NEW MEXICO BUREAU OF MINES AND MINERAL RESOURCES
A DIVISION OF NEW MEXICO INSTITUTE OF MINING & TECHNOLOGY

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Geology of the Bernalillo and Placitas quadrangles, Sandoval County, New Mexico

PLATE III of III.

MAP UNIT DESCRIPTIONS AND CORRELATION OF UNITS

1:24,000

17 February 2000 Revision

Bernalillo quadrangle
NMBMMR OF-DM-16
May 1998

Sean D. Connell[1]

Placitas quadrangle
NMBMMR OF-DM-2
June 1995

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MAP UNIT DESCRIPTIONS

CENOZOIC DEPOSITS

Neogene (Quaternary and Tertiary) System
Colluvial, landslide, eolian, and anthropogenic deposits

This surficial deposits derived from wind and mass-movement processes, or extensive areas disturbed by open-pit aggregate mining or construction.

af — **Artificial fill (Historic)** — Dumped fill and areas affected by human disturbances. Locally mapped where areally extensive or geologic contacts are obscured.

daf — **Disturbed land and artificial fill, undivided (Historic)** — Dumped fill and areas affected by open-pit aggregate mining or construction. Locally mapped where disturbance is areally extensive or geologic contacts are obscured.

Qe — **Eolian sand (Holocene)** — Unconsolidated, light-brown to light yellowish-brown (10YR), moderately to well sorted, fine-to medium-grained sand primarily recognized as low-relief narrow dunes west of the Rio Grande. Soil development is very weak to nonexistent. Variable thickness, ranging from 0-16 ft (0-5 m).

Qae — **Eolian sand and stream alluvium, undivided (Holocene to uppermost Pleistocene)** — Unconsolidated to poorly consolidated, moderately to well sorted, light reddish-brown to light-brown (7.5-10YR), fine- to medium-grained sand and silty sand with scattered pebbles that commonly forms a relatively thin, discontinuous mantle over upland areas west of the Rio Grande. Soil development is weak (Bw and Bwk horizons) with maximum Stage I carbonate morphologic development. Surface is commonly stabilized by vegetation where not disturbed by human activity. May locally contain hydrocollapsible soils. Mapped only where areally extensive or thick. Variable thickness, ranging from 0-16 ft (0-5 m).

Qls — **Landslide debris (upper to middle Pleistocene)** — Poorly consolidated and very poorly sorted, sand, brecciated Santa Fe Group sediment, and coarse, angular blocks derived by mass-movement processes, commonly along steep hillslopes. Locally forms rotated (Tertiary blocks in Sections 8 and 9, T13N, R4E) blocks of gravity-transported basalt and Santa Fe Group sediment that exhibit hummocky topography and bowl-shaped closed depressions along headwall scarps. Locally subdivided into older (Qls1) and younger (Qls2) units. Arrows indicate direction of movement. Estimated thickness ranges from 20-100 ft (6-30 m).

Qca — **Colluvium and alluvium, undivided (Holocene to upper-middle Pleistocene)** — Poorly consolidated, poorly sorted and stratified, fine- to coarse-grained, clast and matrix-supported deposits derived from a variety of mass-movement hillslope processes, including debris flow, shallow slump and creep. Deposits are delineated by sedimentary character and surface morphology. Gravel clasts are typically angular and composition generally reflects local upslope provenance. Locally present on the eastern slope of Sandia Mountains where deposits commonly surround small unmapped bedrock inliers. May locally contain hydrocollapsible soils. Differentiated where areally extensive, thick, or obscures geologic contacts. Variable thickness, ranging from 0-16 ft (0-5 m).

Qcb — **Basaltic colluvium (Holocene to middle Pleistocene)** — Poorly consolidated and sorted sedimentary breccia composed of angular to subangular basalt boulders that mantle slopes below the mesa-capping basalt of Santa Ana Mesa (Tbsa) along the southeastern margin of Santa Ana Mesa. Variable thickness, ranging from 0-16 ft (0-5 m).

Alluvium of the Rio Grande

Fluvial deposits derived from the ancestral and modern Rio Grande. Uncontormably overlies upper Santa Fe Group deposits (commonly Loma Barbon Member and axial-fluvial deposits of the ancestral Rio Grande). Interfingers with eastern-margin piedmont alluvium and western-margin alluvium. Subdivided into six formations on the basis of inset relationships and, to a lesser extent, soil morphology.

Qrp — **Las Padillas Formation (Historic to uppermost Pleistocene)** — Unconsolidated to poorly consolidated, pale-brown (10YR), fine- to coarse-grained sand and rounded gravel with subordinate lensoidal interbeds of fine-grained sand, silt, and clay derived from the Rio Grande. Recognized in drillholes and named for deposits underlying the broad inner valley floodplain near the community of Las Padillas in southwest Albuquerque (Connell et al., 1998). Uncontormably overlies upper Santa Fe Group deposits (QTob and QTsa) and is commonly gravelly at the base. Underlying Santa Fe Group deposits may be locally cemented with calcium carbonate. Probably interfingers with stream alluvium of units QPra and Qcy. Deposit surface (top) comprises the modern surface of aggradation for Rio Grande fluvial deposits. Locally divided into older (Qrp1) and younger (Qrp2) subunits on the basis of inset relationships as estimated from available aerial photography. Also subdivided into modern channel deposits of the Rio Grande (Qrpr) and Rio Jemez (Qrpj). Approximately 50-80 ft (15-24 m) thick.

Qrpr — **Modern channel facies (Historic)** — Unconsolidated sand and gravel within the active channel of the Rio Grande.

Qrpj — **Sandy floodplain alluvium of the Rio Jemez (Historic)** — Unconsolidated sand and gravel at the mouth of the Rio Jemez.

Qra — **Arenal Formation (upper Pleistocene)** — Poorly consolidated deposits of very pale-brown to yellow (10YR) sandy pebble to cobble gravel recognized along the northwestern margin of the Rio Grande inner valley. Named for exposures in the west wall of the Arenal Main Canal in southwest Albuquerque (Connell et al., 1998), where it underlies Lambert's (1968) Primero Alto terrace surface. Gravel clasts are primarily rounded quartzite and subrounded volcanic rocks (commonly welded tuff and rare pumice) with minor granite. Soil development is very weak with Stage I carbonate morphology. The basal contact is approximately 50 ft (15 m) above the top of the Las Padillas Formation (Qrp, Rio Grande floodplain). Approximately 10-20 ft (3-6 m) thick.

Qrd — **Las Duranes Formation (upper(?) to upper-middle Pleistocene)** — Poorly to moderately consolidated deposits of light reddish-brown, pale-brown to yellowish-brown (5-10YR) gravel, sand, and minor sandy clay derived from the ancestral Rio Grande. Locally covered by discontinuous veneer of undivided alluvium and eolian deposits (Qae). Interfingers with, and is overlain by, western-margin alluvium (Qam). Uncomformably overlies deposits of the Loma Barbon Member (QTob). Map relationships and scattered drill-hole data suggests that the basal contact forms low-relief strath approximately 20 ft (6 m) above the top of the Las Padillas Formation (Qrp, Rio Grande floodplain). This basal contact is inset approximately 100 ft (30 m) below the base of the Edith Formation (Qre). Provisionally correlated with the Las Duranes Formation of Lambert (1968). Deposit contains the Rancholabrean mammal Bison latifrons (Locality B-7, Smartt et al., 1991; SW1/4, NE1/4, Section 19, T13N, R4E), which supports a middle Pleistocene deposit age. Correlative deposits to the south locally bury the late-middle Pleistocene (156±20 ka, Peate et al., 1996) basalt of the Albuquerque volcanoes (Connell, 1996, unpubl. data). Approximately 20-23 ft (6-7 m) thick in map area.

Qrm — **Menaul Formation (upper to upper-middle Pleistocene)** — Poorly consolidated deposits of yellowish-brown (10YR) pebble gravel and pebbly sand derived from the ancestral Rio Grande. Named by Lambert (1968) for exposures to the south in Albuquerque. Gravel clasts are dominated by rounded quartzite pebbles that are generally smaller in size than pebbles and cobbles in the Edith Formation (Qre). Forms discontinuous, probably lensoidal, exposures along the eastern escarpment of the inner valley escarpment of the Rio Grande. The basal contact is approximately 85-118 ft (26-36 m) above the top of the Las Padillas Formation (Qrp, Rio Grande floodplain). Poorly exposed remnants of a partially eroded soil on eastern-margin piedmont alluvium (Qam) indicates that the Menaul Formation uncomformably overlies Qam. Conformably overlain by eastern-margin piedmont alluvium (Qamp), and is inset by younger stream alluvium (Qay). May represent lenses of fluvial gravel associated with the Las Duranes Formation (Qrd) east of the Rio Grande. Thickness is generally less than 10 ft (3 m).

Qre — **Edith Formation (middle Pleistocene)** — Poorly to moderately consolidated, locally cemented deposits of pale-brown to yellowish-brown (10YR) gravel, sand and sandy clay derived from the ancestral Rio Grande. Forms laterally extensive outcrops along the inner valley escarpment of the Rio Grande that are physically correlated to Lambert's (1968) type locality to the south (see Connell, 1997; Connell et al., 1998). Forms an upward-fining succession consisting of a 7-26 ft (2-8 m) thick, basal-quartzite-rich, cobble gravel that grades up-section into a 13-32 ft (4-10 m) thick succession of yellowish-brown (10YR) sand and reddish-brown mud. The upper contact is locally marked by a thin, white (5Y) diatomite. Gravel clasts contain abundant rounded quartzite (about 30%) and volcanic rocks (about 40%) with subordinate granite, metamorphic, and sandstone clasts, and very rare welded tuff clasts (Jemez Volcanics). Unit unconformably overlies upper Santa Fe Group deposits (QTob and QTsa), and is conformably overlain by eastern-margin piedmont alluvium (Qam1). A partially exposed buttress uncomformity between eastern-margin piedmont alluvium (Qam2) and upper Santa Fe Group deposits (QTob, QTsa, and QTsp) locally marks the eastern extent. Basal contact is generally well exposed and forms a low-relief strath approximately 40-80 ft (12-24 m) above the top of the Las Padillas Formation (Qrp, Rio Grande floodplain). Locally contains Rancholabrean fossils (Lambert, 1968; Lucas et al., 1988). Moderately developed soils on overlying eastern-margin piedmont deposits (Qam1) suggest a middle Pleistocene age for unit. Variable thickness, up to 10-40 ft (3 to 12 m).

Qrl — **Lomatas Negras Formation (middle Pleistocene)** — Moderately consolidated and weakly cemented sandy pebble to cobble gravel primarily composed of subrounded to rounded quartzite, volcanic rocks, granite and minor basalt. Discontinuously exposed and recognized as a lag of rounded quartzite-bearing gravel approximately 230-245 ft (70-75 m) above the top of the Las Padillas Formation (Qrp, Rio Grande floodplain). Basal contact forms a low-relief strath cut into the Loma Barbon Member (QTob). Uncomformably(?) overlain by western-margin alluvium (Qam). Correlative deposits to the south underlie the late-middle Pleistocene (156±20 ka, Peate et al., 1996) Albuquerque volcanoes basalt. Unit may be correlative to fluvial terrace deposits Qtu of Smith and Kuhle (1998a), which contains the ca. 602 ka Lava Creek B ash. Generally less than 16 ft (5 m) thick.

Middle and lower Santa Fe Group, undivided
Eastern-basin margin piedmont deposits

Tsp — **Piedmont deposits, undivided (lower Pliocene(?) to Miocene)** — Cross section only. Slightly to moderately tilted, well consolidated, and well cemented, sandstone and limestone-dominated conglomerate, sandstone, and mudstone derived from the Sandia Mountains and eastern-basin margin. Deposits are generally better cemented and more steeply dipping than overlying upper Santa Fe Group eastern basin-margin piedmont deposits (QTsp, QTsp$_{ls}$, QTsp$_{cg}$, QTsp$_s$, and QTsp$_{md}$). May be correlative to piedmont-slope and alluvial fan deposits of the Sierra Ladrones or Popotosa formations (Machette, 1978) exposed at the southern margin of the Albuquerque Basin. Estimated thickness is approximately 9,840 ft (3,000 m). Locally divided into five mappable subunits based on dominant deposit texture (see Cather, 1997) and clast composition.

Tsps$_{ls}$ — **Piedmont deposits, limestone-bearing conglomerate subunit** — Well consolidated and cemented, limestone-dominated gravel capping the top of Lomas Altos. Recognized by an abrupt increase in limestone clasts. Approximately 40 ft (12 m) thick.

Tsps$_c$ — **Piedmont deposits, conglomerate subunit** — Conglomerate (conglomerate:sandstone ratio of 2) with subordinate sandstone. Mudstone is absent. Conglomerate is mostly clast supported, although matrix-supported deposits are locally present. Clast content varies upsection. Phaneritic early Tertiary volcanic clasts derived from the Espinaso Formation (Te) are present near the base of the section exposed along the southern end of the Cuchilla de Escala (Locality 97), with Paleozoic and Proterozoic detritus dominating upsection. Volcanic pebbles and cobbles are absent at Lomas Altos (Locality 98).

Tsps$_{cs}$ — **Piedmont deposits, conglomerate and sandstone subunit** — Subequal sandstone and conglomerate. Mudstone is rare. Sandstone is medium- to very coarse-grained and is typically horizontally laminated or trough crossbedded. Conglomerate is mostly clast supported and consists largely of Paleozoic limestone, sandstone, siltstone, and chert with subordinate Proterozoic lithologies.

Tsps$_s$ — **Piedmont deposits, sandstone subunit** — Sandstone (conglomerate:sandstone ratio is less than 0.5), with subordinate siltstone. Sandstone is mostly horizontally laminated with subordinate trough and planar crossbedding. Conglomerate occurs in shallow, lenticular beds, is mostly clast supported, and consists dominantly of pebbles of Paleozoic sedimentary rocks and lesser amounts of Proterozoic crystalline rocks. Siltstone is massive to faintly laminated and forms tabular to broadly lenticular beds.

Tsps$_{md}$ — **Piedmont deposits, siltstone and mudstone subunit** — Subequal siltstone and mudstone, with rare sandstone.

Volcanic and intrusive rocks

Tvc — **Canjilon Tuff (upper Pliocene)** — Oval-shaped tuff-breccia diatreme that intrudes eastritled sandstone of the Loma Barbon Member (QTob); just south of Santa Ana Mesa. Generally dips 50° or less towards the center of the diatreme; bedding is subvertical near faults. Contains numerous basalt dikes and brecciated basalt dikes, flows and plugs, where mappable, that are differentiated as basalt and basaltic breccia beds of the Canjilon Tuff (Tvcb). Contains a circular tuff ring near the center of diatreme. Map of diatreme interior is simplified from Kelley and Kudo (1978).

Tvcb — **Basalt and basaltic breccia beds** — Locally brecciated basalt flows and feeder dikes interlayered within the Canjilon Tuff (Tvc). Yields a K-Ar date of 2.61±0.09 Ma (Kudo et al., 1977) and $^{40}Ar/^{39}Ar$ dates of 2.14±0.66 Ma and 2.52±0.43 Ma (Locality B-2 and B-3; NMGRL 9132 and 9131, respectively, W.C. McIntosh, 1998, written communication).

Tbsa — **Basalt of Santa Ana Mesa (upper Pliocene)** — Tholeiitic flood basalt with modal affinities to alkali olivine basalt (Kelley and Kudo, 1978, p. 9). Locally, a thin (0-13 ft or 0-4 m thick), discontinuous basaltic tuff locally underlies the base (Spiegel, 1961; Cather and Connell, 1998). Bachman and Mehnert (1978) report a K-Ar date of 2.5±0.3 Ma. In the adjoining San Felipe quadrangle, Cather and Connell (1998) report $^{40}Ar/^{39}Ar$ dates of 2.24±0.22 to 1.77±0.21 Ma (NMGRL 8926, 8927, 8928) for this unit. Variable thickness between 20-40 ft (6-12 m) along southern margin of Santa Ana Mesa.

Tmi — **Mafic or intermediate sheet (upper Oligocene)** — A single, approximately 4,000 ft (1,250 m) long, northeast-trending mafic to intermediate dike, about 0.6 m (1 km) north of the village of Placitas (San Antonio de las Huertas Grant). Uncomformably overlain by Santa Fe Group eastern basin-margin piedmont deposits (Tsp$_c$) and yields a $^{40}Ar/^{39}Ar$ date of 30.9±0.5 Ma (NMGRL 3183, W. C. McIntosh, 1995, written communication).

Paleogene System

Te — **Espinaso Formation (Oligocene)** — Cross section only. Unit comprises the remnants of widespread, coarse-grained, volcaniclastic aprons that accumulated adjacent to volcanic vent complexes of the Ortiz Mountains. Consists primarily of upward-coarsening or crudely stratified tuffaceous sandstone, conglomerate, and debris-flow deposits. Variable thickness, up to 4,265 ft (1,300 m).

Tg — **Diamond Tail and Galisteo Formations, undivided (Oligocene to upper Paleocene)** — Cross section only. Unit consists of red to white mudstone, sandstone, and conglomerate deposited within fluvial channels and broad floodplains in an early Tertiary basin between Albuquerque and Santa Fe, New Mexico. Previous workers (Stearns, 1953; Kelley and Northrop, 1975; and Maree, 1989) have mapped Galisteo Formation in the area (NE1/4 of Section 36, T13N, R4E); however, relatively poor exposures, faulting, and ambiguous textural and stratigraphic relationships preclude differentiation on the map. Variable thickness, up to 4,250 ft (1,295 m).

MESOZOIC ERATHEM

Upper Cretaceous

Kmf — **Menefee Formation, undivided** — Contains three informal members: a lower member (324 ft or 99 m thick), the Harmon Sandstone (140 ft or 43 m thick), and an upper member (740 ft or 225 m thick). Upper and lower members are similar and contain, in order of abundance: gray, tan to orange-tan, cross-bedded, and laminated to thick-bedded siltstone and sandstone; dark-gray to olive-gray and black shale; dull, dark-brown to shiny black lignitic coal; and maroon to dark-brown iron concretions. The upper member has a greater abundance of shale, carbonaceous material, ironstone, thicker coal seams, and lenticular beds of calcareous sandstone. The light-gray to buff or gray-tan Harmon Sandstone is a medium grained, well-sorted, quartz sand with cross-bedding and limonite staining. Thickness of the Harmon Sandstone is variable and thins to at least 73 ft (22 m) in the Hagan embayment east of Placitas. The lower contact between the Menefee Formation and the Point Lookout Sandstone (Kpl) is interfingering and gradational. Total unit thickness varies regionally from 680 ft to 1,200 ft (205 m to 365 m) due in part to post-depositional erosion.

Kpl — **Point Lookout Sandstone** — Gray-tan to lightan and drab-yellow, very fine- to fine-grained, massive, quartz sandstone with limonitic sandstone lenses and interbedded thin gray shale. The unit is weakly cemented and a prominent ridge- and ledge-former. Both upper and lower contacts are interfingering and gradational. Unit thickness ranges from about 240 ft (73 m) near Placitas, to 315 ft (96 m) in the Hagan embayment.

Kmu$_s$ — **Mancos Shale, upper member** — Medium- to dark-gray to olive-gray shale, and silty shale, with less abundant very fine to fine-grained, locally gypsiferous sandstone. This unit is an upper tongue of the lower member of the Mancos Shale (Km) and forms valleys and covered slopes between the more resistant Point Lookout Sandstone (Kpl) and Hosta-Dalton Sandstone (Khd). The unit produces poor quality, high sulfate ground water. Upper and lower contacts are gradational. Thickness is variable and difficult to measure due to cover but ranges from about 240 ft (73 m) west of Placitas, to 360 ft (110 m) in the Hagan embayment.

Khd — **Hosta-Dalton Sandstone** — Drab, yellow-gray to yellow-tan, very fine- to medium-grained, weakly cemented sandstone with olive-brown sandstone lenses. The unit is a moderate ridge- and ledge-former. Upper and lower contacts are gradational. Unit thickness ranges from 210 ft (64 m) near Placitas to 370 ft (112 m) in the Hagan embayment (where it contains a considerable amount of siltstone and fissile shale that does not exist in the Placitas area).

Km$_l$ — **Mancos Shale, lower member** — Lithology is similar to the upper Mancos Shale (Km$_u$) with subequal proportions of olive-brown to gray to black shale and laminated to interbedded, olive-brown to gray, very fine grained sandstone, siltstone, and shale. Selenite and white to yellow gypsum are interbedded throughout the unit. The dark gray shale typical of the lower section intertongues with the underlying sandstone of the Dakota Formation (Kd) and the upper contact is gradational. Unit thickness is highly variable regionally and across the study area, ranging from 850 ft (260 m) west of Placitas to 1,850 ft (565 m) in the Hagan embayment. Thickness near the Village of Placitas is intermediate.

Kd — **Dakota Formation** — Medium-bedded, pervasively silica-cemented, medium-grained, yellowish-gray to orange-yellow quartz arenite. Thin interbeds of dark-gray lower Mancos Shale (Km) are common. Sandstones are well cemented and weather to angular and blocky ridges. Unit thickness ranges from 75 ft (23 m) west of Placitas, to less than 25 ft (8 m) in the Hagan embayment.

Upper Jurassic

Jm — **Morrison Formation, undivided** — Three members are commonly recognized in northern New Mexico but are not differentiated in this map area. In descending stratigraphic order, the members are: the Jackpile Sandstone, the Brushy Basin Shale, and the Salt Wash Sandstone (the Westwater Canyon Sandstone of former usage, Lucas et al., 1995). The uppermost Jackpile Sandstone is a distinctive gray-white, kaolinitic, fine- to medium-grained sandstone with a thickness of about 70 ft (21 m) near Placitas. The Brushy Basin member is a gray, green, and maroon mudstone and shale, with interbedded and intercalated gray to tan sandstone. Thickness is about 240 ft (73 m) near Placitas. The Salt Wash Sandstone is a gray to yellow-buff, medium-grained and weakly cemented sandstone, with a unit thickness of 215 ft (66 m) near Placitas. The Recaptive Shale member has been redefined by Lucas et al. (1995) as the Summerville Formation of the upper San Raphael Group (Lucas and Anderson, 1997). However, due to poor exposure in the study area, it remains undifferentiated from the Morrison Formation. The Summerville Formation is approximately 325 ft (100 m) thick and consists of purple-gray, red-brown, and green-gray mudstone interbedded with tan, gray, and green-gray, very fine grained sandstone. Total thickness of the Morrison and Summerville formations combined is relatively uniform regionally, ranging from about 850 ft (260 m) near Placitas to 780 ft (240 m) in the Hagan embayment.

Middle Jurassic

Jt — **Todilto Formation, undivided** — Two members are commonly recognized in north-central New Mexico (Lucas et al., 1995), but are not differentiated in the map area. In descending stratigraphic order, the two members are the Tonque Arroyo Member and Luciano Mesa Member. The Luciano Mesa Member is a medium-gray to olive-gray, laminated, fetid, micritic limestone. Dark-brown to black carbonaceous mud is interbedded with limestone laminations near the base and gypsum interlayers are present from the middle to the top of the limestone member. The Tonque Arroyo Member is locally present as a white gypsum bed. Upper and lower contacts are gradational. The unit is recognized by fairly abrupt increase in gravel content. Tentatively correlated to Kelley's (1977) Ceja Member although stratigraphic position is ambiguous. Unit could also be a coarse-grained lens of gravel surrounding the Luciano Mesa Member (QTob). Approximately 40-60 ft (12-18 m) thick in map area.

QTob — **Arroyo Ojito Formation, Loma Barbon Member (lower Pliocene to upper Miocene)** — Well consolidated, weakly to moderately cemented, yellowish-brown to yellowish-red and reddish-brown (5-10YR), fine-grained silty sandstone with interbedded mudstone and scattered, lensoidal, weakly to well cemented, cobbly to bouldery sandstone interbeds. Gravel clasts are predominantly subangular red quartzite, subrounded basalt and light-gray tuff, and minor sandstone derived from the Jemez Mountains to the west. Gravel clasts are dominated by sandstone and siltstone clasts derived from the Abo and Yeso formations of the Albuquerque Basin and eastern slope of the Sierra Nacimiento. Named after a succession of reddish-brown sandstone, gravel, and mudstone exposed just north of Loma Barbon. A primary ash-flow tuff (Jemez Volcanics) in the deposit (Locality B-1, SE1/4, SW1/4, NW1/4, Section 10, T13N, R3E), present about 10 ft (3 m) below Ceja(?) Member deposits (QTsa(?)), yields a $^{40}Ar/^{39}Ar$ date of 6.82±0.04 Ma (NMGRL 8925, W.C. McIntosh, 1998, written communication) and is tentatively correlated with the Peralta Tuff Member of the Bearhead Rhyolite. A recycled subrounded rhyodacite(?) clast (Locality B-4) yields an $^{40}Ar/^{39}Ar$ date of 4.59±0.21 Ma (NMGRL 9136, W.C. McIntosh, 1998, written communication). Interfingers with, and is overlain by axial-fluvial deposits (QTsa), which are exposed east of the inner valley of the Rio Grande. Correlative deposits (unit QTsl of Cather and Connell, 1998) are overlain by the basalt of Santa Ana Mesa (Tbsa). Locally includes thin, discontinuous lenses of unit QTsa along the margins of the inner valley of the Rio Grande. Estimated hydraulic conductivity is poor to moderate. Base is not exposed but is at least 425 ft thick in borings (e.g., wells RR112 and SAP2).

Upper Santa Fe Group
Western basin-margin deposits (Arroyo Ojito Formation)

QTo — **Arroyo Ojito Formation, undivided (lower Pliocene to upper Miocene)** — Cross section only. Base of unit is not exposed in map area. Estimated thickness is approximately 4,200 ft (1,280 m). Divided into two members in the map area:

QToc — **Arroyo Ojito Formation, Ceja(?) Member (lower Pliocene to lower Pliocene)** — Lightred to reddish-yellow (2.5-7.5YR), moderately consolidated, slightly cemented, slightly tilted, stratified sandstone and pebbly sandstone with minor siltstone and claystone interbeds. Gravel clasts are dominated by subangular to subrounded quartzite, light-gray quartzite, light-gray tuff, and basalt with subordinate chert, sandstone and minor quartzite. Conformably overlies the Loma Barbon Member of the Arroyo Ojito Formation (QTob) and is recognized by fairly abrupt increase in gravel content. Tentatively correlated to Kelley's (1977) Ceja Member although stratigraphic position is ambiguous. Unit could also be a coarse-grained lens of gravely sandstone within the Loma Barbon Member (QTob). Approximately 40-60 ft (12-18 m) thick in map area.

QTob — **Arroyo Ojito Formation, Loma Barbon Member (lower Pliocene to upper Miocene)** — Well consolidated, weakly to moderately cemented, yellowish-brown to yellowish-red and reddish-brown (5-10YR), fine-grained silty sandstone with interbedded mudstone and scattered, lensoidal, weakly to well cemented, cobbly to bouldery sandstone interbeds. Gravel clasts are predominantly subangular red quartzite, subrounded basalt and light-gray tuff, and minor sandstone derived from the Jemez Mountains to the west. Gravel clasts are dominated by sandstone and siltstone clasts derived from the Abo and Yeso formations of the Albuquerque Basin and eastern slope of the Sierra Nacimiento. Named after a succession of reddish-brown sandstone, gravel, and mudstone exposed just north of Loma Barbon. A primary ash-flow tuff (Jemez Volcanics) in the deposit (Locality B-1, SE1/4, SW1/4, NW1/4, Section 10, T13N, R3E), present about 10 ft (3 m) below Ceja(?) Member deposits (QTsa(?)), yields a $^{40}Ar/^{39}Ar$ date of 6.82±0.04 Ma (NMGRL 8925, W.C. McIntosh, 1998, written communication) and is tentatively correlated with the Peralta Tuff Member of the Bearhead Rhyolite. A recycled subrounded rhyodacite(?) clast (Locality B-4) yields an $^{40}Ar/^{39}Ar$ date of 4.59±0.21 Ma (NMGRL 9136, W.C. McIntosh, 1998, written communication). Interfingers with, and is overlain by axial-fluvial deposits (QTsa), which are exposed east of the inner valley of the Rio Grande. Correlative deposits (unit QTsl of Cather and Connell, 1998) are overlain by the basalt of Santa Ana Mesa (Tbsa). Locally includes thin, discontinuous lenses of unit QTsa along the margins of the inner valley of the Rio Grande. Estimated hydraulic conductivity is poor to moderate. Base is not exposed but is at least 425 ft thick in borings (e.g., wells RR112 and SAP2).

Axial-fluvial deposits (ancestral Rio Grande)

QTsa — **Axial-fluvial deposits of the ancestral Rio Grande (lower Pliocene to upper Miocene(?))** — Variable proportions of poorly to moderately consolidated, generally weakly cemented, very pale-brown to yellowish-brown (10YR) subarcosic sandstone to slightly eastritled sand, gravel and mud deposited by the ancestral Rio Grande. Sand is typically well sorted and crossbedded. Sand is locally well cemented along faults (see Locality P-6). Gravel clasts are predominantly rounded quartzite, with volcanics (intermediate, silicic, and basaltic), minor sandstone rocks, granite, and chert. Mudstone ranges in color from light brown to grayish green. Clast imbrication measurements indicate generally south to southwest paleoflow. The presence of recycled clasts of lower Bandelier Tuff (Locality P-3, P-4, and P-5) and an Irvingtonian "aged" Giguere Volcanic Member (Locality B-5; Lucas et al., 1992, p. 6) indicate an early Pleistocene age for the upper part of this unit. Similar fluvial deposits interfinger with western basin-margin deposits beneath the basalt of Santa Ana Mesa (Tbsa). Correlative deposits to the north are late Miocene to early Pleistocene in age (Smith and Kuhle, 1998b). May be correlative with axial-stream deposits of the Sierra Ladrones Formation (Machette, 1978) described along the southern margin of the Albuquerque Basin. Estimated hydraulic conductivity is moderate to high. Base is not exposed. Estimated thickness is 2,200 ft (670 m).

QTsl — **Transitional fluvial-piedmont deposits** — Interfingered axial-fluvial deposits (QTsa) and Santa Fe Group eastern basin-margin piedmont deposits (QTsp$_{ls}$ and QTsp). Transitional deposits are defined as the zone of overlap between the easternmost outcrops of axial river deposits and the westernmost outcrops of piedmont sandstone and conglomerate. Mudstone is commonly ambiguous as to its position within the fluvial system (piedmont-slope, alluvial fan, playa, or axial-fluvial). Unit is not a factor in delineating the fluvial system. A reworked volcanic pumice clast from a lens of fluvial sand and gravel (Locality B-6) has been identified by $^{40}Ar/^{39}Ar$ dating as the ca. 1.6 Ma lower Bandelier Tuff (W. C. McIntosh, 1995 written communication).

Eastern basin-margin piedmont deposits

QTt — **Travertine and spring deposits (middle Pleistocene to Pliocene)** — Lightgray nodular to massive limestone interlayered with mudstone. Prominent outcrop at the northern tip of the Cuchilla de San Francisco (Sections 14 and 15, T13N, R5E) where deposits overlie and interfinger with Santa Fe Group eastern basin-margin piedmont deposits (QTsp$_{ls}$) on the hangingwall of the San Francisco fault. Spring deposits are locally present along depositional contacts and faults. Variable thickness, up to 50 ft (15 m). Thickness is variable, up to 7 ft (2 m).

Qss — **Suela Alluvium (lower Pleistocene)** — Moderately consolidated and weakly cemented deposits of fine-, very pale-brown to white (7.5YR 8/2, 5Y) sandy loam, sand and subrounded to subangular cobble to pebble gravel overlying remnants of extensive, relatively smooth, northwest-sloping pediment surface that cuts across the trace of the Placitas fault. Gravel clasts contain abundant subrounded to subangular limestone, granite, sandstone, and metamorphic rocks. Limestone clasts are typically pitted, and granite clasts are locally grussified. The basal contact is uncomformable along the northern flank of the Sandia Mountains, but becomes conformable with the underlying axial-fluvial deposits (QTsa) northwest of the Escala and Lomas faults. The deposit surface (top) forms a broad, northwest-sloping constructional surface herein named the Las Huertas geomorphic surface. The Las Huertas geomorphic surface is commonly buried by thin veneer of lightbrown eolian sand, diverges downstream of Las Huertas Creek, between about 110-165 ft (34-50 m), and is underlain by moderately to strongly developed soils exhibiting III+ carbonate morphology. In the map area, the Las Huertas geomorphic surface is interpreted to mark the end of upper Santa Fe Group deposition and the initiation of Quaternary incision by the Rio Grande. Barand-swale topography is absent and soils exhibit Stage III+ carbonate morphology, and very few thin silica and clay films. Overlies Bandelier Tuff-bearing piedmont and fluvial deposits (QTsp$_{cs}$ and QTsa) and is thus, younger than about 1.1 Ma. Geomorphic surface Q2 of Connell (1995, 1996). Generally thickens to the northwest, from about 7 to 16 ft (2-5 m).

Qsls — **Gravel of Lomas Altos (upper Pleistocene)** — Well consolidated deposits of very pale-brown to brown (10YR 6-7/3), sandy clay loam, sandy loam and subrounded to subangular, limestone-dominated, cobble to pebble gravel overlying remnants of a formerly broad pediment cut on Santa Fe Group eastern basin-margin piedmont deposits (Tsps$_{ls}$, Tsp$_c$) on Lomas Altos. The basal contact is about 260-328 ft (80-100 m) above local base level, is inset against Santa Fe Group piedmont deposits (Tsps$_c$), and is recognized on the foothills of the Lomas, Escala, and southern Valley View faults. Soils are strongly developed, partially stripped and exhibit Stage IV+ carbonate morphology. Unit may be equivalent to the Tuerto gravel of Stearns (1953) or the gravel of Lookout Park of Smith and Kuhle (1998a). Correlative deposits west of the Escala fault are probably buried beneath the Suela alluvium (Qss) and piedmont deposits of unit QTsp$_{cs}$. Geomorphic surface Q3 of Connell (1995, 1996). Thickness ranges from 13-20 ft (4-18 m) thick.

QTsp — **Piedmont deposits, undivided (lower Pliocene to Miocene)** — Subhorizontally stratified to slightly eastritled, reddish-brown to yellowish-brown and very pale-brown (7.5-10YR) conglomerate, gravelly sandstone, and sandstone with subordinate siltstone and rare mudstone. Conglomerate clasts are predominantly quartzite, but include minor amounts of subangular limestone, metamorphic rock, granite and sandstone. Clast imbrications indicate generally west to southwest paleoflow. Includes unit Tsp on cross section. May be correlative with piedmont-slope and alluvial fan deposits of the Sierra Ladrones Formation (Machette, 1978) exposed at the southern margin of the Albuquerque Basin. Thickness to the east and interfingers with axial-fluvial deposits (QTsa) to the west. Moderate to low estimated hydraulic conductivity. Thickness is variable and estimated to range from 3,000-7,000 ft (915-2,135 m) thick. Divided into four subunits based on dominant deposit texture (see Cather, 1997).

QTsp$_c$ — **Piedmont deposits, conglomerate subunit** — Predominantly conglomerate (conglomerate:sandstone ratio is greater than 2) with subordinate sandstone and very rare mudstone interbeds. Conglomerate clasts contain pebbles, cobbles, and boulders of lithologies similar to clasts in underlying Santa Fe Group eastern basin-margin piedmont deposits (QTsp$_{cs}$). Sandstone is coarse to very coarse and typically crossbedded or horizontally laminated. Matrix-supported conglomerate is common and interpreted to represent debris flow deposits.

QTsp$_{cs}$ — **Piedmont deposits, conglomerate and sandstone subunit** — Subequal conglomerate and sandstone. Conglomerate is typically poorly sorted and clast supported, consisting primarily of pebbles and cobbles of Paleozoic limestone, sandstone, siltstone, and chert, and Proterozoic granite, gneiss, phyllite, and schist. Proterozoic detritus becomes more abundant in the southern part of the quadrangle. Sandstone is horizontally laminated or trough crossbedded, moderately to poorly sorted, and commonly pebbly. Mudstone is rare. Volcanic ash (Locality P-2) is present near the top and may be correlative to the Bandelier Tuff (Dunbar, 1997, personal communication). On the basis of stratigraphic position (e.g., stratigraphically above recycled lower Bandelier Tuff clasts in unit QTsa), this ash is probably correlative to the ca. 1.1 Ma upper Bandelier Tuff.

QTsp$_s$ — **Piedmont deposits, sandstone subunit** — Sandstone (conglomerate:sandstone ratio is less than 0.5), with subordinate siltstone. Sandstone is mostly horizontally laminated with subordinate trough and planar crossbedding. Conglomerate occurs in shallow, lenticular beds, is mostly clast supported, and consists dominantly of pebbles of Paleozoic sedimentary rocks and Proterozoic crystalline rocks. Siltstone is massive to faintly laminated and forms tabular to broadly lenticular beds.

QTsp$_{md}$ — **Piedmont deposits, siltstone and mudstone subunit** — Siltstone and mudstone with rare sandstone.

Mississippian

Ma — **Arroyo Peñasco Group, Espiritu Santo Formation, undivided (locally includes the Log Springs Formation)** — These are the oldest sedimentary rocks in the area and rest unconformably on a relatively planar surface of Proterozoic basement. The Espiritu Santo Formation is composed of a basal member, the Del Padre Sandstone, and an unnamed upper member. Mississippian exposures are discontinuous with the thickest section in the vicinity of the Sandia Mountains found on the west slope