Placitas 7.5′ Quadrangle
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GEOLOGY OF THE PLACITAS 7.5-MINUTE QUADRANGLE, SANDOVAL COUNTY, CENTRAL NEW MEXICO

by
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INTRODUCTION

The Placitas 7.5-minute quadrangle comprises an area of about 158 km^2 (61 mi^2) along the northern flank of the Sandia Mountains in southern Sandoval County, central New Mexico (**Fig. 1**). During the past thirty years, land use in the area has changed from rural and agricultural (primarily rangeland and local farming) to predominantly rural-residential, recreational and to a lesser extent agricultural uses. Significant residential growth along the northwestern flank of the Sandia Mountains has resulted in increased demands on development of local groundwater supplies and suitable building sites. The geologic map (**Plate I**) is the result of detailed field reconnaissance mapping that has refined the structure and stratigraphy of part of the northern Sandia Mountains and the eastern margin of the Albuquerque Basin. This quadrangle should be of use to earth scientists, hydrologists, engineers, landowners and others who are interested in the general configuration of rocks and geologic structures in the area; especially features of interest to a growing community of people in the area who wish to understand the groundwater-resource potential and to avoid or prepare for natural hazards of a mountainous semi-arid environment.

The first published comment of the geology of the northern Sandia Mountains was by E.D. Cope in 1875 (Kelley and Northrop, 1975). Stearns (1953) described the geology of the Santo Domingo basin and Kelley and Northrop (1975) published a geologic map of the Sandia Mountains at a scale of 1:48,000, thereby providing the first detailed geologic description of the study area. Kelley (1977) later published a geologic map and description of the Albuquerque Basin at a smaller scale. Detailed work on the stratigraphy, structure and geomorphology of the northern flank of the Sandia Mountains was completed by Picha (1982), Menne (1989) and Connell (1996).

Geologic mapping was completed in cooperation with the University of New Mexico (UNM) and the New Mexico Bureau of Mines and Mineral Resources (NMBMMR). Aerial photographs were used as an aid to field mapping. The topographic base for the geologic map is the Placitas quadrangle, 7.5-minute topographic series, published by the United States Geological Survey, enlarged to 1:12,000 (one inch equals 1000 feet). The large map scale permits the depiction of geologic structures and rock units that are not included in Kelley and Northrop (1975). Additional mapping was done by Bradley Ilg (UNM) and Orin Anderson (NMBMMR). Radioisotopic ($^{40}Ar/^{39}Ar$) age determinations were made by Bill McIntosh (NMBMMR). Mapping of the basin-fill and Quaternary deposits were performed by Cather and Connell at a scale of 1:24,000. The distribution of pre-Tertiary rocks was incorporated, with little modification, from larger scale maps completed by Picha (1982; scale of 1:12,000) and Menne (1989; scale of 1: 8000). Compilation of data from various sources (**Fig. 2**) and scales of mapping onto the geologic map resulted in significant variations in the apparent precision of mapping across the study area; therefore, differences in map detail are inevitable.

Principal contributions and revisions to previous work (Kelley and Northrop, 1975; Kelley, 1977; Picha, 1982; and Menne, 1989) include: radioisotopic age determinations for a Tertiary igneous dike and volcanic clasts within the upper Santa Fe Group; stratigraphic reinterpretation of the Tertiary dike; differentiation of lithofacies within the Santa Fe Group, the major aquifer in the region; differentiation of post-Santa Fe Group piedmont stratigraphy; recognition of the Lomos fault, a significant, previously unmapped structure; reinterpretation of fold orientations in the Santa Fe Group; and constraints on fault activity.

COMMENTS TO MAP USERS

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This quadrangle map has been Open-Filed in order to make it available as soon as possible. The map has not been reviewed according to NMBMMR standards, and due to the ongoing nature of work in the area, revision of this map is likely. As such, dates of revision are listed in the upper right corner of the map and on the accompanying report. ***The contents of the report and map should not be considered final and complete until it is published by the NMBMMR.***

A geologic map graphically displays information on the distribution, nature, orientation, and age relationships of rock and surficial units and the occurrence of structural features such as faults and folds. Geologic contacts are irregular surfaces that form boundaries between different types or ages of units. Data depicted on this geologic map are based on 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. Significant portions of the study area may have been mapped at scales smaller than the final map; therefore, the user should be aware of potentially 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 everywhere.

Any enlargement of this map could cause misunderstanding in the detail of mapping and may result in erroneous interpretations. The information provided on this map cannot be substituted for site-specific geologic, hydrogeologic, or geotechnical investigations. The use of this map to precisely locate buildings relative to the geological substrate is not recommended without site-specific studies conducted by qualified earth-science professionals.

The cross-sections in this report are constructed based on surficial geology, and where available, subsurface and geophysical data. The cross sections are interpretive and should be used as an aid to understand the geologic framework and not used as the sole source of data in locating or designing wells, buildings, roads, or other structures.

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 U.S. Government.

Accessibility

Two major highways, I-25 and NM-165 (formerly NM-44), and several paved, gravel and dirt roads traverse the study area; however, much of the area is accessible only by foot or on horseback. Most of the land to the north is divided among the U.S. Forest Service (Cibola National Forest), Bureau of Land Management, Town of Tejon, Bernalillo (Felipe Gutierres) and San Antonio de Las Huertas land grants, numerous private land holdings and the Pueblos of Santa Ana and San Felipe; travel within Pueblo land and private property is prohibited or locally restricted. The southern one-third of the quadrangle lies within the Cibola National Forest and Sandia Wilderness. Private land is divided among several owners on former National Forest and land grant areas. The Village of Placitas is within the San Antonio de Las Huertas land grant. The Town of Tejon Grant occupies the northeastern fifth of the study area. The reservations of Santa Ana and San Felipe occupy the northern one-third of the quadrangle.

Geologic and Physiographic Setting

The quadrangle lies within the Basin and Range physiographic province, an area characterized by alternating, block-faulted ridges and valleys. The study area traverses the northern flank of the Sandia Mountains and eastern margin of the Albuquerque basin of the Rio Grande rift in central New Mexico (Woodward and others, 1978; Chapin and Cather, 1994). The Rincon, Placitas and San Francisco faults are major basin-margin structures that juxtapose east- and north-tilted blocks of Phanerozoic sedimentary and Proterozoic crystalline rocks of the Sandia Mountains, Cuchilla Lupe, Crest of Montezuma and the Cuchilla de San Francisco against upper Cenozoic basin sediments.

The study area exhibits 1384 m (4540 ft) of topographic relief, with a maximum elevation of 2938 m (9640 ft) along the crest of the Sandia Mountains to the south, and a minimum elevation of 1554 m (5100 ft) to the north at the mouth of Las Huertas Creek. Topography is generally steep and rugged in upland areas and is characterized by hogbacks and cuestas held up by resistant Pre-Tertiary sedimentary and crystalline rocks. Tertiary and Quaternary rocks are well exposed north of NM-165.

The study area vicinity has a warm, arid-to semi-arid continental climate with a mean annual precipitation of 178 to 254 mm (7 to 10 in) in lowland areas (Williams, 1986; Hacker, 1977). The foothills receive 254 to 356 mm (10 to 14 in) of rainfall per year, and the mountains receive 635 to 762 mm (25 to 30 in) (Hacker, 1977; Williams, 1986). Mean annual temperatures range from 14°C in the lowest regions, to 10°C along the foothills, to 4°C at Sandia Crest (Hacker, 1977). Vegetation is generally sparse, except at springs and along the floors of major arroyos, and consists primarily of juniper, grasses, shrub and cacti at lower elevations. The foothills support a juniper-piñon woodland association and the upland regions of the Sandia Mountains support a Ponderosa pine-mixed conifer woodland association (Williams, 1986).

STRATIGRAPHY

The following is a brief discussion of the distribution and character of upper Cenozoic deposits recognized in the study area.

Tertiary and Quaternary Systems

A northeast-striking, near-vertical mafic or intermediate dike east of Lomos Altos yields a radioisotopic ($^{40}Ar/^{39}Ar$) date of 30.9±0.5 Ma (W.C., McIntosh, 1995 oral communication). The absence of a baked zone and truncation of flow foliation at the contact with lower Santa Fe Group sediments does not support Menne's (1989) interpretation that the dike predates Santa Fe Group deposition.

Santa Fe Group

The Santa Fe Group comprises the major basin fill unit within the Rio Grande. It also is the principal aquifer in the region (Hawley and Hasse, 1992). The name "Santa Fe marls" was used by Hayden (1869 and 1873) to describe deposits within the Rio Grande Valley near Santa Fe, in north-central New Mexico. Darton (1922) later used the term Santa Fe Formation for these rocks. Bryan (1938) extended usage into the Albuquerque basin and Bryan and McCann (1937) divided the Santa Fe Formation into the lower gray, middle red and upper buff members. Spiegel and Baldwin (1963) elevated the Santa Fe Formation to group status. West of the study area, Galusha (1966) defined deposits of the lower Santa Fe Group, along the southern flank of the Jemez Mountains, as the Zia Sand. Machette (1978) defined the Sierra Ladrones Formation (upper Miocene through lower Pleistocene) for predominantly axial-fluvial deposits that interfinger with piedmont alluvium at the southern end of the basin.

The Santa Fe Group is informally divided into upper and lower units within the study area. Upper and lower units are subdivided into lithofacies based on clastic composition and bedding style. The lower Santa Fe Group is divided into three facies (Tsps, Tspcs, Tspc) consisting of slightly to moderately deformed, moderately to well cemented, pebble to cobble conglomerate and sandstone that unconformably rests on early Tertiary and older rocks. Bedding generally dips between 15° and 40° to the north and northeast. The basal conglomerate contains reworked clasts of reddish-brown sandstone and volcaniclastic rocks derived from the Abo and Espinaso Formations, respectively (Menne, 1989). Clasts of limestone, derived from the Madera Formation, and Proterozoic crystalline rocks increase in abundance up section, indicating the area was receiving deposition from steams incising into the rising block of the Sandia Mountains during the Miocene (Menne, 1989; May and others, 1994). Apatite fission-track analyses, an indicator of cooling and uplift, constrains the time of uplift of the Sandia Mountains and initial deposition of the Santa Fe Group between 15 and 35 Ma (S.A. Kelley and others, 1992).

The upper Santa Fe Group is divided into four lithofacies (QTsa, QTst, QTspcs and QTspc) consisting of horizontal to subhorizontal, poorly to well-cemented, pebble to cobble conglomerate, sandstone and variable proportions of mudstone in fault contact with lower Santa Fe Group deposits; no depositional contacts were observed in the study area. Deposits of the upper Santa Fe Group dip 0° to 10° (typically 0° to 5°) to the north and east. Piedmont deposits range from local boulder and cobble conglomerate along the basin margin to interbedded sandstone and conglomerate to the west. Clast contents reflect the dominance of Proterozoic and Paleozoic rocks in the upland source regions. Axial-fluvial deposits (QTsa) contain variable proportions of sand and gravel, intercalated with mud, which were deposited by a through-flowing ancestral Rio Grande fluvial system. These gravels commonly contain rounded quartzite, basalt and minor pumice, indicating an extrabasinal source and a northern provenance. Measurements of gravel imbrication indicate westward paleoflow in the piedmont (QTspcs, QTspc) and transitional (QTst) deposits and southwestward in the axial lithofacies (QTsa). Axial lithofacies, west of the Placitas quadrangle (NE1/4, NE1/4, SE1/4, Section 27, T12N, R04E, NMPM, Bernalillo 7.5-minute quadrangle), yielded a *Glyptotherium* of Irvingtonian age (Lucas and others, 1993, p.6). A radioisotopically dated pumice clast from unit QTst (SE1/4, SW1/4, NE1/4, Section 34, T12N, R03E, Bernalillo 7.5-minute quadrangle) is correlative to the lower Bandelier Tuff (W.C. McIntosh, 1995 oral communication), indicating that deposition continued through at least the early Pleistocene. Ages are further constrained by an occurrence of reworked, highly altered ash of the Bandelier Tuff (Nelia Dunbar, 1996 oral communication) within unit QTspcs (SW1/4, NW1/4, SW1/4, Section 17, T13N, R05E, NMPM).

The top of the upper Santa Fe Group is locally marked by an areally extensive limestone conglomerate (Qp2 and Qpf2) that unconformably overlies nearly flat to gently dipping beds of the upper Santa Fe Group. The absence of topographically higher geomorphic surfaces on the hanging wall of the Valley View, Lomos and Escala faults and the apparent lack of any well developed buried soil, suggests that Qpf2 represents the highest level of piedmont progradation in the basin, just prior to long-term net incision of the Rio Grande in the early or middle Pleistocene.

Age and depositional relations indicate that the upper Santa Fe Group is probably correlative to the Sierra Ladrones Formation (Machette, 1978), an interpretation confirmed by Lucas and others (1993) to the south in Tijeras Canyon. To avoid confusion in the stratigraphic nomenclature by superceding historic use of the terms upper buff formation (Bryan and McCann, 1937) and Ceja member of the Santa Fe Formation (Kelley, 1977), formal correlation to the Sierra Ladrones Formation is reserved until additional mapping is completed to the west and south.

Upper Pliocene(?) and Quaternary alluvial sequence

The Upper Pliocene(?)-Quaternary alluvial sequence, as discussed in this report, is a sequence of stepped piedmont and valley-border landforms, deposits and geomorphic surfaces that unconformably overlie older rocks. Members of this sequence range from historical to probable Late Pliocene in age and are informally defined, mapped and correlated on the basis of stratigraphic superposition, soil-profile characteristics, surface morphology (dissected or non dissected), landscape-topographic position (Connell, 1996, p.75), and to a limited, extent clast lithology (Connell, 1996, p.133). Geomorphic surfaces typically contain suites of landforms and associated deposits that formed during a given interval of time and grade to former base levels (see Gile and others, 1981). A geomorphic surface can extend across constructional and erosional landforms and can typically develop distinctive pedologic (soil) features and surface-morphologic characteristics, such as degradation of bar-and-swale topography or dissection of the ground surface.

Deposits of this alluvial sequence are a mixture of poorly sorted, poorly to moderately stratified, clast- and matrix-supported alluvium having predominantly gravelly and sandy textures. Details of deposit character are discussed in the Explanation of Map Units section accompanying the geologic map (**Plate I**). These deposits record episodes of valley entrenchment and partial backfilling that preceded development of the present valley and arroyo topography. Preserved geomorphic surfaces and alluvial deposits were graded to former base levels of the Rio Grande and major tributary streams. Former floodplain positions (Qvya and Qvo) and piedmont-slope alluvium (QTpf1, Qpo, Qfy) were graded to heights of 3 to 100 m above local base level. Projections of these units show divergence into the basin (Connell, 1996, p.75 and 90), probably related to long-term net incision of the Rio Grande during the Quaternary (Gile and others, 1981; Wells and others, 1987) coupled with uplift along basin-margin faults (Connell, 1996; Connell and Wells, 1996). Clast lithology reflects composition of older units exposed within local upland drainage-basins. Recycling of sediments from older alluvial units are locally common within younger deposits, such as Qal, Qaf, Qvya and Qfy.

Alluvial deposits in the study area are derived from upland and piedmont sources. Upland regions, which occupy the southern one-third and eastern one-fifth of the quadrangle, are dominated by erosion with only local, short-term sediment storage. Mass-movement deposits are common on hillslopes; hyperconcentrated-flow, debris-flow and local stream-flow deposits occur in higher order drainages. Piedmont-slope deposits and geomorphic surfaces, which occupy the southwestern corner and parts of the northern one-half of the quadrangle, are dominated by stream-flow, and local debris- and hyperconcentrated-flow deposits. These deposits form constructional landforms on coalescent piedmont alluvial-fan complexes, alluvium preserved on formerly extensive erosional (pediment) surfaces, and terrace-deposits developed over Santa Fe Group and older deposits. Valley-fill and valley-border deposits are dominated by stream-flow. Slumps and colluvium are common along unit margins and on terrace risers associated with incised drainages. Valley-floor deposits occupy the floodplain of the Rio Grande and terraces associated with ancestral tributary streams.

Unit QTpfo(?) is topographically the highest unit that unconformably overlies Santa Fe Group deposits. Menne (1989) described this unit on Lomos Altos, where it is recognized by an abrupt increase in limestone clasts. The basal contact is sub-parallel to the underlying lower Santa Fe Group, suggesting that this unit may actually be a limestone-rich part of the lower Santa Fe Group (Tspc).

Unit QTpf1 unconformably overlies moderately tilted beds of Tspcs and well cemented and slightly to moderately tilted deposits of QTspcs. Deposits are less than 18 m in thickness and dominated by limestone clasts. This unit is common along the eastern slopes of the Cuchilla de San Francisco and Sandia Mountains, where the surface grades northeastward to the elevation of the Tuerto gravels in the adjacent Hagan quadrangle (Stearns, 1953; Picha, 1982). Thus QTpf1 is correlative to the Tuerto gravels. Correlation of outliers of QTpf1 on the hanging wall of the Placitas and San Francisco faults is less well constrained; however, these deposits occupy a similar stratigraphic landscape-topographic position and are, therefore, likely correlatives to the Tuerto gravels.

Unit Qp2 overlies a formerly broad surface of erosion that extended northwestward from the mountain front, where it thickens and is mapped as unit Qpf2. This unit overlies upper Santa Fe Group deposits in a slight angular unconformity that becomes less angular to the northwest. The apparent lack of higher preserved geomorphic surfaces on the upper Santa Fe Group suggests this unit may represent the westward progradation of piedmont facies shortly after the start of long-term incision by the Rio Grande. The western extent of unit Qpf2 is about 104 m above the Rio Grande floodplain and unconformably overlies early to middle Pleistocene basin-fill deposits of the upper Santa Fe Group. The airport surface (Sunport surface of Lambert, 1968) forms a broad surface at the mouth of Tijeras arroyo (south of Albuquerque) about 114 m above the Rio Grande floodplain. This surface overlies lower to middle Pleistocene deposits of the upper Santa Fe Group, and was abandoned during the middle Pleistocene (about 320 ka, Machette, 1985). Unit Qpf2 occupies similar stratigraphic and landscape-topographic positions and has a similar degree of soil development and may be roughly equivalent to the airport surface.

Holocene deposits (Qal, Qaf) occur as range-front alluvial fans and as valley fills associated with arroyo systems. Upper Pleistocene deposits occur within arroyo systems (Qvya) and on piedmont slopes (Qfy, Qfy3, Qfy2). Middle Pleistocene deposits (Qvo, Qfo, Qpo) comprise arroyo-terrace, fan- and pediment-alluvium that predate extensive dissection of the piedmont. A major episode of valley entrenchment occurred after the formation of unit Qvya and Qvy3 when the Rio Grande incised into the Santa Fe Group, probably during the latest Pleistocene (Lambert, 1968).

A particularly long period of base-level stability is recorded in the aggradation of units Qfy, Qvy, Qfy2, Qfy3 and the alluvium of Edith Boulevard (Lambert, 1968) (west of the study area), which formed after an episode of major basin incision by the Rio Grande (Connell, 1996). Kelley and Northrop (1975, p.73) discuss the history of the terms Placita Marl and Zandia (or Sandia) Clay, terms coined by E.D. Cope in 1875 and 1877. Kelley and Northrop concluded that Cope used these terms synonymously. They also noted that these terms have not been used since Wilmarth (1938, referenced in Kelley and Northrop, 1975, p.73) and, in the absence of detailed descriptions and mapping, should be abandoned. A field sketch by Cope (in Kelley and Northrop, 1975, p.83) notes the location of the Zandia Clay, which corresponds to the broad valley floors near Placitas mapped as Qvya and Qvy3. A Rancholabrean fauna was described within arroyos north of Placitas (Kelley and Northrop, 1975, p.73; F.C. Hibben, 1996 oral communication), however, these localities were never recorded. The occurrence of a late Pleistocene fauna within deposits possessing weakly developed soils indicate that Qvya and Qvy3 recorded a period of aggradation that persisted from the latest Pleistocene through early(?) Holocene. This period of aggradation was followed by development of the present arroyo system sometime later in the Holocene.

STRUCTURAL GEOLOGY

Faults in the Placitas quadrangle exhibit predominantly normal throw of Santa Fe Group deposits , apparently related to development of the Albuquerque basin. Faults in the area consist of two types: north-northeast-striking faults, such as the Valley View, Rincon, San Francisco and Escala faults; and east-northeast-striking faults, such as the Placitas and Lomos faults. The Powerline fault is named for a south-facing topographic escarpment north of the powerlines in sections 17 and 18 (T13N, R05E, NMPM) that was mapped by Kelley (1977). This structure is inferred because of the lack of stratigraphic evidence for displacement. The Lomos fault is a previously unrecognized structure that juxtaposes upper against lower Santa Fe Group deposits.

Stratigraphic throw of upper Santa Fe Group deposits decreases to the northwest, which confirms May and Russell's (1994) interpretation that uplift and erosion of the northern flank of the Sandia Mountains occurred as the locus of faulting migrated into the basin (Connell and Wells, 1996). The juxtaposition of upper Santa Fe against lower Santa Fe Group deposits suggests that syntectonic sedimentation was associated with intrabasinal (synthetic or imbricate) faults (such as the Valley View, Escala and Lomos faults) that developed across a major step in the basin margin defined by the Rincon, Placitas and San Francisco faults (see Woodward and Menne, 1995; Russell and Snelson, 1994; Connell and Wells, 1996).

Two folds are recognized within the lower Santa Fe Group, near Lomos Altos and the Cuchilla de Escala. These synclines are open and plunge to the north-northeast, rather than northwest, as mapped by previous workers (Menne, 1989) and thus, cannot be not used to infer dextral slip along the major basin-margin structures (Menne and Woodward, 1995). These folds may be related to drag along north- to northeast-striking faults. In various publications V.C. Kelley (Kelley and Northrop, 1975 and Kelley, 1977, 1982) proposed that the northern flank of the Sandia Mountains formed a structural ramp that developed in an *en echelon* step between the left-oblique San Francisco and Ranchos-Rincon faults. This step would be considered a restraining bend (Sylvester, 1988) along a left-oblique fault; however, stratigraphic throw, fold orientations and geomorphic relations support normal displacement, rather than any significant left-oblique motion. In contrast, regional studies (Russell and Snelson, 1994; Woodward, 1977) also suggest a northwest-southeast direction of extension. Minor (dextral?) strike-slip movement could be partitioned along the Placitas fault, which would serve as a transfer structure between the dominantly dip-slip north-striking San Francisco and Rincon faults.

GEOLOGIC HAZARDS

Geologic hazards discussed in this section refer to only a few of the potential hazards that could effect residential development in New Mexico. These hazards include, but are not limited to, problems associated with differential expansion or settlement of the foundation substrate, slope instability, flooding, and seismic hazards (see Haneberg, 1992ab). This section presents a preliminary and qualitative assessment of potential geologic hazards within the Placitas quadrangle and is intended only as a general guide to potential geologic hazards, **not** as a substitute for site-specific studies of potential hazards conducted by qualified, professional engineers or scientists.

Data sources are from the geologic mapping and evaluation of previous work (Stearns, 1953; Kelley and Northrop, 1975; Hacker, 1977; Picha, 1982, Menne, 1989; and Connell, 1996). A soil survey of the area (Hacker, 1977), covering the southern one-third of the quadrangle, provides data on the physical and engineering properties of some soils in the study area (**Tables 1 and 2**). Soil-limitation ratings noted in the soil survey are listed below:

S*light*—soil properties are generally favorable for the rated use with only minor limitations;

Moderate—some soil properties are unfavorable but can be mitigated by special planning or design; and

Severe—some soil properties are so unfavorable that major soil reclamation or special design is required.

The use-limitation ratings (Hacker, 1977) of particular soils include (**Table 2**):

Private sewage disposal systems—suitability of soil permeability, depth to water table, slope gradient and susceptibility to flooding;

Shallow excavations (such as, irrigation, power, sewer and telephone lines)—absence of rock outcrops, shallow water table and large clasts;

Buildings—capacity of a soil to support a load and resist consolidation; and

Paved roads—capacity and stability of subgrade, quantity and ease of excavation of cut- and fill-material, shrink-swell capacity and susceptibility to flooding.

Potential hazards to foundations that are not designed for specific soil conditions include volumetric changes (shrink-swell) in earth materials having relatively high proportions of clay. The potential for shrinkage or swelling of a given material is related to the type and quantity of clay (kaolinite, illite, montmorillonite), field moisture content, and loads imposed by the foundation (Costa and Baker, 1981; Hollingsworth and Grover, 1992). Volumetric changes and material strength of a given clay-rich substrate are strongly influenced by the plasticity of the clay-size fraction (Kenney, 1984). Formations containing high-activity clays (such as, illite or montmorillonite) have a greater potential for volumetric change than rocks having lower activity clays (such as, kaolinite). Differential movement of the substrate may occur as foundation loads are imposed across areas underlain by rocks having different bearing strengths and shrink-swell capacities. Fine-grained and clayey intervals are common with the Abo, Petrified Forest, Yeso, Morrison and Menefee Formations (Stearns, 1953; Kelley and Northrop, 1975; Picha, 1982; Menne, 1989). These rocks may contain expansive materials that may also be subject to movement on hillslopes, especially where unsupported bedding planes are exposed.

Hydrocompactive soils are low-density, silty to very fine-gained sand having high void ratios (Dudley, 1970). Compaction occurs when the soil volume decreases when saturated by water (Das, 1984), typically by the introduction of concentrated storm runoff, landscape irrigation or ponding of septic-system effluent on the substrate. Hydrocompactive deposits generally occur within Holocene-aged, fine-grained, weakly to non-cemented sediments that have a low bulk density, high void ratio and have not been extensively irrigated (Haneberg, 1992a; Hollingsworth and Grover, 1992; Shaw and Johnpeer, 1985ab). Quaternary terrace-deposits and valley fills in the study area are generally coarse grained and should not pose a significant collapsible soil hazard; however, fine-grained deposits occur locally within the broad valleys (Qal, Qaf, Qca and Qvya) near Placitas and Tecolote and should be evaluated if encountered.

Slope instability involves a variety of failure and transport mechanisms, including rock falls, landslides and debris flows (Varnes, 1978). Slope failure can occur during earthquakes, after intense rainfall, or by intensive landscape irrigation (Spittler and others, 1990; Haneberg and Tripp, 1991; and Haneberg and Bauer, 1993). Areas susceptible to slope instability may be qualitatively evaluated by: 1) occurrence of existing slope failures; 2) physical properties of substrate and orientation bedding or other planes of weakness; 3) intensity and duration of rainfall; and 4) steepness and height of slopes (Brabb and others, 1989; Crozier, 1984). No morphologic evidence of major shallow or deep-seated landslides was recognized in the study area, therefore, upland slopes have been relatively stable during past and current climates. Changes in land use or significant increases in the type or magnitude of seasonal moisture could establish conditions favorable to mass movement, especially in slopes having large components of unsupported bedding-plane dip or slopes that are underlain by relatively fine-grained colluvial deposits (Campbell, 1975). Steep canyons may be particularly sensitive to debris-flow activity following wildfires (Valentine and others, 1991). Modification of natural slopes during construction of building sites could result in exposure of unsupported bedding planes or poorly consolidated colluvium, which may be subject to translational block-glide failures or flow during or after cut-slope construction. Relatively thick accumulations of colluvium within steep mountain-front drainages could pose a potential for debris-flow activity within stream canyons.

Well-cemented and conglomeratic sections of the Santa Fe Group may be difficult to rip with conventional earth-moving equipment. Pediment alluvium (QTpf1, Qp2, Qpo, etc.) and conglomeratic beds of the Santa Fe Group (QTspcs, QTspc, Tspcs and Tspc) are commonly contain cobbles and boulders; therefore, foundations constructed within these units may be subject to differential compaction of sediment around large clasts if not removed and replaced with select fill.

Solution-related subsidence occurs as salt and calcium-carbonate is dissolved by fresh-water moving through evaporite and limestone. Dissolution results in the development of cavities in the rock that enlarge, resulting in localized ground subsidence or sinkhole development (Ege, 1984). Areas underlain by evaporitic and limestone-rich units (such as the Madera, Yeso, San Andres and Todilto Formations) may be possible sites of solution-related subsidence. These rocks may also locally have high fracture porosity, and may yield sufficient quantities of water. Hacker (1977) considered the deterioration of cement foundations by soils to be low within the study area; however, sulfate-rich (gypsiferous) units, such as the Yeso, Petrified Forest, Entrada and Todilto Formations, could damage cement foundations by cracking, spallation or chemical degradation if not mitigated.

Potential hazards from storm-induced flooding are generally confined to incised drainages (arroyos) that may overflow during intense rainfall events. Steep hillslopes may be subject to run off during intense rainfall events, resulting in local gullying of slopes. Destabilization of cut-banks along low arroyo terraces and the floodplain may occur during flood events, notably during intense summer storms.

Several sets of northwest-, north- and northeast-striking faults cut Proterozoic and Phanerozoic rocks of the Sandia Mountains and Albuquerque basin. Stratigraphic data constrain the latest ground-rupture events of the major faults in the study area. Unit QTpf1 is offset by the Placitas fault. Unit Qp2 buries this structure, indicating that the Placitas fault has not moved since at least the middle Pleistocene. The Lomos, Escala and northern segment of the Rincon and Valley View faults are buried by units Qp3, Qp5 and Qvo5, and have not moved since the middle Pleistocene. Ages of displacements along the southern end of the San Francisco fault are ambiguous. The Escala fault juxtaposes upper-against-lower Santa Fe Group deposits, suggesting that tectonic activity has shifted west of the San Francisco fault during the Quaternary (Connell and Wells, 1996). Evidence of Holocene ground rupture was not recognized within the study area. The Rincon fault exhibits evidence of Holocene ground rupture to the south and may pose a ground-shaking hazard (Connell, 1996); however, recurrence times between rupture events are still poorly constrained.

GROUND-WATER RESOURCES

Detailed studies of ground-water resources are currently underway in the Placitas quadrangle and will be released by NMBMMR upon completion. This section presents a brief summary of a regional hydrogeologic study of the Sandia mountains in the early 1960's (Titus, 1980). This study delineates a north-sloping potentiometric surface that locally discharges at several springs along the northern flank of the mountains.

The hydrogeologic character of the rocks within the study area can be divided into several groups (Titus, 1980): Proterozoic crystalline; upper Paleozoic-Triassic; Jurassic-Cretaceous; Santa Fe Group (Neogene-Pleistocene); and Quaternary rocks deposits. Proterozoic crystalline rocks typically do not transmit water effectively, except locally along fractures. Areas of relatively high fracture porosity within crystalline rocks can locally yield groundwater of sufficient quality and quantity for domestic use; however these fractures may not be sufficiently interconnected for larger yields. The Pennsylvanian Madera Formation is a significant source of quality water east of the Albuquerque basin (Titus, 1980), but are overlain by thick deposits of the Santa Fe Group northwest of Placitas. Upper Paleozoic and Triassic rocks (including Abo, Yeso, Glorieta, San Andres, Santa Rosa Formation and the Chinle Group) can also provide groundwater suitable for domestic use. Wells developed in Jurassic and Cretaceous rocks (such as the Entrada, Todilto, Morrison Formation, Mancos Shale and Mesa Verde Group) are dominated by siltstone and mudstone that typically produce low yields. Pre-Santa Fe Group rocks are highly segmented by faults that partition the aquifer. Water locally occurs within these compartmentalized aquifers, but the quality is highly variable and locally unpotable (P.S. Johnson, 1996 oral communication).

The hydrogeologic character Santa Fe Group has not been fully described within the study area; however, this deposit forms the thickest and most extensive aquifer within the Rio Grande Valley (Hawley and Hasse, 1992; Titus, 1963). Estimates of formation transmissivity have been made to the south in Albuquerque (Hawley and Hasse, 1992), but total storage for the Santa Fe Group has not been defined in the study area. Axial-river facies of the upper Santa Fe Group (QTsa, QTst) are highly to moderately transmissive, whereas, piedmont facies (QTspcs, QTspc) exhibit moderate to low values of transmissivity (Hawley and Hasse, 1992). Water quality is generally suitable for domestic use; however, locally high concentrations of arsenic have been observed (P.S. Johnson and A.R. Groffman, 1996 oral communications).

The hydrogeologic character of Quaternary alluvium has not been described in detail. The quality of water within valley-fill deposits is generally acceptable for domestic use; however, the saturated thickness is typically less 1 m and may not yield water sufficient for domestic use (Titus, 1980, p.36). Older alluvial units occur above the zone of saturation, and may locally contain perched groundwater, particularly down-gradient of springs.

AGGREGATE RESOURCES

A detailed survey of aggregate resources in the Placitas quadrangle was not undertaken during this study. Extensive quarry operations within unit QTsa, at the northwest corner of the Placitas quadrangle and the northeast corner of the Bernalillo quadrangle, attest to the occurrence of commercially viable sand and gravel. This section briefly describes the aggregate-resource potential from geologic mapping and from data published by the New Mexico State Highway Department (NMSHD, 1964) and the Soil Conservation Service (Hacker, 1977). Data presented by NMSHD and SCS use nomenclature developed by American Association of State Highway and Transportation Official (AASHTO) for classifying sediments. The AASHTO classification is graded into seven divisions on the basis of particle-size distribution, liquid limit and plasticity index. Type A-1 soils are gravelly, have high bearing strength and produce exceptional foundation and subgrade materials. In contrast, A-7 soils have low (saturated) strength and makes very poor subgrade (Hacker, 1977, p.85)

Deposits of the Santa Fe Group, within the Bernalillo and Placitas quadrangle, are classed as A-1 and A-2 soils with a thin A-4 overburden (NMSHD, 1964). Quaternary alluvial units (such as Qpf2, Qvo5, Qvya and Qal) locally bury the Santa Fe Group, but are less than 5 m in thickness. Unit QTsa contains quartzite and mixed (limestone-dominated) sand and gravel of good quality and uniformity (NMSHD, 1964). Unit QTst is a mixed (limestone-dominated) aggregate of fair quality and uniformity (NMSHD, 1964). Piedmont deposits are generally more silt rich (A-1 through A-6), less uniform, and would make a poorer source of aggregate (NMSHD, 1964, section 25-13). Within the study area, these deposits are dominated by moderately to well-cemented limestone conglomerate and sandstone and would not be a suitable source of aggregate. Alluvial deposits are generally 2 to < 36 m in thickness and could be selectively removed during quarry operations.

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GEOLOGY OF THE PLACITAS 7.5-MINUTE QUADRANGLE, SANDOVAL COUNTY, CENTRAL NEW MEXICO

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and Mark Picha (eastern portion)

EXPLANATION OF MAP UNITS

COMMENTS TO MAP USERS

Mapping of this quadrangle was funded by a matching-funds grant from the 1998 STATEMAP program of the U.S. Geological Survey, National Cooperative Geologic Mapping Program, under USGS award number 1434-HQ-97-AG-01781, 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).

This quadrangle map has been Open-Filed in order to make it available as soon as possible. The map has not been reviewed according to NMBMMR standards, and due to the ongoing nature of work in the area, revision of this map is likely. As such, dates of revision are listed in the upper right corner of the map and on the accompanying report. ***The contents of the report and map should not be considered final and complete until it is published by the NMBMMR.***

A geologic map graphically displays information on the distribution, nature, orientation, and age relationships of rock and surficial units and the occurrence of structural features such as faults and folds. Geologic contacts are irregular surfaces that form boundaries between different types or ages of units. Data depicted on this geologic map are based on 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. Significant portions of the study area may have been mapped at scales smaller than the final map; therefore, the user should be aware of potentially 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 everywhere.

Any enlargement of this map could cause misunderstanding in the detail of mapping and may result in erroneous interpretations. The information provided on this map cannot be substituted for site-specific geologic, hydrogeologic, or geotechnical investigations. The use of this map to precisely locate buildings relative to the geological substrate is not recommended without site-specific studies conducted by qualified earth-science professionals.

The cross-sections in this report are constructed based on surficial geology, and where available, subsurface and geophysical data. The cross sections are interpretive and should be used as an aid to understand the geologic framework and not used as the sole source of data in locating or designing wells, buildings, roads, or other structures.

Quaternary and Pliocene Series
Alluvial Deposits

Quaternary and Late Pliocene(?) alluvial deposits of the Placitas 7.5-minute quadrangle contain variable proportions of gravel, sand and silt, deposited by intermittent and ephemeral streams; mass-movement deposits typically occur on adjacent hill slopes. Map-unit differentiation is based on stratigraphic position (inset or depositional relations), surface morphology, degree of soil-profile development and sedimentary character. Deposits are a mixture of poorly sorted, poorly to moderately stratified, clast- and matrix-supported alluvium, having predominantly gravelly to sandy textures; silt-clay textures are locally common. Deposits unconformably overlie older basin fill of the Santa Fe Group. Clast constituents typically reflect bedrock composition of local upland drainage systems associated with the northern and western flanks of the Sandia Mountains, Crest of Montezuma and the Cuchilla de San Francisco. Deposits are dominated by limestone clasts derived from the Madera Formation, along the northern flank of the Sandia Mountains. Proterozoic crystalline rocks and minor sandstone generally become more abundant in successively inset (younger) deposits. In contrast, alluvium derived from the western mountain front are dominated by crystalline rocks, with minor limestone constituents.

Soils were described at various, accessible locations within hand-tool excavated pits, stream-cut exposures and construction-site excavations (Connell, 1996). Soil-profile morphology was described using a standard system of diagnostic criteria and nomenclature developed by the U.S. Department of Agriculture (Soil Survey Staff, 1951, 1975, 1992 and 1993) and Gile and Hawley (1966) with modifications after Birkeland (1984). Colors (hues) were described using Munsell (1992) notation. Soils are characterized by weakly to strongly developed accumulations of soil carbonate that are typically less than 1-m thick; older deposits have strongly developed calcic soils exceeding 2 m in thickness. Pedogenic features are best preserved on broad, gently sloping portions of constructional (depositional) surfaces, such as interfluves or terrace treads that have not been significantly modified. Age estimates are based on comparisons of soil-profile development to other alluvial sequences in New Mexico (Gile and others, 1981; Drake and others, 1991; Wells and others, 1990; Kelson, 1986; Pazzaglia and Wells, 1990; Machette, 1978, 1985).

Alluvial deposits are divided into valley-fill alluvium, piedmont-slope alluvium, colluvium and travertine:

Valley-fill alluvium (Qa and Qv subunits) — Stream (floodplain, arroyo-terrace, strath-terrace and fill-terrace) deposits are restricted to major entrenched tributary valleys to the Rio Grande, such as Las Huertas Creek, Arroyo del Ojo del Orno and Agua Sarca. This subdivision also includes valley-border alluvium, younger basin-fill, and alluvial-plain deposits associated with the Rio Grande.

Piedmont-slope alluvium (Qfy, Qp and Qpf subunits) — Stream and alluvial-fan deposits on constructional and erosional parts of piedmont slopes. Units include fan and debris-flow deposits and shallow-valley fills that are not graded to major entrenched arroyo systems.

Colluvium and travertine (Qca, Qcao and QTtv subunits) — Mass-movement deposits and travertine recognized in upland regions and valleys.

Valley-Fill Alluvium

Stream-terrace and undivided valley-fill alluvium — Variable amounts of stream and fan alluvium, locally containing debris-flow and colluvial deposits derived from adjacent slopes and upland areas. Deposits commonly contain sediment recycled from older piedmont and valley-fill deposits. Terraces are associated with major arroyos and streams and are underlain by poorly to moderately stratified alluvium derived from local upland sources. Units typically have an elongated planform shape and are differentiated into fill-terrace and strath-terrace deposits on the basis of deposit thickness and surface morphology.

Qal Stream alluvium, undivided (Holocene) — Unconsolidated deposits of brown, light gray-brown, and yellowish-brown (10YR) sand, sandy clay loam and gravel. Boulders are common along range-front in southwest portion of map area. Unit grades westward to the Rio Grande floodplain. Weakly developed soils exhibit stage I carbonate morphology at depth. Exposed thickness is less than 2 m.

Qvya Younger stream alluvium, undivided (upper Pleistocene to lower Holocene(?)) — Poorly to moderately consolidated, brown to yellowish-brown (8.75YR) gravel, loam, sand loam and minor clay loam. Unit forms a broad low terrace along Las Huertas Creek. Clasts are chiefly rounded limestone and minor sandstone. The basal contact is irregular and unconformable. Soils are weakly developed and exhibit stage I+ carbonate morphology. The terrace tread is 3 to 24 m above local base level and terminates against inner valley escarpment of the Rio Grande at the northwest corner of quadrangle. The deposit surface is locally modified by 1-m) thick, discontinuous fill-cut terraces. Weak soil development and unpublished accounts of late Pleistocene fauna (F.C. Hibben, 1996 oral communication) indicate a latest Pleistocene to early Holocene age for unit. Exposed thickness is less than 6 m.

Qvy3 Younger stream alluvium, undivided (uppermost Pleistocene to lower Holocene(?)) — Poorly consolidated deposits of brown to light-brown (7.5-10YR) loamy sand and gravel. This unit contains greater proportions of sand, silt and clay within valley-fill deposits near the Villages of Placitas and Tecolote. Colluvium and debris-flow deposits are common along adjacent upland areas. The deposit surface is locally dissected by arroyos associated with unit Qal. Weakly developed soils exhibit stage I+ carbonate morphology and minor clay film development. Unit is equivalent to geomorphic surfaces Q7 and Q8 of Connell (1996). Exposed thickness is less than 6 m.

Qvo Older stream alluvium, undivided (middle Pleistocene) — Gravelly alluvium burying low-relief, elongate straths along Las Huertas Creek. Unit is truncated, west of the study area, by a buried escarpment formed during deposition of the alluvium of Edith Boulevard (Connell, 1996). Moderately consolidated deposits of very pale-brown to brown (7.5-10YR) sandy clay loam to silty clay loam and poorly sorted, subangular to subrounded, limestone-dominated cobble to boulder conglomerate. The surface is moderately dissected and forms relatively thin (less than 3 m thick) deposits about 9 to 32 m above local base level.

Qvo5 Older stream alluvium (middle Pleistocene) — Moderately consolidated deposits of pale- to dark-brown (7.5-10YR) clay loam to silty clay loam and cobble to boulder conglomerate. Clasts are dominated by limestone and metamorphic rocks. Unit forms relatively thin (less than 3 m thick) deposits overlying a strath approximately 6 to 27 m above Las Huertas Creek.

Piedmont-slope alluvium

Piedmont alluvium — Complex juxtaposition of poorly sorted, poorly stratified, clast- and matrix-supported deposits consisting of subangular-to subrounded, poorly to well-sorted gravel and sand. Contains primarily granitic, metamorphic and minor limestone clasts.

Qaf Piedmont alluvium (Holocene) — Unconsolidated deposits of brown, light gray-brown, and yellowish-brown (10YR) sand, sandy clay loam and gravel. Boulders are common in mountain-front fans along the southwest corner of the quadrangle. Surface is weakly dissected and possesses well developed bar-and-swale topography. Exposed thickness is less than 3 m.

Qfy Younger piedmont alluvium (upper Pleistocene to lower Holocene) — Poorly to moderately sorted and stratified gravel, sand with minor silt-clay mixtures inset against unit Qfo. Surfaces are moderately dissected and exhibit subdued bar-and-swale topography. Soils possess stage I to II+ carbonate morphology and weak-to moderately developed clay-film development. Unit is locally differentiated into subunits (Qfy3, Qfy2b and Qfy2a) based on soil-profile and inset relations. These units bury the alluvium of Edith Boulevard and terminate against the inner valley escarpment of the Rio Grande (Connell, 1996). Estimated thickness is approximately 36 m.

Qfy3 Younger piedmont alluvium (uppermost Pleistocene to lower Holocene(?)) — Poorly consolidated deposits of very pale-brown to light-brown (7.5-10YR) sand to sandy clay loam and gravel. Slightly dissected surface possesses well developed bar-and-swale topography. Weakly developed soils exhibit stage II carbonate morphology and minor clay film development. Exposed thickness is less than 3 m.

Qfy2b
Qfy2a Younger piedmont alluvium (upper Pleistocene) — Moderately consolidated deposits of very pale-brown to strong yellowish-brown (7.5-10YR), stratified, poorly sorted silty clay and loamy sand and gravel. The surface is slightly to moderately dissected and exhibits subdued bar and swale topography. Soils are moderately developed and characterized by stage II carbonate morphology. Unit Qfy2b is inset against Qfy2a. Exposed thickness is less than 8 m.

Qfo Older piedmont alluvium (middle Pleistocene) — Poorly to moderately sorted and stratified gravel and sand with minor silty-clay mixtures. Deposits are inset against QTpfo(?) and truncated by buried escarpment formed during deposition of the alluvium of Edith Blvd. Unit is equivalent to geomorphic surfaces Q3, Q4 and Q5 of Connell (1996). Exposed thickness is less than 2 m.

Qfo4 Older piedmont alluvium (middle Pleistocene) — Poorly to moderately sorted, moderately consolidated gravel and sandy clay loam, locally contains highly weathered and grusified granite and metamorphic clasts. Unit is inset against Qp3. Surface is locally buried by younger piedmont-slope and valley-fill deposits near NM-165. Soils are strongly developed and locally exhibit stage III to IV carbonate morphology. Exposed thickness is less than 2 m.

Pediment alluvium and pediment-fan complexes — Pediments, as mapped within the study area, are regional, low-relief surfaces of erosional cut by fluvial processes that locally span the mountain front-piedmont junction and cut various rock types. Pediment deposits are common south of NM-165 and exhibit an areally extensive, 1- to 5-m thick, cover of poorly exposed and stratified, poorly sorted, subangular to subrounded conglomerate and sandy gravel. Pediment-fan complexes, common north of NM 165, consists of an erosional surface that has been buried by a 1-to 20-m thick cover of poorly to well stratified, moderately sorted, subangular to rounded alluvium. Older units are dominated by limestone, which becomes less dominant on successively inset units. Deposit surfaces are locally stripped and exhibit complex, polygenetic soil profiles.

Qp5
Qpf5 Pediment alluvium (middle Pleistocene) — Moderately consolidated deposits of pale- to dark-brown (7.5-10YR) clay loam to silty clay loam and cobble to boulder conglomerate. Clasts are dominated by limestone and metamorphic rocks (about 2:3 ratio, respectively). Unit forms broad, northwest-sloping surface covered by a relatively thin conglomeratic veneer inset against Qp2. The deposit is slightly dissected, exhibits subdued bar-and-swale topography and thickens to the northwest. Soils are moderately developed and exhibit weak stage III carbonate morphology and many to continuous, thick clay films.

Qp3 Pediment alluvium (middle Pleistocene) — Moderately consolidated deposits of very pale-brown to brown (7.5-10YR) sandy clay loam to silty clay loam and poorly sorted, subangular to subrounded, limestone cobble to boulder conglomerate. Unit is poorly exposed and forms a 7- to 14-m thick, discontinuous conglomeratic veneer overlying a extensive pediment surface near the Village of Placitas. The deposit surface is moderately dissected and sits about 9 to 32 m above local base level.

Qp2
Qpf2
Qp2a Pediment alluvium (middle to lower(?) Pleistocene) — Moderately consolidated deposits of brown, very pale-brown to white (7.5YR - 2.5Y) sandy loam, sand and subrounded to subangular cobble to pebble conglomerate overlying remnants of extensive, relatively smooth, northwest-sloping pediment surface that cuts across the Placitas fault. The deposit surface is moderately dissected and sits about 34 to 50 m above local base level. Unit Qp2a is recognized in Sections 35 and 35 (T13N, R04E, NMPM) where it is about 12 m higher than Qp2. Bar-and-swale topography is absent and soils exhibit stage III+ carbonate morphology and very few, thin clay films. Deposit is less than 5 m thick.

QTpf1 Pediment alluvium (lower Pleistocene to Upper Pliocene(?)) — Well consolidated deposits of very pale-brown to brown (10YR - 2.5Y), sandy clay loam, sandy loam and subrounded to subangular, limestone-dominated, cobble to pebble conglomerate overlying remnants of a formerly broad pediment preserved on Santa Fe Group deposits on Lomos Altos and surrounding hills. The deposit is 4- to 18-m thick, poorly exposed, non-stratified, sits about 80 to 100 m above local base level and is inset against QTpfo(?). Soils are strongly developed, partially stripped and exhibit stage IV+ carbonate morphology. Unit may be equivalent to the Tuerto gravel of Stearns (1953).

QTpfo(?) Pediment alluvium (Pliocene) — Probably deposit of consolidated upland limestone-dominated gravels unconformably overlying lower Santa Fe Group (Tspcs) deposits on Lomos Altos. Unit is about 12 m in thickness and recognized by an abrupt increase in limestone clasts. The basal contact is about 60 m above local base level. Deposits are subparallel to Tspc and thus may be a limestone-rich unit of the lower Santa Fe Group.

Colluvium and Travertine

Qca Colluvium and alluvium, undivided (Holocene to upper Pleistocene) — Poorly consolidated, poorly sorted and stratified, fine- to coarse-grained, clast- and matrix-supported deposits derived from a variety of mass-movement hill slope processes, including debris flow, shallow slump and creep. Deposits are delineated by sedimentary character and surface morphology. Clasts are typically angular and composition generally reflects local provenance. Locally present on eastern slope of Sandia Mountains where is includes small bedrock inliers. Differentiated where areally extensive.

Qcao Older colluvium and alluvium, undivided (Pleistocene) — Locally preserved on high-elevation slopes along the northwestern flank of the Sandia Mountains.

QTtv Travertine deposits (Pleistocene-Miocene(?)) — Light-gray nodular to massive limestone interlayered with mudstone. Recognized at the northern tip of the Cuchilla de San Francisco, where deposits overlies unit Tspcs. Thin limestone interbed also occur with Tspcs. Deposits also occur along within valleys associated with Qvya (notably along the base of the Cuchilla de San Francisco). Thickness is variable, but can more than 15 m thick at the northern tip of the Cuchilla de San Francisco.

Tertiary System
Upper Santa Fe Group (upper Miocene to middle(?) Pleistocene)

QTsa Axial river deposits — Variable proportions of sandstone, conglomerate and mudstone deposited by the ancestral Rio Grande. Sandstone is typically crossbedded. Clasts in conglomerate are quartzite, chert, granite, gneiss, sandstone, volcanic, siltstone, limestone, schist, phyllite and pumice. Mudstone ranges in color from light brown to grayish green. Paleoflow was south or southwest. Triangles (Δ) indicate selected exposures of axial sandstone and conglomerate used to delineate areal extent of axial river deposits (QTsa) and transitional axial-piedmont deposits (QTst). A *Glyptotherium* reported in the Bernalillo quadrangle (Lucas and others, 1993) indicates an early to middle Pleistocene age for the unit.

QTst Transitional axial-piedmont deposits — Interfingered axial river deposits (QTsa) and piedmont deposits (QTspcs). 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 facies tract (piedmont vs. axial), and thus is not a factor in delineating the transitional facies. A pumice clast from axial river deposits within QTst along the western edge of the quadrangle about 50 m north of NM 165 has been identified by radioisotopic ($^{40}Ar/^{39}Ar$) dating as Lower Bandelier pumice (W. C. McIntosh, 1995 oral communication), thus providing a maximum age of 1.62 Ma in the study area.

QTspcs Piedmont deposits — 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.

QTspc Piedmont deposits — Conglomerate (conglomerate: sandstone ratio is greater than 2). Clasts are pebbles, cobbles, and boulders of lithologies similar to clasts in QTspcs. Sandstone is coarse to very coarse and typically crossbedded or horizontally laminated. Matrix-supported conglomerate (debris-flow) deposits are common. Mudstone is very rare.

Lower Santa Fe Group (Miocene)

Tsps Piedmont deposits — 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 rocks. Siltstone is massive to faintly laminated and forms tabular to broadly lenticular beds.

Tspcs Piedmont deposits — Subequal sandstone and conglomerate. Sandstone is medium to very coarse 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. Mudstone is rare.

Tspc Piedmont deposits — Conglomerate (conglomerate: sandstone ratio is approximately 2:1) with subordinate sandstone. Conglomerate is mostly clast supported, although matrix-supported deposits are also present. Clast content varies upsection. Tertiary volcanic clasts (Espinaso Formation) occur near the base of the section exposed at Lomos Altos, with Paleozoic and Proterozoic detritus dominating upsection. Mudstone is absent.

Tertiary Intrusive Rocks

Ti Mafic or intermediate dike (Oligocene) — A single, approximately 1.1-km long, northeast-striking mafic or intermediate dike, located approximately 1 km north of the Village of Placitas. Unit is buried by Tspc and is dated at 30.9±0.5 Ma by the $^{40}Ar/^{39}Ar$ method (W.C. McIntosh, 1995 oral communication).

Mesozoic Erathem

Kmf Menefee Formation — Gray, tan to orange-tan sandstone, siltstone, gray shale and lignitic, dark brown coal and maroon ironstone lenses; gray Harmon Sandstone Member is 110 m above base. Unit is 250-560 m thick.

Kpl Point Lookout Sandstone — Tan to grayish-white sandstone with limonitic sandstone lenses. Unit is 75 m thick.

Km2 Upper Mancos Shale — Gray to olive-brown shale with minor light gray to orange-tan siltstone and sandstone. Unit is 65 m thick.

Khd Hosta-Dalton Sandstone — Drab, yellow-gray to yellow-tan sandstone with olive-brown sandstone lenses. Unit is 65-115 m thick.

Km1 Lower Mancos Shale — Same lithology as Upper Mancos Shale; lower part contains distinctive platy limestone and calcarenite beds of the Juana Lopez Member. Ammonite collected from Juana Lopez Member has been identified as *Priohocylus quadratus*. Unit is 310 m thick.

Kd Dakota Sandstone — Yellow-gray to orange-yellow sandstone and olive-black to ray shale; contains marine trace fossils. Unit is 22 m thick.

Jm Morrison Formation — Yellowish gray-weathering medium to coarse grained, pebbly, friable sandstone; overlain by grayish yellow green to very pale green claystone and lesser siltstone. Clay is generally smectitic. Unit is up to 70 m in thickness.

Jsu Upper San Rafael Group — Includes light greenish gray siltstone and fine-grained sandstone, light yellowish gray fine-grained sandstone, and dusky red or maroon mudstone and siltstone in lower part, and very pale orange to grayish orange crossbedded sandstone in upper part. Correlates with Summerville Formation and Bluff Sandstone. ***Thickness***

Jt Todilto Formation — light olive gray, laminated, fetid limestone. Limestone is locally overlain by thin gypsum. Unit is up to 15 m in thickness.

Jp Entrada Formation — Reddish-brown with lesser light tan greenish-gray crossbedded (eolian) sandstone. Unit is 35 m thick.

TRc Petrified Forest Formation — Mudstone interbedded with lenticular lavender-gray sandstone; mudstone are reddish-brown to orange-tan in upper part, and purple to reddish-brown in lower part; local limestone-pebble conglomerate lenses. Regional thickness ranges from 400 to 500 m.

TRs Agua Zarca Formation — Light gray to grayish orange or tan, conglomeratic sandstone, and reddish-brown mudstone. ***Thickness***

TRm Moenkopi Formation — Moderate to dusky red micaceous sandstone, commonly laminated. Unit is 25-30 m thick.

Paleozoic Erathem

Psa San Andres Formation — Yellow-brown to gray limestone; some grayish-white sandstone beds similar to Glorieta Formation. Unit is 20-25 m thick.

Pg Glorieta Formation — Light gray, well-indurated sandstone. Unit is approximately 10 m thick.

Py Yeso Formation, undivided — Regional thickness ranges from 165 to 210 m.

Pys San Ysidro Member — Red-brown sandstone and yellow-gray nonfossiliferous limestone.

Pym Meseta Blanca Member — Red-brown to tan-brown sandstone; generally cleaner and finer grained than Abo Formation sandstone.

Pa Abo Formation — Red-brown, texturally and compositionally immature sandstone; red-brown mudstone. Regional thickness ranges from 230 to 330 m.

|Pm Madera Group, undivided — Upper arkosic member of arkosic limestone and sandstone, gray, tan and maroon shale; lower limestone member of gray fossiliferous, cherty limestone. Unit is regionally 380-470 m thick.

|Pm Sandia Formation — Well-cemented, coarse-grained basal sandstone, gray to tan-gray limestone, and olive-green micaceous sandstone. Contact with Arroyo Peñasco Formation is an angular unconformity. Unit is 59 m thick.

Ma Arroyo Peñasco Formation — Upper pinkish-gray saccharoidal and gray limestone; basal Del Padre Sandstone; gray-green, quartz-pebble conglomerate, maroon and gray-green mudstone, and yellow-gray siltstone. Unit is 0- to 23-m thick.

Mau upper quartzite member — Distinctive, white, quartz-pebble quartzite that occurs in uppermost Arroyo Peñasco Formation, along western slope of the Crest of Montezuma. Overlain by gray limestone. Unit is 1-2 m thick.

Middle Proterozoic Erathem

Yp Pegmatite dikes — Dikes, pods and lenses ranging from less than 1 cm to over 15 m in thickness and up to 1.6 km in length. Composed of pegmatite, aplite and quartz (Kelley and Northrop, 1975); 1.4 Ga.

Ys Sandia granite — Megacrystic monzogranite to granodiorite, several-cm-long K-feldspar megacrysts 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; 1.4 Ga.

Early Proterozoic Erathem

Xq Quartzite — Thick-bedded to massive, gray to milky white metaquartzarenite with relict crossbedding and bedding defined by bands of iron oxides; pelitic partings and interbeds typically contain aluminosilicates.

Xqs Quartz-rich pelitic schist, quartz schist, and quartz-chlorite schist (metapelite) — Locally interlayered with amphibolites, mafic metavolcanic rocks, an calc-silicate rocks; commonly contains aluminosilicates.

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

Xa Amphibolite and amphibole-biotite schist — Massive green amphibole-plagioclase metavolcanic rock.

Xms Mica schist and phyllite — Quartz-muscovite schist and phyllite with local andalusite porphyroblasts.

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