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

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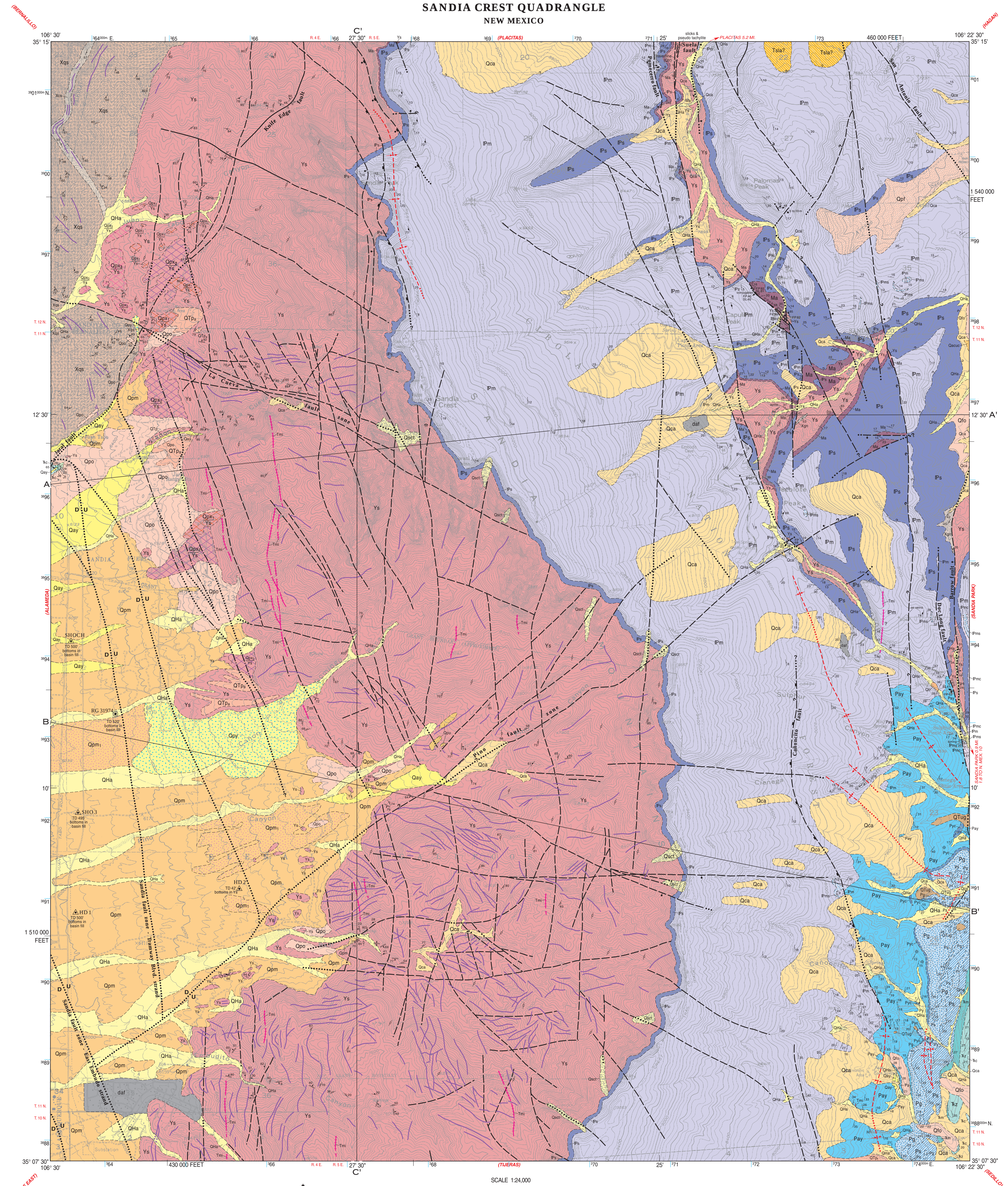
NMBMMR Open File Map Series
OF–GM–6
Map last modified 22 February 2000
Plate I of II.

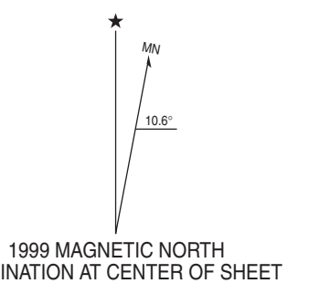
SANDIA CREST QUADRANGLE
NEW MEXICO



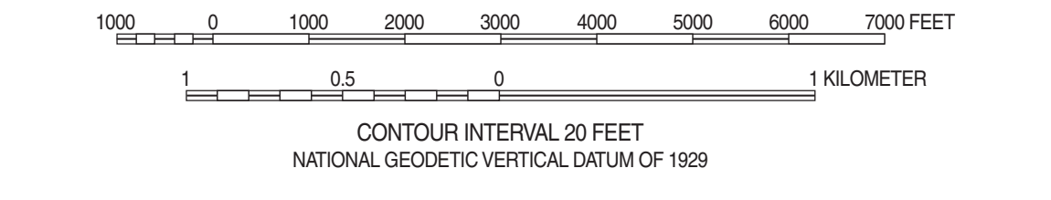
Base from U.S. Geological Survey 1961, photorevised 1967 and 1972
Polyconic projection, 1927 North American datum, 10,000-foot grid based on New Mexico coordinate system, cental zone
1000-meter Universal Transverse Mercator grid ticks, zone 13, shown in blue

Contributing authors and map areas:
Read, A.: Las Huertas, Barro, Madera, Tejano, and Canoncito canyons and vicinity, as well as along the Paleozoic-Proterozoic Unconformity north of Sandia Crest (1:12k); Karlstrom, K. & Kirby, E.: The Sandia pluton and parts of Rincon ridge (1:12k/1:24k); Connell, S.: Quaternary/Tertiary geology of the western edge of the Sandia Mountains. (1:24k); Ferguson, C. & Osburn, G.: The SE corner of the map south of Cienega picnic ground (1:12k); Ilg, B.: Parts of Rincon ridge and along the Paleozoic-Proterozoic Unconformity north of Sandia Crest (1:12k); Van Hart, D.: Mesozoic Rocks south of the Jaral fault (1:100k); Pazzaglia, F.: Quaternary deposits along the eastern edge of the map (1:12k); this map also builds on the work of Kelley and Northrop (1975) and their students.

R. J. Titus and D. J. McCraw: digital cartographic production



1999 MAGNETIC NORTH
DECLINATION AT CENTER OF SHEET



CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

Mapping of this quadrangle was funded by a matching-funds grant from the 1997 STATEMAP program of the National Geologic Mapping Act coordinated by the U.S. Geological Survey and the New Mexico Bureau of Mines and Mineral Resources (Dr. Charles E. Chapin, *Director and State Geologist*; Dr. Paul W. Bauer, *Geologic Mapping Program Manager*).

QUADRANGLE LOCATION

Geology of Sandia Crest quadrangle, Bernalillo and Sandoval Counties, New Mexico

February 1999

22 February 2000 Revision

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UNIT DESCRIPTIONS

CENOZOIC DEPOSITS

Neogene (Quaternary and Tertiary) System

Colluvial, landslide, eolian, and anthropogenic deposits

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

af — **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.

Qca — **Colluvium and alluvium, undivided (Holocene to upper-middle Pleistocene) —** Poorly consolidated, poorly sorted and stratified, fine- to coarse-grained, clast- and matrix-supported gravel derived from a variety of mass-movement hillslope processes, including debris flow, shallow slump and creep. May locally include shallow landslide debris. Gravel clasts are typically subangular to subrounded limestone derived from the eastern dip-slope of the Sandia Mountains. Commonly surrounds small unmapped bedrock inliers. Supports distinct vegetative community and associated drainage density, both of which are represented by a distinct tonal pattern on aerial photographs. Differentiated where areally extensive, thick, or obscures geologic contacts. Variable thickness, up to 16 ft (5 m).

Qsct — **Scree, talus, and colluvium, undivided (Holocene to upper-middle Pleistocene) —** Coarse-grained, angular, clast-supported talus found primarily in first-order hollows on steep, west-facing slopes of the Sandia Mountains.

Qtr — **Travertine (Pleistocene) —** Constructional mounds of travertine ranging from 1 to 10 m thick, typically found around active springs. Variable thickness, between 3-30 ft (1-10 m) thick.

Alluvium

Divided into stream-valley alluvium, eastern basin-margin piedmont alluvium, and eastern-slope alluvium. Stream-valley alluvium typically contain moderately to well sorted, poorly to well stratified, clast- and matrix-supported deposits associated with modern and late Pleistocene entrenched arroyos across the map area. Eastern basin-margin piedmont alluvium contains generally poorly sorted, poorly stratified, clast- and matrix-supported deposits having angular to subangular clasts of granitic, metamorphic, and minor limestone derived from the western and northern slopes of the Sandia Mountains on the footwall of the Sandia fault (eastern margin of the Albuquerque Basin). Eastern-slope alluvium typically contain very poorly to moderately sorted, clast- and matrix-supported deposits associated with drainages developed on the eastern dip-slope of the Sandia Mountains and headwater region of the Tijeras Canyon drainage.

Stream-valley Alluvium

QHa — **Youngest stream alluvium, undivided (Historic to Holocene) —** Unconsolidated deposits of brown, light gray-brown, and yellowish-brown (10YR) sand, silty to clayey sand, and gravel. Underlies arroyos and is inset against younger stream alluvium (*Qay*). Very weakly developed soils exhibit no pedogenic carbonate at the surface and weak Stage I carbonate morphology at depth. Correlative to geomorphic surface Q8 and Q9 of Connell (1995, 1996). Variable thickness, from 0-20 ft (0-6 m).

Qay — **Younger stream alluvium, undivided (Holocene to uppermost Pleistocene) —** Poorly consolidated deposits of pale-brown to light-brown (7.5-10YR) sand to sandy clay loam and gravel. Inset against middle piedmont and western-margin alluvium (*Qpm*). Surface is slightly dissected and possesses weakly developed soils with Stage II carbonate morphology. Remnants of the lower pediment surface (Qpx_3) is preserved in Juan Tabo Canyon and probably corresponds to the basal contact of this unit. Correlative to geomorphic surface Q8 of Connell (1995, 1996). Variable thickness, from 0-25 ft (0-8 m).

Eastern-margin piedmont alluvium

Qp — **Piedmont and stream alluvium, undivided (Historic to middle Pleistocene) —** Cross section only. Undivided deposits of stream-valley (*QHa* and *Qay*) and eastern-margin piedmont alluvium (*Qpm*).

Qpy — **Younger eastern-margin piedmont alluvium (Holocene to uppermost Pleistocene) —** Unconsolidated deposits of brown, light gray-brown, and yellowish-brown (10YR) gravel, sand, and sandy clay loam. Gravel clasts are predominantly cobbles to boulders of angular to subangular, granite with minor subrounded limestone. Soils possess Stage I to II+ carbonate morphology and few thin clay films. Geomorphic surface Q9 of Connell (1995, 1996) Variable thickness, from 0-40 ft (0-12 m).

Qpm — **Middle eastern-margin piedmont alluvium, undivided (upper to middle Pleistocene) —** Poorly to moderately consolidated deposits of very pale-brown to strong-brown and light-gray (7.5-10YR) gravel, sand, and silty to clayey sand. Inset against older eastern-margin piedmont alluvium (*Qpo*) and inset by younger stream alluvium (*Qay*). Gravel clasts are predominantly subangular granite and schist with subrounded limestone, and angular white quartz (aplite dikes) derived from the western front of the Sandia Mountains. Slightly to moderately dissected deposit surface possesses subdued constructional bar-and-swale topography on interfluves. Weakly developed soils exhibit Stage II to III+ carbonate morphology and minor to moderate clay film development. Locally divided into an older subunit. Correlative to geomorphic surfaces Q6-Q7 of Connell (1995, 1996). Variable thickness, estimated from 0-140 ft (0-43 m).

Qpm_1 — **Middle eastern-margin piedmont alluvium, older subunit (middle Pleistocene) —** Moderately consolidated deposits of light- to strong-brown (7.5YR) and very pale-brown to light-gray (7.5-10YR), poorly to moderately stratified and sorted, sand clayey sand and gravel. Dissected deposit surface exhibits erosional ridge-and-ravine topography. Subdued bar-and-swale constructional topography is locally preserved on broad weakly dissected interfluves. Much of the deposit surface is dissected by arroyos and exhibits erosional ridge and ravine topography. Moderately well developed soils with Stage III+ carbonate morphology and many moderately thick clay films. Geomorphic surface Q6 of Connell (1995, 1996).

QTp_a — **Old eastern-margin piedmont alluvium, undivided (lower Pleistocene to upper Pliocene(?)) —** Moderately consolidated, poorly to moderately sorted and stratified gravel and sand with minor, thin silty-clay interbeds. Gravel clasts are granite with rare limestone. Granite clasts are commonly grussified and deeply pitted. Remnants of upper and lower pediment surfaces (Qpx_1 and Qpx_2) are locally preserved on Sandia granite (*Ys*) and probably correspond to the stripped base of unit *QTp*. Correlative to geomorphic surfaces *QT1-Q3* of Connell (1995, 1996), older eastern-margin piedmont alluvium (*Qpo*) or the Suela alluvium (*Qss*) exposed on the Placitas and Bernalillo quadrangles (Connell, 1998, and Connell *et al.*, 1995, respectively). Variable thickness, from 0-45 ft (0-14 m).

Tsla — **Gravel of Lomos Altos (upper Pliocene) —** Thin gravel lag consisting of subrounded limestone pebbles and cobbles derived from eastern dip-slope of the northern Sandia Mountains. Probably correlative to the Gravel of Lomos Altos on the northern flank of the Sandia Mountains (Connell *et al.*, 1995). May also be equivalent to the Tuerto gravel of Stearns (1953). Approximately 3-30 ft (1-10 m) thick.

Eastern-slope alluvium

Qfo — **Eastern-slope alluvial-fan deposits (middle Pleistocene) —** Poorly sorted and stratified, gravel and sand with minor, thin silty-clay interbeds. Gravel clasts are predominantly limestone with subordinate sandstone. Deposit surfaces are approximately 100 ft (30 m) above local base level and exhibit modified bar and swale topography. Soils posses Stage II+ to III+ carbonate morphology. Variable thickness and thickens to the east to over 60 ft (18 m) thick. Correlative to alluvial fan deposits inset below the Tuerto gravel (unit *Qfo*) on the adjacent Sandia Park quadrangle (Ferguson *et al.*, 1996). Probably correlative to eastern-margin piedmont alluvium (*Qpm* or *Qpo*) along western front of Sandia Mountains.

Qpf — **Eastern-slope pediment-alluvial fan complex (middle Pleistocene) —** Alluvial fan deposits that overlie broad, northeast-sloping pediment surfaces cut on older sedimentary rocks. Correlative to piedmont-alluvial fan complexes (unit *Qpf*) on the adjacent Sandia Park quadrangle (Ferguson *et al.*, 1996). Variable thickness, ranging from 10-20 ft (3-20 m).

QTp — **Old eastern-slope alluvium, Tijeras Canyon unit (lower Pleistocene to upper Pliocene(?)) —** Moderately consolidated, poorly to moderately sorted and stratified gravel and sand. Poorly exposed. Gravel locally overlies reddish-brown silty sand. Inset against upland gravel (*QTug*) and recognized at southwestern corner of map area, within the San Antonio Arroyo drainage (major tributary to Tijeras Arroyo). Probably correlative to old eastern margin piedmont alluvium (*QTp*). Approximately 3-10 ft (1-10 m) thick.

QTug — **Upland gravel (middle Pleistocene to upper Pliocene(?)) —** Well rounded, poorly stratified gravel lag deposits that mantle a low-relief upland erosion surface (pediment) approximately 330 ft (100 m) above local base level. May be correlative to the Tuerto gravel of Stearns (1953), or to the gravel of Lomos Altos along the northern flank of the Sandia Mountains (Connell *et al.*, 1995). Correlative to unit *QTug* on the adjacent Sandia Park quadrangle (Ferguson *et al.*, 1996). Thickness is generally less than 3 ft (1 m).

Upper Santa Fe Group

QTsp — **Eastern basin-margin piedmont deposits, undivided (lower Pleistocene to Miocene) —** Cross section only. Poorly to moderately stratified to slightly east-tiled, reddish-brown to yellowish-brown and very pale-brown (7.5-10YR) conglomerate, gravelly sandstone, and sandstone with subordinate siltstone and rare mudstone. Buried by eastern-margin piedmont alluvium (*Qpm*). Conglomerate clasts are predominantly composed of subangular granite with minor subrounded limestone schist, and angular white quartz (derived from aplite dikes exposed in the Sandia Mountains). 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. Thickens to the east and interfingers with fluvial deposits of the ancestral *Rio Grande* to the west (Connell, 1998). Thickness is variable and thickens to the west. Estimated thickness, ranges from 2,000-7,000 ft (610-2,135 m) to the west.

Paleogene-Cretaceous Systems

TKu — **Lower Tertiary and Cretaceous sedimentary rocks, undivided (Paleogene-Cretaceous) —** Cross section only. Undivided lower Tertiary and Cretaceous deposits that may include the Unit of Isleta No. 2 (Lozinsky, 1994), Galisteo Formation, and Menefee Formation.

Tertiary Igneous Units

Tmi — **Mafic or intermediate dike (upper Oligocene?) —** Generally deeply weathered mafic to intermediate, steeply dipping, north trending dikes. These are probably correlative to an Oligocene mafic to intermediate dike exposed on the northern flank of the Sandia Mountains (Connell *et al.*, 1995).

MESOZOIC ROCKS

Upper Cretaceous

Kmf — **Menefee Formation, undivided —** Cross section only. 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 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 —** Cross section only. Gray-tan to light-tan and drab-yellow, very fine- to fine-grained, massive, quartz sandstone with limonitic sandstone lenses and interbedded thin gray shale. Unit thickness ranges from about 240 ft (73 m) near Placitas, to 315 ft (96 m) in the Hagan embayment.

Km_u — **Mancos Shale, upper member —** Cross section only. 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 (*Kml*). Thickness is variable, but ranges from about 240 ft (73 m) west of Placitas, to 360 ft (110 m) in the Hagan embayment.

Khd — **Hosta-Dalton Sandstone —** Cross section only. Drab, yellow-gray to yellow-tan, very fine- to medium-grained, weakly cemented sandstone with olive-brown sandstone lenses. Unit thickness ranges from 210 ft (64 m) near Placitas to 370 ft (112 m) in the Hagan embayment.

Km_l — **Mancos Shale, lower member —** Cross section only. 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. Unit thickness is highly variable regionally and across the study area, ranging from 850 ft (260 m) west of Placitas to 1850 ft (565 m) in the Hagan embayment.

Kd — **Dakota Formation —** Cross section only. Medium-bedded, pervasively silica-cemented, medium-grained, yellowish-gray to orange-yellow quartz arenite. Unit thickness ranges from 75 ft (23 m) west of Placitas, to less than 25 ft (8 m) in the Hagan embayment.

MESOZOIC ROCKS, CONTINUED

Upper Jurassic

Jm — **Morrison Formation, Salt Wash Member —** Light tan to yellowish white, massive, friable sandstone exposed only in a highly fractured fault-bounded block of Mesozoic rocks just south of the Jaral fault and Rincon Ridge. Exposed thickness is approximately 85 ft (26 m) compared to an estimated thickness of 216 ft (66 m) for the Salt Wash Member exposed near Placitas (see Van Hart, *in press*). Total Morrison Formation thickness varies regionally, ranging from about 850 ft (260 m) near Placitas, to 780 ft (240 m) in the Hagan embayment.

Middle Jurassic

San Raphael Group — Locally includes the Summerville (*Js*), Todilto (*Jt*), and Entrada (*Je*) Formations as recently defined by Lucas *et al.* (1995) and Lucas and Anderson (1997). Exposed only within a highly fractured fault-bounded block of Mesozoic rocks located just south of the Jaral fault and Rincon Ridge (see Van Hart, *in press*). Total estimated San Raphael Group thickness in this fault block is 128 ft (39 m).

Js — **San Raphael Group, Summerville Formation —** Purple-gray, red-brown, and green-gray mudstone interbedded with tan, gray, and greenish-gray, very fine grained sandstone. These rocks are assigned to the Summerville Formation based on stratigraphic position (previously called the Recapture Shale Member of the Morrison Formation–see Lucas *et al.*, 1995; and Lucas and Anderson, 1997). Estimated exposed thickness is 50 ft (15 m).

Jt — **San Raphael Group, Todilto Formation (Luciano Mesa Member) —** A thinly laminated, petroliferous, dark-gray, micritic limestone. Fossils are not recognized, but laminations are probably algal in origin. The overlying Tonque Arroyo Member appears to be absent in this area (Van Hart, *in press*). A very small outcrop of this important stratigraphic marker is overlain by the Summerville Formation, underlain by the Entrada Formation, and is approximately 3 ft (1 m) thick.

Je — **San Raphael Group, Entrada Formation —** Variably colored, very fine to fine-grained, weakly cemented, crossbedded, eolian, quartz sandstone with coarser grained components. These rocks are very poorly exposed south of the Jaral fault. The lower contact with the Chinle Group (*TRc*) is disconformable. Estimated local thickness of 75 ft (23 m).

Upper Triassic

TRc — **Chinle Group, undivided (probably Petrified Forest Formation) —** Mudstone with lenticular beds of lavender-gray sandstone; mudstones are reddish-brown to orange-tan in the upper part, and purple to reddish-brown in the lower part; also locally contains limestone-pebble conglomerate lenses. Exposures confined to limited outcrop just south of the Jaral Fault and near the Village of Cañoncito (on the southeastern corner of the map). Total Chinle Group thickness is about 1300 ft (400 m).

TRz — **Chinle Group, Agua Zarca Formation —** The only distinct sub-unit of the Chinle Group recognized during this study (differentiated near the Village of Cañoncito). It is a tan- to light-grayish pink, resistant, thin- to medium-bedded quartz arenite and feldspathic arenite. The lower contact with the underlying Moenkopi Formation (*TRm*) is disconformable. The unit is about 350 ft (105 m) thick.

Middle and Lower Triassic

TRm — **Moenkopi Formation —** A recessive-weathering, dark red, micaceous shale, silty shale and thin-bedded feldspathic sandstone. The unit is about 200 ft (60 m) thick.

PALEOZOIC ROCKS

Upper Permian

Ps — **San Andres Formation —** Light gray and less commonly tan colored, medium- to thick-bedded limestone. The limestones are mostly micrites or skeletal wackstones, commonly with some component of quartz sand. The San Andres Formation is interbedded with the Glorieta Formation (*Pg*) with a total upper Permian (*Ps* and *Pg*) thickness of approximately 400 ft (120 m).

Pg — **Glorieta Formation —** White and pink (along the contact with the underlying Yeso Formation), massive or plane-bedded to low-angle planar cross-stratified quartz arenite. Locally, the sandstones are extensively bioturbated by *Macaronichnus*, and near the contact with Yeso Formation they are feldspathic. The sandstones are typically well sorted, but a thin, feldspathic quartz-pebble conglomerate occurs just below the base of the lowermost San Andres Formation limestone in the Arroyo Armijo area along the boundary between Sandia Park and Sandia Crest quadrangles. Interbedded with the San Andres Formation with each sandstone bed generally less than 30 ft (10 m) thick.

Lower Permian

Pay — **Abo and Yeso Formations, undivided —** The lower two lithostratigraphic units of the Permian represent a red-colored feldspathic to quartzose siliciclastic sequence that, because of generally poor exposure, was mapped as a single unit throughout the study area. The Yeso Formation is a reddish to pink or tan-colored, medium- to thin-bedded, feldspathic sandstone, shale and silty shale with interbedded massive or laminated micritic gray or tan limestone (*Pyc*) near the top. The sandstones are typically cross-stratified and/or cross-laminated and virtually identical to those within the underlying Abo formation except that, rarely, salt hopper casts and molds are present. The Abo Formation is a red and locally tan-colored (particularly near the base), medium- and thin-bedded arkose and feldspathic sandstone interbedded with red, micaceous siltstone and shale, commonly with green reduction spots. The lowermost arkoses are typically lighter-colored and coarser-grained than the younger feldspathic sandstones, and at least one of them is strongly bioturbated (*Macaronichnus*). The sandstones are cross-stratified (typically trough and wedge-planar geometries) and the finer grained rocks are commonly ripple cross-laminated. In addition, mud-chip clasts and plant debris are common. The upper contact with the Yeso Formation (*Py*) is conformable but difficult to distinguish in the field. The lower contact with the Madera Formation (*IPm*) is gradational with interbedded limestone and reddish-brown mudstone. The top of the lowermost laterally continuous and relatively thick limestone bed is chosen as the Madera Formation contact. Total thickness for the Abo and Yeso formations combined is approximately 1,300 ft (400 m).

Pyc — **Yeso limestone —** Intervals of massive or algal/cryptalgal-laminated limestone within the upper part of the Yeso Formation. The limestones are typically micritic, fenestral fabrics are commonly preserved, and they contain abundant quartz sand. Differentiated where possible east of the Village of Cañoncito. Generally less than 16 feet (5 m) thick.

Upper and Middle Pennsylvanian

IPm — **Madera Formation, undivided —** Two informal members, an arkosic limestone and a gray limestone, are recognized but not differentiated. The upper arkosic limestone is a gray, greenish-gray, olive-gray, tan and buff-brown fossiliferous limestone (comprises slightly more than half of member) interbedded with intervals of sub-arkosic sandstone and mudstone. The limestone is thinly to thickly bedded and massive, with sparsely disseminated chert. Sandstones and mudstones vary from reddish-brown to maroon to greenish-gray and gray, are commonly lenticular, and often laterally discontinuous. Arkosic sandstones are typically coarse- to medium-grained and often contain granules and pebbles. The lower gray limestone is a gray, ledge-forming, cherty limestone separated by thinner and less resistant intervals of light-brown, pale greenish-brown, tan, greenish-gray, and gray, argillaceous limestone. The upper and lower members are respectively generally correlative to the Wild Cow Formation and Los Moyos Limestone (Formation) of the Madera Group of Myers and McKay (1976). These informal member names are used because the units were lithostratigraphically defined on the Sedillo (Read *et al.*, 1998) and Tijeras (Karlstrom *et al.*, 1999) 7.5-minute quadrangles rather than biostratigraphically defined and may therefore not strictly correllate with the units defined by Myers and McKay (1976). The Madera Group nomenclature was abandoned because of the gradational contacts between members and the difficulty of distinguishing these contacts in the field. Total thickness is approximately 1,320 ft (402 ft) near Cedro Peak to the southeast (Myers and McKay, 1976) and 1,260 ft (385 m) on the Crest of Montezuma (Picha, 1982) to the north (consistent with thickness estimates based on map relationships in the study area).

IPms — **Madera Formation, sandstone and arkose beds —** Sandstones and arkosic sandstones, mapped as marker units where possible. Up to approximately 60 ft (18 m) thick.

IPmc — **Madera Formation, massive limestone beds —** Prominent ledge forming limestone beds, mapped as marker units where possible. Up to approximately 40 ft (12 m) thick.

IPs — **Sandia Formation —** Consists of a variety of lithologies including, in descending stratigraphic order: interbedded brown claystone and gray limestone, massive gray limestone, and a lower olive-brown to gray, subarkosic, fine- to coarse-grained sandstone. The contact with overlying Madera Formation (*IPm*) is chosen at the base of the lowest thick, ledge-forming limestone. The lower contact is unconformable with the Arroyo Peñasco Group (*Ma*) or Proterozoic crystalline rocks. Limestone in the Sandia Formation is distinct from limestone in the overlying Madera Formation as they are typically thinner-bedded, clast-supported, greenish, and contain abundant siliciclastic material. Approximately 170 ft (50 m) thick.

Mississippian

Ma — **Arroyo Peñasco Group, Espiritu Santo Formation —** The locally thin and discontinuous Espiritu Santo Formation unconformably overlies Proterozoic basement. Generally only the basal Del Padre Sandstone Member is present, but the limestones, dolomites, and limey mudstones of the unnamed upper member are preserved in places north of Sandia Peak. Microfossils from these carbonate rocks near Placitas and other areas indicate an Osagean age (Armstrong and Mamet, 1974). No other formations within the Arroyo Peñasco Group have been recognized in the map area. The thickest section and best exposure of the Arroyo Peñasco Group in the region of the Sandia Mountains is on the west slope of the Crest of Montezuma east of Placitas (Armstrong and Mamet, 1974; Connell *et al.*, 1995). The Del Padre Sandstone is a distinctive sedimentary quartzite and quartz-pebble conglomerate that is generally very white and extremely well lithified. The silicified finer-grained varieties of quartzite from the Del Padre Sandstone are easily mistaken for metamorphic rocks but have no apparent foliation and have visible rounded grains on weathered or broken surfaces. Additionally, these quartzites and associated quartz pebble conglomerates are only seen along the Great unconformity between Proterozoic basement and the Pennsylvanian Sandia Formation. Mineralized faults and fractures containing barite-flourite-galena and quartz are often seen in these rocks. Some of these structures apparently do not extend above the Sandia Formation and are therefore interpreted as the result of pre-Madera Formation deformation. The age of the mineralization is unknown. These rocks were previously considered Proterozoic metasediments (see Kelley and Northrop, 1975) and some clearly are metamorphic based on recent thin section study (Read *et al.*, 1999). However, based on stratigraphic position, the lack of foliation, and on study of several thin sections, the bulk of the rocks mapped as Arroyo Peñasco Group are sedimentary rocks that did not experience the high-grade metamorphism typical of Proterozoic supracrustal rocks in this area. Generally less than 50 ft (15 m) thick where preserved.

PROTEROZOIC ROCKS

Mesoproterozoic igneous rocks

Pegmatite and aplite dikes — Dikes, pods, and lenses ranging from <1 in to >50 ft (<30 cm to >15 m) in thickness and perhaps up to 2,600 ft (800 m) in length; interpreted to be coeval with the Sandia granite (*Ys*).

Ys — **Sandia granite —** Mainly megacrystic biotite monzogranite to granodiorite–K-feldspar megacrysts, up to several cm long, are commonly aligned in a magmatic foliation; contains numerous ellipsoidal enclaves of microdiorite, fine-grained granite, and gabbro (interpreted to be mingled mafic magmas), and xenoliths of quartzite and mafic metavolcanic rock. Pegmatites, aplites, and quartz veins are ubiquitous. Various dates are available: U-Pb zircon plus sphene 1,455±12 Ma (Tilton and Grunenfelder, 1968, recalculated by Steve Getty, *unpublished*); U-Pb zircon of 1,437±47 Ma (Steiger and Wasserburg, 1966, recalculated in Kirby *et al.*, 1995); U-Pb zircon of 1,446±26 Ma (Unruh, *unpublished data*); ^{40}Ar/^{39}Ar from hornblende is 1,422±3 Ma and from muscovite is 1,423±2 Ma (Kirby *et al.*, 1995); apatite fission track dates range from 14±4 Ma at low elevation to 30±5 Ma at high elevation (Kelley *et al.*, 1992).

Paleoproterozoic metamorphic rocks

Xqs — **Quartz-rich pelitic schist —** Quartz-muscovite schist and quartz-chlorite schist locally interlayered with amphibolites, mafic metavolcanics, and calc-silicates; commonly contains aluminosilicates.

Xcs — **Calc-silicate and calc-pelite —** Lensoidal calc-silicate bodies interlayered with quartz-rich pelites (*Xqs*).

Xgn — **Banded granitic gneiss —** Isolated screens (and xenoliths) of banded biotite-rich granitic gneiss intruded by the Sandia Granite in Madera Canyon as well as larger outcrops in Barrow Canyon beneath the Paleozoic-Proterozoic unconformity. May be correlative with pelitic gneiss or the Cibola granite exposed on the Sandia Park Quadrangle (Ferguson *et al.*, 1996).

EXPLANATION OF MAP SYMBOLS

A├──┤A' Location of geologic cross section

Geologic contact—solid where exposed, dashed where approximately located, dotted where concealed, queried where inferred

Fault—Showing dip with arrow showing trend and plunge of slickenlines where measurable; solid where exposed; dashed where approximately located; dotted where concealed; ball-and-bar on downthrown side of normal fault, teeth on upthrown side of reverse fault (combination of reverse fault teeth and bar-and-ball indicates interpretation of normal reactivation of a reverse fault); upthrown (U) and downthrown (D) used where fault dip is unknown

Anticline—Trace of axial plane showing direction of plunge; dashed where approximately located, dotted where concealed, queried where inferred

Syncline—Trace of axial plane showing direction of plunge; dashed where approximately located, dotted where concealed, queried where inferred

Monocline with anticlinal bend—Trace of axial plane; short arrow on steeper bend; dashed where approximately located, dotted where concealed, queried where inferred

Breccia or gouge zones

85 Strike and dip of minor fault

30 Slickensides on fault

30 40 Strike and dip of bedding, ball indicates that younging is known

⊕ Horizontal bedding

80 Strike and dip of joint or fracture

45 Strike and dip of S1 foliation

75 Strike and dip of S2 foliation

56 Strike and dip of magmatic foliation in granite defined by alignment of mafic enclaves

72 Strike and dip of magmatic foliation in granite defined by alignment of megacrysts

34 Strike and dip of pegmatite dikes and veins

60 Trend and plunge of lineation—defined by elongate minerals or stretched grains

⚒ Prospect, mine

◉RG31974 Water-supply well, including number assigned by the New Mexico Office of the State Engineer

SHO3 Exploratory or groundwater monitoring well, including abbreviation. HD-1 and HD-2 data from Geohydrology Associates (1993); SHO3 and SHOCH and data from G. Hall (*unpubl. data*, 1998).

Lower pediment surface — Exposed erosional surface between Sandia granite (*Ys*) and overlying younger stream alluvium (*Qay*). Probably correlative to geomorphic surface Q8 of Connell (1995, 1996).

Middle pediment surface — Broad, relatively low relief erosional surface on the Sandia granite (*Ys*). Surface is topographically lower than pediment surface of unit Qpx_1 and correlated to the base of older eastern-margin piedmont alluvium (*Qpo*). Provisionally correlated to geomorphic surfaces *Q4-Q5* of Connell (1995, 1996).

Upper pediment surface — Broad, relatively low relief erosional surface on Sandia granite (*Ys*). Surface projects to the basal contact of eastern-margin piedmont alluvium (*Qpo)* and is provisionally correlated to geomorphic surfaces Q2-Q3 of Connell (1995, 1996).

REFERENCES

Connell, S. D., 1995, *Quaternary geology and geomorphology of the Sandia Mountains piedmont, Bernalillo and Sandoval Counties, central New Mexico*: [M.S. Thesis] Riverside, University of California, 390 p., 3 plates.

Connell, S. D., 1996, Quaternary geology and geomorphology of the Sandia Mountains piedmont, Bernalillo and Sandoval Counties, central New Mexico: *New Mexico Bureau of Mines and Mineral Resources Open-File Report 425*, 414 p., 3 plates (open-file release of Connell, 1995).

Connell, S. D., 1997, Geology of the Alameda 7.5-minute quadrangle, Bernalillo and Sandoval Counties, New Mexico: *New Mexico Bureau of Mines and Mineral Resources, Open-File Digital Map 10*, scale 1:24,000.

Connell, S. D., 1998, Geology of the Bernalillo 7.5-minute quadrangle, Sandoval County, New Mexico, *New Mexico Bureau of Mines and Mineral Resources, Open-File Digital Map 16*, scale 1:24,000.

Connell, S. D., Allen, B. D., and Hawley, J. W., 1998, Subsurface stratigraphy of the Santa Fe Group using borehole geophysics, Albuquerque area, central New Mexico: *New Mexico Geology*, v. 20, n. 1, p. 2-7.

Connell, S. D., Cather, S. M., Karlstrom, K. E., Read, A. S., Ilg, B., Menne, B., Andronicus, C., Bauer, P. W., and Johnson, P. S., 1995, Geology of the Placitas 7.5-minute quadrangle, Sandoval County, New Mexico: *New Mexico Bureau of Mines and Mineral Resources, Open-file Digital Geologic Map OF-DM 2*, scale 1:24,000.

Ferguson, C. A., Timmons, M., Pazzaglia, F., Karlstrom, K. E., Bauer, P. W., 1996, Geology of the Sandia Park 7.5-minute quadrangle, Bernalillo and Sandoval Counties, New Mexico: *New Mexico Bureau of Mines and Mineral Resources, Open-file Digital Geologic Map OF-DGM 1*, scale 1:24,000.

Geohydrology Associates, Inc., 1993, *Geohydrologic studies at High Desert, Bernalillo County, New Mexico*: Albuquerque, New Mexico, 87107, 13p.

Karlstrom, K. E., Connnell, S. D., Ferguson, C. A., Read, A. S., Osburn, G. R., Kirby, E., Abbott, J., Hitchcock, C., Kelson, K., Noller, J., Sawyer, T., Ralser, S., Love, D. W., Nyman, M., Bauer, P. W., 1999, Geology of the Tijeras 7.5 minute quadrangle, Bernallillo County, New Mexico: *New Mexico Bureau of Mines and Mineral Resources, Open-file Digital Geologic Map OF-DGM 4*, scale 1:24,000.

Kelley, V. C., and Northrop, S. A., 1975, Geology of the Sandia Mountains and vicinity: *New Mexico Bureau of Mines and Mineral Resources Memoir 29*, 136 p.

Kelley, S. A., Chapin, C. E., and Corrigan, J., 1992, Late Mesozoic to Cenozoic cooling histories of the flanks of the northern and central Rio Grande rift, Colorado and New Mexico: *New Mexico Bureau of Mines and Mineral Resources Bulletin 145*, 39 p.

Kirby, E., Karlstrom, K. E., and Andronicus, C., 1995, Tectonic setting of the Sandia pluton: An orogenic 1.4 Ga granite in New Mexico, *Tectonics*, v. 14, p. 185-201.

Lozinsky, R. P., 1994, Cenozoic stratigraphy, sandstone petrology, and depositional history of the Albuquerque basin, central New Mexico, in Keller, G.R., and Cather, S.M., *eds.*, Basins of the Rio Grande rift: Structure, Stratigraphy, and Tectonic setting: *Geological Society of America, Special Paper 291*, p. 73-82.

Lucas, S. G., Anderson, O. J., and Pigman, C., 1995, Jurassic Stratigraphy in the Hagan Basin, North-Central New Mexico, *in*: *New Mexico Geological Society Guidebook, 46th Field Conference Guidebook*, p. 247-255.

Lucas, S. G. and Anderson, O. J., 1997, The Jurassic San Rafael Group, Four Corners region, *in*: *New Mexico Geological Society, 48th Field Conference Guidebook*, p. 115-132.

Machette, M. N., 1978, Geologic map of the San Acacia Quadrangle, Socorro County, New Mexico: *U.S. Geological Survey Geologic Quadrangle Map GQ-1415*, scale 1:24,000.

Myers, D. A., and McKay, E. J., 1976, Geologic map of the north end of the Manzano Mountains, Tijeras and Sedillo quadrangles, Bernalillo County, New Mexico: *U.S. Geological Survey Miscellaneous Investigations Series, I-968*, scale 1:24,000.

Read, A. S., Allen, B. D., Osburn, G. R., Ferguson, C. A., and Chamberlin, R., 1998, The Geology of the Sedillo quadrangle, Bernallio County, New Mexico, New Mexico Bureau of Mines and Mineral Resources, *Open-file Digital Geologic Map OF-DGM 20*, scale 1:24,000.

Read, A. S., Karlstrom, K. E., Ilg, B., *in press*, Mississippian Del Padre Sandstone or Proterozoic Quartzite?, *minipaper in*: *New Mexico Geological Society, 50th Field Conference Guidebook*.

Steiger, R. H., and Wasserburg, G.J., 1966, Systematics in the Pb^{208}-Th^{207}-U^{235}, and Pb^{206}-U^{238} systems, *Journal of Geophysical Research*, v. 71, p 6065-6090.

Stearns, C. E., 1953, Tertiary geology of the Galisteo-Tonque area, New Mexico: *Geological Society of America Bulletin*, v. 64, p. 459-508.

Tilton, G. R., and Grunenfelder, M.H., 1968, Uranium-lead ages, *Science*, v. 159, p. 1458-1461.

Van Hart, D.,1999, Geology of Mesozoic sedimentary rocks in the Juan Tabó area, northwestern Sandia Mountains, Bernalillo County, New Mexico: *New Mexico Geology*, v. 21, n. 4, p. 104-111.

COMMENTS TO MAP USERS

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

Mapping of this quadrangle was funded by a matching-funds grant from the STATEMAP program of the U.S. Geological Survey, National Cooperative Geologic Mapping Program, to the New Mexico Bureau of Mines and Mineral Resources (Dr. Charles E. Chapin, Director; Dr. Paul W. Bauer, P.I. and Geologic Mapping Program Manager). The map has not been reviewed according to New Mexico Bureau of Mines and Mineral Resources standards. Revision of the map is likely because of the on-going nature of work in the region. The contents of the report and map should not be considered final and complete until reviewed and published by the New Mexico Bureau of Mines and Mineral Resources. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the State of New Mexico, or the U.S. Government.