltstone. Unit is finer grained in the lower three-fourths and overall toward the south and east; pebble conglomerate lenses are present in the upper fourth of the section at Arroyo Ojito and include clasts of granite, volcanic porphyries, quartz sandstone, chert, and quartzite. Paleocurrent indicators show transport direction was chiefly toward the east and southeast in the Rincones de Zia area (Connell and others, 1999) and southward in the El Rincon and Arroyo de los Montoyas areas (Personius and others, 2000; Cole and others, 2001a; Cole and Stone, 2002). Thickness about 550 feet (200m) at Arroyo Ojito (Connell and others, 1999). Unit is the Loma Barbon Member of Connell and others (1999). The informal Atrisco member defined by Connell and others (1998) from subsurface data in west-central Albuquerque probably correlates in part with the Loma Barbon Member

Tmn Navajo Draw Member – Light brown to pale yellow, poorly sorted, thin- to thick-bedded, medium-grained sandstone and pebbly sandstone, with minor interbeds of siltstone and mudstone. Pebbles consist of quartz sandstone, chert, red granite, porphyritic volcanic rock, and "Pedernal chert" (Connell and others, 1999). Pebbly units form shallow channel-fills in finer grained sediments. Navajo Draw appears conformable on Cerro Conejo member in the northwest corner of the quadrangle (Tedford and Barghoorn, 1999). Thickness as great as 820 feet (250m). Unit is the Navajo Draw Member of Connell and others (1999).

Tmc Cerro Conejo Member (middle Miocene) – Light brown, pink and yellowish-red, fine- to medium-grained, well sorted, fluvial lithic arkose with minor reddish-yellow mudstone interbeds. Three-fold subdivision (not mapped) is generally evident: lower cross-bedded eolian and fluvial sandstone (about 330 feet; 100m), a middle concretionary sandstone with five or more ash beds (about 230 feet; 70m), and an upper cross-bedded fluvial sandstone (about 430 feet; 130m). Volcanic ash in the middle subunit is 13.6 Ma, and varied vertebrate fossils are typical of the late Barstovian interval at 12-14 Ma. Base of the Cerro Conejo appears to be a disconformity representing at least a million-year gap in sedimentation in the Canada Pilares area (Tedford and Barghoorn, 1999). Total thickness about 1,000 feet (300m). Unit is the Cerro Conejo Member of Tedford and Barghoorn (1999).

Tz Zia Formation (middle to lower Miocene) – Gray to reddish-gray, well sorted eolian sandstone with minor lacustrine and fluvial sandstones and mudstones. Thickness about 1,000 feet (300m). Unit defined by Galusha (1966) and modified by Gawne (1981) and Tedford and Barghoorn (1999). Subdivided as follows:

Tzc Chamisa Mesa Member and Canada Pilares Member, undivided (middle and lower Miocene) – Light yellow, fine-grained cross-bedded, well sorted sandstone, silty sandstone, and siltstone. Dominantly eolian, with interbedded sandy fluviatile and lacustrine beds. The upper part of this unit (Canada Pilares Member) contains laterally persistent beds of green claystone and associated limestone marked by dessication cracks (Tedford and Barghoorn, 1999). Thickness about 600 to 700 feet (180 to 210m)

Tzp Piedra Parada Member (lower Miocene) – Light gray, fine- to medium-grained, well sorted cross-bedded sandstone with discontinuous thin interbeds of pink, muddy sandstone and greenish calcareous mudstone. Unit is dominantly eolian dune sand, with fluviatile and lacustrine beds deposited between dunes; base of unit is an unconformity marked by conspicuous 1 to 3 cm ventifacts of gray volcanic porphyry. Thickness about 400 feet (120m)

Santa Fe Group – Pre-Pliocene units, Hagan Basin

Tbh Blackshare Formation (Miocene) – Pink to light-brown, fine- to coarse-grained, massive to thin-bedded sandstone with lenticular, discontinuous beds of granule to pebble conglomerate and reddish-brown mudstone. Clasts are chiefly porphyritic intrusive rocks and hornfelsed shale eroded from the Ortiz porphyry belt and footwall of La Bajada fault; paleocurrent indicators show fluvial transport toward the west. Base is gradational into Tanos formation and is marked by increase in conglomeratic beds upward. Blackshare Formation contains 11.6 Ma tephra in upper part. Thickness at least 1,800 feet (550m), although top not defined (Cather and others, 2000). Description based on Connell and Cather (2001) and Connell and others (2002).

Tth Tanos Formation (lower Miocene to upper Oligocene) – Sandstone, mudstone, and conglomerate that unconformably overlie the Espinaso Formation in the Hagan Basin. Lower conglomeratic subunit consists of hornfels and porphyry clasts eroded from Ortiz Mountains and contains 25.4 Ma basalt flow near base. Middle mudstone-dominated subunit contains freshwater limestone beds and probably accumulated in lake environment. Upper subunit marked by tabular fluvial sandstones, which grades into overlying Blackshare Formation. Thickness about 830 feet (250m) adjacent to Espinaso Ridge on west side of Hagan Basin; description based on Connell and Cather (2001) and Connell and others (2002).

PRE-MIOCENE SEDIMENTARY UNITS

Te Espinaso Formation (Oligocene and upper Eocene) – Gray and light-brown, andesitic-latitic, tuffaceous sandstone, volcaniclastic conglomerate, and volcanic debris-flow deposits; includes some ash-flow tuff and ash- and pumice-flow deposits. Lower part is calc-alkaline and upper part is alkaline (Erskine and Smith, 1993). Deposited around volcanic vent complexes of the Ortiz porphyry belt. Espinaso contains a 26.9 Ma nepheline latite flow near its top (from Connell and Cather, 2001). Thickness about 1,400 feet (430m) at Espinaso Ridge (Cather and others, 2000)

Tg Galisteo Formation (Eocene) – Variegated yellow, white, and red cross-bedded arkosic sandstone and pebbly sandstone, red and green mudstone, and channel conglomerate. Pebbles and cobbles consist of quartzite, chert, limestone, granite, and sandstone eroded from Laramide fault-block uplifts and deposited in a northeast-trending basin. Thickness highly variable, but locally greater than 4,000 feet (1,200m) in drillholes (Cather, 1992)

Tdt Diamond Tail Formation (lower Eocene to upper(?) Paleocene) – Yellow, orange, and gray, medium- to coarse-grained arkose and subarkose, commonly cross-bedded; with variegated gray, purplish and maroon mudstone. Local conglomeratic beds contain quartzite and chert pebbles; unit contains some petrified wood and ironstone concretions. Deposited in broad floodplains and alluvial channels in Laramide foreland basin; base is erosional unconformity on Cretaceous and older units. Thickness about 450 feet (140m) but variable (Cather and others, 2000). Unit defined by Lucas and others (1997).

MESOZOIC SEDIMENTARY UNITS

Mesaverde Group

Kmv Mesaverde Group, undivided (Upper Cretaceous) – Dark gray and olive-gray shale and light yellow and light brown sandstone; contains coal seams in upper part. Dominantly nonmarine strata. Thickness more than 1,000 feet (300m); locally subdivided as follows:

Kme Menefee Formation – Gray, light brown and orange-brown sandstone with gray and olive-gray shale and coal. Thickness about 1,250 feet (380m)

Kmch Medial sandstone member – Light gray and light brown medium-grained, well sorted, cross-bedded fluvial sandstone. Designated as the "Cliff House Tongue" in the Hagan Basin (Cather and others, 2002) and as "Harmon Sandstone" in the Madrid area (Maynard and others, 2001). Thickness about 330 feet (100m)

Kpl Point Lookout Sandstone – Light gray, light brown, and drab yellow, fine- to medium-grained sandstone with thin interbeds of gray shale. Thickness 125 to 300 feet (40 to 90m)

Kcc Crevasse Canyon Formation, undivided – Dark gray and olive-gray shale with gray, yellow, and brown sandstone and coal. Thickness about 800 feet (240m). Subdivided where appropriate as:

Khd Hosta Tongue of Point Lookout Sandstone and Dalton Sandstone Member, undivided – Yellow-gray and yellowish-brown, fine- to medium-grained moderately cemented sandstone with minor olive-brown shale lenses. Thickness 220 to 370 feet (67 to 110m)

Kcdc Dilco Coal Member – Dark gray carbonaceous shale, silty and sandy shale, and coal. Thickness 0 to 100 feet (0 to 30m)

Kg Gallup Sandstone (Upper Cretaceous) – Yellowish-gray and yellow, medium- to coarse-grained cross-bedded sandstone. Youngest major regressive marine sandstone deposit in the region. Thickness 0 to 60 feet (0 to 18m)

Mancos Shale

Km Mancos Shale, undivided (Upper Cretaceous) – Marine shale and littoral sandstones; dominantly gray to olive-gray sandy shale, yellowish sandstone, and argillaceous limestone. Major marine unit that reflects the youngest (last) marine deposition in the region. Subdivided as follows:

Kms Satan Tongue of the Mancos Shale – Dark gray to olive-gray shale, silty shale, and subordinate very fine grained and fine grained sandstone with local gypsum. Thickness 240 to 440 feet (75 to 135m)

Kps Point Lookout Sandstone (Mesaverde Group) and Satan Tongue of the Mancos Shale, undivided

Kmm Mulatto Tongue of the Mancos Shale – Dark to light gray and olive-gray shale, silty and sandy shale, and fine-grained ripple-marked sandstone. Lateral equivalent of El Vado Sandstone Member (Landis and Dane, 1967). Thickness 380 to 500 feet (115 to 150m)

Kmz Montezuma Valley Member – Gray to olive-gray, well indurated, slightly silty-sandy calcareous shale with numerous septarian concretions, carbonaceous plant material, and ammonites (Leckie and others, 1997). Thickness about 165 feet (50m) in this area

Kmn Niobrara Shale Member – Yellowish-brown to gray, thin-bedded sandy marine shale containing brown calcareous concretions as large as 2-feet in diameter. Total thickness of Niobrara is variable, 280 to 1,350 feet (85 to 410m)

Kmns Sandstone lentil – Light yellowish-gray, thin-bedded sandstone. Thickness about 110 feet (33m)

Kmj Juana Lopez Member – Gray to light yellowish-brown fetid calcareous silty shale and fossiliferous calcarenite. Thickness 3 to 100 feet (1 to 30m)

Kml Mancos Shale, lower part, undivided (Upper Cretaceous)

Kmse Semilla Sandstone Member – Discontinuous lenses of yellowish-gray and light brown, very fine- to coarse-grained, cross-bedded sandstone. Thickness 0 to 60 feet (0 to 18m)

Kmc Carlile Member – Medium-gray, thin-bedded marine shale. Thickness 300 to 370 feet (90 to 110m)

Kmb Bridge Creek Limestone Member – Medium-gray calcareous marine shale. Thickness about 190 feet (60m)

Kmg Graneros Member – Medium-gray marine shale. Thickness about 190 feet (60m)

Kmgg Greenhorn Limestone Member and Graneros Member, undivided – Greenhorn Limestone Member is thin-bedded argillaceous marine limestone with interbedded calcareous shale. Total thickness 210 to 230 feet (66 to 72m)

Kmd Mancos Shale and Dakota Sandstone, undivided

Kd Dakota Sandstone, undivided (Upper Cretaceous) – yellowish-gray to yellowish-orange, fine- to medium-grained sandstone and silty sandstone with local pebble conglomerate lenses. Littoral-sand body, interbedded with variable amounts of marine Mancos Shale. Dakota is major transgressive unit that marks the initial Cretaceous marine flooding of the continental interior. Total thickness variable from 25 to 270 feet (7 to 70m); locally subdivided as:

Kdt Twowells Tongue – Yellowish-gray, lenticular fine-grained sandstone; as compiled, map unit includes the Whitewater Arroyo Tongue of the Mancos Shale. Thickness 0 to 50 feet (0 to 18m)

Kdp Paguate Tongue – Yellowish-gray, fine- to medium-grained sandstone; as compiled, map unit includes the Clay Mesa Tongue of the Mancos Shale. Thickness about 100 feet (30m)

Kdtp Twowells and Paguate Tongues, undivided

Kdc Cubero Tongue – Yellowish-orange, fine- to medium-grained slabby thin-bedded sandstone with conspicuous bioturbation. May include Oak Canyon Member of Dakota Sandstone in western part of map area. Thickness about 120 feet (35m)

Jm Morrison Formation, undivided (Upper Jurassic) – Gray, white, and light brown quartz-rich and arkosic sandstone with gray, green, maroon, and light brown mudstone, and minor conglomerate. Thickness about 850 feet (260m)

Jmj Jackpile Sandstone Member – Gray to white, kaolinitic fine- to coarse-grained, quartzose, cross-bedded sandstone and grayish-green and maroon mudstone. Thickness about 200 feet (60m)

Jmb Brushy Basin Member – Gray, green, and maroon mudstone with minor gray and light-brown, fine- to medium-grained sandstone. Thickness about 450 feet (135m)

Jmjb Jackpile Sandstone and Brushy Basin Members, undivided

Jms Salt Wash(?) Member – Gray to light yellowish-brown, coarse-grained, cross-bedded fluvial sandstone with minor grayish-green and light brown mudstone, and sparse conglomerate lenses. Thickness about 200 feet (60m)

Jw Wanakah Formation (Middle Jurassic) – Light-red, fine-grained sandstone and red to greenish-gray mudstone with minor thin beds and nodules of limestone. Where possible, compiled as separate unit from Morrison Formation. Thickness about 160 feet (50m)

Jwt Todilto Member– Upper part is white to gray, bedded and nodular gypsum, about 215 feet (65m) thick, equivalent to the Tongue Arroyo Member of the Todilto Formation of Lucas and others (1995). Lower part is gray, fetid, micritic limestone containing dark brown to black carbonaceous mudstone and thin gypsum beds; about 20 feet (6m) thick; equivalent to Luciano Mesa Member of the Todilto Formation of Lucas and others (1995)

Je Entrada Sandstone (Middle Jurassic) – Upper part is yellowish-gray, light orange and light brown, fine- to medium-grained, weakly cemented cross-bedded and tabular-bedded sandstone, 35 to 65 feet (10 to 20m) thick (assigned to Slick Rock Member by Lucas and others, 1995). Lower part is reddish-brown siltstone and sandstone; 66 to 80 feet (20 to 25m) thick (assigned to Dewey Bridge Member by Lucas and others, 1995). Total thickness 100 to 145 feet (30 to 45m)

Jte Todilto Member of Wanakah Formation and Entrada Sandstone, undivided

ŦRc Chinle Formation (Upper Triassic) – Reddish-brown, nonmarine mudstone, reddish-brown, medium-grained sandstone with minor mudstone beds, and reddish-brown, purple, and greenish-gray mudstone with minor silty sandstone and limestone-pebble conglomerate lenses, with pervasive gypsum.

Includes variegated mudstone unit correlated with Petrified Forest Member. Total thickness of Chinle is 1,200 to 1,650 feet (400 to 500m)

TRs Santa Rosa Formation (Upper Triassic) – Light gray, light brown, and reddish-brown, cross-bedded nonmarine sandstone and variegated mudstone. Equivalent to Agua Zarca Formation of Lucas and Heckert (1996). Thickness 100 to 220 feet (30 to 70m)

TRm Moenkopi Formation (Middle? and Lower Triassic) – Maroon and brown, thin- to thick-bedded, fine-grained, nonmarine, micaceous sandstone and siltstone, with minor interbedded reddish-brown mudstone. Thickness 45 to 100 feet (14 to 30m)

TRcm Chinle and Moenkopi Formations, undivided

PALEOZOIC SEDIMENTARY UNITS

Ps San Andres Limestone (Lower Permian) – Light gray and light brown, thin- to medium-bedded limestone interbedded with light gray quartz sandstone interbeds near the base. Thickness 80 to 130 feet (14 to 40m)

Pg Glorieta Sandstone (Lower Permian) – White to light gray, thick-bedded, well indurated, medium-grained quartz arenite. Locally includes a thin greenish-yellow silty mudstone near the top, about 3 feet (1m) thick. Total thickness 35 to 50 feet (11 to 14m)

Psg San Andres Limestone and Glorieta Sandstone, undivided (Lower Permian)

Py Yeso Formation (Lower Permian) – Light brown, very fine-grained silty gypsiferous sandstone and light-brown, light-red and gray ripple-laminated sandstone. Thickness about 175 feet (55m)

Pa Abo Formation (Lower Permian) – Reddish-brown mudstone alternating with grayish-white and light-orange lenticular beds of coarse-grained conglomeratic arkose. Thickness about 1,000 feet (300m)

Pya Yeso and Abo Formations, undivided (Lower Permian)

IPm Madera Formation (Upper and Middle Pennsylvanian) – Gray arkosic limestone, subarkosic sandstone, and dense limestone. Thickness about 1,260 feet (385m). Locally subdivided as:

- IPmu Upper arkosic limestone member – Gray, greenish-gray, olive-gray, and brown limestone interbedded with layers of variegated subarkosic sandstone and mudstone. Thickness about 600 feet (180m)

- IPml Lower gray limestone member – Gray ledge-forming cherty limestone with thin interbeds of variegated limestone. Thickness about 650 feet (200m)

IPs Sandia Formation (Middle Pennsylvanian) – Interbedded brown claystone, gray limestone, and olive-brown and gray subarkosic sandstone. Thickness about 190 feet (58m)

Ma Espiritu Santo Formation of the Arroyo Penasco Group (Lower Mississippian) – Green and purplish-brown sandstone and stromatolitic limestone and dolomite. A basal 6-foot (2-meter) cobble conglomerate rests on the beveled surface of Proterozoic rocks (equivalent to Del Padre Sandstone Member of the Espiritu Santo Formation of Armstrong and Mamet, 1974). Discontinuously preserved in the Sandia Mountains. Maximum total thickness about 73 feet (22m)

PROTEROZOIC METAMORPHIC UNITS

Xms Metasedimentary rocks (Early Proterozoic) – Red-brown, strongly crenulated mica schist, quartz-muscovite schist, metaquartzite (some cross-bedded), and quartz-chlorite schist

Xmv Metavolcanic rocks (Early Proterozoic) – Greenish-gray chlorite-amphibole phyllite and schist, gray and light green metadacite tuff, greenschist derived from basalt and andesite, and reddish-orange, banded metarhyolite

IGNEOUS UNITS

Qbc Basaltic cinder and spatter-cone deposits (middle Pleistocene) – Vent deposits on top of Albuquerque volcanoes field

Qb Basalt flows (middle Pleistocene) – Alkali olivine basalt pahoehoe flows erupted within the Albuquerque volcanoes field west of Rio Grande. Consists of plagioclase and olivine phenocrysts in aphanitic, vesicular matrix. Eruption dated at 156 ka by Peate and others (1996); flows interbedded with Segundo Alto fluvial terrace-fill deposits (unit Qrm)

Qbg Guaje Pumice Bed (Otowi Member) of the Bandelier Tuff (lower Pleistocene) – Primary and slightly reworked pumice erupted at about 1.6 Ma from the Valles Caldera north of the quadrangle; occurs as intermittent bed within the older Rio Grande fluvial terrace-fill deposit (Cuarto Alto) of the Albuquerque valley (unit Qroc)

Tvb Basaltic vent breccia and cinder deposits (upper Pliocene) – Cinder-cone and spatter deposits on top of basalt flows at Santa Ana Mesa; youngest eruptive products may be lower Pleistocene

Tb2 Younger basalt of Santa Ana Mesa (upper Pliocene) – Alkali olivine basalt

Tb1 Older basalt of Santa Ana Mesa (upper Pliocene) – Alkali olivine basalt flows and basal hydromagmatic basaltic tuff deposit that mantles slightly eroded paleotopographic surfaces. Oldest flows dated at 2.7 Ma (Smith and Kuhle, 1998)

Tvc Canjilon tuff (upper Pliocene) – Basaltic tuff-breccia deposit erupted in oval diatreme through the upper part of the Arroyo Ojito formation (Santa Fe Group) southwest of Santa Ana Mesa (Kelley and Kudo, 1978)

Tvcb Basalt flows and brecciated basalt in core of the Canjilon tuff diatreme (upper Pliocene) – (Kelley and Kudo, 1978)

Tbj Basalt of Mesita de Juana (upper Pliocene) – Dark gray, vesicular, holocrystalline basalt. Phenocrysts include labradorite, olivine, augite, and minor magnetite. Unit crops out only at north edge of quadrangle west of Cerrillos Hills.

Tbd Benevidez diatreme deposits (Miocene) – Basaltic tuff and tuff breccia intruded into Santa Fe Group sediments; deposit forms the eroded relic of a maar or tuff cone in the western part of the sheet. Basaltic materials enclose considerable gravel and sand incorporated from the surrounding sediments (description based on Kelley and Kudo, 1978).

Tdc Dacite of Cerro Colorado (Miocene) – Dacite plug intruded into trachytic lavas and pyroclastic deposits that are interbedded with Santa Fe Group sediments; located just south of I-40 near the western edge of the sheet (description based on Wright, 1946)

Tbn Basalt of La Mesita Negra (Miocene) – Basalt, forms a tilted relic of a flow or sill within fine-grained beds of the Santa Fe Group, just north of I-40 near the western edge of the sheet (description based on Kelley and Kudo, 1978)

Tbb Basalt flows (Upper Oligocene) -- Basalt interbedded with lower part of Tanos Formation in Hagan Basin; dated at 25.4 Ma (Connell and Cather, 2001)

Intrusive rocks of Ortiz porphyry belt

Tvt Vent breccia and tuff (Oligocene) – Lithic tuff containing abundant chips and blocks of Tertiary and Cretaceous sedimentary rocks and some igneous porphyries; location probably marks one of the sources of the Espinaso Formation volcanic rocks

Tl Latite porphyry (Oligocene) – Light-gray to light-brown, feldspar-phyric latite with trachytic groundmass. Alkali feldspar phenocrysts 2 to 3 mm (2 to 3 cm in stock at Cunningham Gulch in Ortiz Mountains); groundmass contains hornblende and aegirine-augite. Typically forms stocks, plugs, and thick dikes

Tam Augite monzonite (Oligocene) – Gray to dark-gray, medium-grained, equigranular to slightly porphyritic monzonite. Rock appears spotted due to orthoclase rims on andesine phenocrysts and disseminated augite, in matrix of orthoclase and minor biotite. Forms stocks in Cerrillos Hills, San Pedro Mountains, and South Mountain that were intruded about 28 Ma (Sauer, 2001)

Thm Hornblende monzonite (Oligocene) – Gray to dark-gray, medium-grained, equigranular to slightly porphyritic monzonite. with phenocrysts of andesine and hornblende. Forms stocks in Cerrillos Hills; intruded about 28 Ma (Sauer, 2001)

Tqmd Quartz-hornblende monzodiorite (Oligocene) – Medium-gray to light-gray, hypidiomorphic-granular monzodiorite with plagioclase phenocrysts and interstitial quartz and hornblende. Forms a stock at Candelaria Mountain in San Pedro Mountains; similar bodies throughout the Ortiz porphyry belt were intruded about 36-33 Ma (Sauer, 2001)

Tap Andesite porphyry (Oligocene) – Grayish-green and gray intrusive rock that weathers olive- to brownish-green. Contains phenocrysts of plagioclase, hornblende, and rare quartz in aphanitic groundmass. Forms laccoliths, dikes, sills, and irregular bodies throughout the Ortiz porphyry belt; intruded prior to about 36 Ma based on cross-cutting relations (Sauer, 2001)

Tr Rhyolite (Oligocene) – White to light-brown, aphanitic to porphyritic rhyolite; phenocrysts consist of subhedral quartz and rare biotite. Forms sills and dikes in the eastern San Pedro Mountains; intruded prior to about 36 Ma based on cross-cutting relations (Sauer, 2001)

Proterozoic intrusive rocks

Ys Sandia Granite (Middle Proterozoic) – Pink and grayish-pink, very coarse-grained biotite monzogranite to granodiorite porphyry. Microcline phenocrysts show igneous flow-alignment. Rock contains elongate inclusions of microdiorite, fine-grained granite, and blocks of gabbro, as well as irregular xenoliths of metasedimentary and metavolcanic country rock. Intruded at about 1446 Ma (D. Unruh, USGS, unpublished data cited in Karlstrom, 1999)

Yss Sandia Granite, sheared – Rock within broad northeast-trending zone shows protomylonitic fabric and rounded phenocrysts

Yfg Fine-grained granite (Middle Proterozoic) – Pale leucogranite, probably related to Sandia Granite. Discordantly intrudes metavolcanic rocks in fault block near Monte Largo

Xg Granite (Early Proterozoic) – Gray and pinkish-gray, massive to foliated, leucogranite, biotite granite, and biotite monzogranite. Includes granite in the Manzanita pluton (Karlstrom and others, 1994) and foliated granite (the Cibola Gneiss of Kelley and Northrup, 1975) intruded at about 1645 Ma (Karlstrom, 1999)