QUATERNARY GEOLOGY AND GEOMORPHOLOGY OF THE SANDIA MOUNTAINS PIEDMONT, CENTRAL NEW MEXICO

Sean D. Connell
New Mexico Bureau of Mines and Mineral Resources
Socorro, New Mexico 87801

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FOREWORD

This report presents the results of M.S. thesis research conducted along the piedmont of the northern and western flanks of the Sandia Mountains, near Albuquerque, New Mexico. This research was submitted (December 1995) in partial satisfaction of the requirements for the degree of Master of Science in the Geological Sciences at the University of California at Riverside (UCR), where it is on file in the original thesis format. The thesis committee consisted of Drs. Stephen G. Wells (chairperson), David A. Osleger, Peter M. Sadler, and Leslie D. McFadden. The primary purpose of this research was to develop a detailed late Cenozoic stratigraphy for deposits associated with the western and northern flanks of the Sandia Mountains in the Albuquerque basin (see **INTRODUCTION** section). The study area, located within parts of the greater Albuquerque metropolitan area and vicinity, comprises portions of the Alameda, Bernalillo, Los Griegos, Placitas, Sandia Crest and Tijeras 7.5-minute quadrangles. The nominal scale of mapping was 1:24,000; however, selected areas were mapped at larger scales. The geologic maps emphasize Pliocene and Quaternary basin-fill, piedmont and valley fill deposits. Differentiation of major bedrock units is complied from previous studies (Kelley and Northrop, 1975; Menne, 1988).

This report is arranged into three volumes. Volume I contains the main text, figures, tables and references. Volume II contains supporting appendices (Appendix A through E) and includes soil-profile and stratigraphic descriptions. Volume III contains the geologic and geomorphic maps (Plates I through III) and description of map units (Appendix F).

Quadrangle maps, which form the basis for this report, will be placed on Open-File as individual geologic maps as they are completed, revised and integrated with current mapping studies of the bedrock and basin fill. *The contents of this report should not be considered final and complete until they are published as Bulletins or Geologic Maps by the New Mexico Bureau of Mines and Mineral Resources.*

ACKNOWLEDGMENTS

I would like to thank Dr. Steve Wells, my committee chairperson, for introducing me to the geology of the Albuquerque basin and Sandia Mountains. I would also like to thank Dr. Peter Sadler and Dr. David Osleger of the University of California, Riverside and Dr. Les McFadden of the University of New Mexico (UNM) for their advice, assistance, helpful reviews and participation on my committee. This work was supported in part, by the Sigma Xi Scientific Research Society.

I would especially like to thank Dr. John Hawley of the New Mexico Bureau of Mines and Mineral Resources (NMBMMR) and Dr. Frank Pazzaglia (UNM) for discussions and assistance in the field. A preliminary draft was improved by Dr. Pazzaglia. Discussions in the field with Dr. Steve Cather (NMBMMR) greatly aided my understanding of the geology of the northern flank of the Sandia Mountains. Permission to study the piedmont on lands of the Sandia Indian Reservation was graciously granted by the Governors Office of the Pueblo of Sandia. I would like to thank Curtis Francisco of the Pueblo Office of Environmental Protection and Mr. Archie Chavez of Sandia Pueblo for their assistance in obtaining permission to study a geologically significant portion of the piedmont.

Jane Cropp and John Hayden of the U.S. Forest Service granted special-use permits to excavate and describe several soil pits along the northern piedmont. Bob Grant of Energy Resources Exploration and John Roney of the Bureau of Land Management kindly loaned several aerial photographs. Keith Kelson of William Lettis and Associates provided low-altitude oblique aerial-photographs of the Rincon fault.

Olav Elias assisted with the excavation of several pits and John Beeder of Albuquerque provided interesting insights on the piedmont near Domingo Baca Canyon. John and Kathleen Spies of Placitas kindly allowed me to describe a deep excavation near Las Huertas Creek. John Rogers and Carol Treadwell provided thoughtful discussions and assistance in the field. John Rogers also granted permission to use soil profiles (P-26 through P-29). I also want to thank Allan Seward and Brian Swanson of AES Engineering Geology for use of their office to prepare the maps. Dr. Carol Condie of Quivera Research provided information on site archaeology on the Sandia Indian Reservation. Thanks to Jeff Knott, Tanja Williamson, Yvonne Katzenstein, Katherine Kendrick and Kirk and Diana Anderson for comments and help during the course of research.

This study could not have been undertaken without the help of these people; however, I assume full responsibility for all data analyses, errors and interpretations presented herein. This work is dedicated to Teresa Connell and Harriett Taussig, whose love, support and friendship made this project possible.

ABSTRACT OF THE THESIS

Quaternary Geology and Geomorphology of the Sandia Mountains Piedmont, Bernalillo and Sandoval Counties, Central New Mexico

by

Sean David Connell

Master of Science, Geological Sciences

University of California, Riverside, December, 1995

Professor Stephen G. Wells, Chairperson

The western flank of the Sandia Mountains straddles the transition between the northern Albuquerque and Santo Domingo sub-basins of the Rio Grande rift. The piedmont along the Sandia Mountains developed in response to complex interactions between the Rio Grande and mountain-front drainages along a tectonically active extensional rift-basin margin. Geomorphic and stratigraphic measurements, soil-profile descriptions and geologic mapping provide a detailed alluvial stratigraphy that records late Pliocene and Quaternary tectonic and geomorphic history along this basin margin. Numerical age-control was not established; however, comparisons of soil-profile development to numerically dated soil chronosequences throughout New Mexico provide estimates on deposit ages.

Nine, late Pliocene through Holocene, geomorphic surfaces are delineated on the piedmont, which is divided into two distinctive regions marked by a prominent east-step along the rift margin. This step coincides with the intersection of the Rincon,

Ranchos, Placitas and Valley View faults and may represent the major structural boundary between the incisional Santo Domingo and dominantly aggradational northern Albuquerque sub-basins. A series of laterally extensive, generally northwest-sloping, gravel-mantled pediments and strath-terraces characterize the deeply dissected piedmont along the northern flank of the Sandia Mountains. The piedmont to the south is generally dominated by west-sloping alluvial fans derived from the Sandia Mountains, and fluvial deposits of the Rio Grande.

The mountain-front is tectonically segmented into blocks that record uplift during the late Cenozoic. Spatial and temporal patterns of fault activity support basinward transfer of strain across the footwall of basin-margin master faults (e.g., Placitas and San Francisco faults) across this eastward step during the late Cenozoic. Fault activity shifted to the Valley View and Escala faults prior to the middle Pleistocene. The Bernalillo and Rio Grande faults experienced recurrent late Cenozoic movement and may accommodate much of the tectonic subsidence within the basin. The proximity of potentially seismogenic structures to the city of Albuquerque indicates the need to evaluate liquefaction potential and the effectiveness of current building codes.

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INTRODUCTION

Statement of Problem and Purpose

The piedmont associated with the western and northern flanks of the Sandia Mountains crosses a transition between the northern Albuquerque and Santo Domingo sub-basins of the tectonically active Rio Grande rift in central New Mexico (Figs. 1 and 2). A series of en-echelon ramp structures (Kelley, 1982a) defines a right (eastward) step along the northern flank of the Sandia Mountains (Figs. 2 and 3). Landforms recognized on the piedmont of the Sandia Mountains record a complex geomorphic history that reflects the influence of tectonics, lithology and climate during the Pliocene and Quaternary. Integration of mountain-front drainage basins with the Rio Grande, coupled with range-front and intra-basin faulting, were responsible for separating the piedmont into smaller geomorphically distinct areas. Two distinctive geomorphic regions (Fig. 5) were recognized on the basis of landform and depositional character, surface morphology and soil-profile development. A pediment-dominated piedmont occurs along the northern flank of the Sandia Mountains, north of state highway NM 165, where streams deeply incise synrift sedimentary deposits of the late Cenozoic Santa Fe Group. In contrast, a fan-dominated piedmont, comprising the majority of the study area to the south, typically bury deposits of the Santa Fe Group. The intersection of the Rincon, Placitas and Valley View faults forms the boundary between these distinctive piedmont types (Fig. 3).

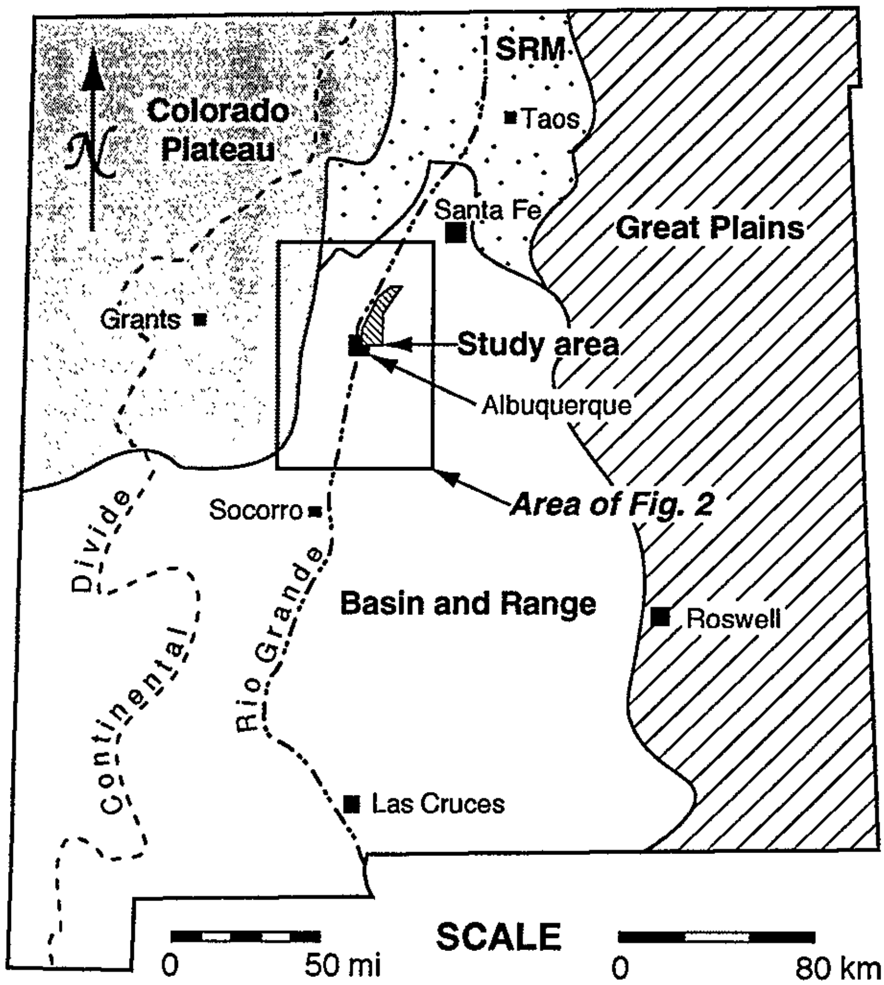


Figure 1. Study area and boundaries of major physiographic provinces in New Mexico: Southern Rocky Mountains (SRM) province in north-central part of state. The study area lies within the Rio Grande rift of the Mexican Highlands section of the Basin and Range geomorphic province (Williams, 1986, p.23-31).

Figure 2. Generalized geologic and geomorphic map illustrating locations of selected features in the Albuquerque physiographic-basin and vicinity. The Albuquerque physiographic basin comprises the Belen, northern Albuquerque and Santo Domingo sub-basins (Kelley, 1977; Woodward and others, 1978; Lozinsky, 1994; Russell and Snelson, 1994). Selected features include: the Colorado Plateau (CP); Basin and Range and Great Plains (BR-GP); City of Albuquerque (ABQ), Albuquerque volcanoes (AV), Hagan embayment (HE), Llano de Albuquerque, Llano de Manzano, Llano de Sandia, Ortiz pediment, Santa Ana (San Felipe) Mesa volcanic field (SAM), Santo Domingo sub-basin (SDB), Cerros del Rio volcanic field (CdR), Santa Ana accommodation zone (SAZ), and the Tijeras fault zone (TFZ), which become the Tijeras accommodation zone (TAZ) in the basin. The Ortiz surface underlies the Santa Ana Mesa volcanic flows. The lines N and S depict locations of geologic cross sections in Figure 7.

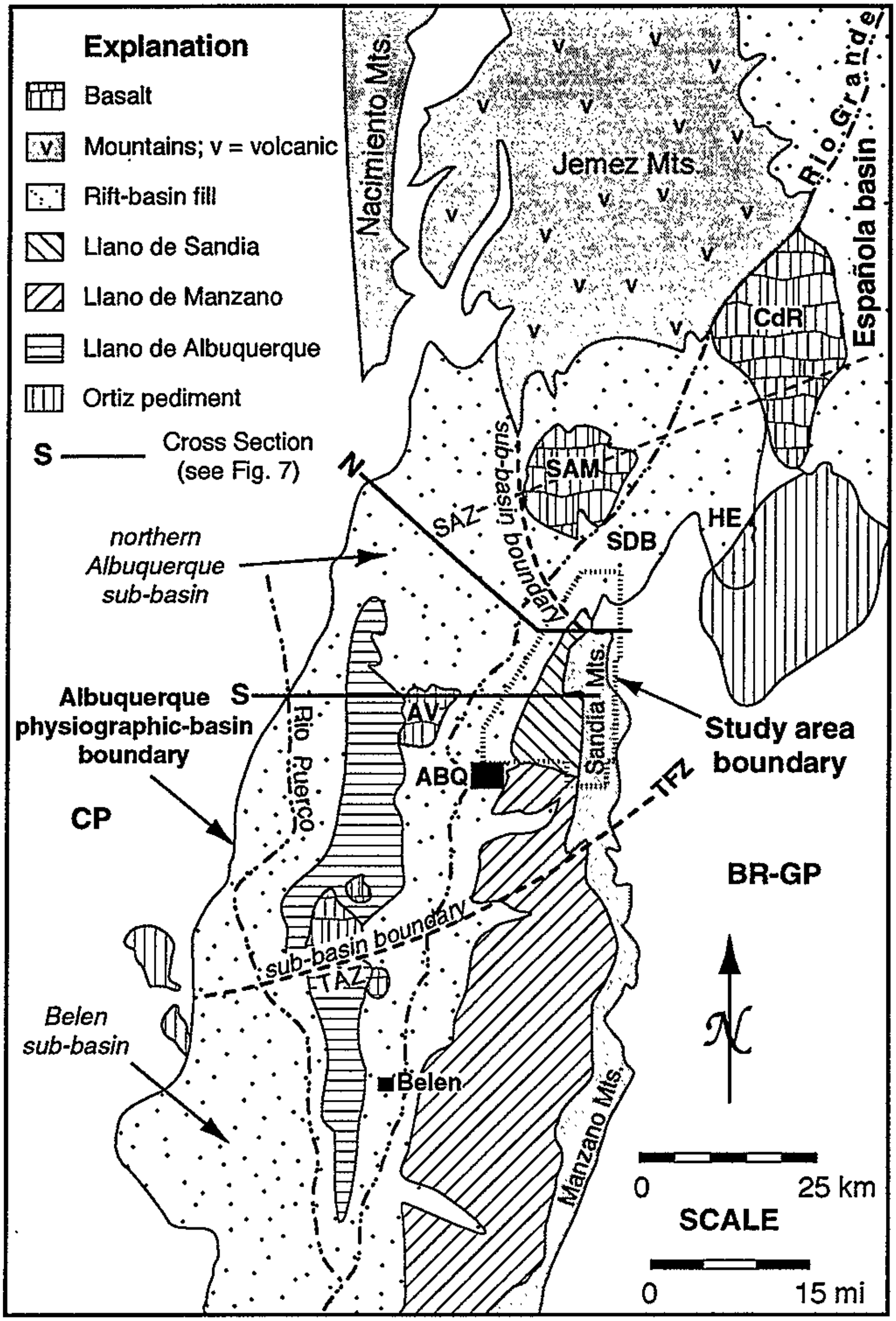
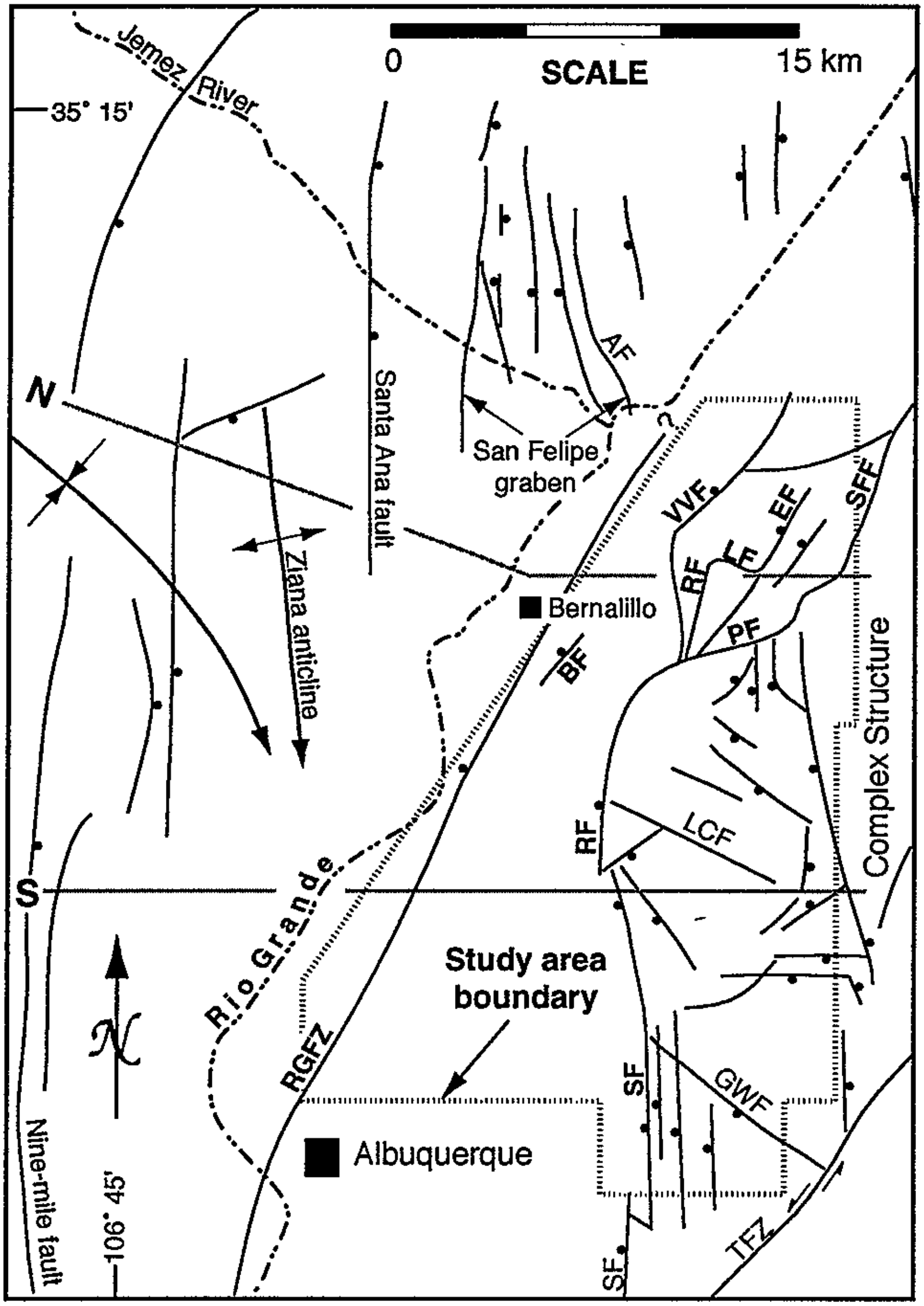

Explanation
Basalt
Mountains; v = volcanic
Rift-basin fill
Llano de Sandia
Llano de Manzano
Llano de Albuquerque
Ortiz pediment
S
Cross Section
(see Fig. 7)
Nacimiento Mts.
Jemez Mts.
Rio Grande
Española basin
CdR
SAM
N
SAZ
sub-basin boundary
SDB
HE
northern
Albuquerque
sub-basin
Albuquerque
physiographic-basin
boundary
AV
Rio Puerco
ABQ
Sandia Mts.
Study area
boundary
TFZ
CP
BR-GP
sub-basin boundary
TAZ
Belen
sub-basin
Belen
Manzano Mts.
0
25 km
SCALE
0
15 mi

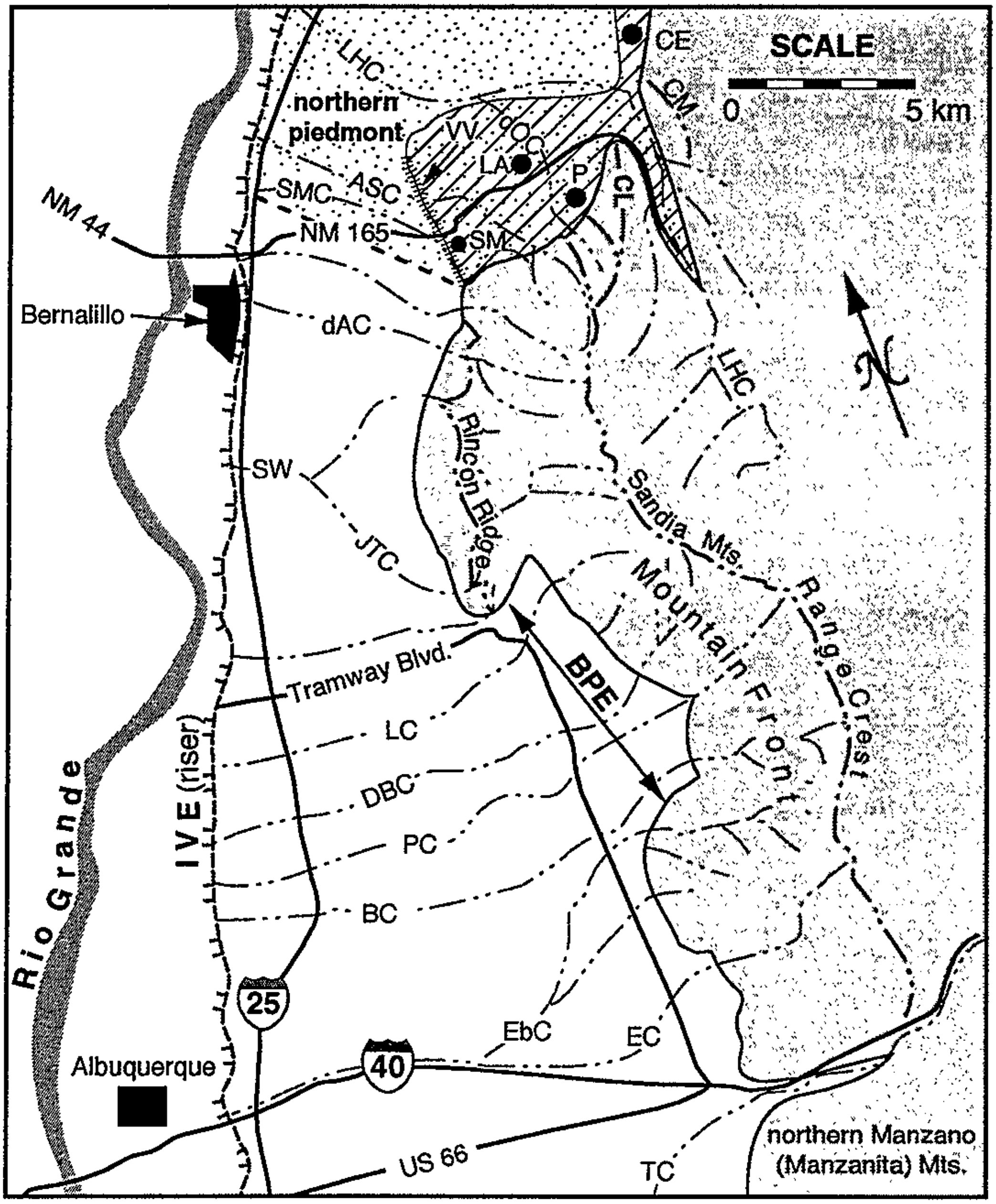
Figure 3. Simplified structure map of study area region, illustrating the approximate locations of selected major faults, folds and cross-section lines (Fig. 7) N and S (Kelley and Northrop, 1975; Kelley, 1977 and Russell and Snelson, 1994). Ball is on downthrown side of fault; arrows denote lateral separation. The Sandia block occupies the lower right-hand corner of the figure and contains several of north-, northeast- and northwest-striking normal- and left-slip faults. Selected structures include: Algodones fault (AF); Bernalillo fault (BF); Groundwater fault (GWF); La Cueva fault (LCF); Placitas fault (PF); Ranchos (RF), Lomos (LF) and Escala (EF) faults; Rio Grande fault zone (RGFZ) of Russell and Snelson (1990 and 1994); Sandia fault (SF); San Francisco fault (SFF); Tijeras fault zone (TFZ); and the Valley View fault (VVF).


0
SCALE
15 km
Jemez River
35° 15'
N
S
Santa Ana fault
San Felipe graben
AF
Ziana anticline
Bernalillo
BF
VVF
EF
SFF
RF
LF
PF
Complex Structure
RF
LCF
Rio Grande
Study area boundary
RGFZ
Albuquerque
SF
GWF
TFZ
SF
Nine-mile fault
106° 45'

A low-lying belt of deeply dissected foothills developed on a block of post-Paleozoic (undifferentiated Mesozoic through lower Santa Fe Group) strata on the hanging wall of the Placitas and San Francisco faults (Fig. 3). This belt occurs south and east of the traces of the Valley View, Lomos and Escala faults, which form a relatively low escarpment defining the piedmont-foothills transition (Figs. 4 and 5). These faults separate the range into distinctive mountain-front segments. The occurrence of contrasting piedmont landforms in a tectonically active, segmented extensional setting provides an opportunity to evaluate the role of tectonics on late Cenozoic evolution of the piedmont. Piedmont deposits are offset by several faults, which also provide an opportunity to study the spatial and temporal distribution of strain along a major basin margin.

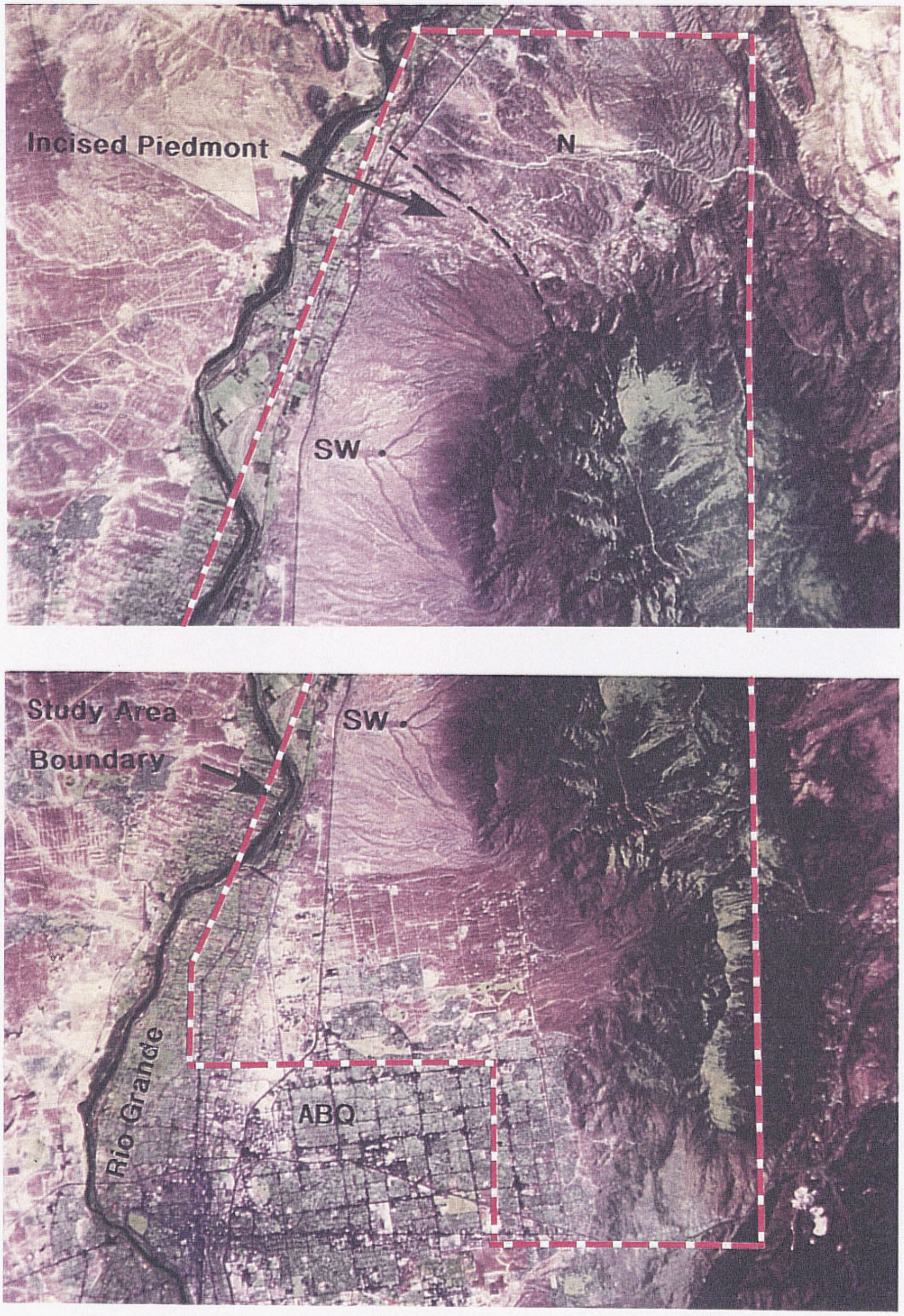
The primary purpose of this study is to document the geomorphic history of the piedmont developed along the western and northern flanks of the Sandia Mountains. Evaluations of age and geomorphic and stratigraphic characteristics of constructional and erosional landforms are made in order to understand piedmont evolution. Major geomorphic surfaces, morphostratigraphic and lithostratigraphic units are compiled onto a Quaternary geomorphic and geologic map (Plates I through III). Mapping is supplemented by previous and current investigations of the Sandia Mountains and Albuquerque basin (Lambert, 1968; Kelley and Northrop, 1975; Kelley, 1977; Menne, 1989; Hawley and Hasse, 1992; Cather and others, in preparation; and Hawley and others, 1995).

Figure 4. Generalized physiographic map of the Sandia piedmont, illustrating selected features: Las Huertas Creek (LHC); Arroyo del Ojo del Orno (dOC); Strip Mine Creek (SM); Strip Mine Canyon (SMC); del Agua Creek (dAC); Sandia Wash (SW); Juan Tabo Creek (JTC); La Cueva Creek (LC); Domingo Baca Creek (DBC); Pino Creek (PC); Bear Creek (BC); Embudito (EbC) and Embudo Creeks (EC); and Tijeras Creek (TC). Major roadways include interstate I-25 and I-40, Tramway Boulevard and state highways NM 44 and NM 165 (formerly NM 44). The inner valley escarpment (IVE) marks the junction between the modern valley of the Rio Grande and the west-sloping piedmont. Upland areas of the Sandia Mountains are shaded gray. The northern, deeply dissected piedmont is dominated by pediments, noted by stippled pattern. The northern mountain-flank and piedmont (diagonal lines) are characterized by deeply dissected foothills near the village of Placitas (P). The northern mountain front is marked by the termination of north-trending salients, such as the Cuchilla Lupe (CL) and Crest of Montezuma (CM). The foothill-piedmont junction is defined by Lomos Altos (LA), Cuchilla de Escala (CE) and a west-facing escarpment formed by the Valley View fault (VV). Erosional landforms dominate the northern piedmont and the Bear-Pino re-entrant (BPE). The piedmont, south of Strip Mine Canyon, displays predominantly constructional topography.



CE
SCALE
0
5 km
LHC
northern piedmont
VV
OC
LA
P
CM
CL
ASC
SMC
NM 44
NM 165
SM
Bernalillo
dAC
LHC
N
Rincon Ridge
SW
JTC
Sandia Mts.
Mountain Front
Range Crest
Tramway Blvd.
BPE
LC
DBC
PC
BC
IVE (riser)
Rio Grande
25
EbC
EC
40
Albuquerque
US 66
TC
northern Manzano (Manzanita) Mts.

Figure 5. Landsat Thematic Mapper (TM) images of northern (top) and southern (bottom) portions of study area (dashed lines) and Albuquerque (ABQ). An eastward-step along the rift-basin margin marks the northern range front, where highly dissected foothills occupy a narrow, northeast-trending belt. The northern piedmont (N) is deeply dissected and exposes Precambrian through Quaternary rocks. Sandia Wash (SW) drains the western flank of Rincon Ridge and the Sandia Mountains.


Incised Piedmont
N
SW
SW
Study Area
Boundary
Rio Grande
ABQ

The city of Albuquerque, the largest metropolitan area in New Mexico, is located within part of the study area. Evaluation of fault activity on the Sandia piedmont has significant implications for seismic hazard assessment and planning for the greater Albuquerque area, especially with respect to liquefaction potential.

Studies (Lambert, 1968; Kelley and Northrop, 1975; Machette, 1978b, 1982, 1985; Hawley and Hasse, 1992; Russell and Snelson, 1990 and 1992; Lozinsky, 1994; and May and Russell, 1994) document basin stratigraphy and structure; however, little detailed geomorphic study of surficial deposits has been performed on the piedmont. Geomorphic and stratigraphic relations, combined with comparisons to several numerically dated soil chronosequences and alluvial sequences, can constrain landform and geomorphic-surface ages (Gile and Grossman, 1979; Gile and others, 1981; Dethier and Demsey, 1984; Grimm, 1985; Machette, 1985; Kelson, 1986; Dethier and others, 1988; Pazzaglia, 1989; Drake and others, 1991; Pazzaglia and Wells, 1990; Wells and others, 1990; and Gonzalez, 1995). Landform ages are crucial to fault-hazard assessments because they can constrain the timing of ground-rupture events.

Study Area Setting

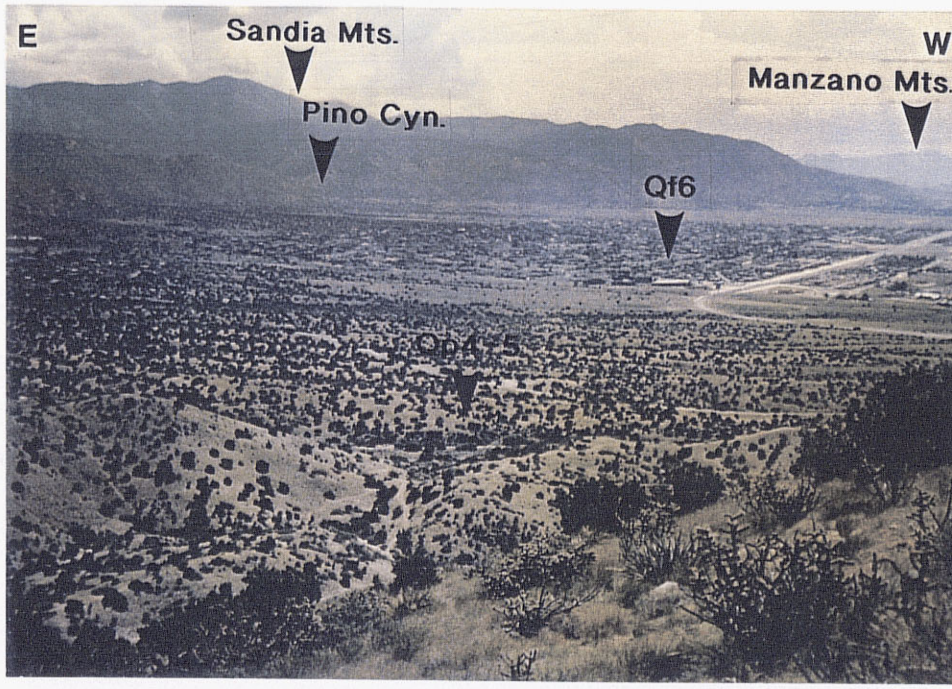
Location and Physiographic Setting

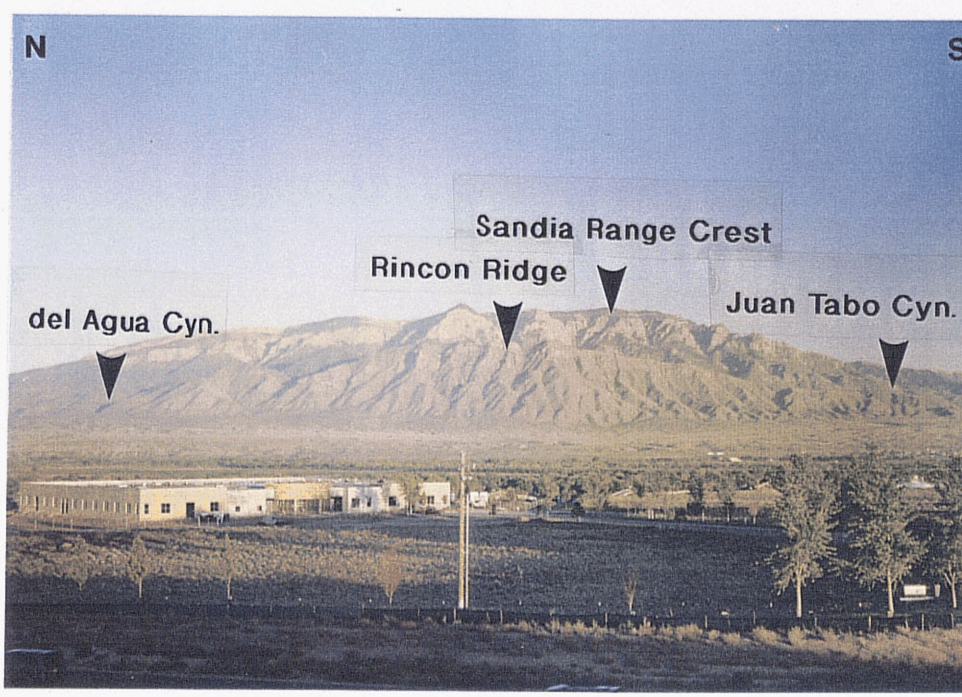
The study area traverses a 36-km length of piedmont along the northeastern margin of northern Albuquerque sub-basin and the southwestern margin of the Santo Domingo sub-basin. The northern Albuquerque and Santo Domingo sub-basins lie within the Rio Grande rift in the Southern Rocky Mountains and Mexican Highlands section of the Basin and Range and physiographic provinces (Fig. 1) (Williams, 1986, p.23-31). The Albuquerque basin is one of the largest physiographic basins of the rift (Kelley, 1977; Hawley, 1978; Lozinsky and others, 1991). The Rio Grande forms the dominant axial drainage, which flows south towards Texas and Mexico.

The western and northern escarpments of the Sandia Mountains defines the eastern margin of the Rio Grande rift in the study area. Sandia Peak, 3255 m (10,682 ft) above mean sea level, marks the highest point in the study area. The northern flank of the Sandia Mountains forms a north-sloping ridge that slopes towards the village of Placitas (Fig. 4). The western flank forms a steep, west-facing escarpment with approximately 1730 m of topographic relief between Sandia Crest and the piedmont. Mountain-front relief decreases to about 1450 m along the southern margin of the range at Embudo Canyon. Rincon Ridge forms a secondary topographic-divide west of the crest of the Sandia Mountains (Fig. 6). Maximum relief along Rincon Ridge is approximately 960 m.

Mountain-front catchments have developed along the western escarpment of the Sandia Mountains and Rincon Ridge yielding coarse-grained debris onto the piedmont. Catchment areas typically are confined to the basin and are generally associated with relatively short, steep streams draining the high-relief footwall escarpment of the Sandia Mountains. Drainage-basins of Tijeras (344 km^2 in size; Lambert and others, 1982) and Las Huertas Creeks (66 km^2) are the largest, each with long shallow streams that originate east of the rift-bounding structures.

Figure 6. Mountain-front characteristics along the Bear-Pino re-entrant and Rincon Ridge. Top: view to south of mountain-front embayment (Bear-Pino re-entrant) south of Rincon Ridge. Bottom: view to east of Rincon Ridge of several small well-developed mountain-front fans surrounded by larger fans originating from del Agua and Juan Tabo Canyons.


E
Sandia Mts.
W
Manzano Mts.
Pino Cyn.
Qf6


N
S
Sandia Range Crest
Rincon Ridge
del Agua Cyn.
Juan Tabo Cyn.

Prominent north-trending en-echelon salients are typically segmented by short northeast-trending re-entrants along the western mountain-front escarpment. Prominent steps in the mountain front occur along the northern flank and along a large re-entrant between La Cueva and Bear canyons, called the Bear-Pino embayment or re-entrant (Kelley and Northrop, 1975). The Bear-Pino re-entrant defines a significant east step of the mountain front along the northern margin of the Sandia fault (Figs. 4 and 6). The inner valley of the Rio Grande forms a low-lying, linear escarpment separating piedmont and axial-river flood-plain alluvium (Fig. 4).

General Rift Properties

Rift tectonics typically produce asymmetric half-grabens (Gibbs, 1984; Bosworth, 1985; Rosendahl and others, 1986) where the direction, or polarity, of basin subsidence shifts through transfer or accommodation zones (Gawthorpe and Hurst, 1993; Rosendahl, 1987). Subsidence of an asymmetric half graben generally produces specific tectonic and geomorphic features, such as, the formation of master rift-margin faults and associated synthetic and antithetic intra-basin faults, and the development of a rift-margin footwall and rift-interior hanging wall (Leeder and Jackson, 1993). The footwall typically tilts away from the main rift axis. Relatively short, steep intra-rift drainages develop on the steep footwall escarpment. A roll-over or hinge typically develops on the hanging wall block (Frostick and Reid, 1987).

Movement along the main rift-margin fault tends to place the axis of maximum subsidence and deposition close to the footwall associated with the basin-margin

(Frostick and Reid, 1987, 1989a). The position of rift-margin and intra-basin structures significantly influences the location of through-flowing axial streams (Alexander and Leeder, 1987; Frostick and Reid, 1989b; Mack and Seager, 1990; Leeder and Jackson, 1993; Jackson and Leeder, 1994).

Catchment areas of most hanging-wall and foot-wall drainages occur almost entirely within a rift basin where most of the surface water originates from high-relief footwall escarpments along rift-shoulder uplifts (Baker, 1986). Streams emanating from the footwall block tend to be relatively short and steep. Larger catchments derived outside the rift typically enter the basin along regional ramp structures or along fault-segment boundaries (Baker, 1986; Menges, 1990ab; Leeder and Jackson, 1993; Jackson and Leeder, 1994).

Geomorphic and Geologic Setting

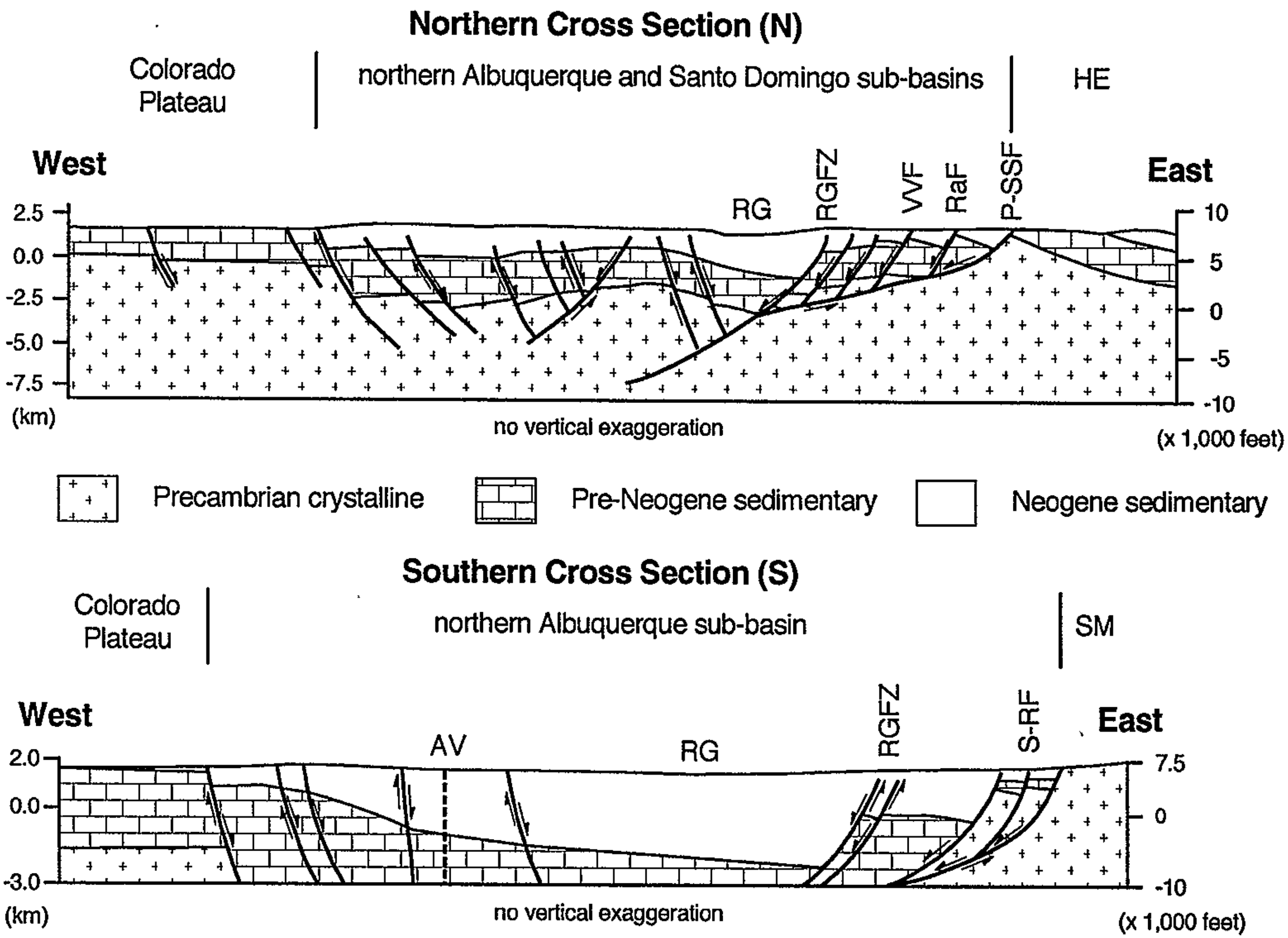
The Basin-and-Range physiographic province is characterized by alternating mountains and valleys. Ranges are block-faulted, generally tilt away from adjoining basins and expose Proterozoic crystalline cores that are overlain by Paleozoic through Mesozoic strata (Hawley, 1986; Baars and others, 1988; Christiansen and Yeats, 1992). The Rio Grande rift forms a series of linked half-grabens extending southward from southern Colorado into New Mexico, northern Chihuahua and western Texas (Bryan, 1938; Hawley, 1978; Woodward and others, 1978; Chapin and Cather, 1994). Half-grabens generally have south-trending longitudinal basin-axes that alternate basin polarity across transverse accommodation structures (Rosendahl, 1987). Transfer zones commonly form transverse structures adjoining basins having similar subsidence directions (Rosendahl, 1987; Chapin and Cather, 1994; Russell and Snelson, 1994).

The Albuquerque physiographic basin (Fig. 2), one of the largest basins of the rift, represents a transitional feature between the well-expressed northern Rio Grande rift of northern New Mexico and Colorado and the Basin and Range province to the south. North of the Albuquerque physiographic basin, the rift is characterized by a series of half-grabens that alternate structural polarity across well-expressed transverse accommodation zones (Woodward and others, 1978; Manley, 1984; and Lozinsky and others, 1991). To the south the rift becomes less topographically distinct and is characterized by a regional pattern of alternating valleys and mountains that typifies basin-and-range physiography (Hawley, 1986; Chapin and Cather, 1994).

The Albuquerque basin comprises a single physiographic and tectonic feature (Kelley, 1977; Woodward and others, 1978; Woodward, 1982); however, recent investigators (Lozinsky and others, 1991; Russell and Snelson, 1990, 1994) recognize three structural sub-basins (Fig. 2). The Belen sub-basin forms a west-tilted half-graben, whereas the Santo Domingo and northern Albuquerque sub-basins are east-tilted half-grabens (Fig. 7). The Tijeras accommodation zone, represented by the extension of the northeast-striking Tijeras fault zone, separates the northern Albuquerque and Belen sub-basins (Lozinsky and others, 1991; Russell and Snelson, 1990, 1994) has undergone intermittent Precambrian through Quaternary movement (Lisenbee and others, 1979; Abbott and Goodwin, 1995). The Ziana anticline and San Felipe graben probably separate the Santo Domingo and northern Albuquerque sub-basins (Figs. 2 and 3) (Kelley, 1977; Thorn and others, 1993; Lozinsky, 1994; and May and Russell, 1994). The Santo Domingo sub-basin (Stearns, 1953) lies between the Jemez Mountains and La Bajada, San Francisco and Placitas faults (Fig. 2) (Lozinsky, 1994; May and Russell, 1994). The Rio Puerco fault zone defines the boundary between the Albuquerque basin and the eastern Colorado Plateau (Slack and Campbell, 1976). The Belen and northern Albuquerque sub-basins are typified by wide, structurally high, sub-alluvial benches developed between flanking uplifts and major intra-basin faults (Kelley, 1982; Russell and Snelson, 1990 and 1994; May and Russell, 1994), probably the result of basinward (footwall) migration of rift-margin faults (Chapin and Cather, 1994).

Inception of the Rio Grande rift began during the late Oligocene or early Miocene (Bachman and Mehnert, 1978; Lipman and Mehnert, 1975). Rift basins initially developed as bolsons (Gile and others, 1981) where broad coalescing alluvial-fan deposits graded basinward into fine-grained, alluvial-plain and playa sediments (Chapin and Cather, 1994). During the late Miocene and early Pliocene, rift-basins filled, became topographically linked and through-flowing drainage of the ancestral Rio Grande developed (Lozinsky, 1994; Bachman and Mehnert, 1978; Gile and others, 1981). Basin deposition ceased the during the early to middle Pleistocene (Gile and others, 1981) when entrenchment by the Rio Grande began following capture of drainage from the San Luis basin in northern New Mexico and southern Colorado (Wells and others, 1987a). Other causes of incision are attributed to regional uplift (Bachman and Mehnert, 1978; Dethier and Demsey, 1984), shift in regional climate (Dethier and others, 1988) or a combination of regional uplift and drainage integration

Figure 7. Simplified geologic cross sections along lines N and S of Figure 2 and 3 (Russell and Snelson, 1994; Hawley and others, 1995). Selected features include: Albuquerque volcanoes (AV), Hagan embayment (HE) and Sandia Mountains (SM). Faults include the Placitas-San Francisco fault zone (P-SFF), Ranchos fault (RaF), Rio Grande fault zone (RGFZ) of Russell and Snelson (1990 and 1994), Sandia and Rincon faults (S-RF) and Valley View faults (VVF). Imbricate fault blocks overlie a listric master-fault that merges with the RGFZ at depth.

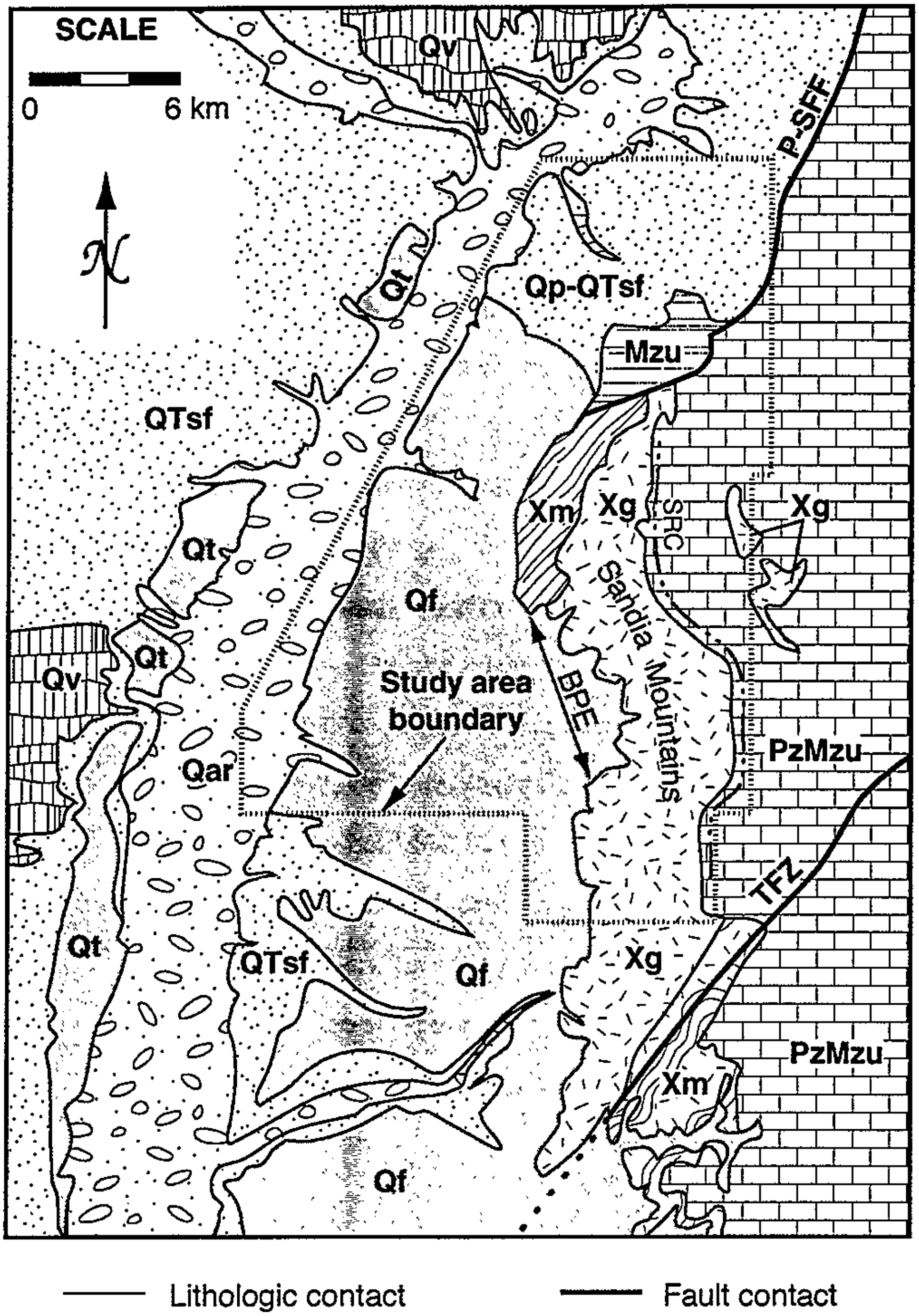

Northern Cross Section (N)
Colorado Plateau
northern Albuquerque and Santo Domingo sub-basins
HE
West
East
RG
RGFZ
VVF
RaF
P-SSF
2.5
0.0
-2.5
-5.0
-7.5
(km)
10
5
0
-5
-10
(x 1,000 feet)
no vertical exaggeration
Precambrian crystalline
Pre-Neogene sedimentary
Neogene sedimentary
Southern Cross Section (S)
Colorado Plateau
northern Albuquerque sub-basin
SM
West
East
AV
RG
RGFZ
S-RF
2.0
0.0
-3.0
(km)
7.5
0
-10
(x 1,000 feet)
no vertical exaggeration

(Personius and Machette, 1984). At least 4900 m of Neogene synrift fanglomerate, fluvial, eolian and playa deposits comprise the Santa Fe Group (Lozinsky and others, 1991; Russell and Snelson, 1994).

The Sandia Mountains form an east-tilted block of Phanerozoic sedimentary and Precambrian crystalline rocks (Figs. 7 and 8) that is bounded to the west by northwest- to northeast-striking faults: Sandia, Rincon and Placitas faults. The San Francisco fault bounds the north-trending salient of the Cuchilla de San Francisco. Several northwest, north and northeast-striking faults and shear zones cut Precambrian and Paleozoic rocks of the Sandia block (Fig. 2, 7 and 8). Some structures accommodate normal and left-lateral slip (Kelley and Northrop, 1975); however, the orientation of fold axes recognized in pre-Quaternary rocks along the northern flank of the range suggest a dextral slip component (Woodward and Menne, 1995).

Uplift of the Sandia Mountains began during the Neogene. Conglomerate of the lower Santa Fe Group contains abundant clasts of reddish-brown sandstone and volcanic rocks derived from the Abo and Espinaso Formations, respectively (Menne, 1989; Cather and others, in preparation). Limestone clasts of the Pennsylvanian-Permian Madera and Sandia Formation increase in abundance up section. Increases of limestone clasts indicate unroofing of strata derived from the northern Sandia Mountains during the late Miocene (Menne, 1989; May and others, 1994). Another line of evidence for Neogene uplift comes from apatite fission-track analyses, which indicate rapid cooling of the Sandia block between 15 and 35 Ma (S.A. Kelley and others, 1992;

Figure 8. Generalized lithologic map of Sandia Mountains and piedmont. The Sandia Mountains are primarily composed of Precambrian metamorphic (Xm), granitoid (Xg) and Paleozoic sedimentary (Pzu) rocks. Basin deposits are dominated by the late Cenozoic Santa Fe Group (QTsf), which is unconformably overlain by Quaternary alluvial-fan (Qf), terrace (Qt) and floodplain facies of Rio Grande (Qar). Pediment alluvium (Qp) is common along northern margin of Sandia Mountains; alluvial fans are common along western margin. The northern margin contains a well-exposed sequence of Mesozoic (Mzu) strata (Kelley and Northrop, 1977; Menne, 1989; Hawley and others, 1995; Woodward and Menne, 1995).


SCALE
0
6 km
N
Qv
Qt
Qp-QTsf
P-SFF
Mzu
QTsf
Xm
Xg
SPC
Xg
Sandia Mountains
Qt
Qf
Qt
Qv
Study area boundary
BPE
PzMzu
Qar
TFZ
Qt
QTsf
Qf
Xg
PzMzu
Xm
Qf
Lithologic contact
Fault contact

May and others, 1994). Uplift may be partly caused by flexural isostatic adjustments of the lithosphere accompanying tectonic unloading of the footwall by basin-margin faults (May and Russell, 1994).

The piedmont is characterized by stepped valley-border landforms and alluvial, fluvial, eolian and volcanic rocks that were laid down during post middle-Pleistocene entrenchment of the Rio Grande (Gile and others, 1981). Four regional Plio-Quaternary landforms recognized from previous studies (Fig. 2) are discussed below.

The Ortiz surface (Fig. 2) forms the highest of several erosional surfaces in the Ortiz Mountains, northeast of the study area (Johnson, 1903ab; Ogilvie, 1905; Bryan and McCann, 1938). Many previous workers considered the Llano de Albuquerque to be equivalent to the Ortiz pediment surface (Bryan, 1938; Bryan and McCann, 1936 and 1938; Kelley, 1977). Bachman and Mehnert (1978), however, point out that the Ortiz surface is a complex erosional surface capped by Pliocene (about 2.5 to 3.0 Ma) basalt and is, therefore, much older than the Llano de Albuquerque. The Ortiz "surface" is differentiated into at least two surfaces bounding the Plio-Pleistocene Ancha Formation (Spiegel and Baldwin, 1963) and Tuerto gravels (Stearns, 1953) of the Española basin and Santo Domingo sub-basin. Deposits associated with the Ortiz surface are recognized just north of the study area (Picha, 1982).

The Llano de Albuquerque (LdA, Fig. 2) forms a prominent south-sloping alluvial tableland between the valleys of the Rio Grande and Rio Puerco (Lambert, 1968; Kelley, 1977; Machette, 1978b, 1985). The LdA is a landform that is located about 110 to 215 m above the modern Rio Grande (Machette, 1985) and represents the highest level of basin aggradation during final stages of deposition of the upper Santa Fe Group deposition prior to incision by the Rio Grande between 1100 and 500 ka (Hawley and others, 1976; Hawley, 1978; Bachman and Mehnert, 1978; Gile and others, 1981; and Machette, 1985; Kelley, 1977; Lozinsky and others, 1991). Incision of the Rio Grande and subsequent abandonment of the LdA may have begun since 600 ka in northern New Mexico (Wells and others, 1987a) and about 500 ka in central and southern New Mexico (Hawley and others, 1976; Hawley, 1978; Machette, 1985). The LdA is estimated to be about 500 ka based on studies of pedogenic-carbonate accumulation rates in soils (Machette, 1985).

The Llano de Manzano (LdM, Fig. 2) forms an extensive west-sloping piedmont that grades to an alluvial tableland located approximately 92 to 113 m above the modern Rio Grande (Machette, 1985). The LdM is inset below LdA and forms much of the piedmont of the Manzanita and Manzano Mountains. The airport surface (Machette, 1985; Lambert, 1968), although slightly higher than the LdM, may be equivalent to the LdM (Machette, 1985). The airport surface is estimated to be middle Pleistocene (about 320 ka) in age based on pedogenic calcium-carbonate accumulation rates (Machette, 1985).

The Llano de Sandia (LdA, Fig. 2) forms the western piedmont of the Sandia Mountains and comprises the majority of the study area. Piedmont alluvium of the Sandia Mountains generally is inset below the Llano de Albuquerque and Llano de Manzano. Other major landforms include the Primero Alto, Segundo Alto and Tercero Alto terraces (Bryan and McCann, 1938; Lambert, 1968; Machette, 1985). The Tercero Alto terrace lies about 73 m above the valley floor and forms a constructional surface underlain by fluvial deposits associated with the Rio Grande (Bachman and Machette, 1977). This unit is inset below the eastern escarpment of the Llano de Albuquerque and stratigraphically underlies basalt flows of the late Pleistocene (155 to 250 ka; Geissman and others, 1990) Albuquerque volcanoes.

Lambert (1968) recognizes three major fluvial deposits and associated surfaces along the inner valley of the Rio Grande. These units are generally well expressed west of the Rio Grande. The alluvium of Los Duranes Boulevard underlies the Segundo Alto terrace and consists of sandy alluvium deposited by the Rio Grande. The alluvium of Edith Boulevard underlies the Primero Alto terrace and consists of gravelly axial-river alluvium. The Primero Alto terrace is inset below the Segundo Alto terrace. The alluvium of Menaul Boulevard consists of gravelly alluvium east of the Rio Grande. Although the alluvium of Los Duranes, Edith and Menaul Boulevards are mapped as a three inset units (Lambert, 1968), they may have been laid down during a period of overall basin aggradation (J. W. Hawley, 1995, personal communication) instead of in three distinct cut-fill events.

Climate and Vegetation

Vegetation of the study area is transitional between black grama Chihuahuan Grassland association, near Albuquerque, and rice-grass and galleta Great Basin Grassland association in the northern portion of the field area in Sandoval County (William, 1986, p.67-73). The Sandia foothills support a pinyon (*Pinus edulis*) and juniper (*Juniperus scopolorum*) woodland association, whereas portions of the mountains at higher elevations support a ponderosa pine (*Pinus ponderosa*) mixed-conifer forest association (William, 1986, p.67-73). Commonly encountered vegetation includes juniper, grasses and cactus (*Opuntia*).

The Sandia piedmont experiences an arid, continental climate (Anderson, 1961) with a mean annual precipitation (MAP) of 178 to 254 mm (7 to 10 inches). The Manzano Mountains and adjoining foothills to the south, receive 254 to 356 mm (10 to 14 inches) and the Sandia Mountains receive 635 to 762 mm (25 to 30 inches) of rainfall per year (Hacker, 1977; Williams, 1986, p.37-45). Approximately half of the MAP occurs during the summer and fall seasons, July through October, during intense convective storms (Williams, 1986, p.44-45). Mean annual-temperatures range from 14°C in Albuquerque, to 10°C, along the Sandia foothills, to 4°C at Sandia Crest (Hacker, 1977).

Previous Work

General

Early workers recognized the basin-fill deposits of the Rio Grande Valley (Herrick and Johnson, 1900; Johnson, 1903ab). Bryan (1909) identified fluvial gravels associated with an ancestral Rio Grande in Albuquerque. He also recognized the rifted nature of the Rio Grande Valley (Bryan, 1938) and provided the initial Quaternary geologic framework for the region (Bryan, 1938; Byran and McCann, 1936, 1937 and 1938). Kelley (1952 and 1978) summarized the tectonics and deposits of rift basins south of the San Luis basin. Several studies (Soister, 1952; Stearns, 1953; Anderson, 1960; Spiegel, 1961; Spiegel and Baldwin, 1963; Hoge, 1971; Picha, 1982; Menne, 1989; Woodward and Menne, 1995) of the Albuquerque and Española basins describe basin structure and history.

The geomorphology and stratigraphy of the Albuquerque area were described in detail by Lambert (1968), who performed a detailed Quaternary geologic study of the Albuquerque basin area. Kelley and Northrop (1975) describe the stratigraphy and structure of the Sandia Mountains. Kelley (1977) summarizes the geology and geomorphic history of the Albuquerque basin. Bachman and Mehnert (1978) and Geissman and others (1990) provide radiometric and paleomagnetic constraints on the ages of volcanic events in the region. Ages of regional geomorphic surfaces, such as the Llano de Albuquerque and Llano de Manzano are estimated from studies of calcic soils (Bachman and Machette, 1977). Studies of late Quaternary fault activity provide additional constraints on deposit age and stress history of the region (Machette, 1978a, 1978b and 1982).

Recent studies on the rift-basin fill and structure documents the basin geometry and structure (Russell and Snelson, 1990, 1994; Chapin and Cather, 1994; May and others, 1994; Lozinsky, 1994; May and Russell, 1994; and Hawley and others, 1995). Menne (1989) documents the complex structure along the northern flank of the Sandia Mountains near Placitas. Delineation of subsurface basin structure was described using gravity survey (Cordell, 1978; Thorn and others, 1993), seismic-reflection (Wu, 1986; Russell and Snelson, 1994), and exploration-well data (Lozinsky and Tedford, 1991; Lozinsky and others, 1991; Hawley and others, 1995; Hawley and Hasse, 1992).

Several geomorphic studies provide soil chronosequences and soil-based alluvial chronologies that are used to estimate ages of alluvial deposits in this study. These studies include the Desert Project in southern New Mexico (Gile and Grossman, 1979; Gile and others, 1981), San Luis basin in northern New Mexico and Colorado (Kelson, 1986; Pazzaglia, 1989; Pazzaglia and Wells, 1990), eastern Colorado Plateau (Grimm, 1985; Wells and others, 1990; Drake and others, 1991), northern Albuquerque-Belen sub-basins (Bachman and Machette, 1977; Machette, 1978ab, 1985) and the Jemez Mountains and Española basin (Gonzalez and Dethier, 1991; Dethier and others, 1988; and Gonzalez, 1995).

Pre-Rift Stratigraphy

Descriptions of pre-Quaternary stratigraphy (Fig. 9) are modified from discussions presented in previous studies (Lambert, 1968; Kelley and Northrop, 1975; Kelley, 1977; Menne, 1989; Cather and others, in preparation; Woodward and Menne, 1995).

Rincon Ridge metamorphic complex (Xm)

The Proterozoic (1.7 Ga) Rincon Ridge metamorphic complex, found on Rincon Ridge, is described from exposures of resistant micaceous quartzite and quartz-mica schist (White, 1979; Kelley and Northrop, 1975). Green and Callender (1973) describe a contact aureole formed by the intrusion of the Sandia Granite. Pegmatite and aplite dikes related to the emplacement of Sandia Granite intrude this complex (Kelley and Northrop, 1975).

Sandia Granite (Xg)

The Sandia Granite is a Proterozoic (1.45 Ga) megacrystic monzogranite and granodiorite containing microcline phenocrysts in a groundmass of quartz, feldspar and mica (Cather and others, in preparation; Brookins, 1982; Kelley and Northrop, 1975). The Sandia Granite forms the dominant lithology exposed along the western flank of the Sandia Mountains.

Undifferentiated Paleozoic and Mesozoic sedimentary (PzMzu)

The Paleozoic through early Cenozoic sedimentary sequence (PzMzu) consists of Mississippian through early Tertiary deposits and intrusive rocks (Fig. 9) that unconformably overlie Precambrian crystalline rocks of the Sandia Mountains (Kelley and Northrop, 1977). Exposures of PzMzu are dominant along the crest and northern flank of the range. Resistant limestone of the Sandia and Madera Formations make up rocks of the range-crest divide.

Undifferentiated Mesozoic sedimentary (Mzu)

Faulted blocks of undifferentiated Mesozoic sedimentary rocks occur along the western and southeastern flank of Rincon Ridge on the Alameda Quadrangle (Plates II and III). This unit consists of highly sheared, reddish- to purplish-brown mudstone and yellowish brown sandstone, possibly correlative to deposits of the Chinle Group and Entrada Formation.

Figure 9. Stratigraphic column of the northern Sandia Mountains piedmont and vicinity (compiled from Kelley and Northrop, 1975; Menne, 1989; and Cather and others, in preparation).

System/ Erathem	Group/ Formation/ Lithodeme	Maximum Thickness (m)	Lithology
Tertiary	Santa Fe Grp.	4400	Mudstone, sandstone, conglomerate.
Cretaceous	Mesa Verde Grp.	325 - 625	Gray, tan-orange, white sandstone, siltstone and gray lignitic coal.
	Mancos Grp.	462 - 512	Gray and olive-brown shale, siltstone and sandstone; yellow, yellowish-brown and grayish-black sandstone and shale.
Jurassic	Morrison Fm.	70-260	Variegated yellow-gray pebbly sandstone and grayish-green mudstone.
	Upper San Raphael Grp.	---	Light-greenish gray siltstone and sandstone.
	Todilto Fm.	15 - 17	Limestone and gypsum.
	Entrada Fm.	35	Reddish-brown to light-tan cross-bedded eolian sandstone.
Triassic	Chinle Grp.	400 - 500	Reddish-brown and lavender-gray mudstone, sandstone and conglomerate.
	Agua Sarca Fm.	---	Light-gray to gray-orange or tan conglomeratic sandstone and reddish-tan mudstone.
	Moenkopi Fm.	25 -30	Moderate-red micaceous sandstone
Permian	San Andres Fm.	25	Limestone and sandstone
	Glorieta Ss.	10	Sandstone
	Yeso Fm.	210	Orange-brown sandstone and limestone
	Abo Fm.	330	Reddish-brown mudstone and sandstone
Pennsylvanian	Madera Fm.	470	Limestone, shale and sandstone
	Sandia Fm.	59	Limestone, shale and sandstone
	Log Springs Fm.	4	Hematitic shale and sandstone
Mississippian	Arroyo Peñasco Fm.	28	Limestone, conglomerate and shale
Precambrian	Sandia Granite	---	Porphyritic granitoid
	Rincon Ridge Metamorphics	---	Schist and gneiss

METHODS

Field Investigation

Geologic and Geomorphic Mapping

Identification and location of Quaternary deposits, landforms and associated geomorphic surfaces were made by aerial-photographic and field reconnaissance. Color and black-and-white stereographic, aerial photographs, supplemented by field measurements of sedimentary and geomorphic units, were used to construct the geologic and geomorphic maps (Plates I, II and III). Base maps were assembled from U.S. Geological Survey (USGS) 7.5-minute topographic maps (scale 1:24,000). The study area is approximately 285 km^2 (110 mi^2) in size and includes parts of the Alameda, Albuquerque East, Bernalillo, Los Griegos, Placitas, Sandia Crest and Tijeras quadrangles. Map enlargements of the Rincon Ridge range-front and part of Strip Mine Cañyon (Plate III) illustrate selected map relations in greater detail. Field study was completed in approximately seventy days during several two-week field sessions conducted between July and November of 1995. Additional field work was conducted in April 1995. Mapping was supplemented by other investigations in the study area and vicinity (Fig. 10) (Lambert; 1968; Kelley and Northrop, 1975; Kelley, 1977; Menne; 1989; Hawley and Hasse, 1992; Hawley and others, 1995; Cather and others, in preparation). Locations of pre-Pliocene sedimentary units and range-bounding structures were modified from previous and current studies (Kelley and Northrop, 1975; Menne, 1989; Cather and others, in preparation).

Detailed field study was conducted within the southern parts of the Bernalillo and Placitas quadrangles and the northern portion of the Alameda quadrangle. Aerial-photographic interpretation and limited field reconnaissance, supplemented by previously published and unpublished data, were extensively used to complete the remaining areas. As a result, significant variations in detail of map coverage are expressed on the maps (Fig. 10).

Quaternary geologic and geomorphic map units were differentiated using lithostratigraphic, morphostratigraphic and geomorphic-surface characteristics. A given deposit may be associated with more than one landform; several landforms may develop on a single deposit. Identification of landforms was primarily made from aerial photographs and evaluated and described in the field. Descriptions of stratigraphy, soil-stratigraphy, surface morphology and landscape position were made in the field. Mapped units are therefore, either lithostratigraphic, morphostratigraphic or soil-stratigraphic units. Estimates of surface morphology (i.e., constructional topography) and surface dissection using surface dissection classes (Gile and others, 1981) provides qualitative estimates of the degree of surface dissection and modification; class 1 represents surfaces. The degree of dissection progressively increases to the highly dissected terrain of class 5.

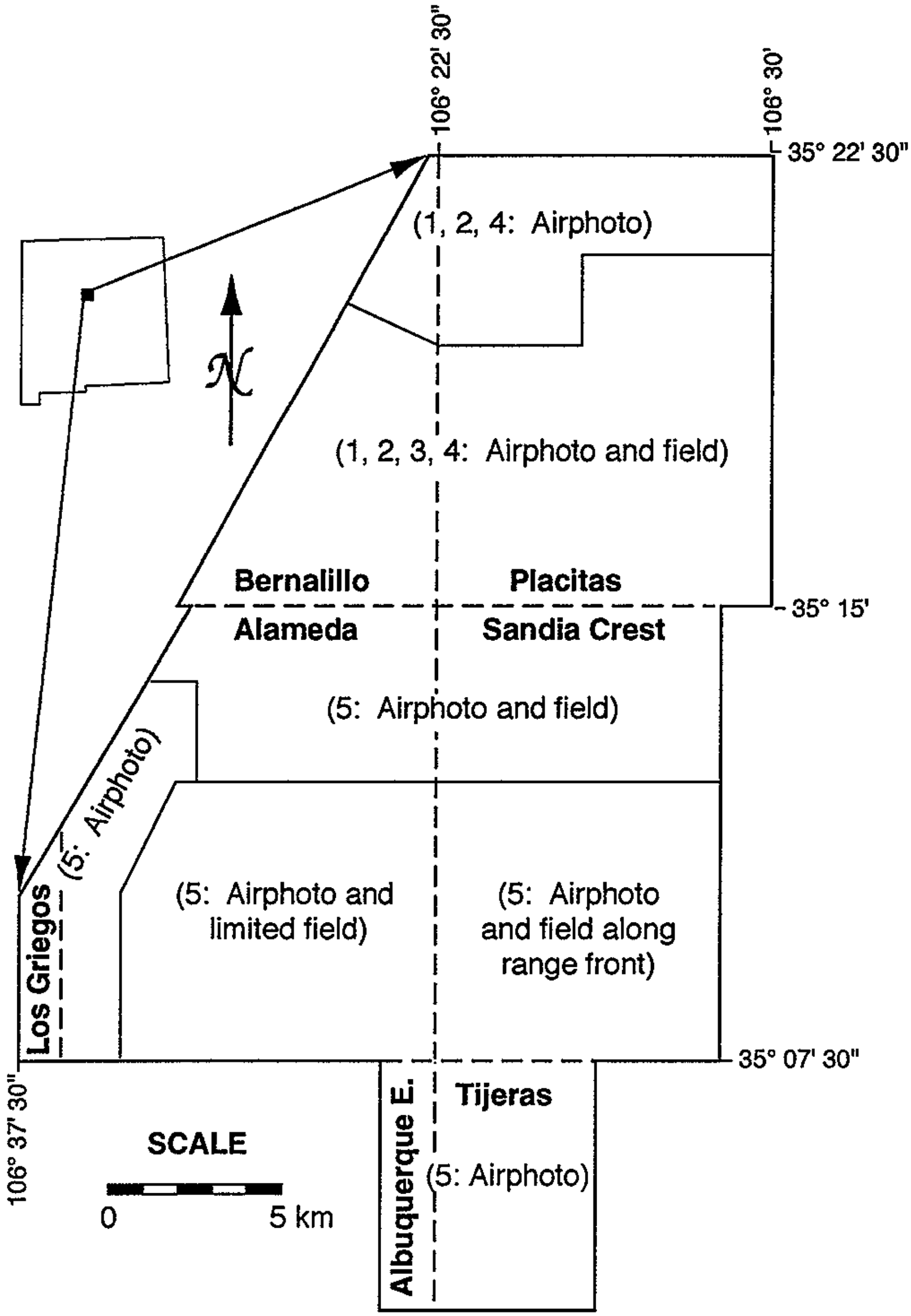
Stratigraphic, Morphostratigraphic and Geomorphic-Surface Descriptions

Sedimentary characteristics include: clastic texture, matrix color, grain sorting and rounding, clast composition, abundance and rounding, sedimentary fabric, bounding contacts and surface morphology using methods and nomenclature described in Compton (1985), Dutro and others (1986) and Gardiner and Dackombe (1983). Stratigraphic sections are denoted by the symbol "S." For example, S-1 refers to stratigraphic section 1 (Appendix D). Stratigraphic thickness was measured using Jacob Staff and compass or estimated from topographic maps having contour intervals of 10 or 20 feet. Soil-profile and stratigraphic descriptions were made within stream-cuts along deeply incised arroyos, excavations at construction sites or using hand-tool dug pits. Pebble counts of selected Quaternary deposits were made along 30-m linear transects or estimated using charts (Dutro and others, 1986). Descriptions of clast weathering were made using cobble-weathering stages (Bull, 1991). Cobble-weathering stages were classified from stage 1, describing unweathered, slightly pitted clasts, to stage 4 to weathered and grussified clasts of stage 4.

A morphostratigraphic unit is an informal stratigraphic term defined as a body of rock or sediment primarily recognized by surface form, rather than from some distinguishing lithologic property (Frye and Willman, 1962). Morphostratigraphic evaluation of the piedmont easily lends itself to photogeologic interpretation. A morphostratigraphic unit describes the surface form, or topographic expression, of a given deposit, including local relief, slope, height above local base level and type of vegetation. Stream-terrace and alluvial-fan landforms constitute the major morphostratigraphic types found within the study area.

A pediment is a gently sloping surface of erosion that may be thinly veneered by alluvium or weathering mantle (Cooke and others, 1993). Pediments, as used here, form broad shallow-gradient surfaces of erosion that exhibit relatively low surface relief. Pediments are generally formed by fluvial processes and typically have concave-upwards longitudinal profiles; however, they can also develop by chemical weathering

Figure 10. Index depicting sources of geologic information and base maps used in study. The study area occupies parts of the Alameda, Albuquerque East, Bernalillo, Los Griegos, Placitas and Sandia Crest USGS 7.5-minute quadrangles. Compilation of map was supplemented by: (1) Kelley (1977); (2) Kelley and Northrop (1975); (3) Menne (1989); (4) Cather and others (in preparation); and (5) Lambert (1968). Field work was conducted along the southern portions of the Bernalillo and Placitas quadrangles and northern part of the Alameda quadrangle. Remaining areas were mapped using aerial photographic interpretation, limited field reconnaissance and results from previous studies.


106° 22' 30"
106° 30'
35° 22' 30"
(1, 2, 4: Airphoto)
N
(1, 2, 3, 4: Airphoto and field)
Bernalillo
Placitas
35° 15'
Alameda
Sandia Crest
(5: Airphoto and field)
(5: Airphoto)
(5: Airphoto and limited field)
(5: Airphoto and field along range front)
Los Griegos
35° 07' 30"
106° 37' 30"
Albuquerque E.
Tijeras
SCALE
(5: Airphoto)
0
5 km

in humid and sub-humid regions (Cooke and others, 1993). Pediments typically originate at the mountain front and cut across older deposits. In the study area they generally are laterally extensive and commonly capped by conglomeratic veneers. Progressive long-term dissection of the piedmont topographically isolates pediments in the study area.

Alluvial fans consist of a body of stream deposits whose surface approximates a cone that radiates down-slope from a point where the stream leaves an upland area (Bull, 1968). Fans can develop at various spatial scales and along different piedmont segments. Fans develop where drainage basins traverse the mountain front and along mid-to distal piedmont areas as the result of base level lowering. Small areally restricted fans occur within tributary drainages and arroyos.

Fluvial terraces represent the former levels of streams. Terraces form because of isolation of terrace treads caused by channel incision. Terraces consist of three basic types: depositional, fill-cut and strath (Leopold and Miller, 1956; Howard, 1959; Howard and others, 1968; Ritter, 1986; and Bull, 1991). Depositional (fill) terraces form when channel incision, following a period of valley aggradation, abandons the former valley floor. Depositional terraces commonly leave isolated, paired terrace treads. Terraces develop when stream power shifts from net aggradation to net incision (Bull, 1979); however, this shift may not be synchronous throughout the drainage (Schumm, 1973) along the entire length of stream. Fill-cut and strath-terraces are erosional landforms that develop by lateral stream erosion and valley-floor widening. Fill-cut terraces form in valley-fill alluvium laid down during earlier aggradational events. Strath terraces are typically cut into older (basin-fill) deposits or bedrock.

Erosional and depositional terraces are distinguished by deposit thickness and nature of basal contact (Mackin, 1937; Ritter, 1986). Erosional terraces typically cut a broad, uniform base that underlies a uniformly thick layer of gravelly alluvium. Depositional terraces on the other hand, fill in older topography and therefore, have an irregular base and variable deposit thickness. Depositional and strath terraces are recognized within major drainages. Minor fill-cut terraces are recognized locally, but are generally too small to differentiate at the scale of mapping.

A geomorphic surface consists of a suite of landforms and deposits that form during a given interval of time and grade to a given base level (S.G. Wells, 1994, personal communication). Geomorphic surfaces extend across depositional (constructional) and erosional landforms and are subjected to periods of landscape stability and erosion that influence soil-morphologic characteristics (Gile and others, 1966 and 1981; Gile and Hawley, 1966). Specific time-dependent pedologic features should occur in a given geomorphic surface (Gile and others, 1981). Most geomorphic surfaces comprise one or more genetically related landforms (morphostratigraphic) that are inset below or overlap onto pre-existing geomorphic surfaces. Geomorphic surfaces are, therefore, time-stratigraphic units recognized primarily on the basis of soil-profile development, stratigraphic and geomorphic position, height above local base-level and degree of surface modification.

Map-Unit Nomenclature

Map symbols delineated on geologic and geomorphic maps (Plates I, II, and III) provide information on landforms and geomorphic surfaces. Capital letters designate geologic age, such as Quaternary (Q) or Plio-Pleistocene (QT). Lower-case letters delineate morphostratigraphic units, such as: (p) pediment alluvium; (pf) undifferentiated complex of fan and pediment alluvium; (t) strath or fill terrace alluvium; (f) fan alluvium (afp) floodplain alluvium; (sct) undifferentiated talus and scree; and (a) undifferentiated alluvium. Numerical designations indicate a specific geomorphic surface, with 1 the being oldest and 9 the youngest. For example, Qp2 refers to pediment landforms and deposits associated with geomorphic surface Q2.

Soil-Profile Descriptions

Soil-profile morphology was described using a standard system of diagnostic criteria and nomenclature developed by the Soil Conservation Service (Soil Survey Staff, 1951, 1975, 1992 and 1993), and Gile and others (1966) with modifications after Birkeland (1984). Soil-profile descriptions were conducted from hand-tool excavated pits, construction-site excavations and along stream banks or road-cut exposures at accessible sites. Soil-profile descriptions are denoted by the symbol "P." For example P-5 refers to soil-profile description number 5 (Appendix B). Soil profiles are generally described at sites reflecting the most stable landscape position (i.e., little or no surface modification) in an attempt to minimize soil-profile variability on a given geomorphic surface (Harrison and others, 1990).

Several soil properties recorded at each site include horizon designation, depth, thickness, dry and moist color, texture, structure, dry and moist consistence, clay film development, stone content, root and pore development, pedogenic carbonate development and morphology (Gile and others, 1966; Birkeland, 1984) and lower horizon boundary characteristics. Carbonate-morphological stages were determined for coarse- or fine-grained deposits using methods described by Gile and others (1966) as modified by Birkeland (1984). Carbonate stages progressively increase from weakly developed (stage I) to strongly developed (stage IV) in the study area. The symbol "-" (e.g., stage I-) denote soils that exhibit weak development of a given carbonate stage. The "+" symbol (e.g., stage IV+) denote soils that exhibit a strongly developed carbonate stage. Colors are described using Munsell (1992) notation. Hue refers to color (e.g., YR is yellow-red). Value and chroma refer to lightness and intensity, respectively. The vertical arrangement of soil horizons and associated properties were described from the land surface down to relatively unweathered parent material or to the base of stream-cuts or excavations (Appendix B). In cases where parent material was not exposed within excavations, color and textural comparisons relative to parent material was made using alluvium from nearby active drainages.

Soil-profile descriptions provide a basis for development of a soil chronosequence (Birkeland, 1984) on geomorphic-surface (soil-stratigraphic) units that can be used for correlation within the study area and to numerically dated chronosequences elsewhere. Variations in soil morphology can be semi-quantitatively evaluated by use of the soil-profile development index (PDI) (Harden, 1982). The index provides a system for quantification of standardized field data that can semi-quantitatively evaluate the magnitude of pedogenic development relative to parent material. The index is normally calculated by comparisons of field-measured properties relative to parent material (Harden, 1982; Harden and Taylor, 1983; Birkeland and others, 1991) and is computed for color (i.e., rubification, melanization, paling and lightening), structure, consistence, texture, clay-film and carbonate development.

Rubification (Xrn), or soil reddening, represents increases in chroma and hue. Color paling (Xpn) represents decreases in chroma and hue. Melanization (Xvn-) and color lightening (Xvn+) represent increases and decreases, respectively, in value relative to parent material. Total texture (Xtn) represents increases in clay, stickiness and plasticity relative to parent material. Dry (Xdn) and moist (Xmn) consistence represent changes in cohesion of peds. The soil-structure property (Xsn) refers to variations in type and grade of soil structure. Peds form blocks of soil that exhibit greater internal cohesion than adhesion to other blocks (Soil Survey Staff, 1993). Texture provides an indication of relative increases in clay and silt accumulation. Carbonate development (Xcsn) measures the degree of pedogenic carbonate development; computed as the product of color lightening and carbonate morphology (Harden and Taylor, 1983).

Differences between soil and parent-material properties presumed to be the result of pedogenic processes are compared and numerically graded. Values are assigned in ten-point intervals for each interval of increase in development relative to parent material; five-point intervals are assigned for intermediate steps in development. For example, a horizon exhibiting a hard consistence relative to loose parent material (consistence scale: <u>lo</u>-so-sh-<u>h</u>-vh-eh) is three steps above parent-material development and assigned a value of 30 points. Soil properties are normalized to "current maximum" values (Harden and Taylor, 1983; Birkeland and others, 1989), which can allow for comparisons to be made with other profiles; however, comparisons require that all soils be described in the same manner (i.e., minimal operator variance among individual descriptions of soil profiles). Normalization results in values typically between 0 (no development) to 1 (maximum development). Larger values occur when profile development exceeds current maximum; however, this does not present a problem because all profiles are normalized to the same values. Determination of the clay-film development index may result in negative values for soils with low accumulated clay; these soils are arbitrarily assigned to 0. Summation of horizon-properties through the profile results in the soil-property index (Appendix C).

<u>Fault-Scarp Survey and Degradation Models</u>

A fault scarps are characterized by a planar surface cut into deposits exposed along a fault. Soon after formation, the scarp becomes progressively modified by erosional at the top of the scarp, coupled with deposition at the base. Scarp profiles were surveyed perpendicular to the trace of the Rincon fault using a Jacob Staff and compass (Appendix E). Topographic fault-scarp profiles were used to measure height, maximum slope-angle and vertical offset for a given scarp. Surveyed scarps were formed during a single ground-rupture event, or by repeated movement. Single-event scarps commonly have a well-developed slope (Fig. 11). Scarps formed during multiple events typically have compound slopes expressed by variations in slope angle (Fig. 11).

Fault-scarp age estimates are made using techniques discussed by Machette (1982, 1989). Age estimates are made by comparisons of scarp-height-slope-angle relations of a given slope to numerically dated scarps in western North America (Bucknam and Anderson, 1979; Machette, 1982, 1989; Machette and Personius, 1984; and Personius and Machette, 1984). Scarp-morphological models require several assumptions (Machette, 1989), such as similarity of deposit character, climate, orientation (microclimate) and vegetation. Morphologic dating models also require that the scarps develop in poorly consolidated deposits that are modified by similar rates and types of denudational processes acting on transport-limited slopes throughout the region of comparison (Bucknam and Anderson, 1979; Nash, 1986; Machette, 1989). Scarp-degradation rates are strongly influenced by scarp orientation, relief, deposit texture, climate and biologic activity (Wallace, 1977; Bucknam and Anderson, 1979; Pierce and Colman, 1986; and Machette, 1989). The rate of scarp degradation may be reduced by soil development, which causes an increase in soil consistence and cementation over time (K. Kendrick, 1994, personal communication). Soil development on scarp faces can therefore, yield apparently younger scarp ages (i.e., underestimate the age of ground rupture).

Laboratory Investigation

Aerial-Photographic Interpretation

Photogeologic interpretation conducted on vertical stereo-pair color and black-and-white aerial photographs (Appendix A) provided qualitative information on surface characteristics. Photogeologic interpretation delineates geomorphic surfaces and morphostratigraphic units on the basis of textural, tonal and color differences, inset relations, relative relief, and degree of surface dissection. Erosional landforms are primarily recognized as smooth, broad, gently sloping surfaces that are generally deeply incised by major mountain-front drainages. Constructional landforms are typically recognized by elongated or circular fan-shaped surfaces that originate from mouths of mountain-front drainages.

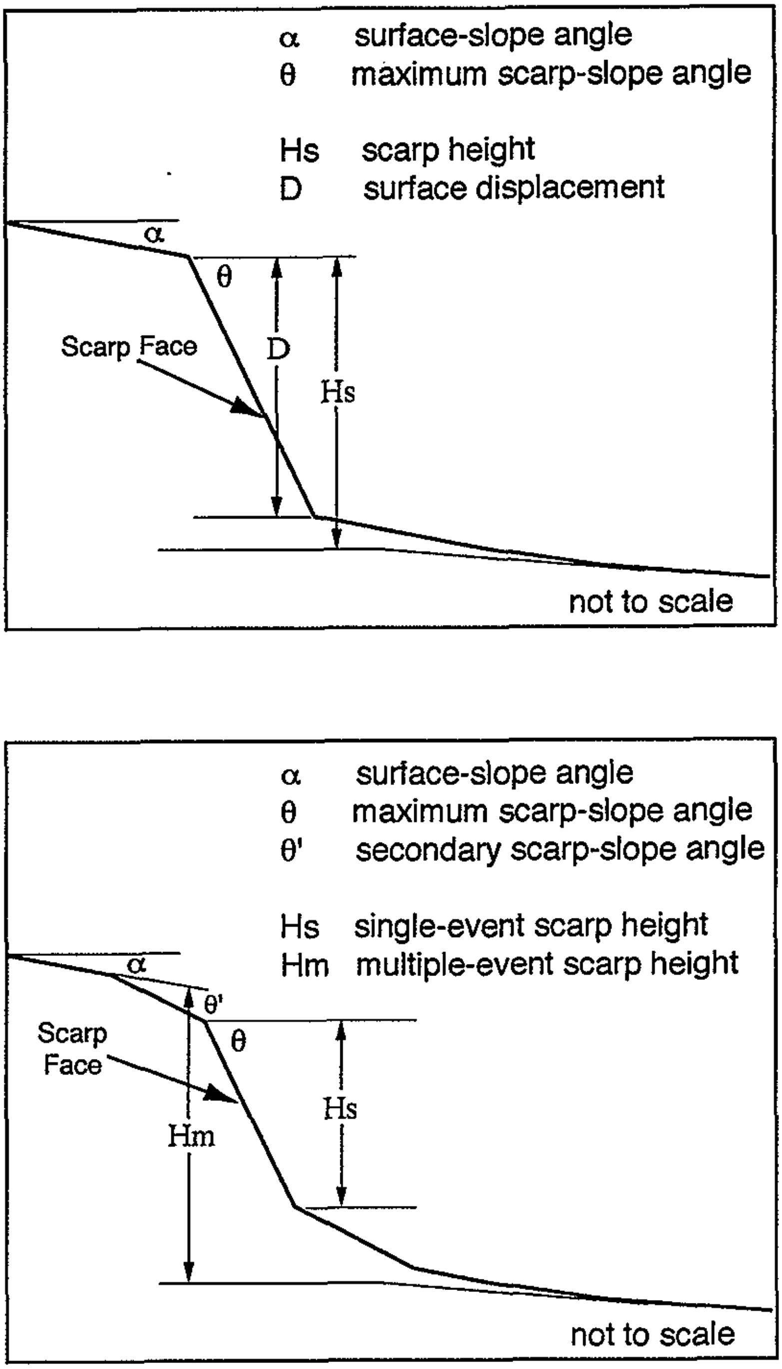


Figure 11. Schematic profiles of two fault scarps (modified from Machette, 1982). Top: profile resulting from a single rupture event. Bottom: profile resulting from multiple rupture events.

Relative ages were established by inset relations and degree of dissection of landform. Aggradational landforms typically exhibit progressive dissection by low-order piedmont drainage systems. Erosional landforms do not typically exhibit progressive modification by drainages developed on the piedmont; however, relative ages are commonly well expressed by inset relations. Overall, younger landforms are yellowish-brown (light tone) and show little surface dissection. A notable exception occurs near Strip Mine Canyon, where streams erode reddish-brown Permian, Triassic and Jurassic sediments.

Morphologic Methods

Morphologic measurements of mountain-front and piedmont morphology are determined from projections of selected geomorphic surfaces. These measurements semi-quantitatively evaluate variations in shape and position of landforms across the study area. Measurements of areal and linear data, using a map wheel and polar-arm planimeter and digitizer (LASICO Model 52P), provide qualitative and semi-quantitative estimates of mountain-front and piedmont variability. More robust analyses of morphology, such as drainage-network, drainage-basin and mountain-front morphometry are not used in this study.

Drainage basins are delineated along topographic divides between drainages that flow across the mountain-front (Fig. 12ab). Drainage-basins and streams were drawn using USGS 30- by 60-minute topographic maps (scale 1:100,000). Streams follow "blue lines" on the map or follow topographic crenulations within large mountain-front drainage basins. This method illustrates the extent of major drainage basins containing drainages of various magnitudes of stream-order.

Longitudinal profiles constructed along the thalweg of selected piedmont drainages illustrate the position of a given geomorphic surface relative to modern streams, which provide the local base-level datum (Fig. 12d). Longitudinal profiles were constructed from USGS 7.5-minute topographic maps at 20- to 100-foot intervals where contour lines cross the thalweg of a given stream. Projections of geomorphic surfaces were made perpendicular to the profile line. Where significant meandering of the thalweg occurs, measurement intervals were increased in order reduce variations in geomorphic-surface projections into the profile. It also has the effect of reducing apparent drainage slope, but forms smoother lines on profiles. Positions of geomorphic surfaces relative to the Rio Grande were graphically projected along the line of profile.

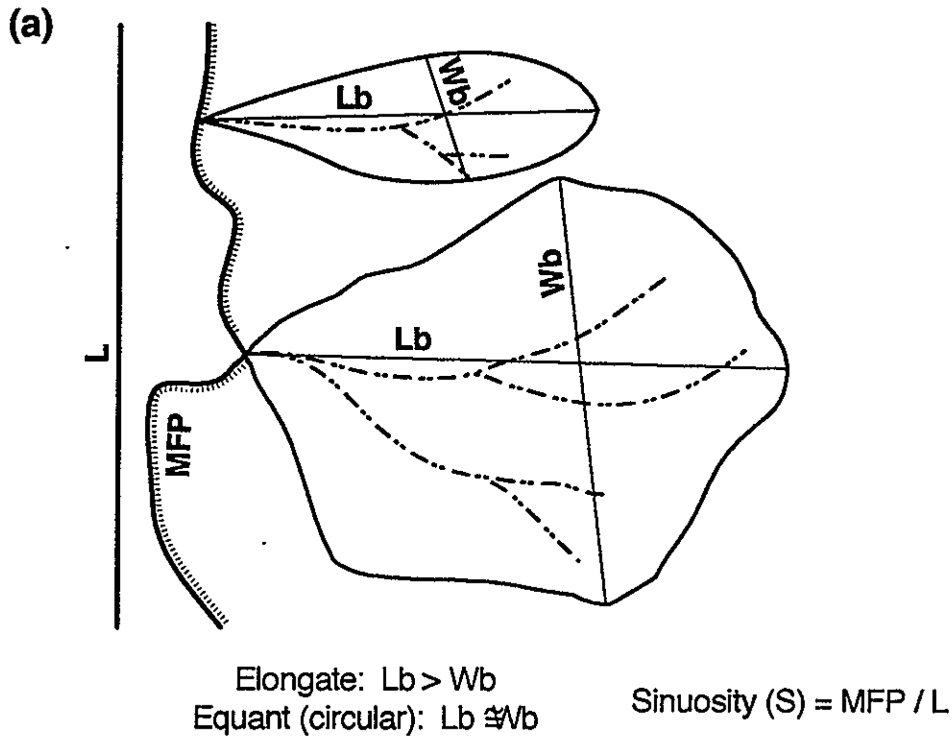
Range-axis profiles illustrate spatial variations of projected crest, base and selected geomorphic features along the length of the range (Fig. 12c). Range-axis projections were constructed using USGS 7.5-minute topographic maps (scale 1:24,000) and a polar-arm digitizer (Menges, 1988). Range-crest, mountain-front and selected subparallel geomorphic features were plotted onto topographic maps. The locations of features were projected horizontally into the profile plane. Geomorphic features tilting towards the profile plane are projected using two different methods. Positions of selected geomorphic features were projected down-slope along to the edge of the Rio Grande floodplain (Fig. 4). Another method involves trigonometric projections of surfaces to the Rio Grande. Orientations of selected geomorphic surfaces, determined using the three-point method for strike and dip (Davis, 1984), were projected, down-dip, to the inner valley escarpment of the Rio Grande (Fig. 4).

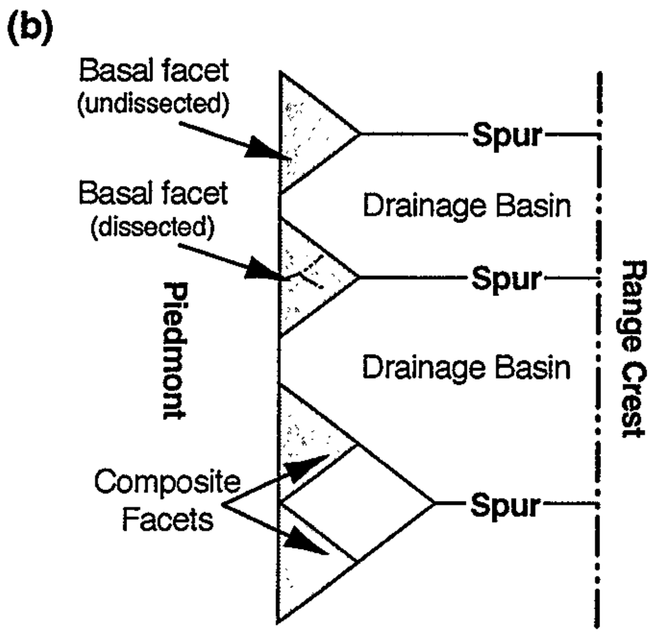
Spur ridges are subordinate to the main range-crest and form topographic divides between drainage-basins (Fig. 12b). Spur-ridge profiles span the full mountain-front escarpment and illustrate the positions of basal facets and mid-escarpment benches developed on the range-front. Profiles were measured between selected drainage basins and drawn down-slope from the range-crest to the mountain-front facet, where the line is projected perpendicular to the maximum slope to the mountain-front piedmont junction (Menges, 1988).

Mountain-front morphology results from tectonic and lithologic influences and can be evaluated using a linear measure of mountain-front sinuosity (Bull and McFadden, 1977; Bull, 1984; Keller, 1986; Mayer, 1986; and Dohrenwend, 1987). Mountain-front sinuosity (S) is ratio of mountain-front length divided by the straight-line length (Fig. 12a). Mountain-fronts are placed into tectonic-activity classes based on sinuosity and river-valley morphology (Bull and McFadden, 1977; Dohrenwend, 1987). Mountain fronts can be classified as highly active (class 1), moderately active (classes 2 through 4) and inactive (class 5).

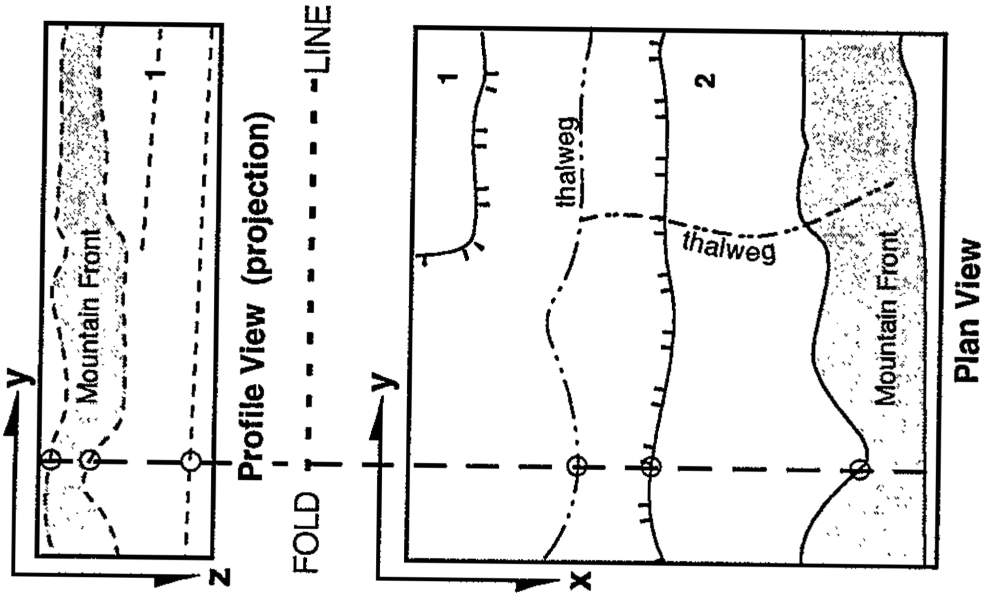
Active mountain-front segments (class 1) have sinuosity values ranging from S=1.2 and S=1.6. Class 1 mountain-fronts typically display non-entrenched fans, steep slopes, elongate drainage-basins and narrow valleys. Moderately active mountain-front segments have sinuosity values ranging from 1.8 and 3.4. Class 2 morphology typically exhibits v-shaped valleys; class 3 generally have u-shaped valleys; and class 3

Figure 12. Piedmont and mountain-front morphometric techniques. Variables x, y denote relative plan-view axes and z indicates the relative elevation. Notable features include: (a) Drainage-basin forms and mountain-front sinuosity; (b) Spur-ridges, basal and composite facets, including dissected and undissected facets; (c) schematic map depicting method of range-axis profile measurements; and (d) longitudinal profile along hypothetical stream channel. Elongate drainage basins have a dominant long axis, whereas, equant or circular basins have nearly equal basin dimensions. Mountain-front sinuosity (S) is measured using the length of the mountain front-piedmont junction (MFP) divided by the straight-line length (L). Numbers denote relative landscape-position (lower numbers denote older surfaces) of geomorphic surfaces.


(a)
Lb
Wb
Lb
Wb
L
MFP
Elongate: Lb > Wb
Equant (circular): Lb ≅ Wb
Sinuosity (S) = MFP / L

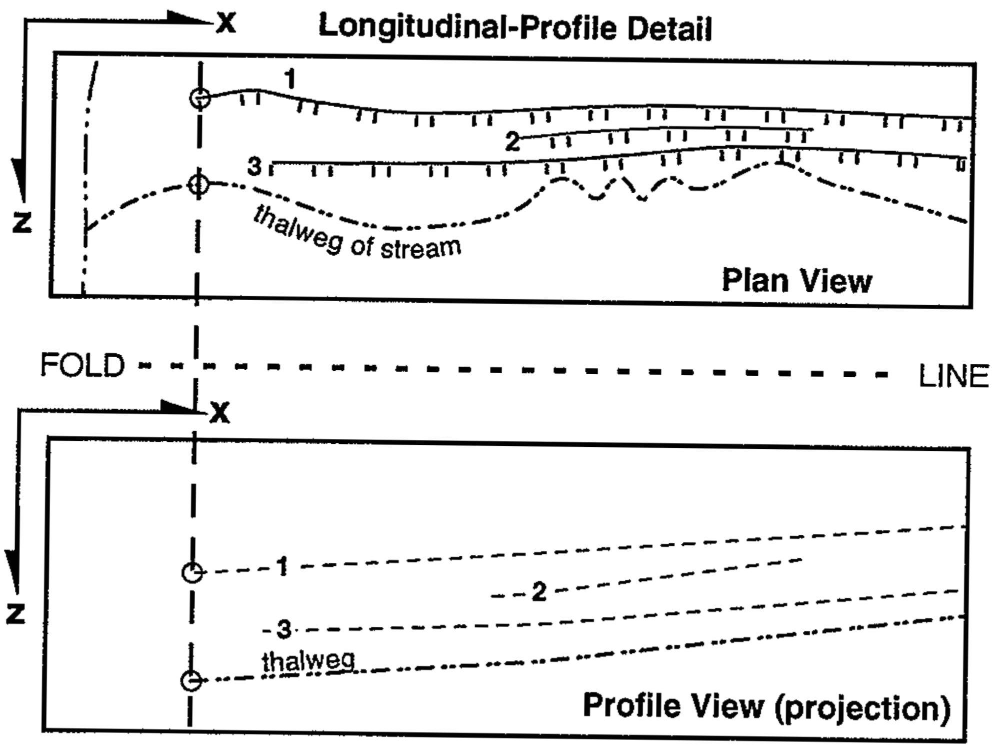

(b)
Basal facet
(undissected)
Spur
Basal facet
(dissected)
Drainage Basin
Spur
Piedmont
Range Crest
Drainage Basin
Composite
Facets
Spur

(c)



Profile View (projection)
Mountain Front
1
y
z
FOLD
LINE
thalweg
thalweg
1
2
Mountain Front
Plan View
y
x

(d)



x
Longitudinal-Profile Detail
1
2
3
thalweg of stream
Plan View
z
FOLD
LINE
x
z
1
2
3
thalweg
Profile View (projection)

forms pedimented, embayed mountain-fronts. Inactive (class 4) mountain-fronts typically vary from 1.8 to 7.2 and exhibit deeply embayed, pediment-dominated piedmonts. Sinuosity may also be somewhat scale dependent. Mountain-front morphology is also influenced by lithologic variations (Bull and McFadden, 1977).

Mountain-Front Segmentation Criteria

Evaluation of mountain-front segmentation is based on systematic cross-sectional and planform variations in mountain-front orientation, linearity, faceted spur morphology, drainage-basin, piedmont and fault-scarp characteristics (Menges, 1988, 1990ab). The Sandia Mountains form a topographically well-defined escarpment that is segmented by en-echelon range-front faults (Kelley and Northrop, 1977; Russell and Snelson, 1990 and 1995). Systematic variations in mountain-front morphology have been recognized along the Sangre de Cristo Range in the northern Rio Grande rift (Menges, 1988, 1990ab; Pazzaglia, 1989).

Mountain-front segments and subsegments were delineated by variations in mountain-front orientation, linearity, lithologic distribution, faceted-spur morphology, spur benches, drainage-basin form, piedmont and fault characteristics (Fig. 12). Mountain-front orientation was measured along the base of the mountain front. Sinuosity was calculated using sinuosity ratios (Bull and McFadden, 1977; Bull, 1984). Sinuosity (S) was arbitrarily ranked, in this study, into linear ($S = 1$ to 1.5), moderately sinuous ($S = 1.6$ to 1.9) and sinuous ($S \geq 2$) mountain fronts.

Drainage-basin form was determined by qualitative estimates of length and width (Fig. 12a). Elongate basins have a single dominant dimension (Lb). Equant (circular) basins are typically described by two nearly equal axes (Wb=Lb). Fault segmentation was determined from stratigraphic and structural relations from this study and on regional maps (Figs. 3 and 8; Plates I, II, III) (Kelley and Northrop, 1977; Menne, 1989; Cather and others, in preparation).

Faceted spur-ridges, common along many range-front segments, were described by the distribution, height and dissection of facet faces. Dissection was qualitatively evaluated by contour-crenulation patterns on the faceted-spur faces. Spur-ridge plots allow for qualitative evaluation of prominent benches on spurs (Menges, 1988). These were drawn along drainage divides between facets. Evaluation of fault-segmentation patterns is obscured by burial of range-front faults, south of Rincon Ridge; however, the position of buried range-front structures are constrained by stratigraphic relations and linear trends on aerial photography.

Stratigraphic Correlation

Estimates of the age of axial-river deposits and piedmont landforms and associated deposits are based on cross-cutting (inset) relations and soil-stratigraphic correlation to chronosequences developed in similar physiographic settings (Fig. 13; Table 1).

Soil Correlation

Estimates of geomorphic-surface ages were derived from comparisons of morphologic properties to numerically calibrated soil chronosequences and soil-based alluvial chronologies (Fig. 13, Table 1) described in southern New Mexico (Gile and others, 1979, 1981; Harden and Taylor, 1983), northern New Mexico (Kelson, 1986; Dethier and others, 1988; Pazzaglia, 1989; Pazzaglia and Wells, 1990), eastern Colorado Plateau (Grimm, 1985; Wells and others, 1990; Drake and others, 1991), and the Albuquerque basin (Machette, 1978ab, 1985; Smith and others, 1982; and Geissman and others, 1990).

Factors that define the state of a soil system include climate, biology, topography, parent material and time (Jenny, 1941). The climatic factor refers to the annual distribution and amount of temperature and precipitation. Biological factors refer to surface and soil organism interaction with the soil, including bioturbation and type of vegetation (Graham and Wood, 1991). Topographic factors refer to shape, elevation, slope and aspect of a landform that can affect the long-term stability of a given surface (Harrison and others, 1990). Parent material refers to composition and texture of deposit. The time factor refers to duration, since deposition, of exposure to pedogenic processes. In addition to these factors locally or regionally important influences, such as atmospheric dust flux, are important in semi-arid and arid regions (Gile and others, 1981; Machette, 1985; and Birkeland and others, 1989).

A soil chronosequence is developed when profile-characteristics progressively change though time (Jenny, 1941; Birkeland, 1984; Birkeland and others, 1989). Other factors (variables), such as climate, vegetation, aspect, parent material and topography, are negligible or constant in a given sequence. Soil chronosequences are useful for correlation of geomorphic surfaces throughout regions subjected to similar climate that tend to favor generally similar pedogenic processes (Table 1; Fig. 13). Soil-profile variability resulting from variations in other soil-forming factors may hamper the utility of soils as a precise geochronologic tool (Birkeland, 1984); however, soil-profile development is one of the most useful and consistent morphologic tools for geomorphic-surface correlation (McFadden and others, 1989).

Specific soil-morphological characteristics, including calcium-carbonate accumulation (Gile and others, 1966, 1981; Machette, 1985) and clay-film development (McFadden and Weldon, 1987; McFadden and others, 1986 and 1987) are generally time dependent and thus, can provide estimates of geomorphic-surface age through comparisons to numerically dated soil chronosequences and soil-based alluvial chronologies elsewhere. Carbonate morphologic-stages are useful for distinguishing geomorphic surfaces having similar textural, compositional and climatic conditions; however, accumulation of pedogenic carbonate is strongly influenced by climatic, lithologic and topographic factors (Dohrenwend, 1987) and can vary by a full morphologic stage on a given geomorphic surface (Machette, 1985). Carbonate morphology is well expressed in arid and semi-arid regions of southwestern North America (Harden and Taylor, 1983; Machette, 1985; and Wells and others, 1987b).

Soils formed on alluvial landforms of different geomorphic surfaces (ages) reflect, in part, distinct landscape positions that generally grade to specific base levels. Soils exhibiting minimal profile development are commonly associated with young geomorphic surfaces exhibiting minor surface dissection and are inset below older geomorphic surfaces. A strictly defined soil chronosequence (Jenny, 1941) is probably rare because of the unique conditions required for constraining all other factors. The soil-chronosequence concept was used, in this study, in a less restrictive sense in an attempt to demonstrate progressive variations in soil development through time. Study area soils are compared to soils described in aridic soil-moisture regimes with similar vegetational and parent material characteristics (Table 1). Use of the soil-chronosequence concept, in this study, is not intended to replace the need for numerical age control, but provides a much needed framework for comparisons to other geomorphic surfaces.

Several generally time-dependent variations in soil-profile development are recognized in New Mexico (Machette, 1978b, 1985; Gile and others, 1981; Grimm, 1985; Kelson, 1986; Pazzaglia, 1989; Dethier and others, 1988; Wells and others, 1990; and Drake and others, 1991). Soils with cambic horizons (Bw) are typically found on middle to early Holocene (4 to 10 ka) deposits and landforms, but are generally absent on older ones. Argillic (Bt) horizons tend to locally develop on middle to early Holocene deposits and landforms. Argillic horizons generally become strongly developed on late Pleistocene landforms and deposits. Calcic soils typically are weakly developed and generally exhibit stage I morphology on early and middle Holocene geomorphic surfaces. Progressive development of calcic soils commonly increases with time and generally exhibits stage II or II+ in late Pleistocene soils and stage III in late-middle Pleistocene soils. Strongly developed stage IV (petrocalcic) soils typically occur on pre-middle Pleistocene geomorphic surfaces.

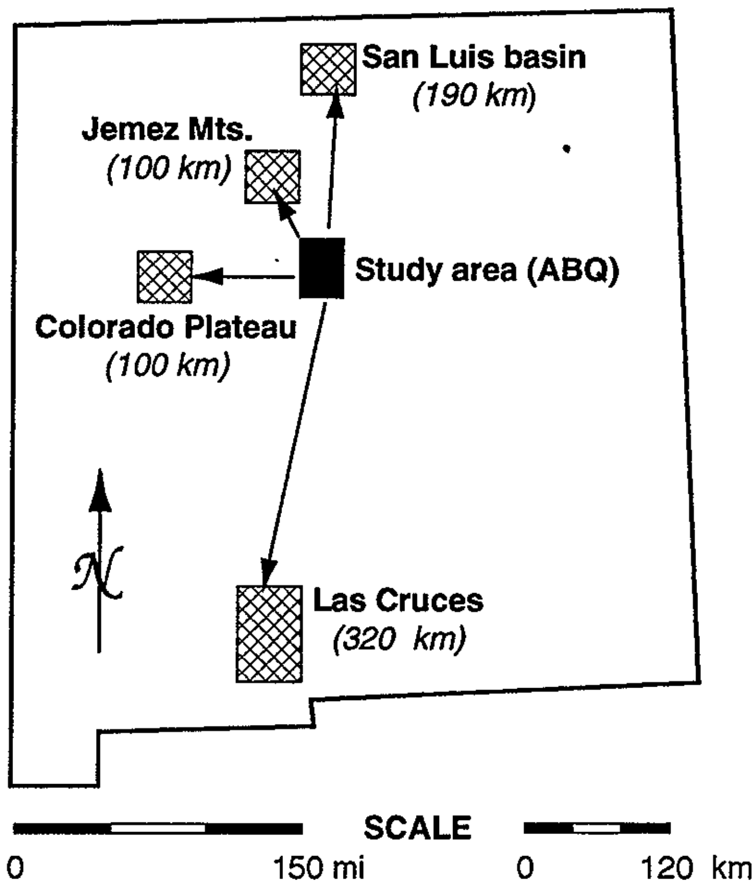


Figure 13. Location of soil chronosequences and soil-based alluvial chronologies developed in similar physiographic settings and distance to study area. The Las Cruces chronosequence, developed in southern New Mexico (Gile and others, 1979, 1981; Harden and Taylor, 1983) is approximately 320 km south of the study area. The eastern Colorado Plateau area contains soil chronosequences and alluvial chronologies described in Chaco Canyon (Wells and others, 1990) and the Grants-Mount Taylor area (Grimm 1985; Drake and others, 1991), the Jemez Mountains (Dethier and others, 1988; Gonzalez, 1995) and the San Luis basin of northern New Mexico (Pazzaglia and Wells, 1990). Soil-based age-estimates of alluvial deposits are described in the Albuquerque (ABQ) basin (Machette, 1978ab; 1985).

Table 1. Summary of regional climate, elevation, parent material and vegetation in study area and selected chronosequences (Folks, 1975; Gile and others, 1981; Machette, 1985; Dethier and others, 1988; Drake and others, 1991; Pazzaglia and Wells, 1990; Wells and others, 1990).

Location (Fig. 13)	Climatic regime	Mean annual temperature (°C)	Mean annual precipitation (cm)	Elevation range (m)	Parent material	Vegetation
Albuquerque basin central New Mexico **(This study)**	Warm arid to semi-arid	10° to 14°	20 to 38 [64 to 76 in mountains]	1520 to 2075	Granitoid, metamorphic and sedimentary	Chihuahuan and Great Basin Grassland
Grants-Laguna western New Mexico	Semi-arid	10 to 13°	18 to 26	1750 to 2290	Volcanic and sedimentary	Great Basin Grassland
Chaco Canyon northwestern New Mexico	Semi-arid	Summer: 38° Winter: 5°	18 to 20	1500 to 2200	Eolian sand	Great Basin Grassland and Desert Shrub
Las Cruces southern New Mexico	Warm semi-arid	16°	21 to 28	1180 to 1310	Volcanic, granitoid and sedimentary	Chihuahuan Grassland and Shrub
Española basin northern New Mexico	Semi-arid	10°	25 to 46	1900	Volcanic and sedimentary	Great Basin Grassland and Montane
Taos Plateau northern New Mexico	Cool semi-arid	4° (Nov.-July)	32	2400 to 2700	Granitoid, sedimentary, metamorphic	Great Basin Grassland and Mixed Conifer Montane

RESULTS

Stratigraphy of Sandia Piedmont

The stratigraphy of the Sandia piedmont is divided into discussions of Neogene synrift-basin fill of the Santa Fe Group and post-Santa Fe Group piedmont and fluvial deposits derived from the Sandia Mountains and ancestral and modern Rio Grande. Relative age relations of stratigraphic units are established using inset relations, height above base level and degree of soil-profile development (Fig. 14; Appendix F).

Santa Fe Group Stratigraphy

The term "Santa Fe" has been previously used as a formation or group term to describe late Cenozoic extensional basin deposits associated with the Rio Grande rift (Chapin and Cather, 1994). The "Santa Fe" is presently used as a group term used to indicate Cenozoic synrift basin-fill that predates middle Pleistocene entrenchment of the Rio Grande (Spiegel and Baldwin, 1963; Chapin and Cather, 1994). The Santa Fe Group is a lithostratigraphic term with an allostratigraphically defined top (Spiegel and Baldwin, 1963): a meaning that may have contributed much confusion in stratigraphic use.

Historically, the name "Santa Fe marls" was used by Hayden (1873) to describe deposits within the Rio Grande Valley near Santa Fe, north-central New Mexico. 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. Galusha (1966) adopted the term Zia Sand Formation (Zia

Sandstone of Kelley, 1977) for the Lower Gray and part of the Middle Red formations. Kelley (1977) considered the Middle Red formation as an undifferentiated "main body" of the Santa Fe Formation. Spiegel (1961) mapped Middle Red formation along the northwestern margin of the study area. Manley (1978) placed Middle Red formation into Cochiti Formation on the basis of color and texture. Use of these terms extended to reddish-brown piedmont deposits in the study area, west of Bernalillo (Hawley, 1978); however, it is likely that middle Santa Fe Group is buried along most of the piedmont. Furthermore, Smith and Lavine (1994) recommend that the Cochiti Formation be restricted to volcaniclastic deposits found within the Jemez Mountains. Lambert (1968) continued use of the terms Upper Buff and Middle Red formation. Kelley (1977) used the term Ceja Member of the Santa Fe Formation to describe the same deposits.

Machette (1978b) defined the Sierra Ladrones Formation (upper Santa Fe Group) for predominantly axial river deposits that interfinger with piedmont alluvium in the Belen (southern Albuquerque) sub-basin. The lower (1.55 Ma) and upper (1.1 Ma) Bandelier Tuff provide numerical-age constraints for the upper Santa Fe Group (Smith and others, 1970; Bachman and Mehnert, 1978). Net incision of the Santa Fe Group basin probably began between 500 ka and 1.1 Ma (Gile and others, 1981; Machette, 1985).

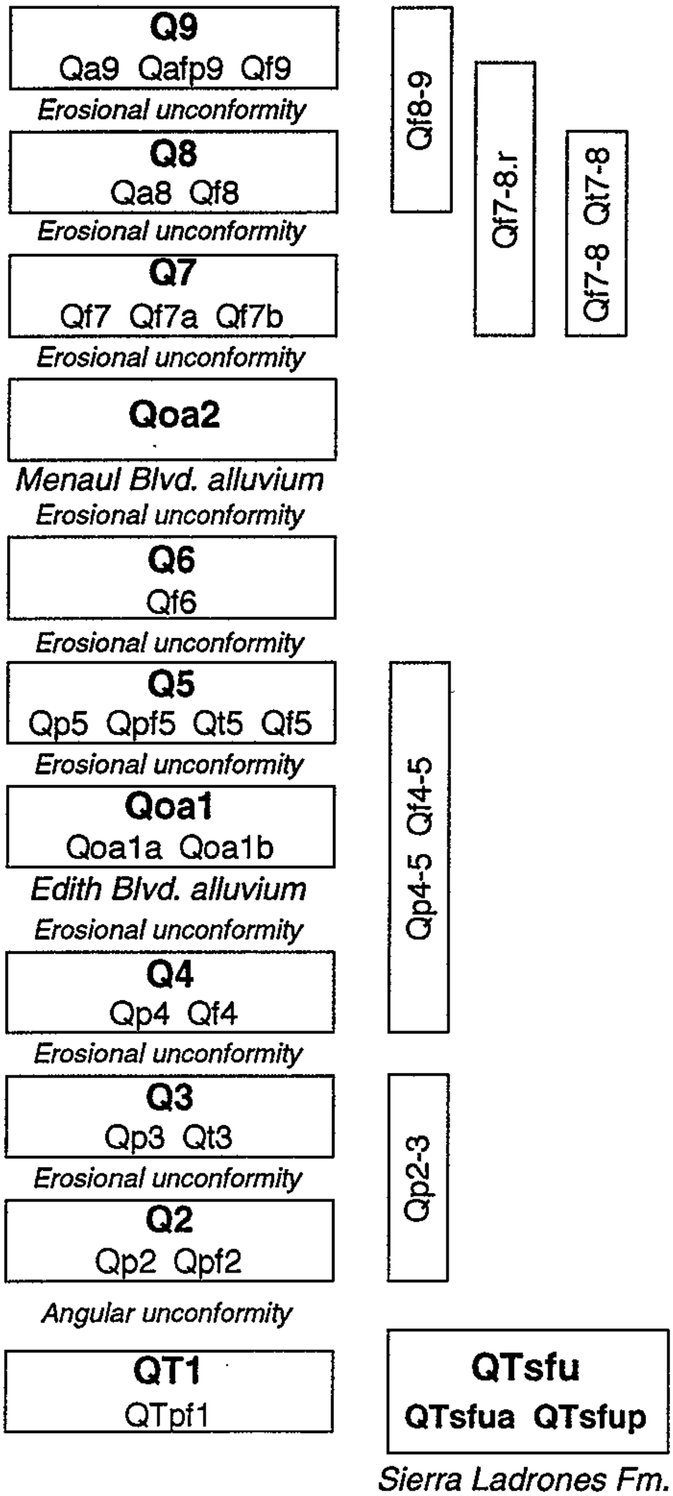
Lower Santa Fe Group

Undifferentiated lower Santa Fe Group (Tsfl)

The lower Santa Fe Group (Tsfl), in this study, represents undifferentiated deposits of the lower and middle Santa Fe Group synrift basin-deposits underlying the

Figure 14. Generalized stratigraphic column illustrating relative ages of stratigraphic units within study area. Units are differentiated on the basis of inset relations, height above local base level and degree of soil-profile development and listed in order of increasing relative age; oldest unit at the bottom.

Major Geomorphic Surfaces and Deposits



Sierra Ladrones Formation. The lower Santa Fe Group (Tsfl) consists of moderately well-cemented pebble to boulder conglomerate and sandstone unconformably overlying Mesozoic and older deposits (S-7 and S-8; Appendix D). Tsfl is in fault contact with the upper Santa Fe Group (QTsfu), generally tilts to the northwest and northeast (16°NW to 25°NE), and is recognized on the footwall of the Ranchos, Lomos and Escala faults. These deposits underlie prominent topographic features, such as Cuchilla de Escala and Lomos Altos (Plate I) and may be correlative to the Miocene Popatosa, Zia Sand, Middle Red or Tesuque Formations (Spiegel and Baldwin, 1963; Bryan and McCann, 1937; Kelley, 1977; Machette, 1978b; and Manley, 1984).

Basal beds of the lower Santa Fe Group are dominated by reddish-brown sandstone and volcanic clasts. Metamorphic, granitoid and limestone clasts increase in abundance up section. Sandstone clasts may be derived from the Permian Abo Formation, a unit that stratigraphically lies above the limestone of the Madera and Sandia Formations on the range-crest of the Sandia Mountains. The occurrence of fanglomerate on the hanging wall of the Placitas and San Francisco faults and an up-section relative increase in limestone clasts marks the inception of a positive rift-flanking highland, possibly related to the uplift of the Sandia Mountains during the Miocene (May and others, 1994; Menne, 1989). A Miocene time of uplift is consistent with uplift of rift-flanking ranges to the north in the Española basin (Ingersoll and others, 1990).

Upper Santa Fe Group

Sierra Ladrones Formation (QTsfu, QTsfup, QTsfua)

The Sierra Ladrones Formation (QTsfu) is named for alluvial-fan, valley, piedmont-slope, floodplain and axial-stream deposits with interbedded basalt flows that are exposed along the southern margin of the Belen sub-basin (Machette, 1978b). The Sierra Ladrones Formation is time equivalent to the Upper Buff and part of the Middle Red members of the Santa Fe Formation (Machette, 1978b). Other time-equivalent deposits include the Camp Rice and Palomas Formations in southern New Mexico (Hawley, 1975; Hawley and others, 1976), and the Puye and Ancha Formations in the western Española basin (Spiegel and Baldwin, 1963; Griggs, 1964; Smith and others, 1970). Sierra Ladrones Formation is preferred instead of Upper Buff formation because the Sierra Ladrones Formation is a formally defined lithostratigraphic unit (Machette, 1978b).

The Sierra Ladrones Formation forms a dominant basin-fill sequence that underlies most of the piedmont. Bedding is typically subhorizontal, but gently (generally less than 10°) tilts eastward towards the Escala, Valley View and small piedmont faults. The Sierra Ladrones Formation consists of yellowish-to reddish-brown, fine-to coarse-grained sand, pebbly sand and pebble to cobble conglomerate (stratigraphic sections S-1 through S-6; Appendix D). The Sierra Ladrones Formation is differentiated into axial-river facies (QTsfua) associated with the ancestral Rio Grande, and piedmont facies (QTsfup) derived from the Sandia Mountains. The base of the Sierra Ladrones Formation is not observed and the top is marked by an angular unconformity with pediment and fan alluvium of unit Qpf2.

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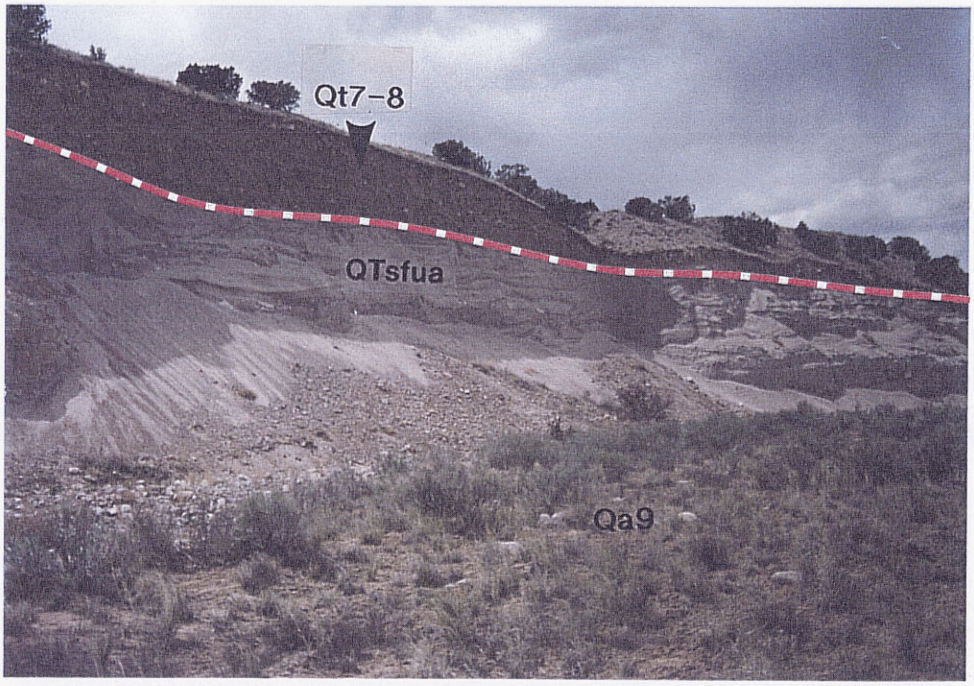
The axial facies (QTsfua) consist of moderately to well-sorted deposits of very pale-brown and light-gray to white (2.5YR to 10YR), subangular to rounded, poorly to well indurated, poorly consolidated, calcium-carbonate cemented, very fine-grained to very coarse-grained sand (arenite and lithic arenite), pebbly sand and interbedded moderately sorted, imbricated pebble to cobble conglomerate (Fig. 15; S-1 through S-3; Appendix D). Deposits contain minor interbeds of reddish-brown, well-indurated claystone and light-brown sandstone. Bedding typically is massive or cross bedded. Conglomerate of the axial facies typically contain imbricated, subrounded to rounded, subprismoidal to subdiscoidal pebbles and cobbles that contain abundant purplish quartzite, phaneritic and aphanitic volcanic and shallow intrusive clasts. Clast constituents include quartzite, vesicular basalt, silicic and mafic aphanitic rocks indicating a northern source area (Stearns, 1953; Lambert, 1968).

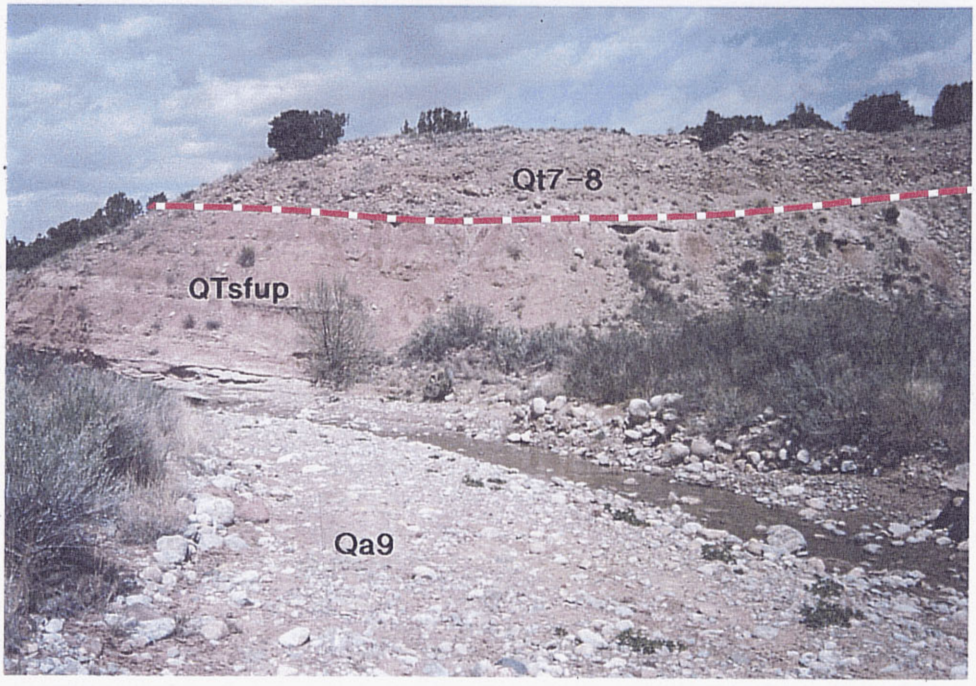
The piedmont facies (QTsfup) consist of reddish-brown and very pale-brown to yellowish-brown, moderately consolidated, poorly to well-indurated, poorly to moderately sorted, subangular to subrounded, very fine-to coarse-grained sand and subangular to subrounded pebble to cobble conglomerate (Fig. 15). Clast abundance is highly variable and occurs as scattered clasts in matrix and tabular to lensate conglomerate beds. Clasts typically are composed of variable amounts of granitoid, metamorphic and limestone with minor sandstone constituents that indicate local provenance. This facies thickens to the east and interfingers with the axial facies to the west.

Rounded pumice clasts recognized in the axial facies (SE1/4, SW1/4, NE1/4, Section 34, T12N., R03E., NMPM, Bernalillo 7.5-minute quadrangle) belong to the lower Bandelier Tuff (1.62 Ma; Cather and others, in preparation) which places a maximum age of early or middle Pleistocene on these deposits. Lucas and others (1993) describe a *Glyptotherium* from a gravel quarry near Algodones (NE1/4, NE1/4, SW1/4, Section 27, T13N., R04E., NMPM, Bernalillo 7.5-minute quadrangle), indicating an Irvingtonian (late Pliocene to middle Pleistocene) age of deposits (Cather and others, in preparation).

The Sierra Ladrones Formation is best exposed within the northwestern quarter of the study area, where deposits had been previously mapped as (Miocene) Middle Red formation (Lambert, 1968; Spiegel, 1961) or Cochiti Formation (Manley, 1978; Hawley, 1978). The Sierra Ladrones Formation can generally be distinguished from lower Santa Fe Group strata by the following characteristics: generally shallow stratal tilt, lower consolidation, and rounded quartzite clasts. The occurrence of deposits associated with the ancestral Rio Grande containing clasts of Bandelier Tuff and an Irvingtonian fauna indicates these deposits belong to the Plio-Pleistocene upper Santa Fe Group, or Sierra Ladrones Formation. Previous attribution of deposits to the lower Santa Fe Group was made partly on the basis of the reddish-brown color and fine-grained texture; however, much of the color came from reddish-brown Permian, Triassic and Jurassic rocks derived from Strip Mine Canyon.

Figure 15. Outcrops of Sierra Ladrones Formation along Las Huertas Creek (Plate I). Qa9 denotes Holocene alluvium. Top: subhorizontal axial-stream facies (QTsfua) underlying terrace alluvium of Qt7-8. Bottom: slightly tilted piedmont facies (QTsfup) underlying terrace alluvium of Qt7-8. Dashed lines mark the contact between the overlying terrace alluvium of Qt7-8 and the underlying Sierra Ladrones Formation.


Qt7-8
QTsfua
Qa9


Qt7-8
QTsfup
Qa9

Piedmont Stratigraphy

Alluvial fans, stream-terraces and gravel-mantled pediments dominate the piedmont of the Sandia Mountains . The piedmont is characterized by nine major geomorphic surfaces (QT1 through Q9) consisting of pediment, fan and terrace alluvium that is inset into the Santa Fe Group (Fig. 16). Piedmont surfaces typically display divergent longitudinal profiles, probably related to long-term net incision of the Rio Grande coupled with uplift along range-front faults of the Sandia Mountains. Assignment of landforms or deposits to specific geomorphic surfaces may be ambiguous because of poor exposures, parent material variability or limited field confirmation. Units having poorly understood geomorphic-surface affinities are grouped into a set of likely geomorphic surfaces (e.g., Qf4-5, Qp2-3). Unit terms with a suffix (e.g., Qf7-8.r) are restricted to specific locations.

Erosional landforms and deposits

Pediments typically form surfaces of erosion along the mountain front that are commonly covered by a thin alluvial veneer grading westward and northwestward into the basin. Pediments predominantly occur north of del Agua Canyon and along a narrow span of the piedmont south of Rincon Ridge (Figs. 4 and 8; Plates I and II). These are separated into bedrock-floored surfaces having little or no alluvial cover, and pediments typically are covered with about 3 to 5 m of pediment alluvium. Pediment-fan (pf) complexes distinguish erosional surfaces with up to 18 m of overlying

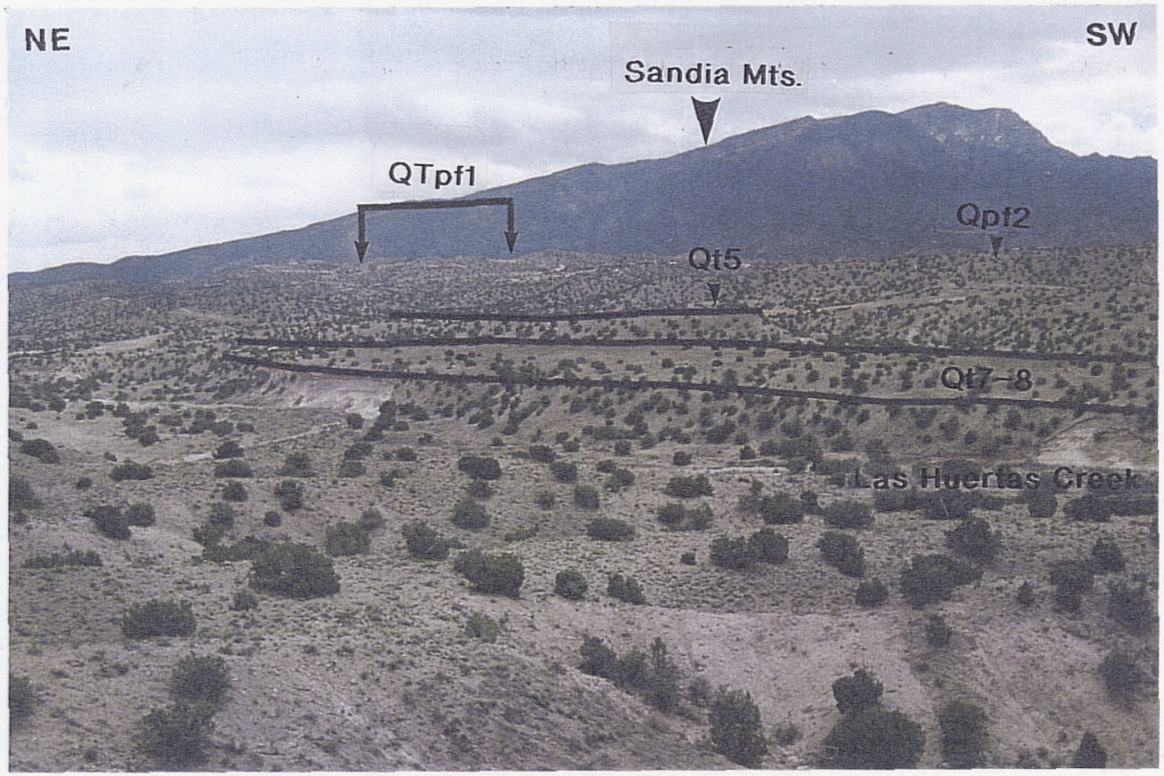


Figure 16. View to southeast of inset geomorphic surfaces along Las Huertas Creek. Units Qpf2, Qt5 and Qt7-8 form a stepped sequence of terraces and pediments within the deeply dissected northern piedmont. Alluvium of Qt7-8 forms an extensive low-lying terrace unconformably overlying axial facies of the Sierra Ladrones Formation (white outcrops) immediately above the floodplain. Several dissected hills are discontinuously overlain by unit QTpf1. Solid lines mark locations of terrace risers between Qt5 and Qt7-8.

conglomerate and conglomeratic sand. Pediment (erosional) surfaces are depicted on geologic maps. Cross-hatched patterns on the geologic maps (Plates I through III) depict bedrock-floored erosional surfaces.

Pediment alluvium (QTpf1)

Pediment alluvium (QTpf1) associated with geomorphic surface QT1 is well expressed as a prominent north-sloping gravel-capped ridge on Lomos Altos (Plate I). Unit QTpf1 is recognized along the northern piedmont by several high discontinuous and isolated ridges unconformably overlying the Santa Fe Group (Fig. 16). The surface originally extended from the range-front as a broad, north-and northwest-sloping pediment. Alluvial deposits of QTpf1 are 4 to 18 m in thickness and overlie indurated, north-tilted proximal-piedmont facies of the lower Santa Fe Group (Tsfl) and Sierra Ladrones Formation (QTsfu). Thickness is commonly less than 12 m, but increases to approximately 18 m just south of the Lomos fault where the basal contact slightly steepens. QTpf1 is approximately 82 to 98 m above local base level, measured along Arroyo del Ojo del Orno (Fig. 17).

Deposits (P-5, P-30; S-7; Appendix A and B; Plate I) are poorly exposed and consist of pebble to cobble conglomerate. Clasts consist of limestone, minor sedimentary and highly grussified granitoid rocks. Soils developed on QTpf1 are distinguished by a strongly developed petrocalcic horizon with platy structure. Constructional bar-and-swale topography is nearly absent and weakly developed stone pavements occur locally on the ground surface, which is typically modified by erosion and accumulation of silt. The soil (P-5) is characterized by a 3.6-m thick, pale-brown to brown (10YR to 2.5Y) buried Bkm horizon with sandy clay loam to sand loam texture, strong angular-blocky and platy structure and stage IV and IV+ carbonate morphology (Fig. 18). The soil-profile was described along the shoulder of the surface, which has been locally modified by erosion. Picha (1982) differentiates deposits, referred to as the Tuerto gravel (Stearns, 1953) associated with one of the "Ortiz" pediments (elevation of about 1910 m) on the Crest of Montezuma (along the footwall of the San Francisco fault); an elevation consistent with the landscape-topographic position of unit QTpf1.

Pediment alluvium (Qp2, Qpf2, Qp2a)

Alluvium associated with geomorphic surface Q2 (P-32; S-8, S-9; Appendix B and C; Plate I) is differentiated into pediment alluvium and pediment-fan complexes (units Qp2 and Qpf2). Pediment alluvium (Qp2) forms thin, 2- to 5-m thick, conglomeratic veneers covering lower Santa Fe Group and pre-Cenozoic strata. An undifferentiated pediment and fan alluvium (Qpf2) thickens to about 12 m and rests upon Sierra Ladrones Formation (Fig. 19). Geomorphic surface Q2 is inset below QTpf1 and is about 6 and 18 m above the base level of Arroyo del Ojo del Orno and 34 to 70 m above Las Huertas Creek. Deposits are less than 122 m above the Rio Grande floodplain (Fig. 17 and 20). Unit Qpf2 forms the highest and most laterally extensive unit north and west of Lomos Altos and Cuchilla de Escala, respectively. Q2 slopes north and northwestward from the mountain front across the hanging wall of the Placitas fault zone into the Santo Domingo basin, where deposits thicken into Qpf2 west of the Cuchilla de Escala.

Figure 17. Longitudinal profile of geomorphic surfaces projected along portions of Arroyo del Ojo del Orno and Las Huertas Creeks illustrate inset relations among geomorphic surfaces. Surfaces of deposits are projected into the profile along the thalweg of the modern stream (Qa9). The base of alluvial deposits of QTpf1 is marked to illustrate marked thickening to the northwest. The profile illustrates the generally concave-upwards nature of pediments and divergent trend of geomorphic surfaces away from the mountain front. Locations of the traces of Placitas fault (PF), Lomos fault (LF) and Valley View fault (VVF) where they cross the line of profile.

Longitudinal profile along portions of Las Huertas and del Orno Creeks

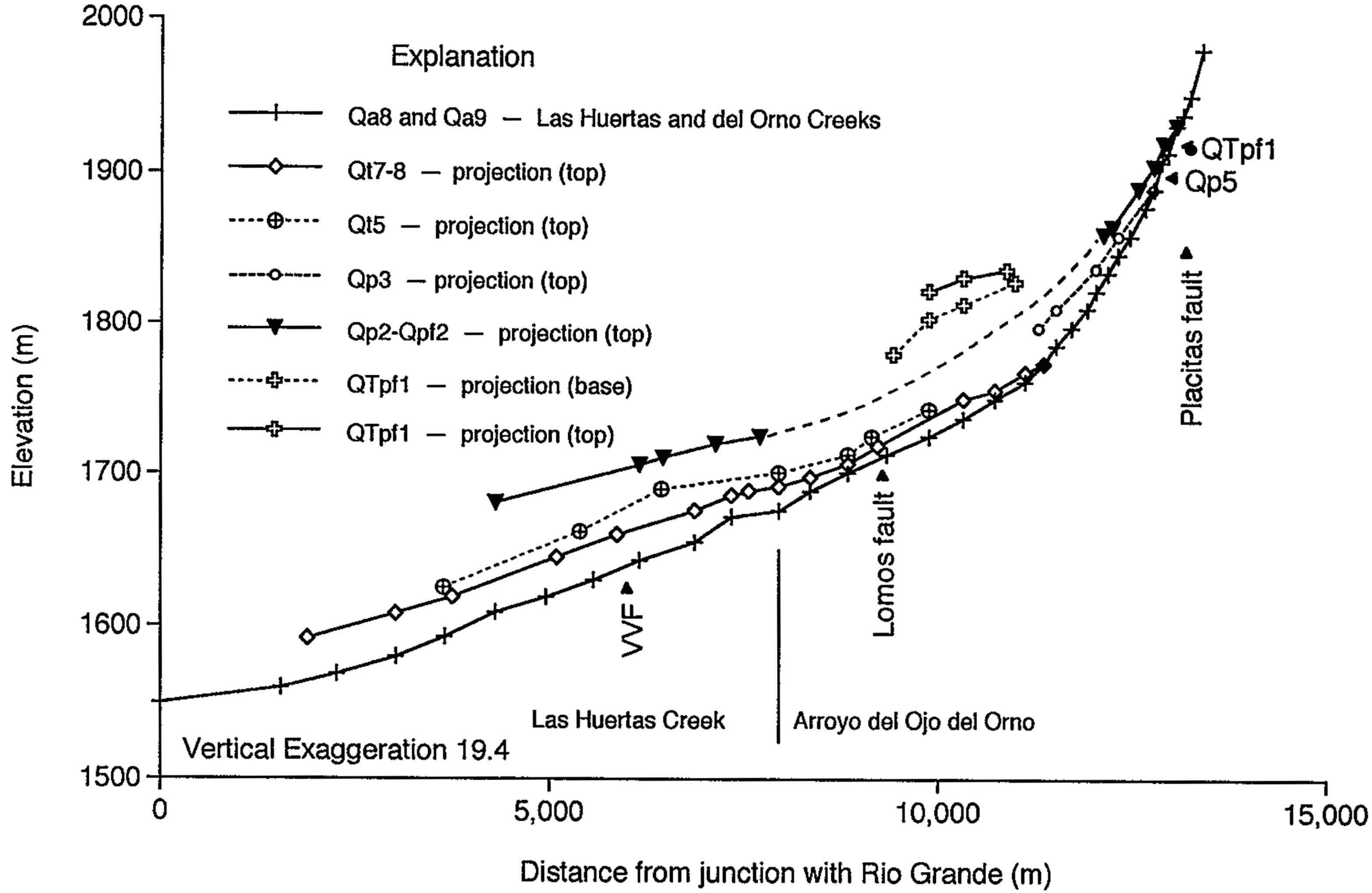
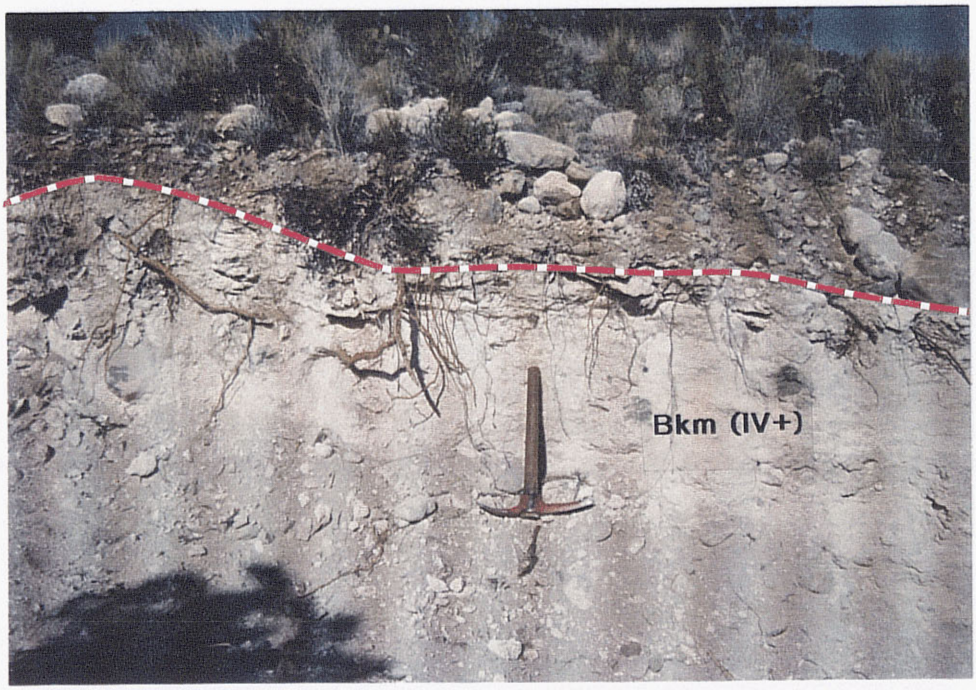


Figure 18. Soil-profile of unit QTpf1 described along road-cut west of the southern end of Rainbow Valley Road (P-5; Plate I). Top: soil exhibits platy structure and stage IV+ carbonate morphology. Dashed line marks the boundary between major soil horizons. Bottom: clasts are predominantly limestone, but contain rare clasts of grussified granite and granodiorite (arrow).


Bkm (IV+)

Deposits of Q2 consist of pebble to boulder conglomerate dominated by subrounded to subangular limestone and minor reddish-brown, weathered sandstone clasts. The surface is modified by erosion and reworking of underlying deposits and is slightly to moderately dissected. Constructional bar-and-swale topography is absent or subdued and weakly developed stone pavements locally occur on the ground surface.

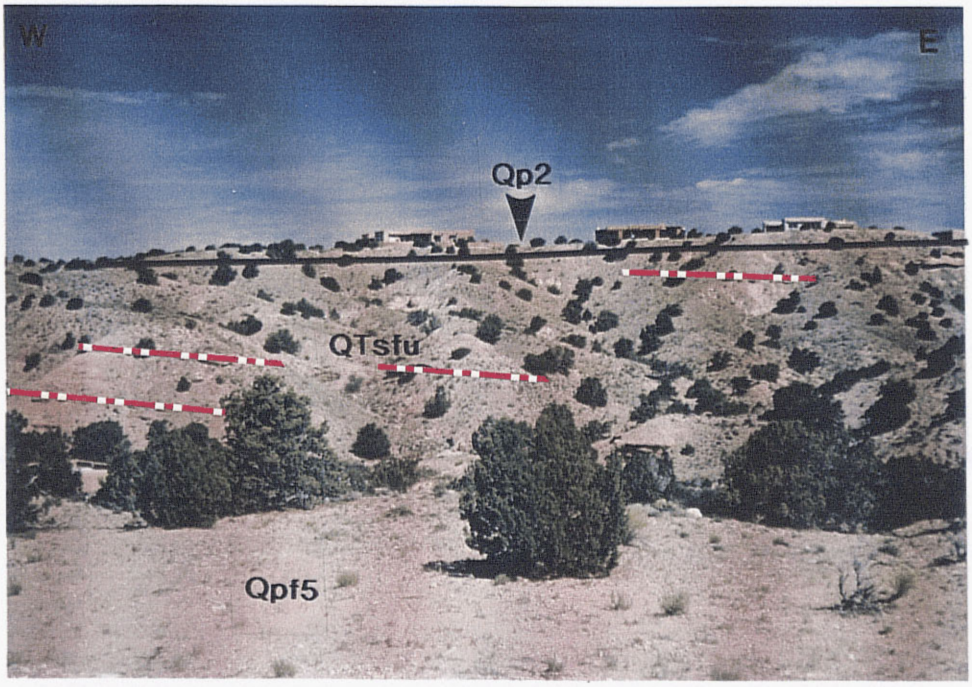
The soil developed on Qpf2 is described within a foundation excavation south of Camino de Las Huertas (P-32; Plate I). Geomorphic surface Q2 is distinguished by a moderately developed calcic soil (Fig. 21) that is characterized by a 63-cm thick very pale-brown to white (10YR to 2.5Y) petrocalcic (Bkmq) horizon with sandy loam texture, moderate angular-blocky and platy structure, stage III+ carbonate morphology and very few thin clay films. Very few, moderately thick, yellowish-brown films clasts are interpreted to be pedogenic silica on the basis of color and resistance to slaking in dilute solution of hydrochloric acid. Soil-profile development decreases down profile and is characterized by a 90-cm thick, very pale-brown to brown (7.5YR to 10YR), calcic (Bk) horizon with sandy loam and sand texture, weak granular structure, very few thin clay films, and stage II carbonate morphology. Few thin to moderately thick accumulations of pedogenic silica occur on clasts. Unconformably overlying this unit are weakly developed calcic soils associated with fine-grained silty sand of unit Qf8-9. This soil forms a light yellowish-brown to yellowish-brown silt loam and loam with weak angular-blocky structure and stage I carbonate morphology. A poorly exposed pediment (Qp2a), north of highway NM 165 (Plate I; W1/2 of section 36, T12N., R04E., NMPM, Placitas 7.5-minute quadrangle), occurs on ridges about 12 m higher than Qp2, but is inset below QTpf1.

Pediments and pediment alluvium (Qp2-3, Qp4-5)

Pediments associated with Qp2-3 and Qp4-5 refers to discontinuous occurrences of pediment alluvium and rock fans (Johnson, 1932) south of Strip Mine Canyon. Soils were not described, making correlation to geomorphic surfaces Q2, Q3 or Q5 ambiguous. Qp2-3 forms the highest mountain-front pediment deposit on the hanging wall of the Sandia and Rincon faults. Qp2-3 is well preserved within the Bear-Pino re-entrant, extends across the southern drainage-divide of the Juan Tabo Creek, and extends about 1.5 km into the basin between La Cueva and Pino Canyons, where it is inset by Qp4-5 and Qf6. Unit Qp2-3 is approximately 25 to 31 m above Juan Tabo Creek; however, a relatively flat bench about 110 m above the creek may represent a former surface of erosion cut on Rincon Ridge that may be related to Qp2-3 or an older (QTpf1?) surface. Deposits consist of highly weathered, pitted and locally imbricated cobbles and large boulders of Sandia granite. Correlation to geomorphic surfaces Q2 or Q3 is constrained by inset relations, geomorphic position and clast weathering. Granitoid clasts, although very large, are not entirely grussified and, therefore, may post-date formation of QTpf1. Inset relations indicate that unit Qp2-3 is older than Qp4-5 and Qp6. Unit Qp2-3 could be correlative to geomorphic surface QT1; however, physical correlation could not be established and soils could not be described because of the bouldery nature of the deposit.

Pediment alluvium of Qp4-5, recognized south of Juan Tabo Canyon, forms a west-sloping pediment inset below the southern drainage divide of Juan Tabo Canyon.

Figure 19. Inset relations among units QTsfu, QTpf1, Qp3 and Qp5. Top: view to north of bluffs forming Valley View fault scarp exhibiting a thin gravelly veneer of Qp2 that unconformably overlies slightly tilted Sierra Ladrones Formation (QTsfup). The Solid line marks the boundary between alluvium of Qp2 and underlying QTsfup. Dashed lines highlight bedding within QTsfup. Bottom: view to east of limestone-dominated gravels of Qp5 resting upon Mesozoic strata near Strip Mine Canyon. The hills in the background are capped by QTpf1. Dashed lines mark the contacts between pediment alluvium and underlying bedrock.


W
E
Qp2
QTsfu
Qpf5

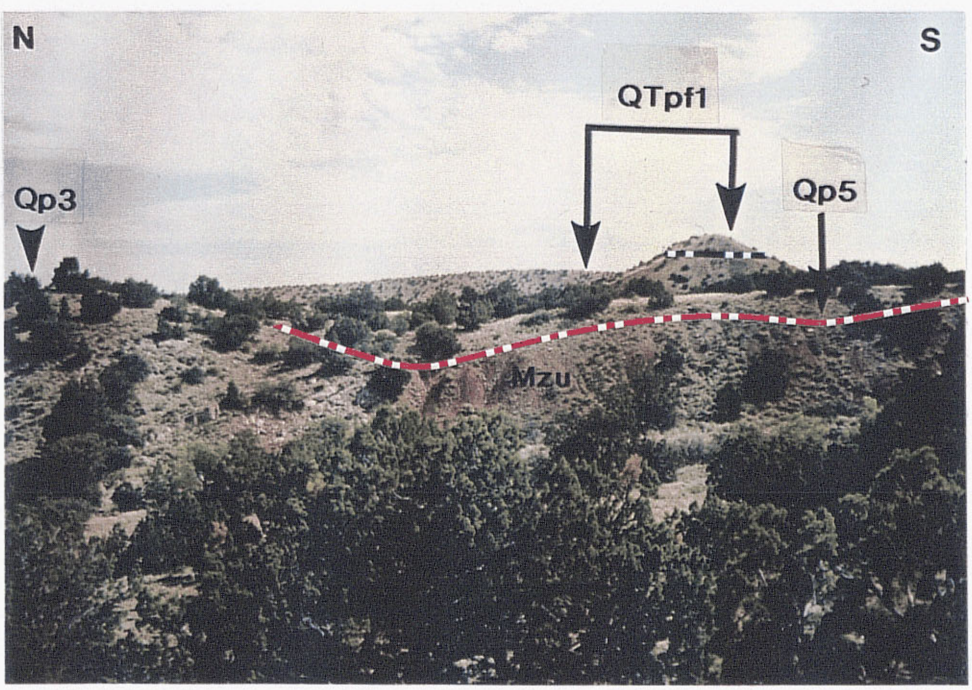
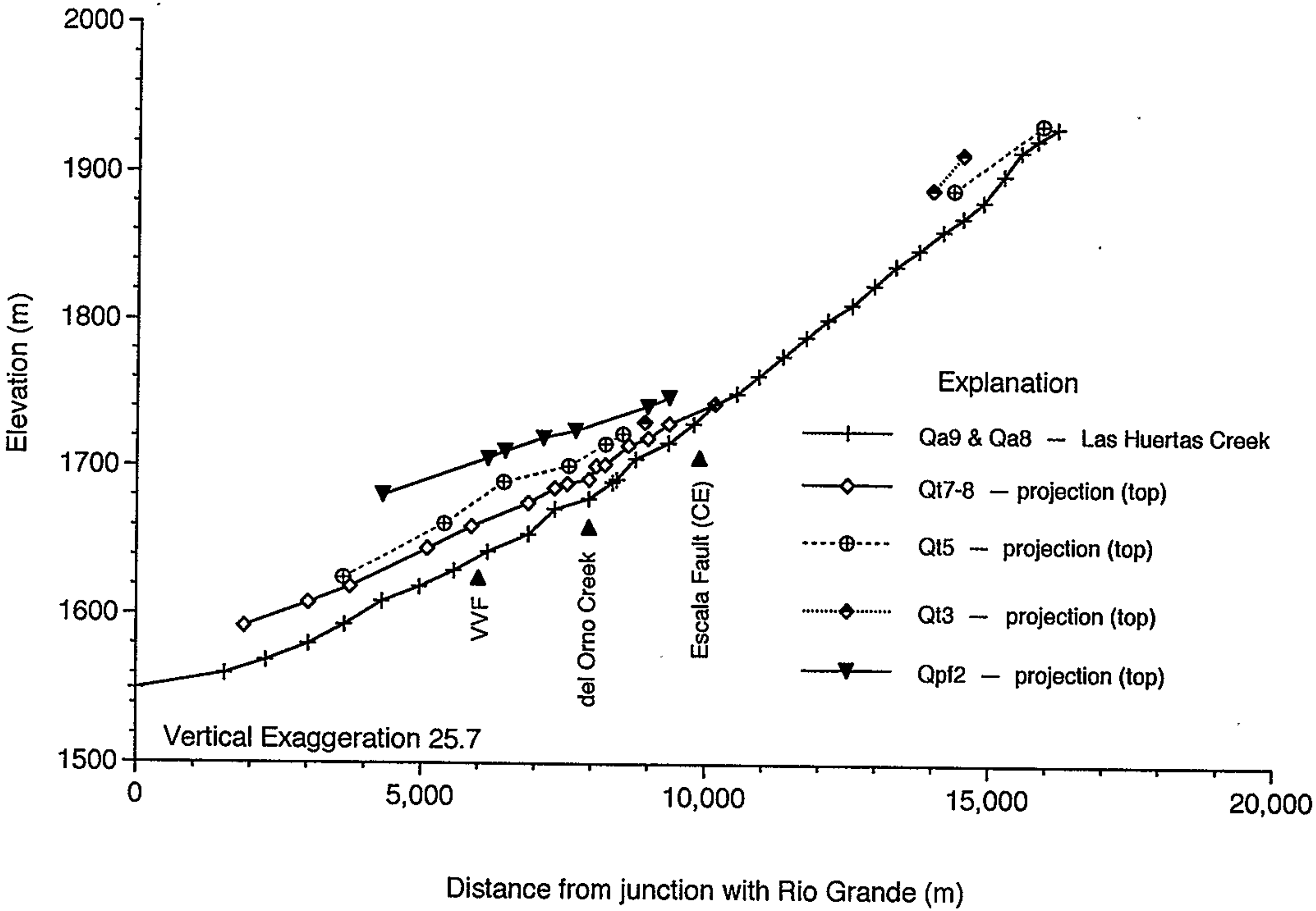

N
S
QTpf1
Qp3
Qp5
Mzu

Figure 20. Longitudinal profile of geomorphic surfaces along Las Huertas Creek illustrates inset relations among geomorphic surfaces. The surfaces (top) of alluvial deposits are projected into the profile along the thalweg of the modern stream (Qa9 and Qa8). The trace of the Valley View fault (VVF), western extent of the Cuchilla de Escala (CE) and the confluence with Arroyo del Ojo del Orno (del Orno Creek) are plotted for reference.

Longitudinal profile along Las Huertas Creek



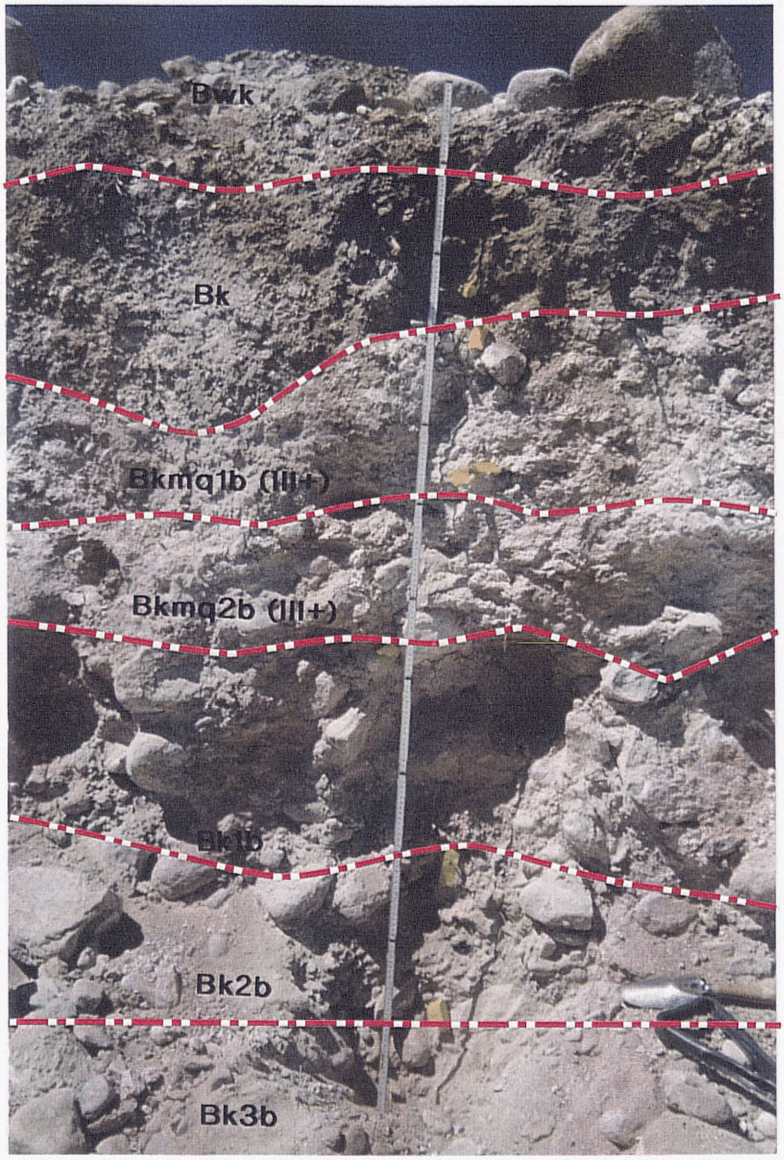


Figure 21. Soil profile of Qpf2 described in a 2-m deep foundation-excavation north of Las Huertas Creek (P-32; Plate I). Dashed lines mark the boundary among major soil horizons. Soil exhibits stage III+ carbonate morphology. Bwk and Bk horizons are developed on deposits of Qf8-9.

Unit Qp4-5 unconformably overlies undifferentiated Mesozoic sedimentary rocks near the southern tip of Rincon Ridge. Qp4-5 is about 6 m above local base level and extends about 2 km west into the basin along the Bear-Pino re-entrant.

Pediment and strath alluvium (Qp3, Qt3)

Pediment and strath-terrace alluvium associated with geomorphic surface Q3 is preserved on scattered hilltops near Placitas and within Las Huertas Creek (Plate I). Qp3 is preserved as remnants of a formerly extensive pediment inset below Qp2 (Figs. 17, 19 and 20). Qp3 forms north-and west-sloping surfaces that are about 9 to 32 m above local base level and has a concave-upwards profile indicative of pediments (Figs. 17, 19 and 22). Qp3 is recognized between Las Huertas Creek and Strip Mine Canyon. Exposures are typically poor and soils are not described. Constructional bar-and-swale topography is generally absent or subdued. Alluvium of Qp3 (S-12, S-13; Plate I) is characterized by an approximately 7- to 14-m thick, moderately consolidated limestone conglomerate. Clasts comprise about 35 to 40 percent of the deposit and consist of limestone, metamorphic and minor sandstone clasts.

Strath-terrace alluvium (Qt3) is recognized by a thin limestone conglomerate overlying a gently sloping strath cut into Las Huertas Creek. Unit Qt3 is about 27- to 42-m above Las Huertas Creek and forms the highest preserved surface within the north-flowing reach of this drainage (Plate I). Exposures of Qt3 are typically covered; however, a partly stripped soil exposed along a stream-cut is characterized by a pale-brown to brown (7.5 to 10YR) calcic (Btk) horizon with sandy clay loam to silty clay texture, moderate angular blocky structure, few to common, moderately thick clay films and stage II+ carbonate morphology (P-4; Plate I). This soil developed in a brown to light brown (7.5YR to 10YR) silty clay and sandy clay loam deposit derived from fine-grained Mesozoic sedimentary rocks.

Pediment and strath alluvium (Qp5, Qpf5, Qt5)

Pediment and strath alluvium associated with geomorphic surface Q5 forms an extensive surface north of highway NM 165 and is inset below Q3 and incised by alluvium of Qf7 (Fig. 19). Geomorphic surface Q5 forms pediments east of the mouth of Strip Mine Canyon and is differentiated into morphostratigraphic sub-units based on surface-form and thickness. Qp5 is about 2- to 5-m thick but thickens to more that 6 m to the west. Pediment-fan complex Qpf5 becomes thicker and forms a laterally extensive surface north of NM 165. Strath alluvium Qt5 overlies a relatively smooth, west-sloping surface inset below Qpf2 in Las Huertas Creek, where this unit forms a thin, elongate terrace. Q5 is about 6- to 27-m above local base level (Figs. 20 and 22). Constructional bar-and-swale topography is subdued and the ground surface is generally smooth and slightly dissected.

Pediment alluvium of Qpf5 (P-7, P-13; S-10, S-11; Appendix B and C; Plate I) consists of moderately consolidated, very pale-brown to yellowish-brown, subangular to subrounded, cobble to boulder conglomerate. Clasts are dominated by limestone and metamorphic rocks. Accessory clasts include weathered sandstone and partly weathered granitoid rocks.

The soil developed on Qp5 and Qpf5 (P-7, P-13; Plate I) is distinguished by a moderately developed argillic and calcic horizon (Fig. 23). The soil is characterized by a 39- to 59-cm thick, dark-to light-brown (7.5YR) argillic (Bt and Btk) horizon with silty clay loam to clay loam texture, strong angular-blocky structure, stage II carbonate morphology and many to continuous thick clay films in pores and on ped faces. A very pale-brown (10YR), 62-to 77-cm thick calcic (Bk) horizon underlies the argillic horizon. This horizon exhibits silty clay loam to clay loam texture, weak angular-blocky structure, stage III- carbonate morphology and very few to few thin clay films in pores and on ped faces. Soil-profile development is similar to Qf7; however deposits of geomorphic surface Q5 are inset by Qf7.

Equivalent units mapped south of highway NM 165 may include Qp4-5. Map patterns suggest that geomorphic surface Q5 may be buried by alluvium of Edith Boulevard (Qoa1), indicating that it may pre-date deposition of Qoa1. Soil development on Q5, however, suggests that this unit is similar to in age to geomorphic surface Q6, a unit that overlies Qoa1.

Pediments and pediment alluvium (Qp6, Qp8)

Mountain-front pediments associated with Juan Tabo Canyon and the Bear-Pino re-entrant contains locally discontinuous gravelly alluvium composed of granitoid rocks. Unit Qp6 is discontinuously overlain by a pebble to boulder granitoid conglomerate that merges basinward with the alluvium of Qf6. A bedrock-floored surface related to Qp6 is preserved on a south-sloping hanging valley developed along the southern margin of the Juan Tabo drainage divide (Plate II and III). Qp8 forms a stripped bedrock surface of erosion within the Juan Tabo drainage basin and is recognized by gently sloping bedrock surfaces about 6 to 12 m above modern streams.

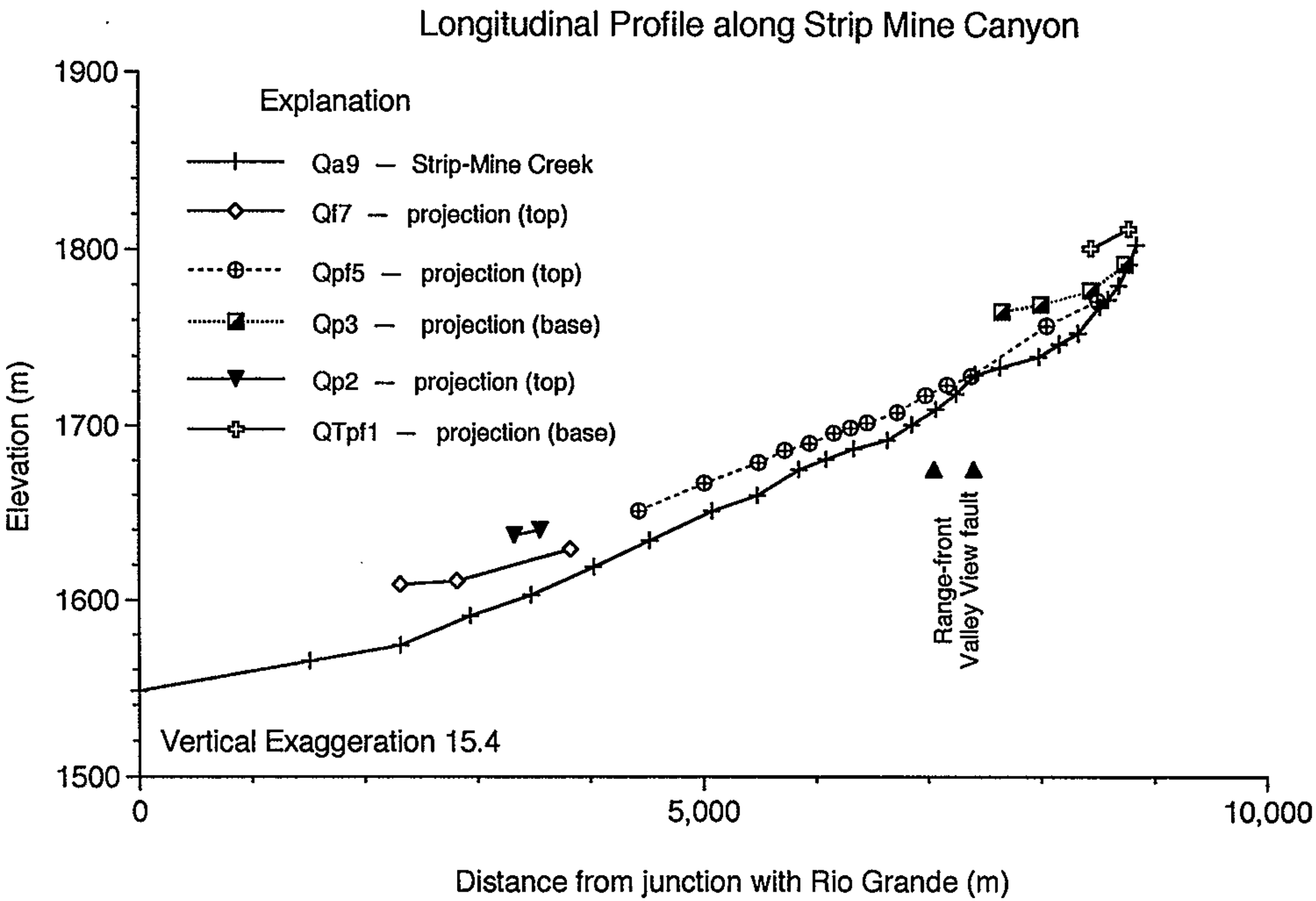
Undifferentiated pediments and alluvium (Qpfy and Qpo)

Pediments of Qpfy form locally dissected remnants of gravelly fan- and pediment-alluvium along the base of Rincon Ridge. Qpfy locally is preserved on the tops of faceted spurs associated with the Rincon fault. Qpfy is truncated by the Rincon fault and is inset by alluvium of Rincon Ridge (Qf7-8.r) and Qf6-7, indicating it is older than geomorphic surfaces Q6 or Q7. The overlying alluvium consists of metamorphic clasts derived from Rincon Ridge. Pediments of Qpo refer to bedrock benches that are common south of Juan Tabo Canyon. Qpo is higher than QT1; however, some of these benches may be related to intra-range faults or to differential erosion along lithologic variations (e.g., dikes) within the range (Kelley and Northrop, 1975, geologic map).

Constructional landforms and deposits

Fan and stream-terrace alluvium consist of variable amounts of gravel, sand and silt deposited by perennial, intermittent and ephemeral streams. Stream deposits are mapped as deposits associated with floodplain, strath, fill-cut or fill-terraces derived from the Sandia Mountains. Deposits are composed of a complex mixture of poorly sorted, poorly stratified, clast and matrix supported, debris- and hyperconcentrated-flow dominated alluvium. Clasts generally are subangular and angular, derived primarily

Figure 22. Longitudinal profile of geomorphic surfaces along Strip Mine Canyon illustrates inset relations among geomorphic surfaces, which are projected into the profile along the thalweg of the modern stream (Qa9). The surfaces (top) of alluvial deposits are projected into the profile except for units Qp3 and QTpf1, which have degraded tops. The base of pediment alluvium is used in projections of unit Qp3 and QTpf1.


Longitudinal Profile along Strip Mine Canyon
Explanation
Qa9 — Strip-Mine Creek
Qf7 — projection (top)
Qpf5 — projection (top)
Qp3 — projection (base)
Qp2 — projection (top)
QTpf1 — projection (base)
Elevation (m)
1900
1800
1700
1600
1500
Range-front
Valley View fault
Vertical Exaggeration 15.4
0
5,000
10,000
Distance from junction with Rio Grande (m)

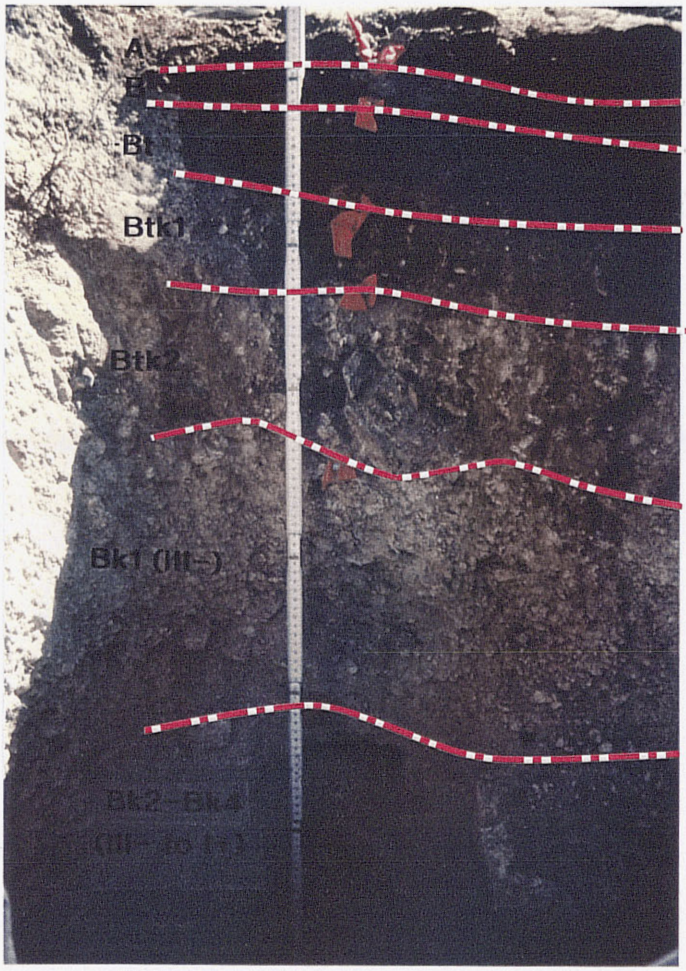


Figure 23. Soil profile of Qpf5 described in 1.2-m deep excavation (P-7; Plate I). Dashed lines mark major soil-horizon boundaries. The soil exhibits stage III- carbonate morphology.

from granitoid, weathered granitoid (grus), metamorphic (micaceous quartzite), and limestone. Geomorphic surfaces and associated alluvium are differentiated by their relation to stream alluvium, alluvial fans and erosional surfaces, their relation to modern (local) stream level and surface preservation, and differences in soil-profile development (Fig. 23). Thin "dash-dot" lines (Plates I and II) depict the approximate boundaries of selected geomorphic surfaces used to delineate the Quaternary stratigraphy.

Fan alluvium (Qf4)

Geomorphic surface Q4 consists of fan alluvium associated with the piedmont developed along the western mountain-front south of Strip Mine Canyon (Plate I). Unit Qf4 (P-35; Plate I) is distinguished by a strongly developed calcic soil (Fig. 25). The soil is characterized by a buried, 85-cm thick, very pale-brown (10YR) petrocalcic (Bkm) horizon with sandy clay loam texture, weak to moderate angular-blocky structure, stage IV carbonate morphology and few thin colloidal clay films on clasts. The surface is characterized by dissectional ridge-and-ravine topography and generally darker and redder surface tones and colors.

The surface is locally buried by younger deposits and highly modified by local overlap and incision of deposits associated with geomorphic surfaces Q7 and Q8. Unit Qa9 is inset into low-order drainages developed into the fan surface. The complex association of geomorphic surface Q4 with units Qf7 and Qa8 are noted on the geologic map by the symbol "Qf7-8/Qf4" (Plate I). Outcrop patterns (Plate I) suggest that geomorphic surface Q4 is cut by a now buried escarpment formed during deposition of the alluvium of Edith Boulevard.

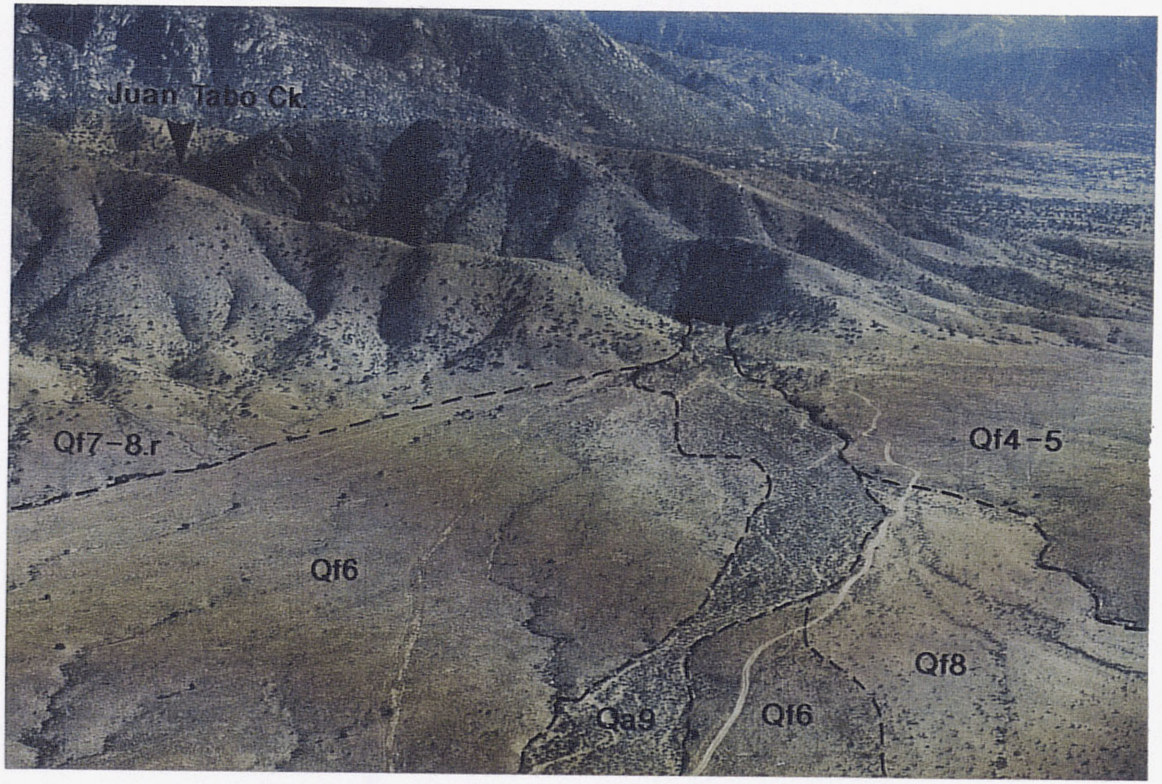


Figure 24. View to southeast of Rincon Ridge where Juan Tabo Creek enters the piedmont. Fans originating from Juan Tabo Creek and smaller range-front drainages are differentiated on the basis of inset relations, surface characteristics (modification) and soil-profile development. Units are identified on this photograph by relative variations in drainage density and surface color. Younger alluvium has lighter tone and the surface is not dissected. Older alluvium typically has reddish color and is incised by several low-order drainages developed on the piedmont. Low fault-scarps and faceted spur-ridges mark the trace of the Rincon fault (RiF) at the north (left). Photograph provided courtesy of Mr. Keith Kelson.

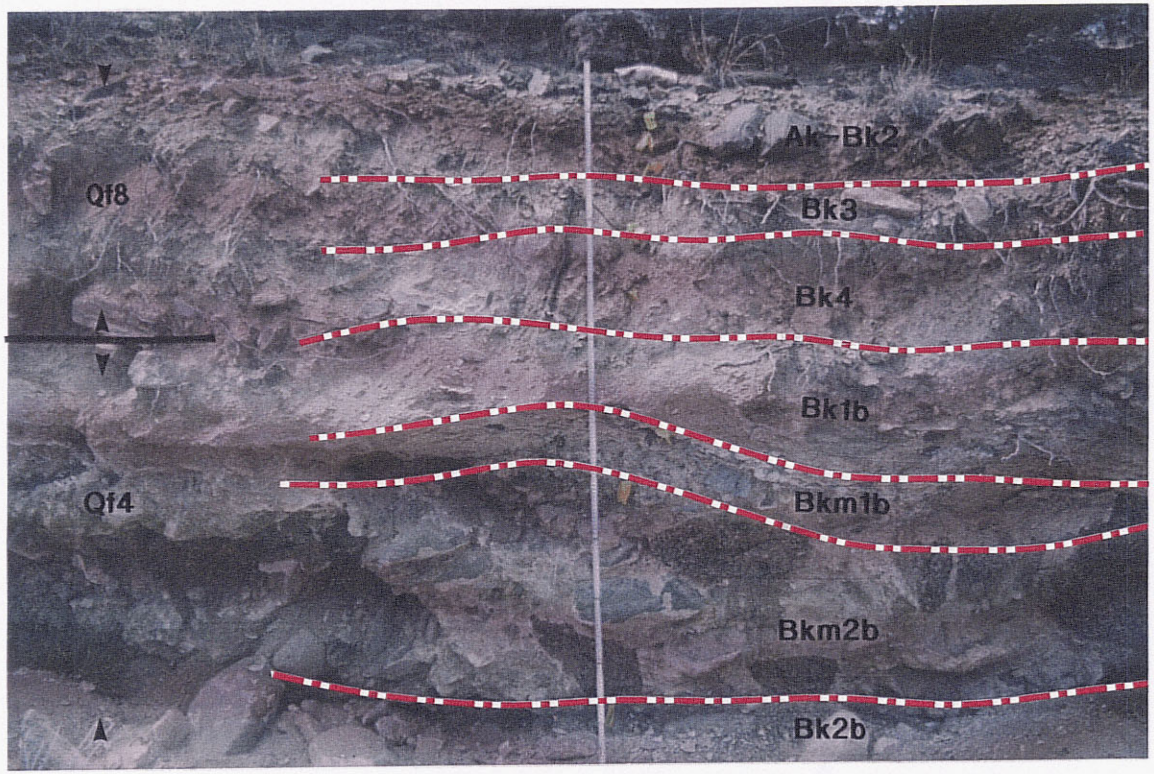


Figure 25. Soil profile of Qf4 described in a 2-m deep stream-cut exhibiting stage IV carbonate morphology (P-35; Plate I). Dashed lines mark major soil-horizon boundaries. Qf8-9 overlies a strongly developed petrocalcic horizon developed on Qf4.

Fan alluvium (Qf6)

Fan alluvium associated with geomorphic surface Q6 is recognized south of Sandia Wash and forms the most laterally extensive deposit cut into Santa Fe Group within the study area. Qf6 consists of poorly to moderately consolidated sand and gravel dominated by granitoid and metamorphic clasts (P-1, P-15, P-16, P-23; Appendix B; Plates I and II). Clasts are composed of subangular to subrounded granitoid and minor subrounded limestone rocks.

The surface is moderately dissected, inset below Qf4-5 and exhibits subdued constructional bar-and-swale topography preserved on interfluves; cobble and boulder bars are common. Qf6 is inset below the Llano de Manzano (Lambert, 1968, geologic map), unconformably overlies the alluvium of Edith Boulevard and is overlain by the alluvium of Menaul Boulevard. Qf6 is at least 15 m thick; however, deposits of Qf6 and Qf7 may have a combined thickness of 30 to 45 m above the Edith alluvium. The surface of Qf6 ranges from a few meters to about 17 m above local base level (Figs. 26 and 27). Soil development is variable across the study area and is attributed to the occurrence of inset geomorphic surfaces that are too small to differentiate at the scale of mapping. Overall, soil development on unit Qf6 is distinguished by a moderately developed argillic and calcic soil. Three soil-profiles that illustrate soil variability are discussed here.

Along a retaining-wall excavation north of the intersection of Tramway Boulevard and San Bernardino Avenue (Fig. 28; P-1; Plate II), the soil is characterized by a 19-cm thick, brown (7.5YR) argillic (Bt and Btk) horizon with silty clay texture, moderate angular-blocky structure, slight carbonate accumulation, and common moderately thick-to thick clay films on bridges and ped faces. Beneath this horizon is a 49-cm thick, buried, pale-brown, yellowish-brown and light gray (10YR to 2.5Y) petrocalcic (Bkm) horizon with loamy sand to sand texture, moderate angular-blocky structure, stage III- carbonate morphology and few thin colloidal stains and clay films on ped faces. Carbonate forms moderately thick rinds around clasts. This suggests that development is enhanced where deposit permeability and porosity decrease along the clast surface. The deposit contains approximately 35-to 60-percent clasts composed of pitted and weathered granitoid rocks.

At a stream-cut along Juan Tabo Creek (Fig. 28; P-15; Plate II), the soil consists of a 36-cm thick, light-to strong-brown (7.5YR) argillic (Bt and Btk) horizon with silty clay to clay texture, strong angular-blocky and prismatic structure, stage II carbonate morphology, and common to many moderately thick clay films on bridges, pores and ped faces. Beneath this horizon is a 40-cm thick, very pale-brown (10YR) petrocalcic (Bkm) horizon with silty clay texture, weak angular-blocky and platy structure, and stage III- carbonate morphology.

On a road-cut along Spain Avenue (Fig. 28; P-23; Plate II), the soil is characterized by a 42-cm thick, brown argillic (7.5YR) horizon with silty clay loam and clay loam texture, moderate to strong angular-blocky and prismatic structure, stage II+ carbonate morphology, and few to common moderately thick colloids and clay films on bridges. Underneath the argillic horizon is a 97-cm thick, very pale-to pale-brown (10YR) petrocalcic (Bkm) horizon with loamy sand and sand texture, weak subangular-to angular-blocky structure and stage III carbonate morphology. This soil profile is less developed and may be from a younger fan inset below the better developed soils of P-1 and P-15. Detailed mapping by students at the University of New Mexico conducted in the Elena Gallegos Grant (near Albert Simms Park) refined piedmont stratigraphy (F.J. Pazzaglia, 1995, personal communication); however, these units are generally too small to adequately demonstrate at the scale of mapping used in this study.

Overall, geomorphic and pedologic features associated with Q6 are characterized by a 29- to 44-cm thick, brown, Bt and Btk horizon exhibiting angular-blocky and prismatic structure, few to many thick clay films, stage II+ carbonate morphology overlying 35-to 97-cm thick, pale-brown petrocalcic (Bkm) horizon exhibiting stage III to III- morphology. The surface exhibits moderate surface dissection. Soils are typically preserved on stable interfluves. Soil profile P-28 best illustrates soil development for geomorphic surface Q6. A soil described along Juan Tabo Creek (P-16; Plate II) exhibits multiple layers of laminar, Stage IV+ platy carbonate, probably formed by non-pedogenic, gully bed cementation (Lattman, 1973) as Juan Tabo Creek incised into Qf6.

Fan and stream alluvium (Qf7, Qf7a, Qf7b, Qt7-8)

Alluvium associated with geomorphic surface Q7 forms broad fans and terraces common on the piedmont north of Rincon Ridge (P-3, P-8, P-22, P-26, P-27 and P-28; Appendix B; Plates I, II and III). Deposits contain sand and gravel dominated by granitoid, metamorphic and minor limestone clasts. Geomorphic surface Q7 is inset

Figure 26. Longitudinal profile of geomorphic surfaces along a portion of Juan Tabo Creek illustrates inset relations among geomorphic surfaces, which are projected into the profile along the thalweg of the modern stream (Qa9 and Qa8). The surface (top) of alluvial deposits and erosional surfaces are projected into the profile. This profile intersects the longitudinal profile drawn along Sandia Wash (see Fig. 29).

Longitudinal Profile along a Portion of Juan Tabo Creek

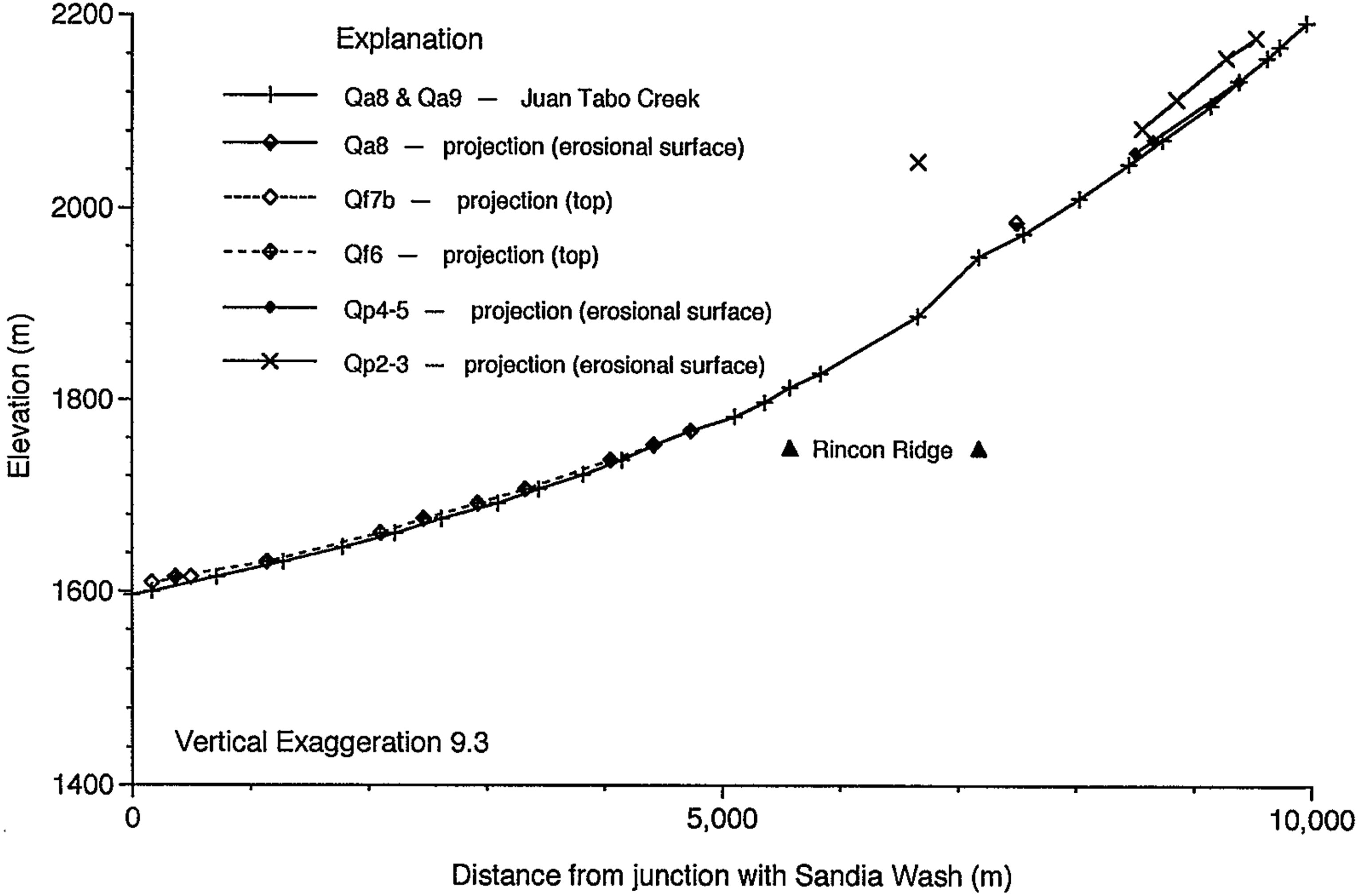
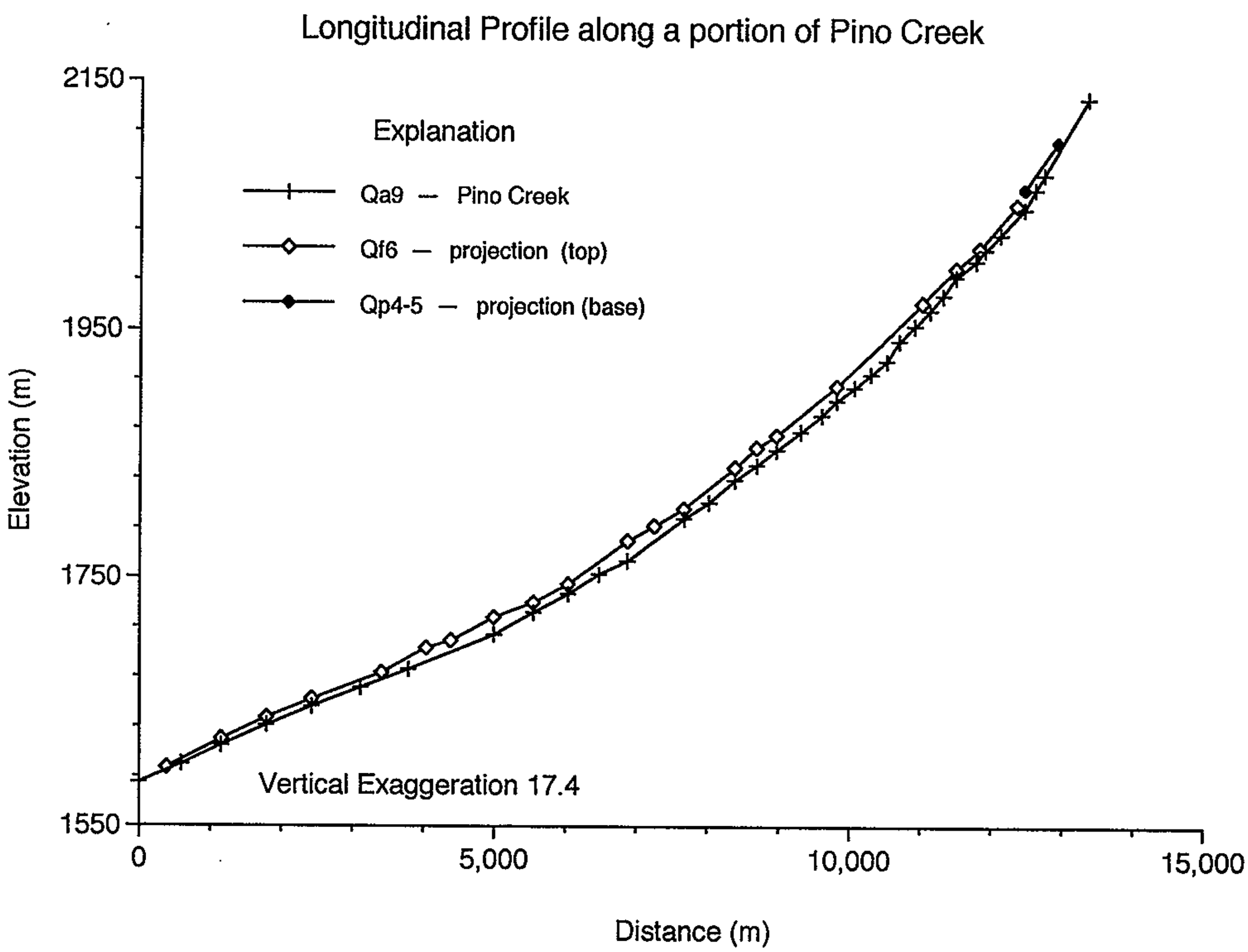


Figure 27. Longitudinal profile of geomorphic surfaces along a portion of Pino Creek illustrates inset relations among geomorphic surfaces, which are projected into the thalweg of the modern stream (Qa9). The surface (top) of alluvial deposits and pediment surface (base) are projected into the profile.



Longitudinal Profile along a portion of Pino Creek
Explanation
Qa9 — Pino Creek
Qf6 — projection (top)
Qp4-5 — projection (base)
2150
1950
1750
1550
Elevation (m)
Vertical Exaggeration 17.4
0
5,000
10,000
15,000
Distance (m)

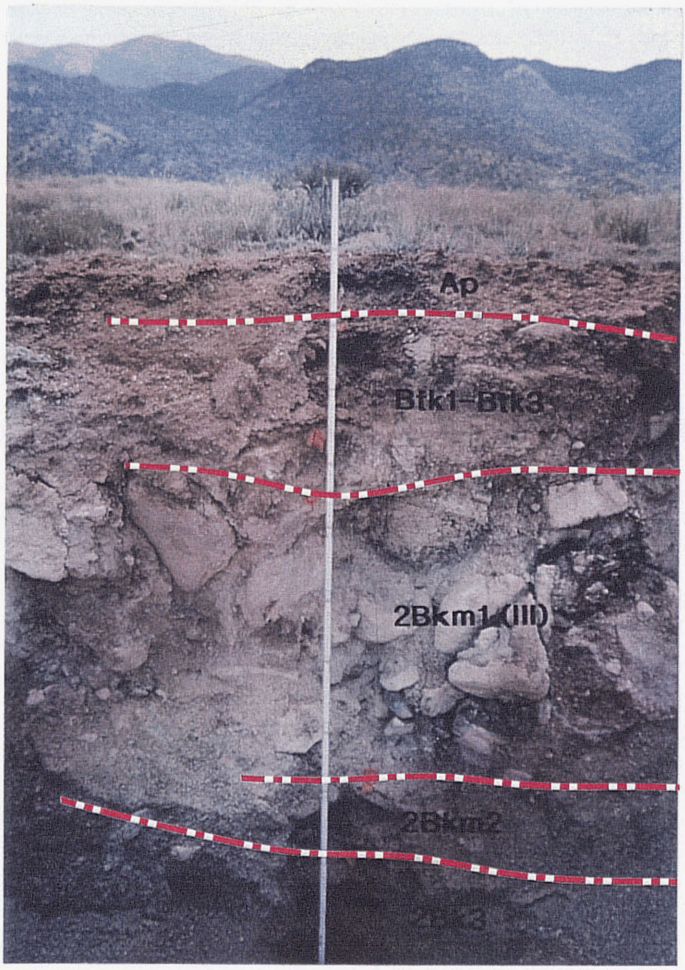
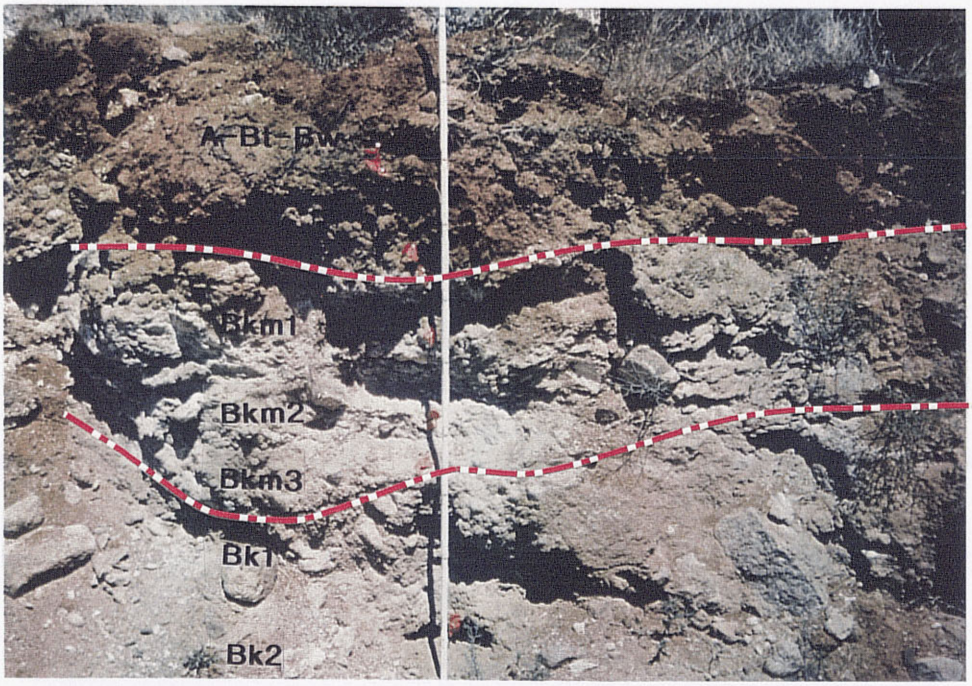
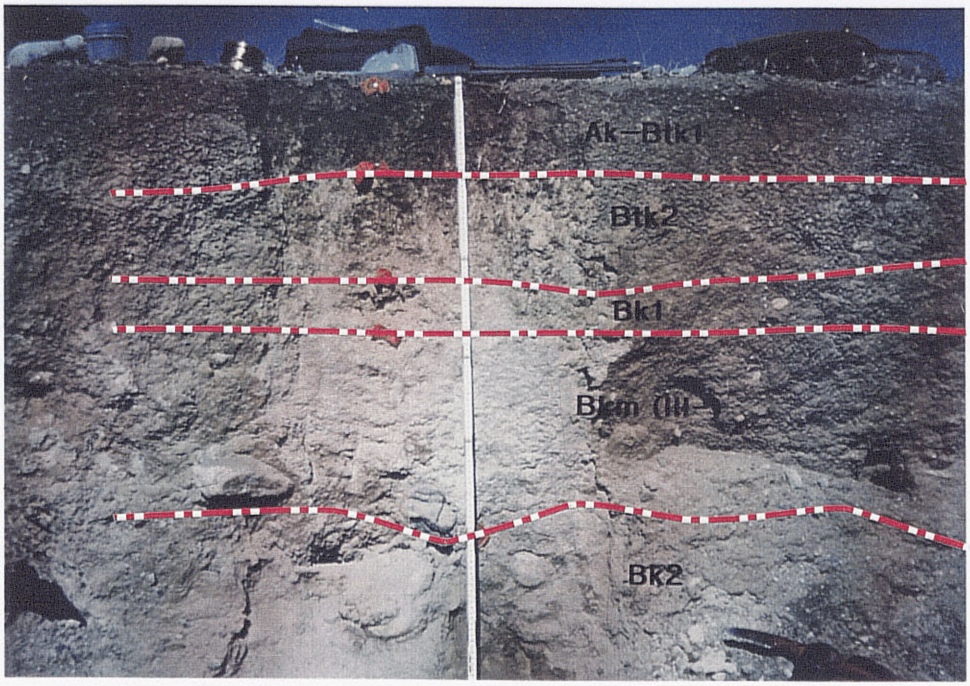


Figure 28. Soil profiles described on Qf6. Dashed lines mark major soil-horizon boundaries. Soil-profile of Qf6 (P-23; Plate II), described in 1.9-m deep excavation north of the intersection of Spain Avenue and Tramway Boulevard, exhibits stage II+ carbonate morphology. Soil probably formed on alluvium inset below well-developed soils described on P-1 and P-15 (following page). Following page (top): soil-profile described in 1.4-m deep excavation near San Bernardino Ave (P-1; Plate I). Following page (bottom): soil-profile (1.2-m deep) described along Juan Tabo Creek (P-15; Plate II). Soils possess stage III- carbonate morphology.


A-Bt-Bw
Bkm1
Bkm2
Bkm3
Bk1
Bk2


Ak-Btk1
Btk2
Bk1
Bkm (III-)
Bk2

below Q5 and forms fill-terraces within Las Huertas Creek and alluvial fans elsewhere. The surface of Q7 sits about 18 m above local base level and 18 to 28 m above the Rio Grande (Figs. 29 and 30).

Qf7 is divided into Qf7a and Qf7b on the basis of inset and soil-stratigraphic relations. Qf7 is undifferentiated where the surface has been significantly modified, most notably along the distal margins of the piedmont. The base of Qf7 disconformably overlies the alluvium of Edith Boulevard (Qoa1). Deposits of Qf7 may be as much as 36 m thick where they overlie Qoa1. A disconformity and buttress-unconformity marks the contact between Qf7 and the underlying Sierra Ladrones Formation (Fig. 30). Clasts of rounded quartzite pebbles and cobbles derived from axial-facies of the Sierra Ladrones Formation are typically recognized west of this unconformity. The surface is slightly to moderately dissected and possesses subdued to well-expressed constructional bar-and-swale topography with local boulder bars.

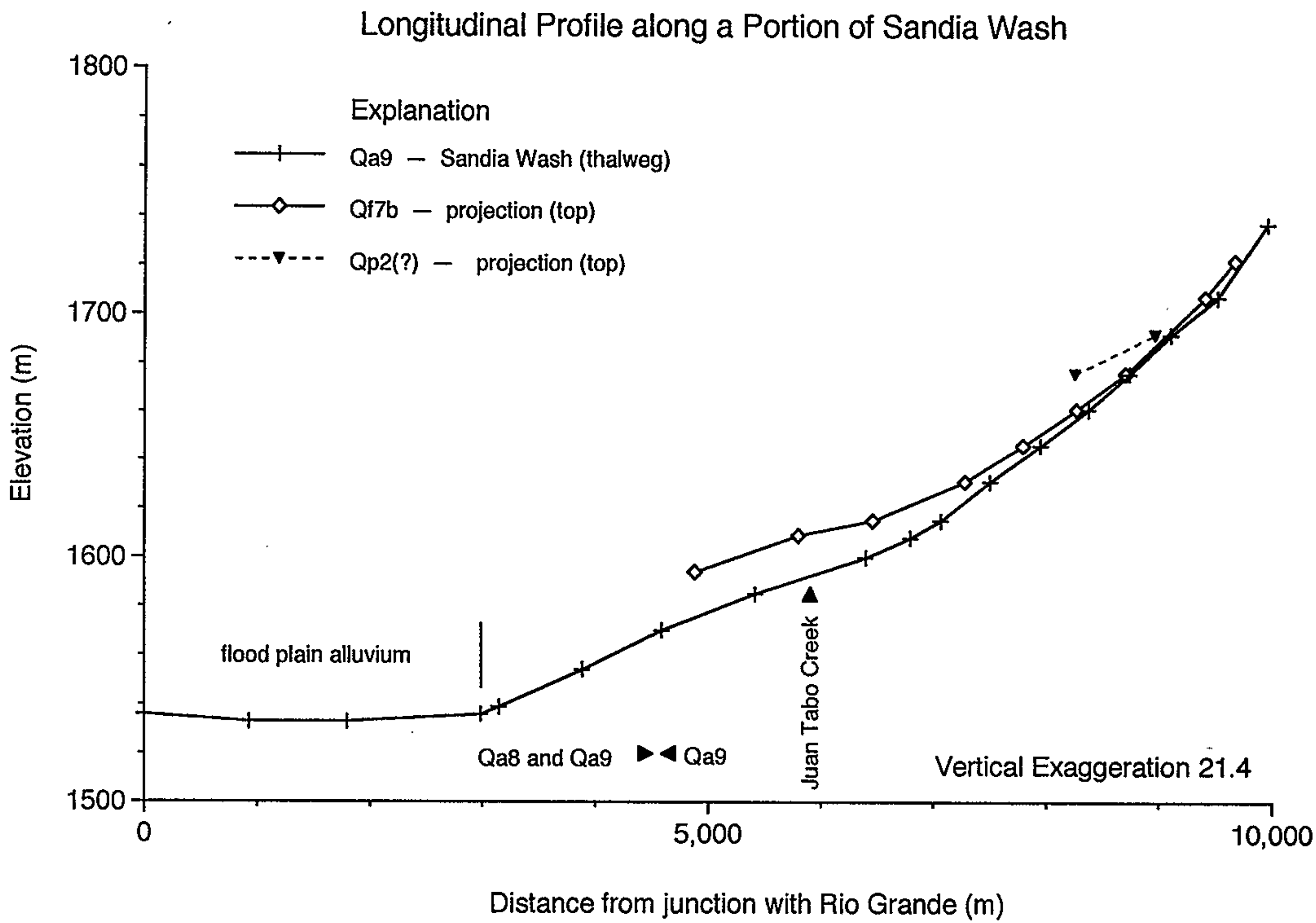
Qf7a is distinguished by soils with moderately developed argillic and calcic horizons. Soil described in P-8 (Fig. 31; Plate I) is characterized by a 29-cm thick, strong-brown (7.5YR to 10YR) argillic horizon with silty clay to clay texture, moderate angular-blocky structure, stage I carbonate morphology and common thin clay films on bridges and in pores. Beneath this horizon is a 44-cm thick, light yellowish-brown (10YR) calcic horizon with sandy clay texture, weak angular-blocky structure and stage II+ carbonate morphology. Qf7a forms a fan that becomes constricted between a gap cut into Sierra Ladrones Formation near highway NM 165 (Plate I).

Qf7b, inset below Qf7a, is distinguished by poorly developed calcic soils (Fig. 31). Soils developed on Qf7b (P-3, P-22; Plate I) are characterized by an 11- to 35-cm thick brown (7.5YR to 10YR) argillic (Bt and Btk) horizon with silty clay loam to clay texture, moderate angular-blocky structure, common thin-to moderately thick clay films and stage I to II carbonate morphology. Underneath is a 70- to 121-cm thick very pale-brown to strong yellowish-brown (10YR) calcic and petrocalcic (Bk and Bkm) horizon with loamy sand and sandy and silty clay texture, weak angular-blocky structure and stage II+ carbonate morphology.

Qt7-8 is inset below Qt5 and forms the lowest terrace within Las Huertas Creek (P-34; Plate I). Deposits, consisting of interbedded pebbly to cobbly sand and gravel, are about 5- to 6-m thick and form an irregular basal contact with the Sierra Ladrones Formation. The surface is about 3 to 24 m above local base level; however, this soil is less developed than those formed on Qf7.

Overall, deposits associated with geomorphic surface Q7 are greater than 30 m thick. The top of the deposits is about 21 to 34 m above the Rio Grande floodplain along the inner valley escarpment. Geomorphic surface Q7 exhibits slight to moderate dissection of the surface and overlies alluvium of Edith and Menaul Boulevards. Soil-profile development is characterized by moderate to strong angular blocky and weak platy structure, stage II+ carbonate morphology and common, moderately thick clay films. Unit Qf7b forms elongate, well-preserved surfaces along proximal and medial parts of the piedmont. Unit Qf7b is inset below Qf6 and Qf7a and is inset by Q8 and Q9. Soil development on Qf7a suggests similarity to Qpf5 and Qp5, but Qf7a is inset below unit Qpf5.

Figure 29. Longitudinal profile of geomorphic surfaces along a portion of Sandia Wash illustrates inset relations among geomorphic surfaces, which are projected into the thalweg of the modern stream (Qa9) Surfaces (top) of alluvial units are projected into the profile. A highly dissected remnant of Qp2(?) developed on Sierra Ladrones Formation.



Longitudinal Profile along a Portion of Sandia Wash
Explanation
Qa9 — Sandia Wash (thalweg)
Qf7b — projection (top)
Qp2(?) — projection (top)
1800
1700
1600
1500
Elevation (m)
flood plain alluvium
Qa8 and Qa9
Qa9
Juan Tabo Creek
Vertical Exaggeration 21.4
0
5,000
10,000
Distance from junction with Rio Grande (m)

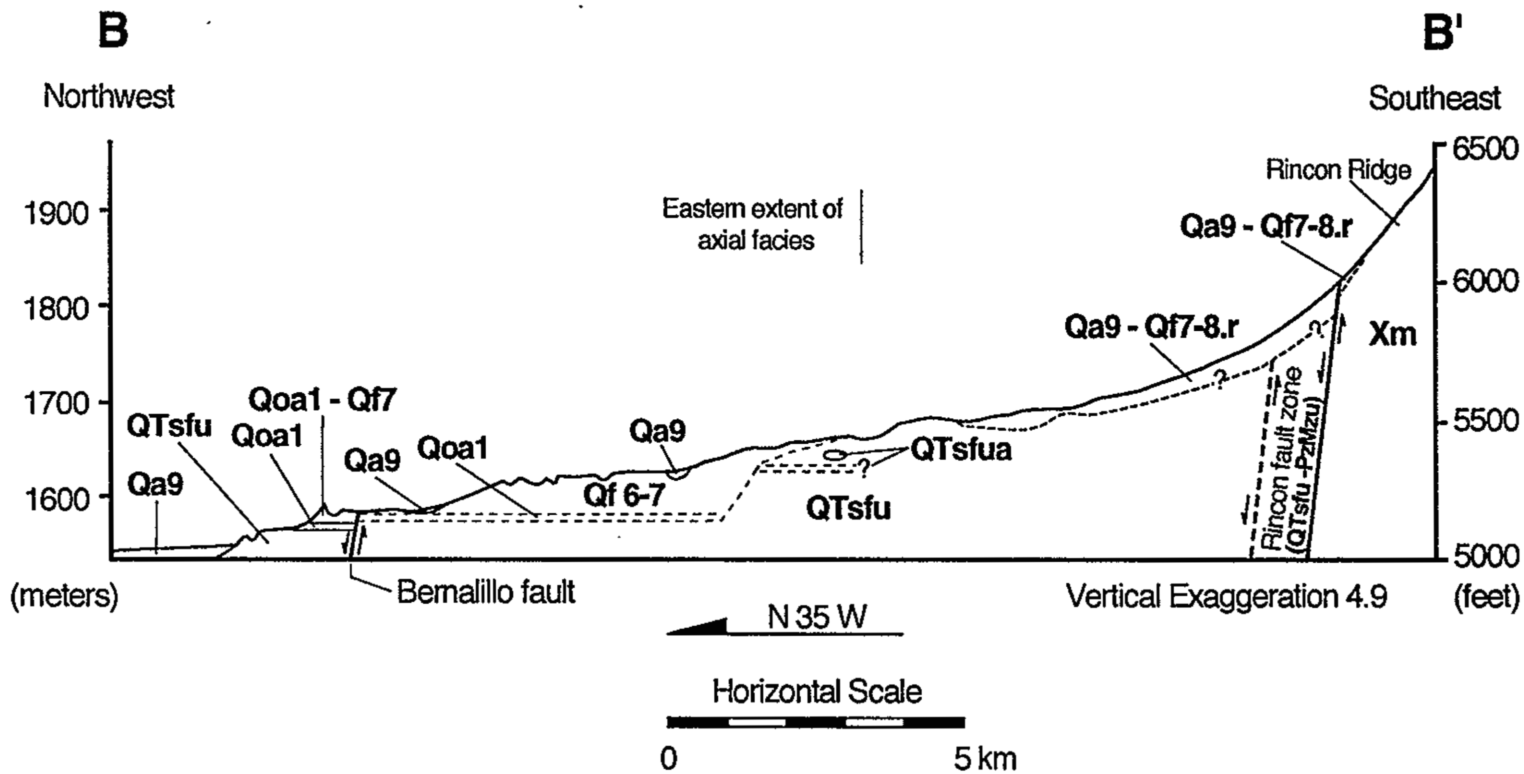


Figure 30. Cross section along line B-B' of geologic map (Plate I). Piedmont alluvium (Qf6-7, Qf7-8.r, Qa9) and alluvium of Edith Boulevard (Qoa1) unconformably overlie axial- (QTsfua) and piedmont- (QTsfup) facies of the Sierra Ladrones Formation (QTsfu). Fan alluvium of Qf9 cuts the Rincon fault. Vertical exaggeration (4.9) increases apparent fault-dips, which dip steeply to the west. The Rincon fault forms a narrow zone that juxtaposes crystalline (Xm) rocks on the footwall, against Mesozoic (Mzu) and upper Santa Fe Group strata to the west. Alluvium of Qoa1, Qf6 and Qf7 forms a buttress unconformity against the Sierra Ladrones Formation. This unconformity marks the easternmost extent of Qoa1. The Bernalillo fault displaces Qoa1 approximately 7 m down to the west. A ridge of Sierra Ladrones Formation forms a deeply dissected surface at similar elevation to Qpf2 recognized north of line A-A' (Plate I).

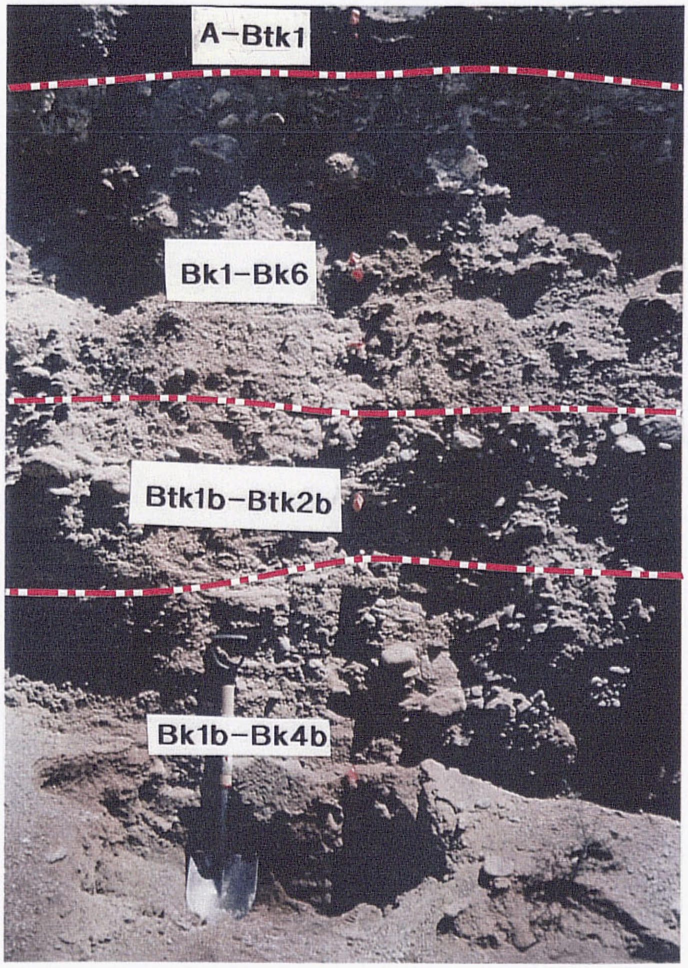
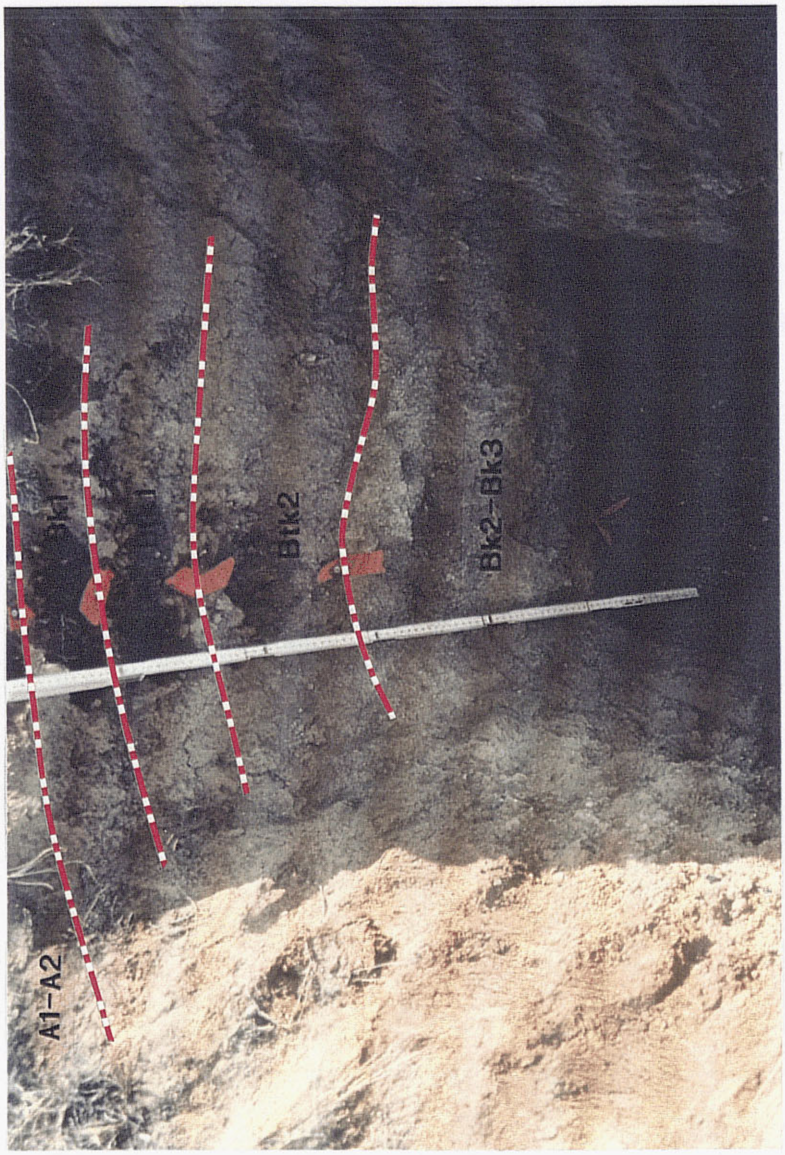


Figure 31. Soil profiles of Qf7a and Qf7b. Dashed line marks major soil-horizon boundaries. Unit Qf7b is described along a 3.4-m deep steep-walled stream cut in unnamed arroyo (P-3; Plate I). Soils exhibit stage II+ carbonate morphology. Unit Qf7a (following page) is described in a 1-m deep excavation east of U.S. Forest Service access road FS 445 (P-8; Plate I).


A1-A2
Btk2
Bk2-Bk3

Fan alluvium of Rincon Ridge (Qf7-8.r)

Fan alluvium of Rincon Ridge (Qf7-8.r) is restricted to coarse-grained, proximal fan deposits derived from the western flank of Rincon Ridge, between Juan Tabo and del Agua Canyons. Unit assignment is based on ambiguity in correlation to other geomorphic surfaces. Deposits consist entirely of clasts of micaceous quartzite, aplite and undifferentiated rocks derived from the Rincon Ridge metamorphic complex. Qf7-8.r is inset below Qf6 and may occupy an intermediate position to Qf7 and Qf8. This unit is locally overlain by bouldery fan alluvium of Qf9 originating from Rincon Ridge. The surface possesses moderately developed constructional bar-and-swale topography with common cobble and boulder bars.

Soils formed on Qf7-8.r (P-17, P-18; Plate I) are characterized by a 36- to 81-cm thick, brown to yellowish-brown (7.5YR to 10YR) argillic (Bt and Btk) horizon with silty clay loam to silty clay texture, moderate angular-blocky structure and few to common, thin clay films bridging grains. Underlying this is a weakly developed 65- to 95-cm thick, brown to yellowish-brown (10YR) calcic horizon with silty clay to clay texture, moderate to strong angular-blocky structure, few thin to moderately thick clay films bridging grains and on ped faces, and stage I to II carbonate morphology (Fig. 32). Pedogenic carbonate was recognized 44 to 85 cm below the ground surface.

Fan and stream alluvium (Qf8 and Qa8)

Alluvium associated with geomorphic surface Q8 is common along the distal and medial portions of the piedmont and forms elongate fans and terraces inset below

Qf6 and Qf7. This unit is differentiated into fan alluvium (Qf8) and undifferentiated valley-floor, fan and terrace alluvium (Qa8) based on surface form and location within major drainages. Qf8 grades towards the inner valley escarpment of the Rio Grande, where it forms the lowest inset deposit that is cut by deposits associated with geomorphic surface Q9. Qf8 is common south of del Agua Canyon and forms undifferentiated terraces of Qt7-8 to the north. Q8 is distinguished by a weakly developed calcic soil that exhibits 10YR hues, stage II carbonate morphology and the development of thin clay-films.

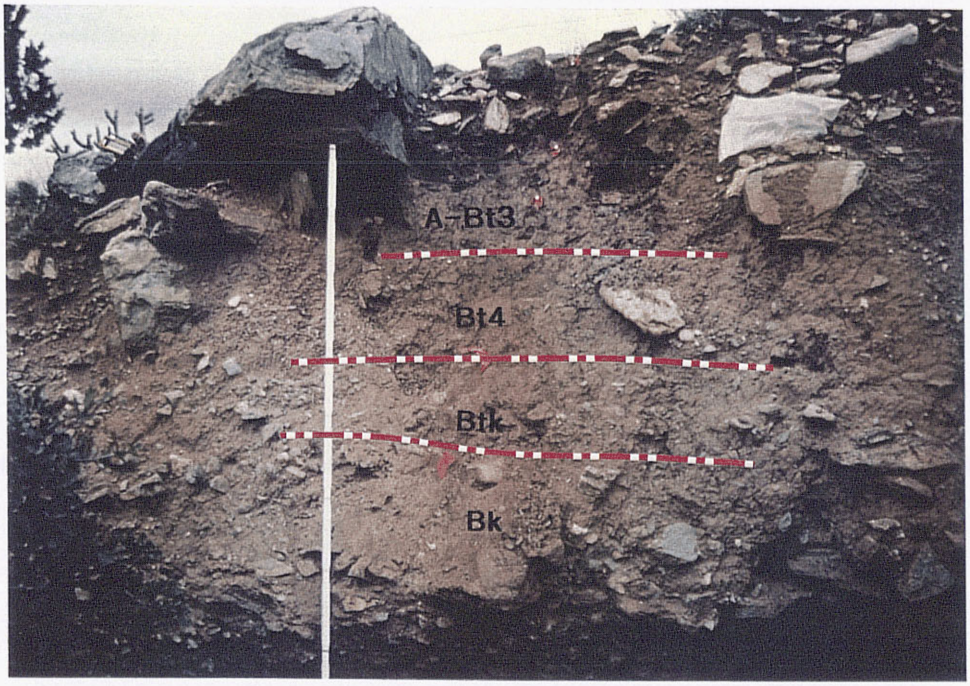
The surface is slightly dissected and underlain by at least 21 m of poorly consolidated, brown to dark yellowish-brown and very pale brown and yellowish-brown sandy loam to silty clay loam. Q8 is approximately 21- to 24-m above the Rio Grande along the inner valley escarpment and about 3 m above local base level in piedmont drainages. Qf8 generally overlies alluvium of Edith Boulevard (Qoa1) south of the Sandoval-Bernalillo County line, but becomes inset below Qoa1 south of Sandia Wash (Plates I and II). *Opuntia* (Cholla) and grasses are common and give the surface light tones on aerial photographs. Scattered, locally imbricated boulder bars (Fig. 33) of granitoid and minor limestone clasts locally crop out about 3 km west of the mountain front (Plate II). These boulders form linear bars mark an otherwise smooth sandy surface.

Soils are described at three locations (P-6, P-9, P-19; Appendix B; Plate I and II). Unit Qa8 is described along a stream-cut exposure west of Rainbow Valley Road (P-6; Plate I). The epipedon is a 7-cm thick dark grayish-brown loam with disseminated pedogenic carbonate. The subsoil is characterized by a brown (10YR), 53-cm thick calcic horizon with sandy loam and loamy sand texture, weak subangular-blocky structure and stage I carbonate morphology. This is underlain by a 80-cm thick, light brown (7.5YR) calcic horizon with loamy sand and sandy texture, single grain structure, few thin colloids and clay films on bridges, and stage I+ carbonate morphology. This is underlain by a 100-cm thick, light-brown (7.5YR) sand with weak subangular-blocky structure, very few, thin colloidal stains and stage I carbonate morphology.

Qf8 (P-9, Plate I) is characterized by a 91-cm thick, brown (10YR) calcic (Bk and Btk) horizon with sandy clay loam to sand loam texture, moderate angular-blocky structure, few thin colloids and clay films on bridges, and stage I carbonate morphology (Fig. 33). Qf8, described along a 3.6-m deep stream-cut exposure (P-19, Plate II), is characterized by a 298-cm thick, very pale-brown to brown (10YR) calcic (Bk) horizon with sand loam to silty clay loam texture, weak angular-blocky structure and stage II carbonate morphology.

Soils on Q8 are distinguished by weakly developed calcic soils with 7.5- to 10YR hues, weak subangular-blocky structure, few thin clay colloidal stains and clay films on grains, and stage I to II carbonate morphology. The surface is slightly dissected and possesses well-developed constructional bar-and-swale topography, locally dominated by boulders.

Figure 32. Bouldery fan (Qf9) and alluvium of Rincon Ridge (Qf7-8.r). Top: soil profile of Qf7-8.r (Rincon Ridge range-front alluvium) described along a 1.8-m deep stream cut (P-17; Plate II). Dashed lines mark major soil-horizon boundaries. Soil exhibits pedogenic carbonate 85-cm below the ground surface and exhibits common thin clay films. Bottom: imbricated metamorphic boulders associated with Qf9 overlie deposits of unit Qf7-8.r along Rincon Ridge; field book for scale.


A-Bt3
Bt4
Btk
Bk

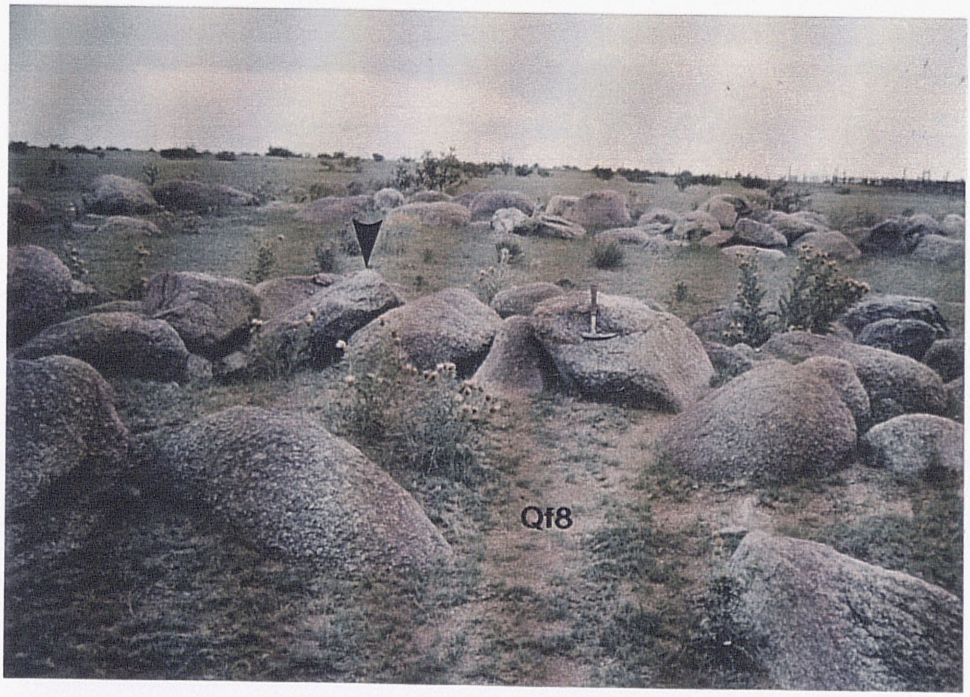
Fan and stream alluvium (Qf9, Qa9)

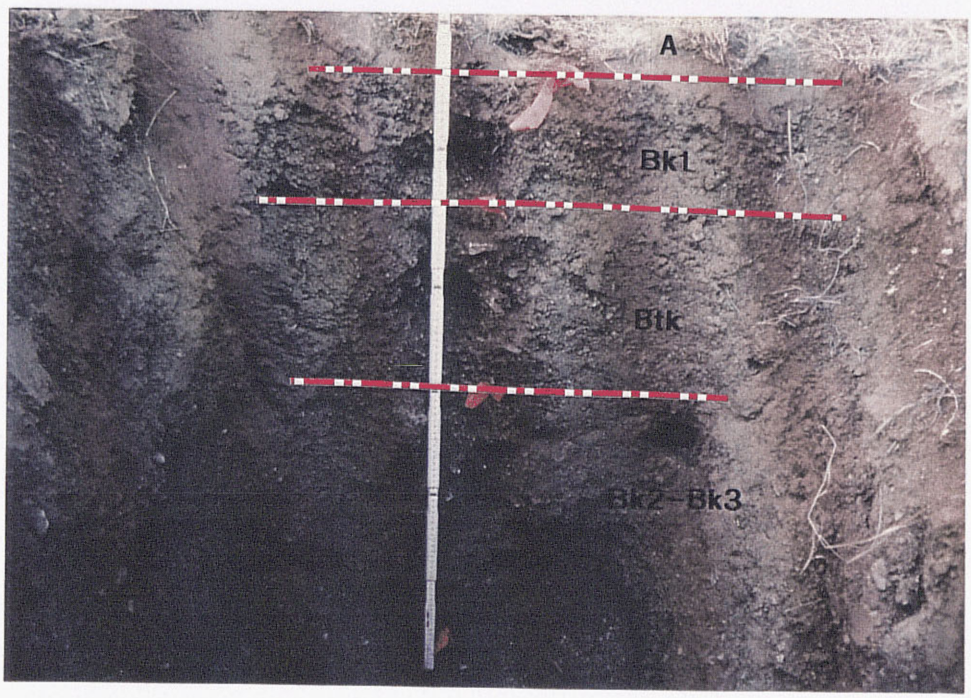
Geomorphic surface Q9 (P-2, P-14; Appendix B; Plates I and II) consists of fan, stream-terrace and undifferentiated alluvium characterized by poorly consolidated, light grayish-brown, brown and yellowish-brown sand and sandy clay loam and gravel comprising tributary-fan alluvium from ephemeral streams grading to the Rio Grande. Clasts are dominated by granitoid, micaceous quartzite and minor limestone rocks.

Geomorphic surface Q9 includes modern alluvium on floodplains, stream channels and low terraces along arroyo floors. Fans of geomorphic surface Q9 typically are inset below Q8 except along the range front where they locally bury older deposits. Qa9 is described in an excavation near a retaining dam in Bear Creek (P-2, Plate II) in the Sandia Crest 7.5-minute quadrangle and is characterized by a dark-gray to pale-brown (10YR) sand and silt loam that exhibits weak subangular-blocky structure. Traces of pedogenic carbonate are recognized 52 cm below the surface. Qa9 (Fig. 34) is described in a stream-cut exposure along the western margin of the Placitas quadrangle (P-14, Plate I). The soil is characterized by a brown to yellowish-brown (10YR) loam that exhibits weak subangular-blocky structure. Pedogenic carbonate, recognized 17 cm below the ground surface, exhibits stage I carbonate morphology.

Overall, Qa9 is characterized by a weakly developed soil, containing slight accumulations of pedogenic carbonate at depth. The soil has a weak granular to subangular-blocky structure and contains very few clay films on grains. The surface possesses well-developed constructional bar-and-swale topography and are slightly dissected.

Figure 33. Surface and soils of geomorphic surface Q8. Top: imbricated granitoid boulders on sandy alluvium of Qf8. Photograph taken approximately 3 km west of the mouth of Juan Tabo Canyon. Bottom: soil profile of Qf8 (P-9; Plate I) exhibits stage I carbonate morphology; excavation is about 94 cm in depth. Dashed lines mark major soil-horizon boundaries.


Qf8


A
Bk1
Btk
Bk2–Bk3

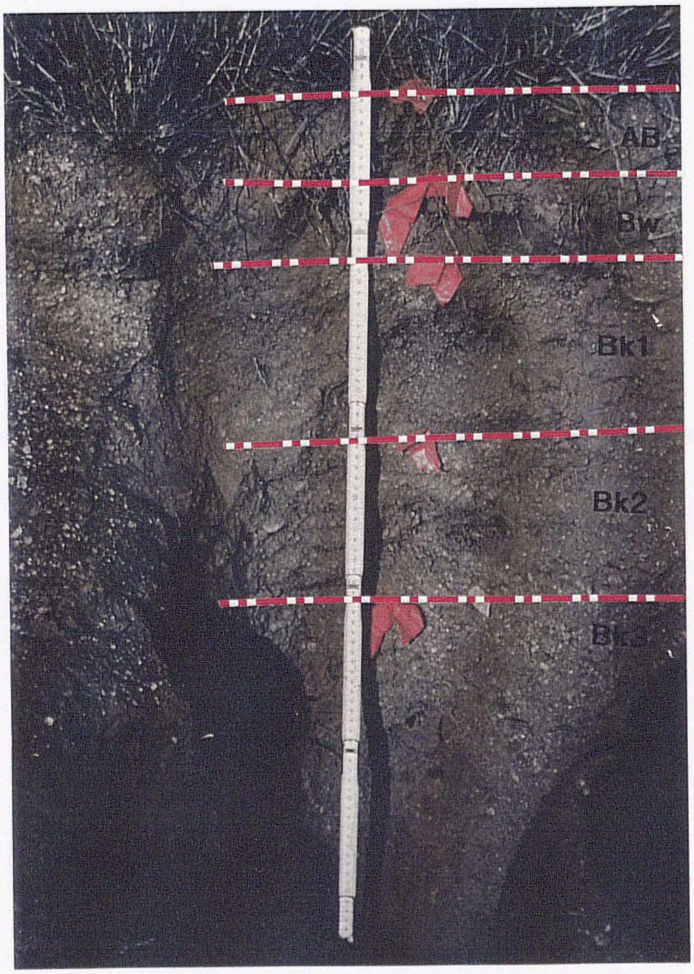


Figure 34. Soil-profile of Qa9 (P-14; Plate I) exhibiting trace to weak stage I carbonate morphology at depth. Excavation is about 1 m deep. Dashed lines mark horizon boundaries.

Fluvial deposits associated with the Rio Grande

Fluvial deposits associated with aggradational events of the ancestral Rio Grande are differentiated on the basis of lithostratigraphic and geomorphic relations. Gravel-mining operations along the distal piedmont, immediately east of the inner valley escarpment of the Rio Grande, has made mapping parts of the distal piedmont difficult. Therefore, locations of the alluvium of Edith and Menaul Boulevards, south the Sandoval-Bernalillo County line are made from aerial-photographic interpretations and are supplemented from mapping by Lambert (1968, geologic map).

Alluvium of Edith Boulevard (Qoal)

The alluvium of Edith Boulevard (Qoal) is an informal stratigraphic term for exposures of rounded, pebble- to cobble-conglomerate along Edith Boulevard in the Albuquerque area (Lambert, 1968). Qoal (Edith alluvium) locally underlies the Primero Alto terrace on the west side of the Rio Grande (Lambert, 1968) and form outcrops out along the inner valley escarpment of the Rio Grande. Edith alluvium overlies Sierra Ladrones Formation in a slight angular unconformity and is disconformably overlain by deposits of Qf6 and Qf7, alluvium of Menaul Boulevard and Qf7 (Fig. 30). Outcrops are laterally continuous along the inner valley escarpment. The basal contact with the Sierra Ladrones Formation is planar and is situated about 12- to 24-m above the Rio Grande floodplain. A poorly exposed buttress unconformity with the Sierra Ladrones Formation (Fig. 30) is recognized north of highway NM 165 (NW1/4, NE1/4, SE1/4, Section 32, T12N., R04E, NMPM, Placitas 7.5-minute quadrangle; Plate I). This buttress unconformity is buried along most of the piedmont and marks the eastern extent of the alluvium Edith Boulevard.

The Edith alluvium (S-1, S-3, S-4; P-24; Appendix B and D; Plate I) form a fining-upward sequence that is divided into a 2- to 8-m thick basal conglomerate (Qoa1a) and overlying, 4- to 10-m thick sequence of sand and sandy clay and diatomite (Qoa1b). The basal gravel consists of a pale-brown, moderately sorted, subrounded-to rounded, subprismoidal, pebble-to cobble conglomerate that grades up-section to a pale-brown to yellowish-brown, well sorted, subrounded-to subangular sand, sandy clay and local diatomite (Fig. 35). Accumulations of small gastropods are locally recognized in fine-grained deposits of the Edith alluvium.

The diatomite discontinuously crops out above the basal conglomerate in the Sandia Indian Reservation. A sample (S-3), analyzed by J. Platt Bradbury of the U.S. Geological Survey, reveals the occurrence of the following dominant taxa:

Pseudostaurosira brevistriata (dominant taxon)
Staurosira construens v. subsalina
Rhopalodia gibba
Navicula oblonga
Epithemia argus
Epithemia turgida
Epithemia adnata
Cymella mexicana
Synedra ulna
Synedra capitata
Aulacoseira crenulata
Cocconeis placentula.

These taxa are mainly benthic species indicative of fresh, slightly alkaline water that probably existed in a small pond or slough associated the ancestral Rio Grande (J.P. Bradbury, 1995, written communication).

A partly stripped soil marks an erosional unconformity between the Edith alluvium and overlying piedmont deposits of Qf6, Qf7 and the alluvium of Menaul Boulevard (P-24; Plate I). Much of the soil is eroded and displays remnant Bw horizons; however, moderately thick clay films are recognized on hills at the same stratigraphic level. The fining-upwards sequence and diatoms indicate deposition of a basal gravel (Qoa1a) followed by deposition of an overbank facies and local ponds (Qoa1b).

The basal conglomerate contains abundant clasts of purplish quartzite and minor vesicular basalt and aphanitic rocks, which indicate a distant northern source; the Sangre de Cristo or Tusas Mountains of northern New Mexico and southern Colorado. A dark-gray, densely welded tuff containing chatoyant sanidine crystals may be derived from the Valles Caldera by the Jemez River (J.B. Rogers, 1994, personal communication). The occurrence of *Bison* indicates a Rancholabrean age for the Edith alluvium; therefore deposits are no older than the middle Pleistocene, or Illinoisan glacial age (Hibbard and others, 1965, referenced in Lambert, 1968).

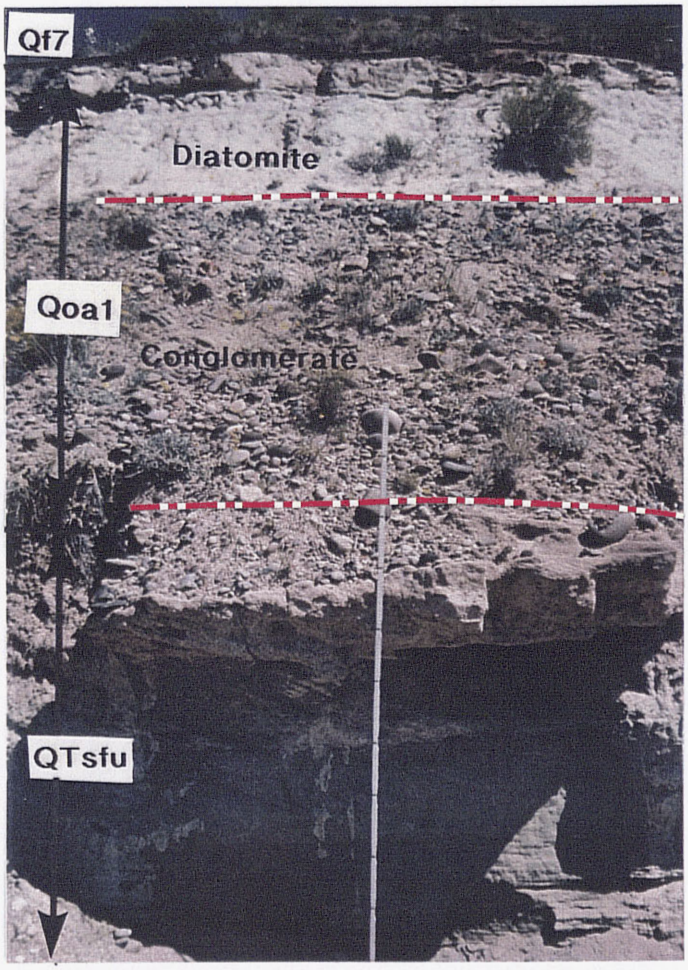


Figure 35. Alluvium of Edith Boulevard (Qoa1) overlying well cemented, cross-bedded Sierra Ladrones Formation (QTsfu) axial facies (S-3; Appendix D; Plate I); scale is about 1.9 m in length. Dashed lines mark major contacts between units described in stratigraphic section 3 (Appendix D). Qoa1 consists of quartzite cobble conglomerate (Qoa1a) overlain by overbank (floodplain) facies (Qoa1b), which locally grades upwards to a diatomite bed. Fan alluvium of Qf7 overlies Qoa1.

Alluvium of Menaul Boulevard (Qoa2)

The alluvium Menaul Boulevard (Qoa2) is an informal stratigraphic term for exposures of rounded pebble conglomerate near Menaul Boulevard (Lambert, 1968). Qoa2 (Menaul alluvium), along the northern margin of Sandia Wash (S-4; Appendix D; Plate I), consists of 2.65-m thick, yellowish-brown (10YR), poorly consolidated, medium-to very coarse-grained quartzite-rich pebbly sand derived from the ancestral Rio Grande. Clasts contain abundant rounded quartzite pebbles and minor subangular boulders and cobbles that are generally smaller than clasts of the Edith alluvium. The top of Qoa2 is unconformable, irregular and recognized by the lowest occurrence of Qf7 and Qf8 piedmont alluvium derived from the Sandia Mountains containing limestone, metamorphic and granitoid clasts. Stripped soils are described (P-20, P-25; Plate I) on hill slopes. Qoa2 sits about 26 to 36 m above the floodplain of the Rio Grande and occurs as discontinuous outcrops along the distal piedmont. Outcrop patterns suggest Qoa2 unconformably overlies geomorphic surface Q6 and occurred after deposition of unit Qf6.

Floodplain alluvium (Qafp9)

Qafp9 represents floodplain deposits associated with the modern Rio Grande. The deposit is approximately 37 m thick and consists of unconsolidated, fine-to coarse-grained sand and gravel (Hawley and Hasse, 1992).

Colluvial Deposits

Undifferentiated scree, talus and colluvium (Qsct)

Colluvial deposits (Qsct) consist of poorly sorted, gravity-generated scree, talus and colluvium formed on high slopes in the Sandia Mountains. Qsct is differentiated by surface morphology where areally extensive. Clast composition reflects local provenance.

Eolian Deposits

Undifferentiated eolian sand

Isolated discontinuous mounds of eolian sand are observed on the surface of Qf7 (S-4; Appendix D; Plate I) along the western margin of the piedmont. Deposits exhibit weakly developed soils that consist of yellowish-brown, well-sorted, fine-to medium-grained sand.

Disturbed Land

Several areas on the piedmont have been significantly modified by human activity. The base maps depict some of these areas with a dense stippled pattern (standard USGS topographic pattern for disturbed land) on the Alameda 7.5-minute quadrangle.

Summary

Stratigraphy of the Sandia piedmont, developed from cross-cutting relations (Table 2), landscape position (Table 3), lithology and soil-profile characteristics (Table 4), consists of a suite of erosional and depositional landforms and deposits inset into Plio-Quaternary strata of the Sierra Ladrones Formation (Plates I, II and III; Appendix F). Pediments are common along the range-front south of Rincon Ridge and north of del Agua Canyon; alluvial-fans are dominant elsewhere. Fluvial deposits, associated with the Rio Grande, interfinger with fans along the distal piedmont. Piedmont and axial facies of the Sierra Ladrones Formation forms the most extensive basin-fill unit in the study area. Faunal (Lucas and others, 1993) and clast-provenance (lower Bandelier Tuff) evidence indicate a late Pliocene to early Pleistocene age of deposition (Cather and others, in preparation).

Several units are inset into pre-Quaternary rocks and form a stepped sequence of erosional and constructional landforms and associated deposits that exhibit systematic variations in clast composition. Clasts measured on geomorphic surfaces QT1, Q2, Q3, Q5 and Q7, north of del Agua Canyon, document a progressive decrease in limestone abundance with lower (younger) landscape position (Fig. 36; Appendix D). QTpf1 and Qp2 are dominated by limestone. Metamorphic and granitoid clasts progressively increase in abundance from pediments Qp3 through Qp5 and Qf7 (Fig. 36). Sandstone is derived from local sources where Paleozoic-Mesozoic rock is capped by deposits of geomorphic surface Q5. This indicates a geomorphic unroofing sequence of pediments across the Placitas fault as the northern piedmont and mountain-front became deeply dissected during the late Pliocene and Quaternary.

Geomorphic surfaces generally exhibit a progressive decrease in height above local base level. Geomorphic surface QT1 occupies the highest elevation and Q9 forms modern base level. Soil-development progressively increases on higher geomorphic surfaces (Table 4; Fig. 37). Soils formed on geomorphic surfaces Q8 and Q9 are weakly developed and characterized by minor destruction of primary sedimentary fabric and little accumulated clay, calcium carbonate and reddening. Stage I to II carbonate morphology is commonly recognized on these surfaces.

Soils formed on geomorphic surfaces Q5 through Q7 display reddening of grains and destruction of primary sedimentary character as well as progressive increases in clay film development and carbonate morphology. Soils are characterized by argillic horizons with 7.5 to 10YR hues and moderately thick clay films that develop over calcic or petrocalcic horizons with 10YR hues and stage II to III pedogenic-carbonate morphology. Soils formed on QT1 through Q4 show a sharp reduction or absence in argillic horizon development and an increase in calcic and petrocalcic horizon development. Soils typically have 10YR to 2.5Y hues with paler and lighter coloration, slight development of silica films and stage III+ to IV+ carbonate morphology. Exceptions to these trends are found in soils described on geomorphic surfaces Q5, Q3 and Q2. Soils on unit Qpf5 exhibit similar carbonate development relative to Qf7; however, Qf7 is inset below geomorphic surface Q5 and is, therefore, an older landform. Soils on Qpf2 exhibit less developed carbonate morphology than on Qf4 and QTpf1 because the surface has been modified by younger deposits (Qf8 and Qf9). Soils developed on Qt3 have weakly developed calcic horizons that could be the result of increased precipitation or decreased dust-flux within the Sandia Mountains.

Table 2. Summary of stratigraphic, landscape-stratigraphic and cross-cutting relations of geomorphic surfaces on the Sandia Piedmont. Units are listed in increasing order of relative age; youngest at top.

Geomorphic surface or deposit	Characteristics
Q9	Lowest surface; associated with modern alluvium and undifferentiated low terraces; inset below all other units.
Q8	Inset below Q6 and Q7; associated with broad valley floors and elongated fan segments; inner valley escarpment of the Rio Grande inset below Q8.
Q7-8	Forms extensive terraces north of Agua Sarca Creek; surface grades to level to Q7 and merges with Q8 upstream (east) along Las Huertas Creek.
Q7-8.r	Forms small, steep range-front fans that have generally equant planform; inset below Q6 and grades to similar level as Qf7b.
Q7	Extensive fans dominate piedmont north of Juan Tabo Creek; overlies Q4 and Qoa2 and inset below Q5 and Q6; generally mixed granitoid, metamorphic and minor limestone rocks associated with local source areas.
Qoa2	Alluvium of Menaul Boulevard: unconformably overlies Q6; buried by Q7.
Q6	Extensive fans that dominate the piedmont south of Sandia Wash; overlies Qoa1 and inset below Q7 and Llano de Manzano.
Q5	Complex of pediment and fan alluvium; forms dominant landform north of NM 165; inset below Q3 and Q4; buries trace of Valley View and Rincon faults.

Table 2 (continued).

Geomorphic surface or deposit	Characteristics
Qoa1	Alluvium of Edith Boulevard: overlies Sierra Ladrones Formation in slight angular and buttress unconformities; overlain by Q6, Qoa2 and Qf7.
Q4 & Q4-5	Locally preserved fan segments along the range-front; inset below QTsfup, Q3 and Q2(?); forms isolated remnants of fans along proximal piedmont; map patterns suggest Qoa1 is inset below Q4.
Q3	Strath-terraces and pediment that are locally restricted to northern mountain-front and within Las Huertas Creek; inset below Q2; deposits generally contain, limestone, metamorphic and minor limestone clasts.
Q2-3	Pediment locally overlain by weathered granitoid boulders; discontinuously recognized along range-front south of Strip Mine Canyon; forms highest preserved pediment to the south; boulders are pitted but not grussified.
Q2	Fan and pediment complex dominant along northern range-front; inset below QTpf1; dominated by limestone with minor metamorphic and limestone clasts.
QT1	Highest preserved pediment; unconformably overlies tilted proximal piedmont facies of the lower and upper Santa Fe Group (Tsfl and QTsfup); predominantly limestone and rare, highly weathered and grussified granitoid clasts.

Table 3. Summary of geomorphic surface positions above local base level and, where applicable, the Rio Grande. Projections are made to top or base of deposits and refer to horizontal (h) and down-slope (s), graphical or trigonometric projections.

Geomorphic Surface	Base level Elevation (m)	Projected base level Elevation (m)
	Las Huertas Creek	**Rio Grande**
QTpf1 (base)	80	232 (h)
Qpf2 (base)	34 to 70	122 (h)
Qp3 and Qt3 (top)	27 to 42	---
Qt5 (top)	24 to 30	73 (h)
Qt7-8 (top)	3 to 24	***14 (s)***
		24 (h)
	del Orno Creek	**Las Huertas Creek**
QTpf1 (top)	82 to 98	---
QTpf1 (base)	72 to 77	---
Qp2 (top)	6 to 18	---
Qp3 (top)	10 to 20	---
Qp5 (top)	6 to 15	---
Qt7-8 and Qa8 (top)	6 to 9	---
	Strip Mine Canyon	**Rio Grande**
QTpf1 (base)	10 to 40	54
Qp2 (base)	34 to 38	46 (s)
		58 (h)
Qp3 (base)	9 to 32	---
Qp5 and Qpf5 (top)	6 to 20	---
Qf7 (top)	18 to 36	---
	Sandia Wash	**Rio Grande**
Qp2(?) / QTsfup	0 to 15	138 (h)
Qf7b	0 to 18	24 (s)
		57 (h)
	Juan Tabo Canyon	
Qp2-3	25 to 31	---
Qp4-5	0 to 6	---
Qf6	8	---
	Pino Canyon	
Qp4-5	7 to 13	---
Qf6	0 to 17	---

Table 4. Summary of selected soil-profile characteristics of geomorphic surfaces described on the Sandia piedmont study area. Nomenclature is from Soil Survey Staff (1951, 1975, 1992 and 1993), carbonate morphology after Gile and others, 1966 as modified by Birkeland (1984).

Unit	Pedon number **Appendix B**	Thickness (cm)	Maximum B-horizon properties					
			Carbonate morphology	Hue (dry)	Bk thickness (cm)	Bt or Btk thickness (cm)	Modified surface or soil	Structure *Clay films*
Qa9	2, 14, 29	60 to 123	trace, I	10YR	0 to ≥85	0	no	1csbk *n.o.*
Qf8-9	33	169	I+	8.75YR	≥166	0	no	1cabk *n.o.*
Qt8 Qf8	34 6, 9, 19, 35	54 to 358	I, I+, II	7.5-10YR	54 to ≥298	0 to 80	no	1-2cabk *1ncobr*
Qf7	20	122	II	10YR	98	0	no	1cabk *n.o.*
Qf7-8.r	17, 18	109 to 180	I, II	7.5YR	0 to ≥70	65 to 126	no	2-3cabk, 3mpr *4kbrpf*
Qf7b	3, 22, 28	85 to 335	II+	7.5YR	68 to ≥124	0 to 35	no	2cabk, 1cpl *2mkcobrpf*

Table 4 (continued).

Unit	Pedon number **Appendix B**	Thickness (cm)	Maximum B-horizon properties					
			Carbonate morphology	Hue (dry)	Bk thickness (cm)	Bt or Btk thickness (cm)	Modified surface or soil	Structure *Clay films*
Qf7a	8, 26, 27	85 to 743	II+, ≥II	7.5-10YR	53 to 85	0 to ≥29	no	2vcsbk, 2cabk *2nbrpo*
Qf6	1, 15, 16, 23	127 to 188	III	7.5YR	80 to 138	7 to 42	yes	2-3cabk, 3mpr *2-3mkbrpopf*
Qpf5	7, 13 31	121 to 211	II, III-	7.5YR	71 to ≥211	0 to 52	no	3vcabk *2-3mk-kbrpf*
Qf7-8 / Qf4	10, 35	131 to 186	II+, IV	7.5-10YR	100 to ≥132	0	yes	3cabk *2mkpocobr*
Qt3-5	4	137	II+	7.5YR	0	≥137	n	2mabk *3mkpf*
Qp3	na	nd	≥II		nd	nd	yes	nd *nd*
Qpf2	32	184	III+	10YR	≥184	0	yes	2cabk, 2vcpl *1ncobr*
QTpf1	5, 30	268 to 393	III+, IV+	10YR-2.5Y	158 to ≥250	21 to ≥100	yes	2-3cabk, 3vcpl *2npf*

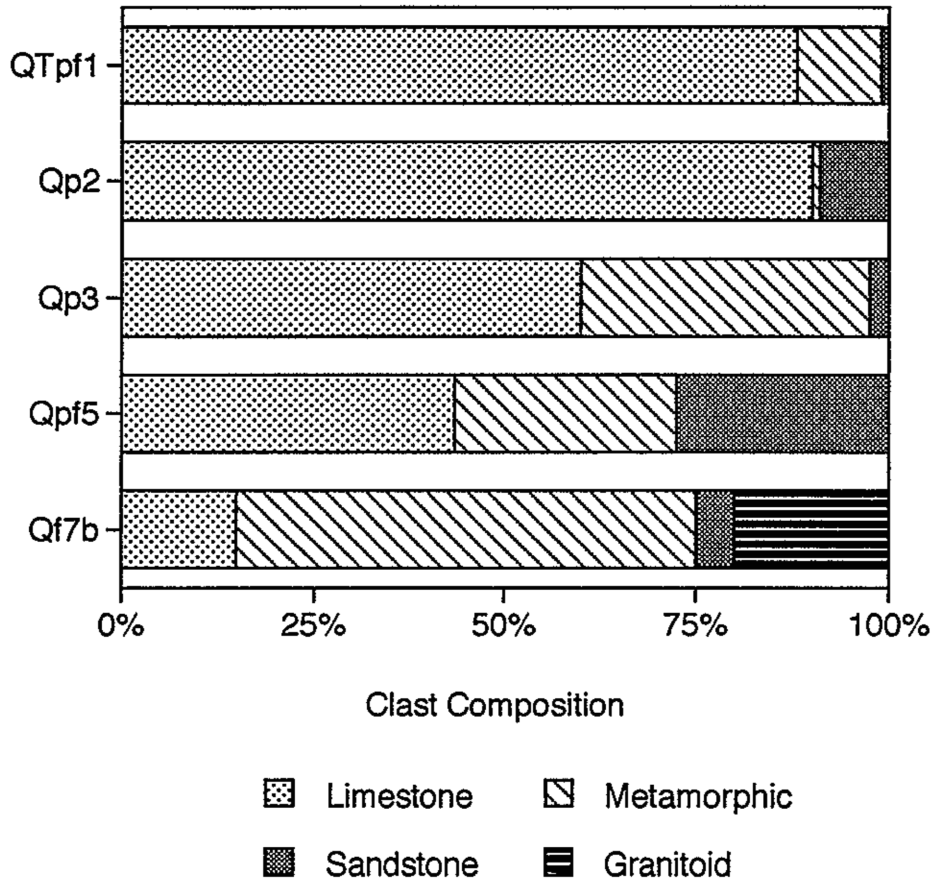


Figure 36. Variations in clast-composition on geomorphic surfaces along the northern piedmont north of del Agua Canyon (Plate I; Appendix D). Abundance was determined from clast counts and volume estimates. Geomorphic surfaces QT1, Q2, Q3, Q5 and Q7 are plotted in inverse stratigraphic order to illustrate the shift from limestone-dominated to metamorphic-dominated clasts in pediment and fan alluvium. This shift in composition reflects the removal of upper Paleozoic strata from the range-flank as mountain-front drainages incised into the hanging wall of the Placitas fault during the Quaternary and late Pliocene.

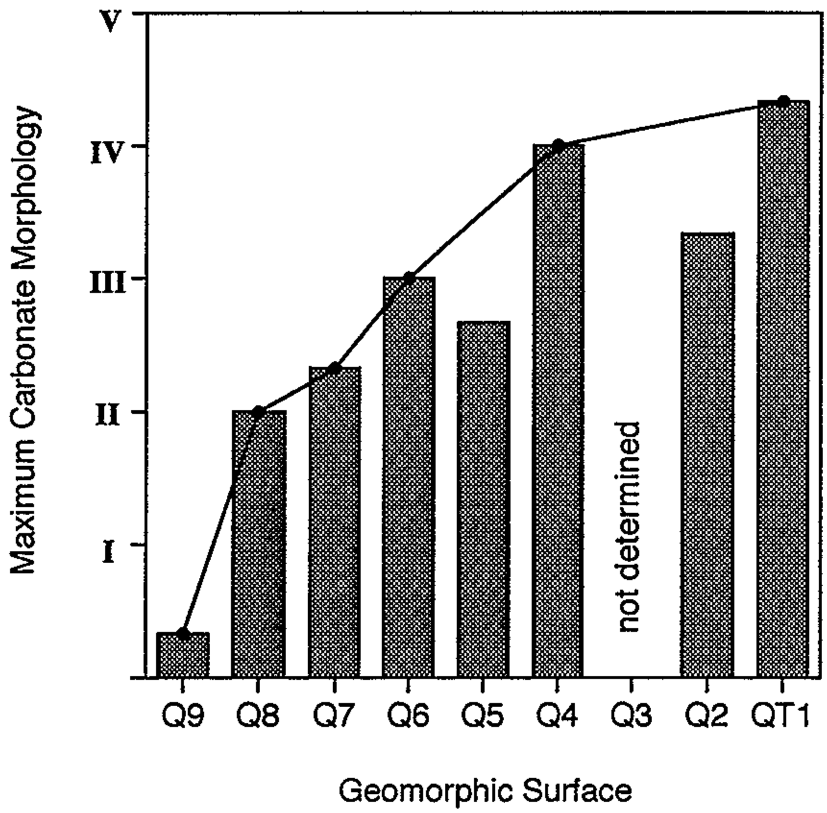


Figure 37. Maximum calcium-carbonate morphological stages recognized on geomorphic surfaces. The vertical axis denotes carbonate morphology (stages I through V). Intermediate steps in carbonate morphology (e.g., stage I+ or III-) are arbitrarily scaled between stages. These intermediate "sub-stages" are intended to differentiate "well-developed" from "weakly developed" stages of carbonate morphological development. Carbonate morphology is variable, but generally increases on higher geomorphic surfaces.

Structural Geology of the Sandia Piedmont

Mountain-Front and Piedmont Faults

The Sandia piedmont contains several structural elements that mark the transition between the northern Albuquerque and Santo Domingo sub-basins (Figs. 2, 3 and 7). Overall, a generally north-striking system of en-echelon faults lie between the northeast-striking Tijeras and San Francisco-Placitas fault zones (Figs. 3 and 7). These north-striking faults are typically separated into smaller segments separated by short northeast-striking cross faults.

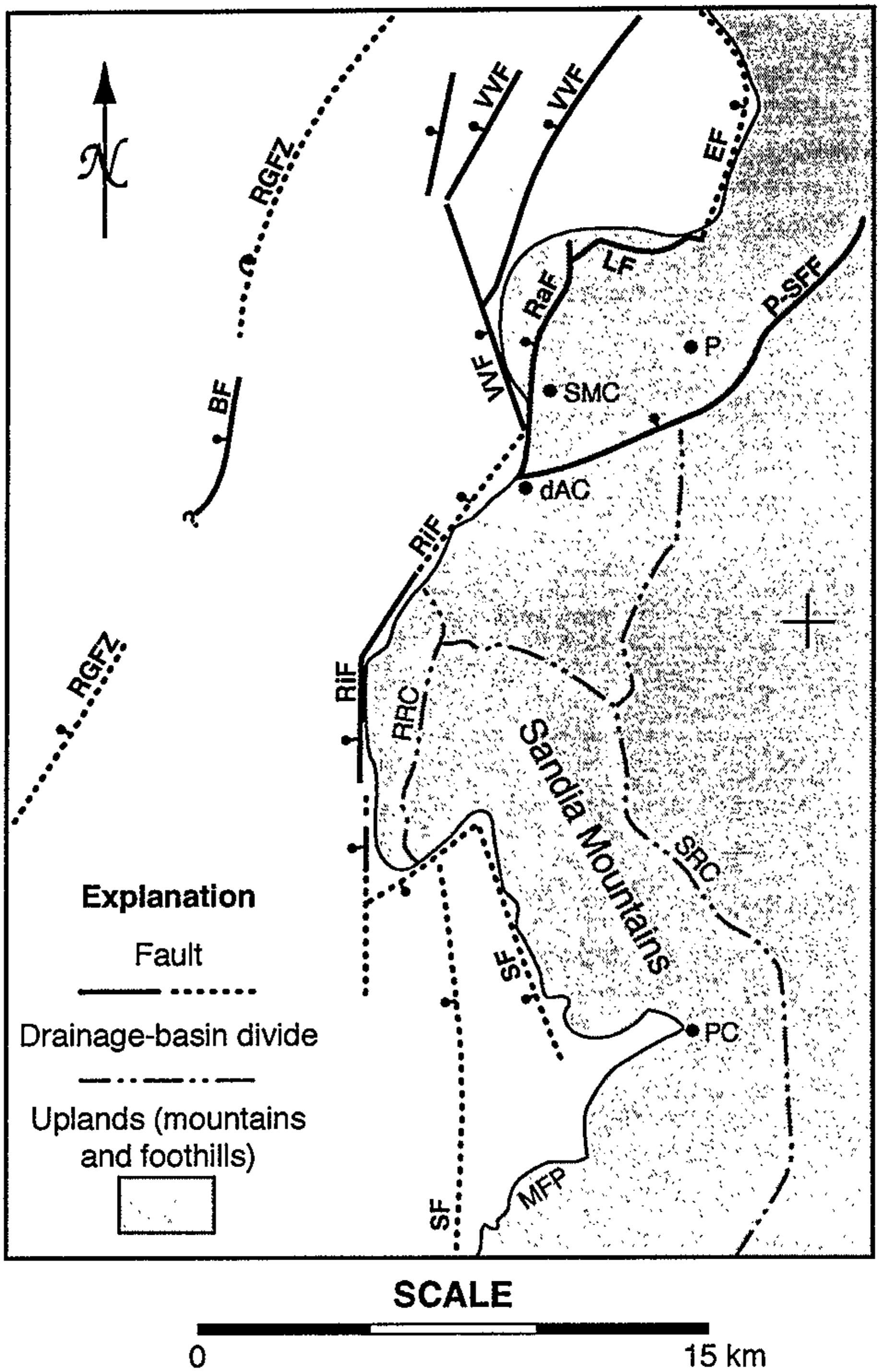
The Rio Grande fault zone (RGFZ) of Russell and Snelson (1990 and 1994) is a dominant structure in the northern Albuquerque sub-basin (Figs. 3 and 7), located along the eastern edge of the Rio Grande valley, near highway I-25 (Hawley and others, 1995). The RGFZ is poorly expressed at the surface; however, it is well expressed in seismic reflection and in exploratory wells (Russell and Snelson, 1990, 1994; May and Russell, 1994) as a west-dipping listric normal-fault exhibiting approximately 4600 to 6100 m of structural relief (Russell and Snelson, 1994). The Sandia-Rincon and San Francisco-Placitas faults form range-bounding structures that probably merge with the RGFZ at depth (Fig. 7) (Russell and Snelson, 1994).

The Rincon and Sandia faults form a master-fault system bounding the western mountain-front that juxtaposes Precambrian crystalline rock against Paleozoic through Cenozoic strata (Figs. 7 and 38). A series of buried, basinward-stepping synthetic normal faults are associated with this master-fault (Figs. 7 and 38). The San Francisco and Placitas faults form an arcuate, northeast- to north-trending escarpment that marks the northeastern margin of the Sandia Mountains. These faults form low-angle, listric normal master-faults that juxtapose Precambrian crystalline and Paleozoic rocks against Mesozoic through Cenozoic strata. The Escala, Ranchos and Valley View faults are synthetic normal-faults associated with the Placitas and San Francisco master faults (Russell and Snelson, 1994).

Sandia fault

The Sandia fault is approximately 23 km in length and forms the dominant structure along the eastern margin of the northern Albuquerque sub-basin (Kelley and Northrop, 1977). The fault displays down-to-the-west (normal) displacement, a northerly trend and forms a zone of en-echelon faults that juxtapose Precambrian crystalline rock against undifferentiated Paleozoic and Mesozoic strata and Santa Fe Group. The Sandia fault is buried by piedmont deposits in the study area; however, it is exposed as a west-dipping fault at Tijeras Creek (Kelley and Northrop, 1975). The fault is recognized by stratigraphic juxtaposition, discontinuous vegetation lineaments formed on stripped pediment-surfaces and dissected faceted spur-ridges along the mountain front. A linear, northwest-trending segment of mountain-front between Juan Tabo and Pino Canyons is associated with numerous discontinuous vegetation lineaments and faceted spurs is informally named the Domingo Baca segment for well-developed, dissected faceted spur-ridges near Domingo Baca Canyon (Plate II). This segment is about 5.5 km in length and has a trend of N20°W to N30°W.

Figure 38. Simplified fault map illustrating locations of major faults within study area. Major faults include, the Rio Grande fault zone (RGFZ), Bernalillo, (BF), Escala (EF), Lomos (LF), Placitas-San Francisco (P-SFF), Rincon (RiF), Ranchos (RaF), Sandia (SF) and Valley View (VVF) faults. Selected drainage features include Strip Mine Canyon (SMC), del Agua Canyon (dAC), Pino Canyon (PC) and Rincon Ridge (RRC) and Sandia Crest (SRC) drainage divides. Uplands (shaded) generally experience long-term erosion and include a belt of foothills along the northern flank.


N
RGFZ
VVF
VVF
EF
LF
RaF
P-SFF
P
SMC
VF
BF
dAC
RiF
RiF
RRC
Sandia Mountains
SRC
SF
PC
SF
MFP
RGFZ
Explanation
Fault
Drainage-basin divide
Uplands (mountains and foothills)
SCALE
0
15 km

The northern terminus is marked by a northeast-trending (about N35°E) linear mountain front located just north of an inlier of highly sheared Mesozoic mudstone. This structure forms a cross fault between the Rincon fault and the Domingo Baca segment of the Sandia fault. The southern end of the Domingo Baca segment is defined by a northeast-trending mountain front between Pino and Embudito Canyons. A cross fault was not recognized in the field; however, a west step between the Domingo Baca segment and the Sandia fault near Embudo Canyon and the occurrence of Mesozoic strata south of Rincon Ridge suggests the occurrence of a re-entrant structure or, at least, considerable oblique fault motion along north-striking intra-range faults or folding (ramps) between Bear and Embudito Canyons (see Figs. 3 and 39; Kelley and Northrop, 1975, geologic map). South of Embudito Canyon, the Sandia fault is characterized by a linear range-front and highly dissected faceted spur ridges and composite facets (Plates II and III). The trace is constrained by outcrops of Paleozoic limestone preserved on low hills on the piedmont (Kelley and Northrop, 1975).

Rincon fault

The Rincon fault is approximately 11 km in length and bounds the western flank of Rincon Ridge and the northern Sandia Mountains (Fig. 29; Plates I, II and III). The Rincon fault forms a narrow zone of north- and northeast-trending, subparallel, en-echelon fault segments along the base of Rincon Ridge (Fig. 39). This fault juxtaposes Precambrian crystalline rocks on the hanging wall, against Mesozoic and Cenozoic strata to the east. The southern end is buried and may extend south of Rincon Ridge

(Hawley and others, 1995; Hawley and Hasse, 1992). The northern end merges into a structurally complex zone at the intersection of the Valley View, Ranchos and Placitas faults.

The Rincon fault marks the base of a steep, linear mountain-front that exhibits well developed, undissected to slightly dissected faceted spur-ridges and composite facets. Drainage is generally dominated by elongate, low-order streams that typically are confined to the west slope of Rincon Ridge, except where del Agua, Juan Tabo and an unnamed drainage have cut through the ridge. Vertical separation is about 8,300 m (Kelley and Northrop, 1975) and decreases towards the northern margin of the range (Menne, 1989). The fault is oriented N02°W, 76°SW for 5 km along the southern portion and shifts to N24°E, 65°NW, just north of the peak of Rincon Ridge, for about 6 km. The northern terminus occurs at the intersection of the Placitas, Ranchos and Valley View faults.

Exposures of the Rincon fault consist of a 60-to 100 cm thick zone of reddish-brown to purple clay gouge and cataclastic rock (Fig. 40). A small wedge of deformed yellowish-brown and reddish-brown sandstone and claystone possibly related to the Chinle Group (Triassic) and Entrada Formation (Jurassic) is recognized on the hanging wall (Plate III), indicating the presence of large-slip normal faults within the basin (to the west).

The Rincon fault displays a set of relatively low, discontinuous, west-facing fault scarps that displace gravelly deposits of Qf7-8.r, Qf6-7 and Qpfy down to the west (Figs. 39 and 40) for a distance of approximately 3.7 km. Four profiles (Appendix E)

Figure 39. View to east along Rincon Ridge. The trace of the Rincon fault is marked by a series of vegetation lineaments (arrows) and faceted spurs along mountain front-piedmont junction. Photograph provided courtesy of Mr. Keith Kelson.

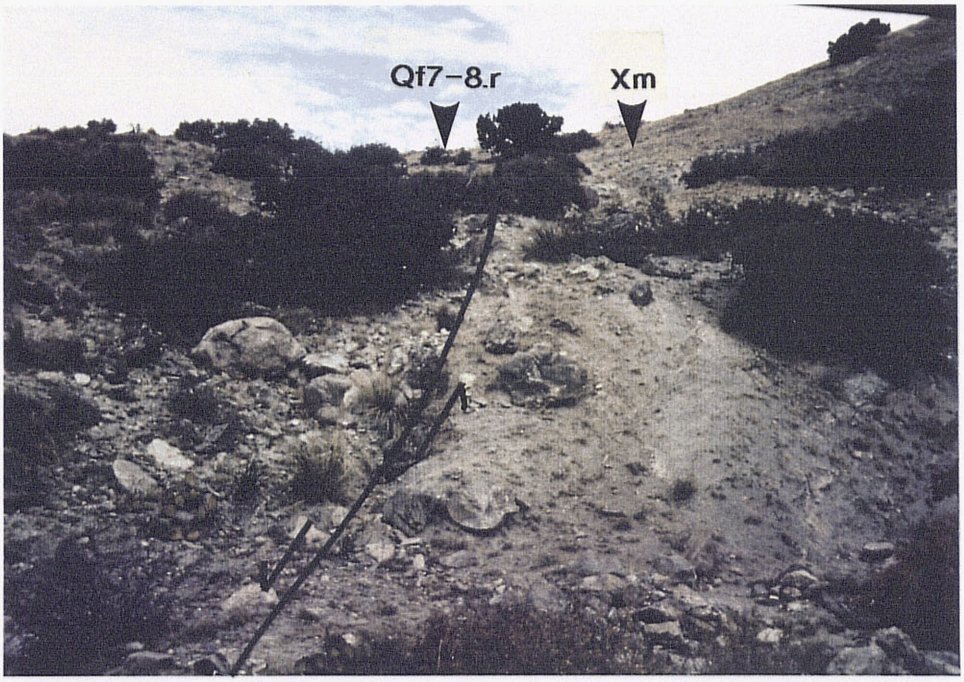
Figure 40. View to east of Rincon fault along base of Rincon Ridge. The fault is recognized by low, west-facing scarps and selected basal faceted spur-ridges along the mountain front-piedmont junction. Photograph provided courtesy of Mr. Keith Kelson.

surveyed across the lowest scarp are developed in gravelly alluvium and displace Qf7-8.r by approximately 1.8 to 2.6 m (mean height is 2.29 ± 0.38 m) (Fig. 41). Scarps have fairly uniform slope angles indicative of formation during a single rupture event (Machette and Personius, 1984; Wallace, 1977).

Three fault-scarp profiles (Appendix E) surveyed across an intermediate-height scarp developed in Qf6-7 reveal compound-slopes that indicate the scarp was formed during multiple ground-rupture events. The scarp is between 6.2 and 8.0 m in height; having a mean of 6.9 ± 0.97 m. Profiles typically exhibit two distinctive scarp slopes that indicate rupture of an older, degrading slope that probably developed during at least two separate rupture events. The latest rupture event offsets Qf6-7 between 3.4 and 3.9 m, with a mean of 3.7 ± 0.26 m.

Profiles on Qf7-8.r and Qf6-7 were measured along two en-echelon strands, within a 1-km distance along strike. The average displacement of Qf7-8.r is 2.3 ± 0.38 m, about one-third of the displacement observed on unit Qf6-7 (Fig. 41). This difference could be attributed to along-strike variations in fault offset; however, larger displacements are recognized on older (Qf6-7) deposits. It is likely that these scarps formed during three separate ground-rupture events; the recent 2.3-m event and two previous 1- to 2.3-m ground-rupture events (Fig. 41). Uncertainty in the delineation of multiple-event scarp segments may occur because of the coarse-grained nature of the faulted deposits; therefore, the scarps may only represent two events. If the single-event scarp heights on Qf6-7 and Qf7-8.r developed during a single episode of ground-rupture, the average vertical displacement during the latest event would be approximately 2.9 ± 0.79 m.

Figure 41. Scarps and exposed contact along Rincon fault. Top: view to north along trace of Rincon fault, which juxtaposes light-gray crystalline rock (Xm) on the right (east) against gravelly alluvium (Qpfy) on the left (west). Arrows indicate relative sense of movement; down to the left (west). Bottom: view to east of Rincon fault (dashed lines). The lowest (1.8- to 2.6-m) fault scarp is in foreground. An intermediate-height (6.2- to 8.0-m) scarp marks base of ridge and a prominent faceted spur-ridge (F) marks a 13-m high scarp that cuts gravel-capped bedrock.


Qf7-8.r
Xm


F
Low Fault Scarp

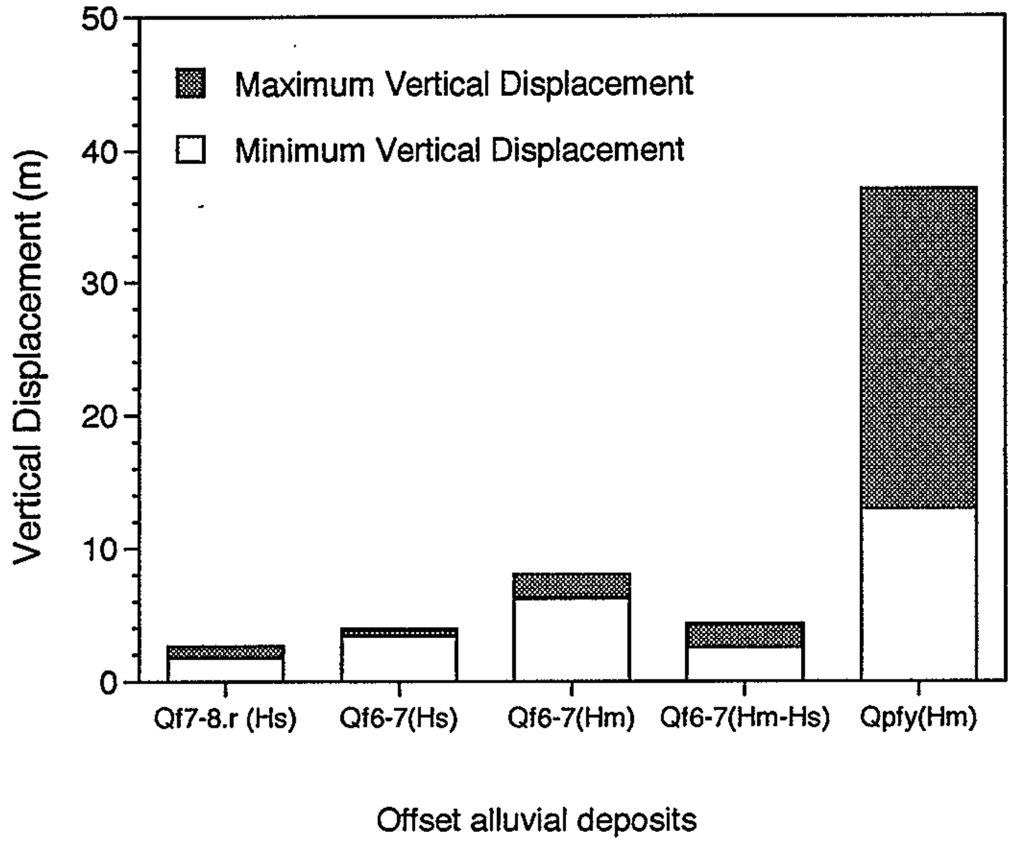


Figure 42. Vertical displacement measured from fault scarps and fault-scarp profiles (Appendix E). Displacements measured on scarps formed during a single ground-rupture event (Hs) are recognized on Qf7-8.r and Qf6-7. Scarps developed during multiple events (Hm) are recognized on Qf6-7 and Qpfy. Residual displacement (Hs-Hm) calculated on Qf6-7 indicates that the scarp formed by at least one or, possibly, two events prior to the latest rupture event. Compound-slope angles, expressed as knickpoints are recognized on a 13-m high scarp that cuts Qpfy and Precambrian rocks. Knickpoints (Appendix E) suggest that scarp was formed by at least four events.

Scarps developed on Qpfy range from 13 to 37 m in height and expose crystalline bedrock. A surveyed fault-scarp (Appendix E) exhibits about 13 m of vertical displacement of Qpfy. This profile contains slight variations in slope angle (knickpoints), suggesting formation during at least four separate ground-rupture events.

Surface-rupture age estimates are based on comparisons between maximum scarp-height and slope relative to numerically dated scarps in southern New Mexico and Utah (Fig. 43) (Personius and Machette, 1984; Machette, 1982; Bucknam and Anderson, 1979). Holocene fault-scarp data is derived from studies of scarps in southern and central New Mexico (4 to 5 ka: Machette, 1982, 1989) and Fish Springs, Utah (approximately 2 ka: Bucknam and Anderson, 1979; Machette, 1989). The latest Pleistocene scarp data is derived from studies of wave-cut shorelines formed by Lake Bonneville, Utah, and dated at about 15 ka (Machette, 1982, 1989) and late Pleistocene scarps near Panguitch in southern Utah (100 ka: Bucknam and Anderson, 1979; Machette, 1989).

Maximum slope-angles and heights are plotted for the lowest single-event scarps that offset Qf7-8.r and Qf6-7. Single-event scarp data for the latest scarp-forming event, lies between the 2 ka and 5 ka lines (Fig. 43) and are therefore, interpreted to have formed during the middle Holocene (≤5 ka). The data determined from single-event scarps lie on the 5-ka best-fit line derived from studies in New Mexico; therefore, regional climatic influences on scarp degradation rates should be similar. Scarp data from the intermediate scarp and multiple-event scarps lie along the

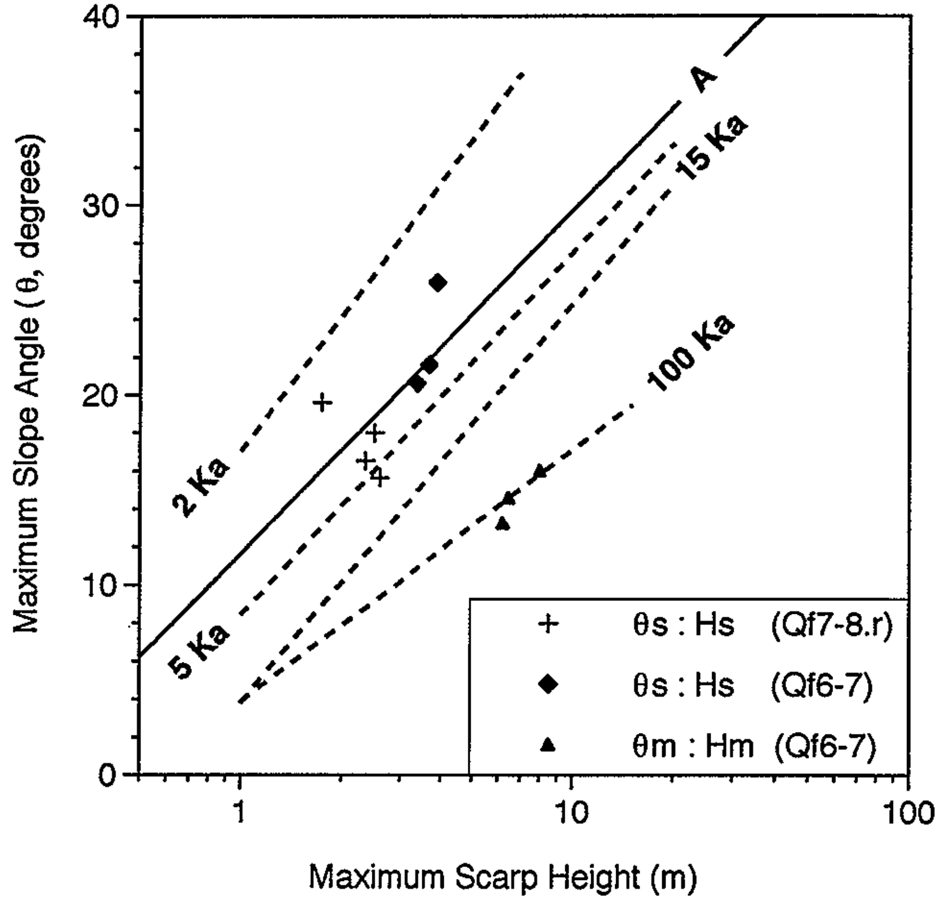


Figure 43. Estimates of ground-rupture ages along Rincon fault based on scarp-morphologic models (Bucknam and Anderson, 1979; Machette, 1982). Scarp-morphology data include maximum scarp-slope angle (θ) and height for multiple-event (Hm) and single-event (Hs) scarps. Dashed lines are derived from numerically dated scarps (modified from Machette, 1982, 1989; Bucknam and Anderson, 1979). The best-fit line (A: $\theta s = 11.4 + 18.1(\text{LOG Hs})$, $r^2 = 0.41$) is derived from single-event scarps data measured on Qf7-8.r and Qf6-7. The coefficient of variation shows weak correlation; however, scarps formed by a single ground-rupture event lie between the 2- and 5-ka line, indicating a middle Holocene age of latest ground rupture. Scarps developed during multiple events plot between the 15- and 100-ka lines, placing a maximum estimate of late Pleistocene (≤100 ka) on the penultimate event.

100-ka line. This suggests that the penultimate ground-rupture event developed on Qf6-7 occurred during the late Pleistocene at about 100 ka. Age estimates of scarps that cut Qpfy are not made because of the highly lithified nature of the scarp face; however, the total scarp height developed prior to late Pleistocene offset of unit Qf6-7 and are therefore, pre-late Pleistocene in age.

Estimation of the earthquake generated during the latest ground-rupture event along the Rincon fault is determined by using the average rupture of 2.29±0.38 m as the characteristic event (dePolo and Slemmons, 1990); however, if the penultimate event was larger in magnitude, then use of a "characteristic earthquake" is questionable. Statistical relations of North American faults (Bonilla and others, 1984) indicate that ground-rupture on the Rincon fault would generate a surface-wave magnitude (Ms) of about 7.0 to 7.4 Ms; however, this magnitude corresponds with a 32 to 63 km length of fault, which is clearly less than the length of the 11 km length of the Rincon fault. A 4 km rupture length corresponds to an event that would be less than 6.5 Ms (Bonilla and others, 1984); therefore, smaller magnitude earthquakes (less than 6 Ms) are more likely to occur along this fault.

<u>Bernalillo fault</u>

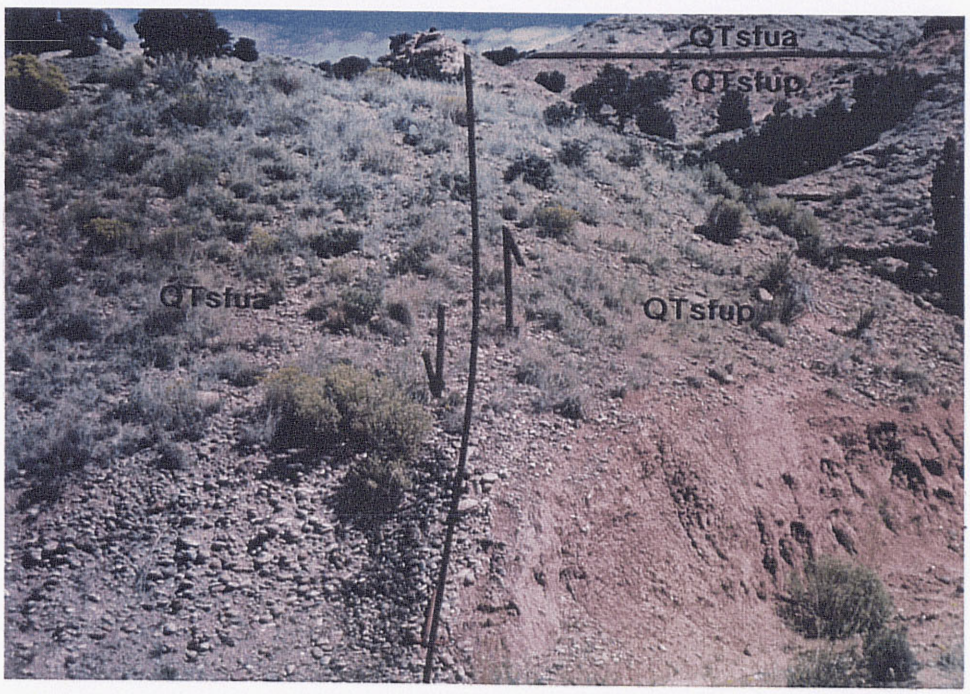
The Bernalillo fault is recognized southeast of the town of Bernalillo (Hawley, 1978, p.159) and forms a 2-km long, steeply dipping normal fault oriented N09°E, 83°NW. The fault is about 5 km west of the mountain front and is recognized by offset of a distinctive white diatomite bed of the alluvium of Edith Boulevard (Plate I). The Bernalillo fault displaces this bed between 6.2 to 7.5 m down to the west and truncates alluvium of Menaul Boulevard and is buried by Qf7 (Figs. 44 and 45). The fault lies near the projected trace of the Rio Grande fault zone (Russell and Snelson, 1994) and may represent the surface expression of the Rio Grande fault zone within the study area.

Valley View fault

The Valley View fault (Kelley and Northrop, 1975) is named for a low west-facing escarpment and northwest and northeast-trending fault traces are recognized north of Strip Mine Canyon. The Valley View fault dips between 21° and 45° NE and displaces Sierra Ladrones Formation, QTpf1 and Qpf2 down to the west. Deposits of Qp5 and Qpf5 bury the fault. Seismic-reflection studies indicate that this structure forms a synthetic normal fault associated with the hanging wall of the San Francisco and Placitas faults (Figs. 7 and 38; Plate I).

The Valley View fault is approximately 10 to 12 km long and extends from the intersection of the Rincon, Ranchos and Placitas faults, near Strip Mine Canyon (Plate I), to the northeast where it ends against the Escala fault (Cather and others, in preparation). The fault-trace trends about N20°W along the southern terminus and forms a low escarpment, marked by the foothills-piedmont transition, that rises to about 78 m above the surface of Qpf5. The trend of the Valley View fault trace bends to about N30°E at Agua Sarca Canyon and splits into three segments. Traces of the Valley View fault are recognized by strong photographic lineaments where Qpf2 is displaced down to the west. Exposures are poor, but the fault generally forms a series

Figure 44. Exposures of the Bernalillo fault and a splay of the Valley View fault. Arrows indicate relative sense of displacement. Top: view to northwest along the trace of the Bernalillo fault. The relative sense of movement is down to the left (west). A white diatomite bed and rounded quartzite conglomerate associated with the alluvium of Edith Boulevard are displaced by about 6.5 to 7.4 m down to the west. Bottom: exposure of fault related to Valley View fault juxtaposing axial (QTsfua) and piedmont (QTsfup) facies of the Sierra Ladrones Formation. Clasts are vertically oriented within mineralized fault zone. The relative sense of movement is down to the left (west).


QTsfua
QTsfup
QTsfua
QTsfup

of discrete faults. A short fault segment that merges into the Valley View fault forms a narrow, northeast-trending zone (N22°E, 97°NW and N40°E, 72°NW) recognized by the juxtaposition of vertically oriented quartzite clasts (Fig. 44).

Deposits of Qpf2 and Qp3 are offset and buried by Qpf5 and Qt5. Displacement decreases northwards. Qpf2 is offset by a maximum of 76 to 91 m. The magnitude of displacement across Qpf2 decreases to approximately 21 m, south of Las Huertas Creek, and 6 to 18 m north of Las Huertas Creek. Unit Qp3 is not recognized on the hanging wall, however, a graphical projection of Qp3 to the ground surface underlain by Sierra Ladrones Formation constrain maximum displacement between 24 and 37 m (Fig. 45).

Lomos, Escala and Ranchos faults

The Lomos, Ranchos and Escala faults form a series of north- to northeast-trending faults that juxtapose lower Santa Fe Group against Sierra Ladrones Formation. The Ranchos fault extends northward from the intersection of the Valley View, Placitas and Rincon faults to the intersection with the Lomos fault. The Lomos fault forms a northeast-trending fault that stops at the north-northwest-trending Escala fault.

The Lomos fault is named for an east-to northeast-trending (N65°E to N82°E and N70°W) normal fault along the northern slope of Lomos Altos (Plate I). The Lomos fault is approximately 3 km in length and is recognized by the juxtaposition of moderately tilted conglomerate of the lower Santa Fe Group (Tsfl) to the south, against slightly deformed piedmont facies of the Sierra Ladrones Formation (QTsfup) on the

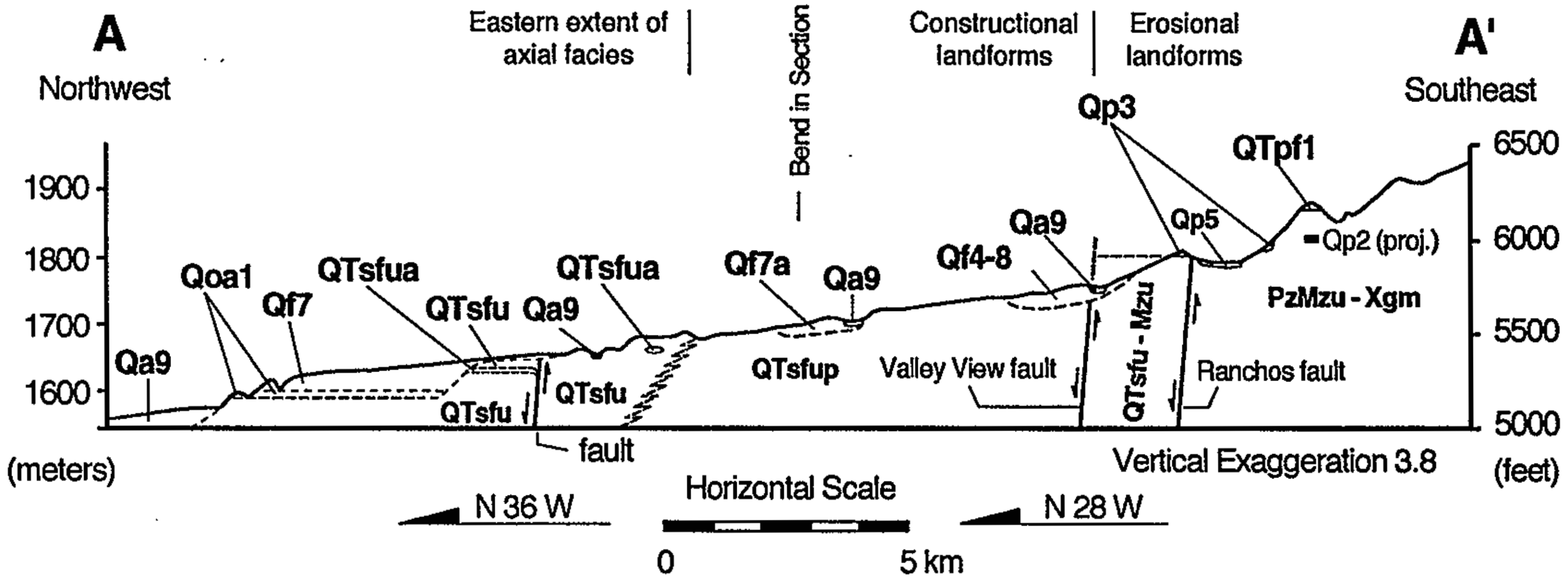


Figure 45. Cross Section along line A-A' of geologic map (Plate I). Vertical exaggeration (3.8) steepens apparent dips in cross section. Cross section illustrates positions of erosionally and depositionally dominated piedmonts. Pediment alluvium (QTpf1, Qp3, Qp5) occurs on the pediment-dominated piedmont on the footwall of the Valley View and Ranchos faults. Piedmont (QTsfup) and axial stream (QTsfua) deposits of the Sierra Ladrones Formation (QTsfu) are unconformably overlain by Qf4 through Qf8, Qa9 and the alluvium of Edith Boulevard (Qoa1). These deposits comprise the fill-dominated piedmont on the hanging wall of the Valley View and Rincon faults. The Ranchos fault juxtaposes crystalline (Xgm) and Paleozoic-Mesozoic (PzMzu) rocks, on the eastern footwall, against deposits of Sierra Ladrones Formation and Mesozoic strata. The Valley View fault is buried along the line of section and displaces deposits of QTsfup. Piedmont facies of the Sierra Ladrones Formation (QTsfup) interfingers with axial facies (QTsfua) to the west. The base of Qf7 forms a buttress unconformity against QTsfu that marks the easternmost extent of deposition of Qoa1. The Valley View fault truncates pediments of Qp2 and Qp3 and is buried by Qp5 and Qpf5. Graphical projections of Qp3 across the trace of the Ranchos fault indicate relative inactivity since formation of Qp3.

north side of Lomos Altos. Graphical projections of QTpf1 across the Lomos fault indicate at least 80 m of down-to-the north stratigraphic offset (Fig. 46). The basal contact of QTpf1 steepens towards the trace where deposits thicken to more than 18 m. The Lomos fault may displace Qpf2 by about 18 m to the north; however, field relations are not clear (Plate I). Qp5 buries the trace of the Lomos fault.

The Escala fault is named for the west-facing escarpment on Cuchilla Escala (Plate I), which comprises the footwall of a north (N10 to 30°W) trending, arcuate fault trace that juxtaposes lower Santa Fe Group against Sierra Ladrones Formation. Deposits of geomorphic surfaces Q2 and Q5 bury the Escala fault. The southern end of the fault ends against a complex set of faults associated with the eastern terminus of the Lomos fault. Deposits of the Sierra Ladrones Formation typically tilt to the east between the Valley View and Lomos faults. The arcuate nature of the escarpment and juxtaposition of lower Santa Fe Group against Sierra Ladrones Formation indicate down-to-the-west displacement.

The Ranchos fault exhibits normal separation of Santa Fe Group and older strata. This fault, mapped by Kelley and Northrop (1975) and Menne (1989), trends about due north to N30°E and is exposed along a roadcut at the "Las Placitas" historical marker on highway NM 165. Faulting is complex and juxtaposes Mesozoic and lower Santa Fe Group strata to the east against deposits of Sierra Ladrones Fm. Kelley and Northrop interpret this structure to be an extension of the Rincon fault, however, Menne (1989) reports no direct connection. The juxtaposition of lower Santa Fe Group to the east, against Sierra Ladrones Formation requires the presence of an accommodation or transfer structure, therefore, the use of the term Ranchos is favored north of Strip Mine

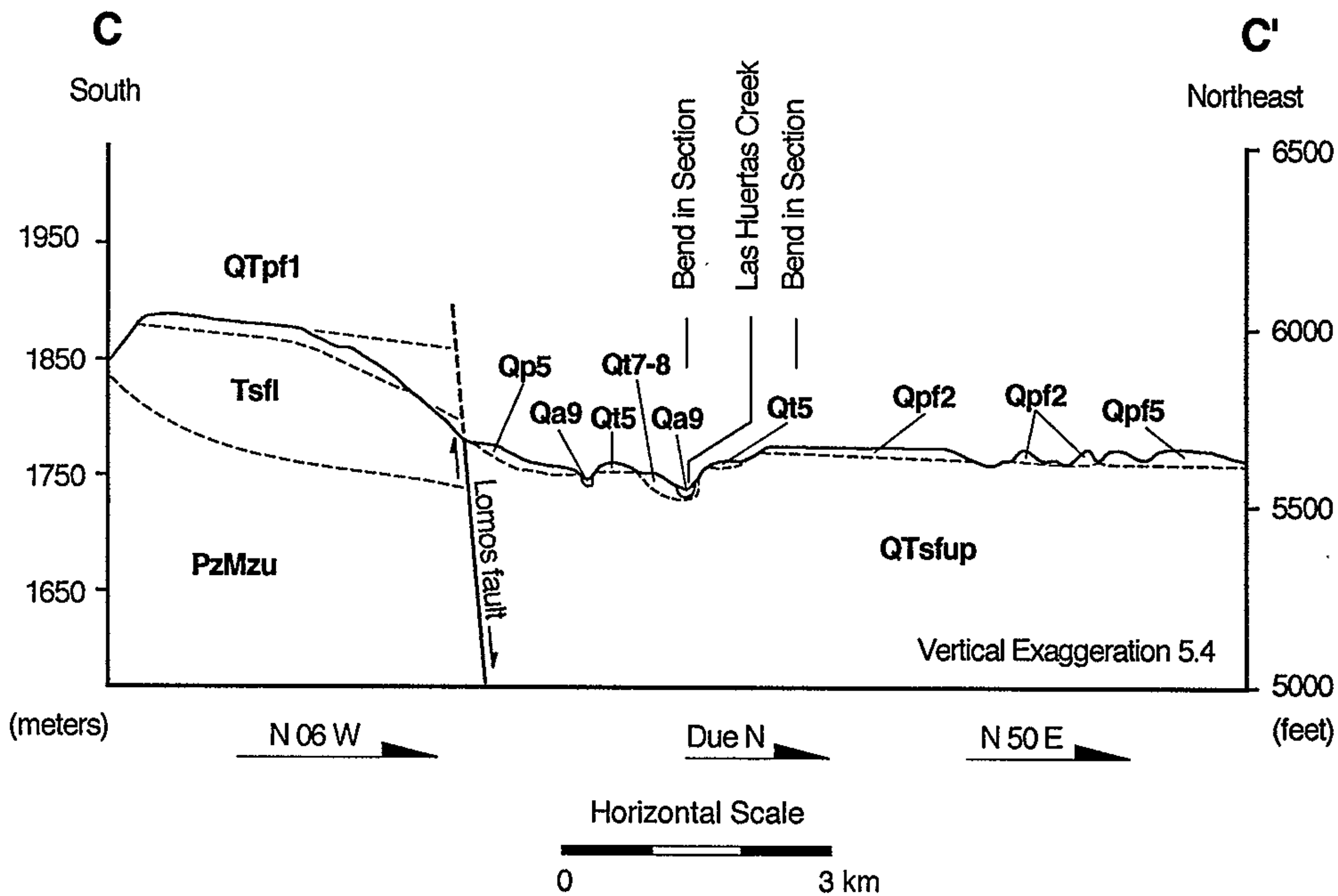
Canyon. Graphical projections of unit Qp3 across the trace indicates relative inactivity since formation of Qp3 (Fig. 45).

Placitas and San Francisco faults

The Placitas and San Francisco faults bound the northern margin of the Sandia Mountains and form transfer structures between the northern Albuquerque and Santo Domingo sub-basins and the Hagan embayment (Kelley and Northrop, 1975; Kelley, 1977; Picha, 1982). The Placitas fault is a 6.5-km long, northeast-trending, rift-margin structure near the town of Placitas (Kelley and Northrop, 1977; Kelley, 1975; Menne, 1989). The Placitas fault has a steep dip that decreases with depth (Fig. 7) and exhibits normal separation of Paleozoic strata. This fault merges with the Rio Grande fault zone at depth (Russell and Snelson, 1990, 1994). This fault forms a transfer zone between the Rincon and San Francisco faults and exhibits approximately 850 to 1700 m of stratigraphic throw that places Precambrian through Mesozoic strata on the footwall, against Precambrian through Pennsylvanian strata to the south (Menne, 1989). The Placitas fault zone can be separated into short, relatively straight, northeast-trending strands separated by north-trending cross faults. The trace of the Placitas fault is discontinuously buried by Qp2. Isolated exposures of QTpf1 on the hanging wall indicate no significant displacement of QTpf1 (Fig. 17; Plate I).

The San Francisco fault forms the major rift-bounding structure separating the Santo Domingo basin and Hagan embayment. The southern end of the San Francisco fault is recognized along the eastern boundary of the study area, where it juxtaposes

Figure 46. Cross section along line C-C' of the geologic map (Plate I) illustrates inset relations of geomorphic surfaces QT1 through Q9 across Las Huertas Creek. Vertical exaggeration (5.4) steepens apparent dips in cross section. Piedmont deposits unconformably overlie lower Santa Fe Group (Tsfl) and piedmont facies of the Sierra Ladrones Formation (QTsfup). The Lomos fault is a steeply dipping fault that juxtaposes Tsfl against QTsfup. Unit QTpf1 is recognized on the footwall of the Lomos fault and is offset by more than 80 m to the north. Qpf5 and Qt5 form pediments and straths, respectively, that are inset below Qpf2. Qt7-8 forms a fill-terrace inset below units Qt5 and Qa9 comprises modern alluvium and low terraces.


C
South
C'
Northeast
1950
1850
1750
1650
6500
6000
5500
5000
QTpf1
Tsfl
PzMzu
Bend in Section
Las Huertas Creek
Bend in Section
Qp5
Qt7-8
Qa9
Qt5
Qa9
Qt5
Qpf2
Qpf2
Qpf5
Lomos fault
QTsfup
Vertical Exaggeration 5.4
(meters)
(feet)
N 06 W
Due N
N 50 E
Horizontal Scale
0
3 km

158

Precambrian through Mesozoic strata against the lower Santa Fe Group. Stratigraphic separation decreases northwards and becomes buried by the Santa Fe Group north of Espinaso Ridge (Kelley, 1977). A wind gap north of Cuchilla Lupe may be related to a surface formed by geomorphic surfaces Q2, Q3 or Q5 (Plate I).

Structural separation along the San Francisco fault decreases northward from approximately 2150 m near Tecolote (Plate I) to less than 60 m north of Espinaso Ridge, north of the study area (Kelley, 1977). Slickenlines indicate that motion is dominantly normal with a minor component of left-separation (Picha, 1982). Lower Santa Fe Group deposits are restricted to the hanging wall, indicating that much of the activity occurred during the Miocene (Picha, 1982; Menne, 1989). Displacement of Quaternary deposits is not recognized in the study area (Menne, 1989; Kelley and Northrop, 1975); however, deposits associated with the Ortiz pediment are displaced northeast of the study area (Picha, 1982).

<u>Unnamed faults</u>

Several short, north- to northeast-striking faults that display minor displacement are recognized in the study area. A northeast-trending fault cuts deposits of QTpf1 in the vicinity of measured soil profile P-5 (Plate I) and may be buried by deposits of Qp2 to the east. This fault is recognized by a low, northwest-facing scarp that is preserved on the surface of QTpf1. A north-trending fault, exhibiting down-to-the-west displacement of Sierra Ladrones Formation is exposed south of highway NM 165 (Plate I: W1/2, Section 34, T12N., R04E., NMPM) in the Placitas 7.5-minute quadrangle. The fault is recognized by an abrupt steepening of bedding within deposits of the Sierra Ladrones Formation.

Summary

The study area contains several, well-defined, normal faults that define the eastern boundary of the northern Albuquerque and Santo Domingo sub-basins. Faults are separated into three categories on the basis of cross-cutting relationships (Table 5). The Placitas, San Francisco and Sandia faults offset deposits of the Sierra Ladrones Formation and are buried by QT1 and Q2. The Lomos fault truncates QT1 and is buried by Q5. This fault may also truncate Q2; however, field relations are not clear. The Valley View fault displaces geomorphic surface Q2 and is buried by geomorphic surface Q5. Bernalillo and Rincon faults displace Santa Fe Group and younger deposits. The Bernalillo fault truncates deposits of the alluvium of Menaul Boulevard and is buried by fan alluvium of geomorphic surface Q7. The Rincon fault displaces Santa Fe Group, Qf7-8.r, Qf6-7 and Qpfy and last moved during the middle Holocene (Fig. 43).

Bedding within the Sierra Ladrones Formation becomes moderately to strongly tilted to the east near faults. Bedding is only slightly tilted elsewhere. The Sierra Ladrones Formation generally tilts towards the eastern basin margins. Deposits of the lower Santa Fe Group are steeply tilted east towards the basin margin along the San Francisco fault.

Table 5. Summary of faults, including location, orientation, length, sense of separation and offset deposits within the study area. The Rincon fault (*) displays well-expressed scarps along a 3.7-km long segment at the base of Rincon Ridge.

Fault name	Location (Plate)	Length Orientation	Sense of separation Offset units [separation, m]
Sandia	South of Rincon Ridge (Plate II)	22 km North, N30W and N35E	Normal Paleozoic, Mesozoic and Santa Fe Group
Rincon	Rincon Ridge (Plates I - III)	11 km (3.7 km*) N02W, 76SW N24E, 65NW	Normal Qf7-8.r [2.3] Qf6-7 [3.7] Qpfy [5 to 21] Qp2-3 [>46]
Bernalillo	South of Bernalillo (Plate I)	2 km N09E, 83NW	Normal Qoa1 [6 to 7] Qoa2 [truncated: ≥2]
Valley View	NM 165: (Plate I)	11.5 km N20W to N30E	Normal: decreases to north Qpf2 [S: 76 to 91; N: 6 to 18] Qp3 [S: 24 to 37]
Lomos	Lomos Altos (Plate I)	3 km N65-85E & N70°E	Normal QTpf1 [≥80] Qpf2(?) [approx. 18]
Escala	Cuchilla de Escala (Plate I)	≥6 km N10E to N30W	Normal Tsfl-QTsfu
Placitas	Northern Sandia Mountains. (Plate I)	6.5 km NE	Normal or oblique Mesozoic
San Francisco	Northern Sandia Mountains. (Plate I)	20 to 30 km (Kelley, 1977) NE	Oblique Miocene to Pliocene Separation decreases northward

Geomorphology of the Sandia Piedmont

Introduction

The western flank of the Sandia Mountains is characterized by a steep escarpment characterized by several linear, northeast and northwest-trending mountain-front segments (Figs. 47, 48 and 49). Evaluation of range-front and piedmont morphology was based upon qualitative assessments of mountain-front orientation, lithology, relief, relative shape and size of drainage basins (Fig. 12), association with faults, faceted basal spur-ridges and piedmont character (aggradational or erosional). A nearly continuous topographic divide along the crest of the Sandia Mountains is marked by a resistant limestone cap (Madera and Sandia Formations). All streams eventually enter the Rio Grande, which forms the regional base level. The divide separates west-flowing streams that directly drain onto the piedmont, from streams originating east of the range crest and enter the basin through large canyons along the northern and southern margins of the range (Tijeras and Las Huertas drainage basins). Mountain-front drainage-basins are generally elongate in plan view and extend to range-crest divides (Fig. 47). The largest drainages, Las Huertas and Tijeras Creeks, originate east of the crest and enter the piedmont along the northern and southern margins of the Sandia Mountains. Other piedmont drainages originate west of the divide.

The mountain front-piedmont junction is marked by a series of generally north-trending linear mountain-fronts (salients) juxtaposed with northeast-trending re-entrant segments that shift the position of the junction; a well-expressed pattern between Juan Tabo and Embudito Canyons and along the northern range flank (Figs. 47 and 49). Larger drainage basins commonly occur near shifts in mountain-front position and orientation (Fig. 47). The western mountain-front is bounded by the Sandia and Rincon faults. Range-crest elevation decreases northward along the northern margin and splits into several northwest-stepping, en-echelon mountain-front salients that end against the Placitas and San Francisco faults (Figs. 4 and 47). These salients generally confine drainage within narrow, elongate basins that widen onto the hanging wall of the San Francisco and Placitas faults (Figs. 47 and 48).

A secondary drainage-divide separates mountain-front fluvial systems originating from Rincon Ridge (Figs. 4 and 47). West of this divide, streams form within short, elongated, low-order drainage basins that convey flow directly onto the piedmont. The del Agua and Juan Tabo drainages originate along a common divide that connects Rincon Ridge to the Sandia range crest and enter the piedmont around the flanks of Rincon Ridge (Fig. 47). The northwest-flowing del Agua drainage forms an elongated basin that enters the piedmont along the northern margin of Rincon Ridge. The southwest-flowing Juan Tabo drainage forms a generally equant (circular) basin that enters the piedmont near the southern margin of the ridge. Juan Tabo Creek cuts a deep canyon into a prominent bench along the southern margin of Rincon Ridge (Plates II and III).

A narrow belt of low-lying, deeply dissected foothills on the hanging wall of the Placitas and San Francisco faults rise about 75 to 140 m above the valley floor. These foothills are underlain by deposits of the Santa Fe Group and Mesozoic strata. The foothills are deeply dissected and form a stepped sequence of erosional landforms that typically span the mountain front-foothills-piedmont transition (Figs. 4 and 47; Plate I).

The foothills are marked by a break in slope along the base of escarpments associated with the Valley View, Lomos and Escala faults (Figs. 38 and 47; Plate I).

Las Huertas Creek is confined to a graben bounded to the east by linear, northeast-trending, mountain-front salients of the Crest of Montezuma and Cuchilla Lupe (Fig. 48). The direction of stream flow abruptly shifts to the west where the creek crosses the trace of the San Francisco fault and is not confined by pre-Cenozoic rock. Tijeras Creek enters the piedmont along the southern margin of the Sandia Mountains along the trace of the Tijeras fault.

Mountain-Front Segmentation Patterns

Mountain-front form is expressed as several patterns and qualitatively divided into several distinctive segments and sub-segments on the basis of systematic variations in lithology, orientation, sinuosity, position of the mountain-piedmont junction, drainage-basin and mountain-front form, structural features, offset deposits, occurrence and form of faceted spurs, and character of piedmont landforms and deposits (Figs. 47, 48, 49, 50, 51; Table 6).

Mountain-front segments 1 and 2 mark the northern margin of the range front. Segments 1 and 2 are characterized by a series of east-stepping salients bounded by the Placitas and San Francisco faults. A 3- to 4.5-km wide zone of foothills marks the mountain front-piedmont transition (Figs. 46 and 47). The northern flank of the Sandia Mountains display a stepped sequence of straths and pediments that cut across Santa Fe Group and older rocks (Fig. 17; Plate I). The northern flank has low relief (less than

1000 m) with a maximum ridge height of 2870 m along Agua Sarca Creek. Maximum relief of the foothills is about 100 to 140 m above valley floors. The Placitas and San Francisco faults mark the base of the mountain front. The Valley View, Lomos and Escala faults and mark the foothills-piedmont junction. Drainages developed along segments 1 and 2 primarily drain sedimentary rocks and span the mountain front-foothills transition, where they enter the piedmont through steep-walled arroyos or valleys. Las Huertas Creek forms the largest drainage and originates along the eastern slope of the Sandia Crest (3255 m) and enters the piedmont across the transition between segments of the Placitas and San Francisco faults (Plate I; Kelley and Northrop, 1975; Menne, 1989, geologic maps).

Mountain-front segment 1 is defined as the foothill-piedmont junction along the base of the Cuchilla de Escala. The trace of the Escala fault coincides with the base of the foothill-piedmont junction and is characterized by a linear escarpment with a mountain-front sinuosity (S) ratio of 1.39 (Fig. 49). The segment is bounded to the south by Las Huertas Creek, which flows through a gap cut into deposits of the lower Santa Fe Group immediately north of the junction between the Lomos and Escala faults. The piedmont is deeply dissected and dominated by pediment landforms and deposits. Small elongated drainage-basins originate within the Cuchilla de Escala, which exhibits several slightly dissected, 24- to 43-m high faceted spurs. Segment 1 is distinguished from segment 2 by differences in orientation, relative basin size and occurrence of faceted spurs. Las Huertas Creek marks the transition between segments 1 and 2.

Segment 2 marks the transition between erosionally and constructionally dominated piedmonts along the northern margin of the west-facing escarpment of the Sandia Mountains. This segment contains a fairly wide transitional zone of foothills between the mountain front and piedmont. Segment 2 is characterized by a sinuous (S = 1.95 to 3.53) foothill-piedmont junction that displays dissected, v-shaped and u-shaped valleys containing a sequence of stepped pediments or straths cut across the Santa Fe Group and older rocks (Fig. 49; Plate I). This segment is divided into two sub-segments on the basis of orientation and sinuosity. Segment 2a is approximately 5 km in length and marks a transition between segment 1 and 2b along Las Huertas Creek. Segment 2a marks a sinuous (S = 1.53 to 3.77) northeast-trending escarpment formed along Lomos Altos and Las Huertas Creek. Segment 2b is distinguished by a linear (S = 1.22) northwest-trending escarpment along the Valley View fault (Table 6). Strip Mine and Agua Sarca Canyons comprise the dominant drainage developed on the hanging wall of the Placitas fault. Segment 2b is distinguished from segment 3 by a northwest trend and lack of neotectonic features (i.e., faceted spur-ridges and fault scarps).

The western mountain-front escarpment (mountain-front segments 2, 3 , 4 and 5) is generally dominated by constructional landforms that form a stepped sequence of alluvial fans overlying Sierra Ladrones Formation. Streams primarily drain crystalline bedrock and form southwest- to west-sloping alluvial fans. Modern streams form shallow to deep arroyos inset below piedmont fans. The mountain front contains three segments that are divided on the basis of mountain-front position, orientation and tectonic features.

Figure 47. Simplified map of the Sandia Mountain front illustrating major drainage-basins (shaded), faceted spur-ridges (triangles) and mountain-front segments. Selected features include: Las Huertas Creek, del Agua Canyon (dA), del Ojo del Orno (dO); Juan Tabo Canyon (JT), Bear (BC), Pino (PC), Embudo (Eb); and Embudito (Ebo) Creeks; and the eastern margin of the Rio Grande Valley (IVE). Profile view of mountain front is illustrated on Figure 48. A series of small, elongate, low-order drainage basins developed on the western face of Rincon Ridge (RR). Sub-segment 4a forms a short, linear, northeast-trending mountain-front marking the transition from 3c to 4b.

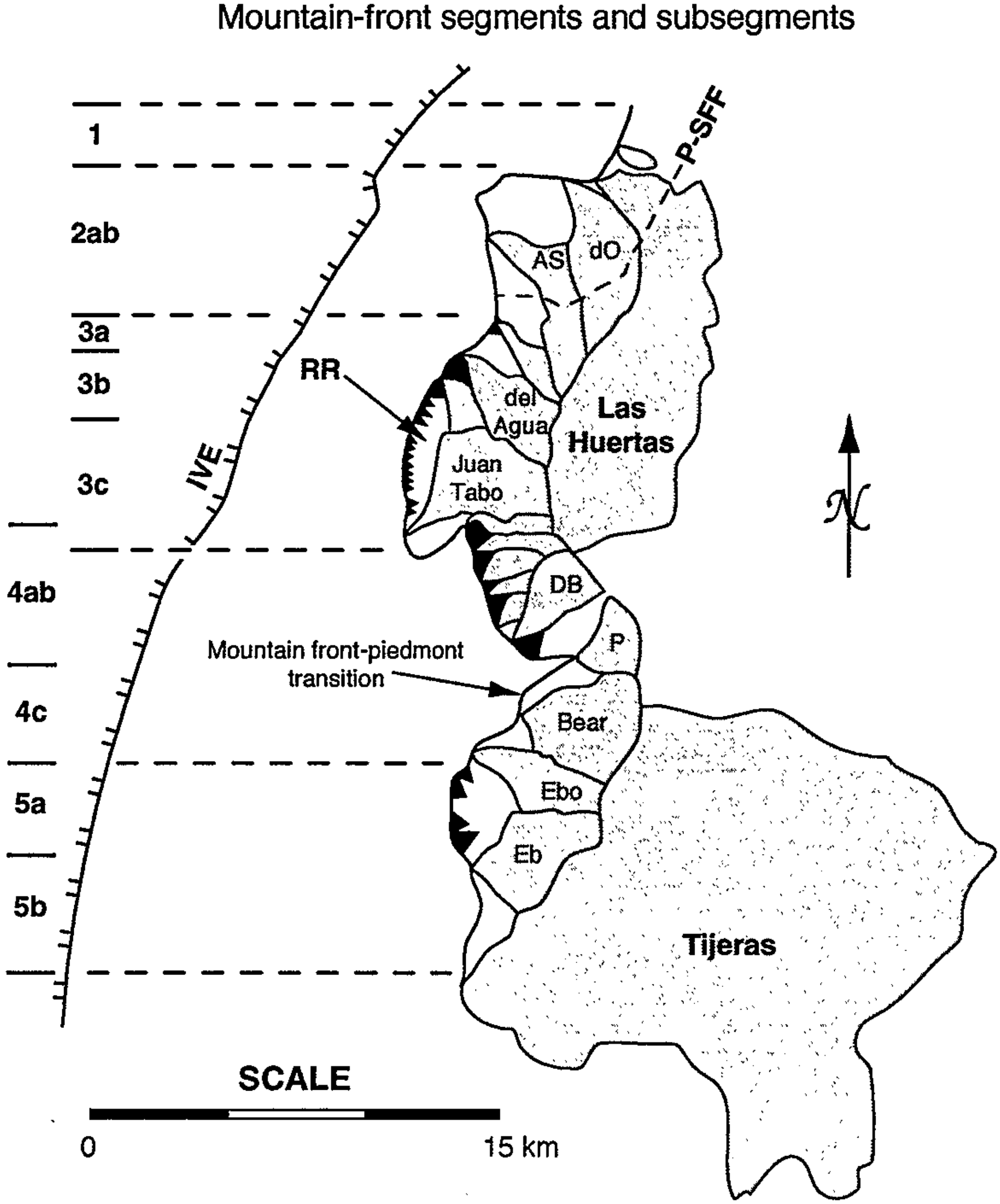
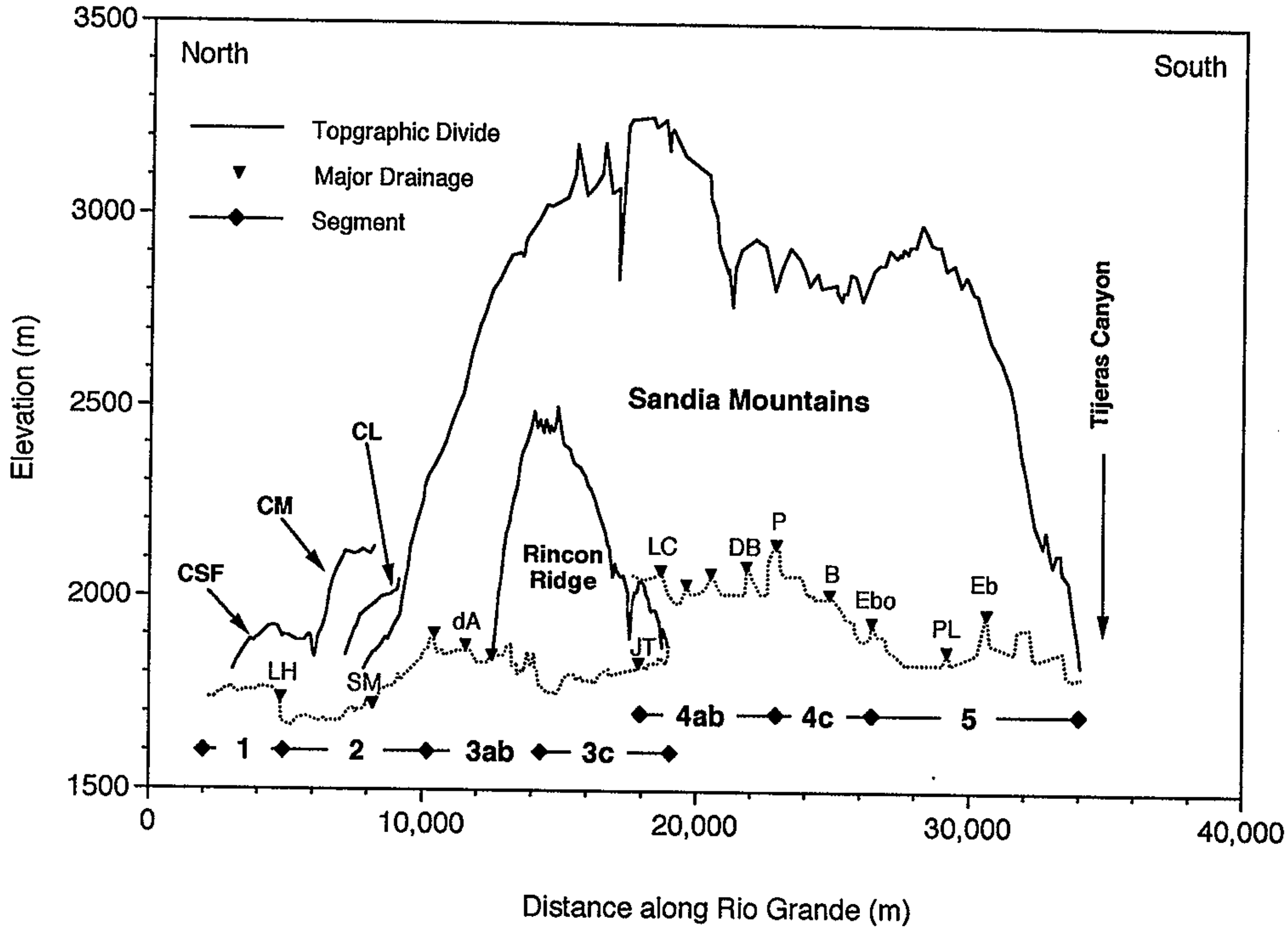
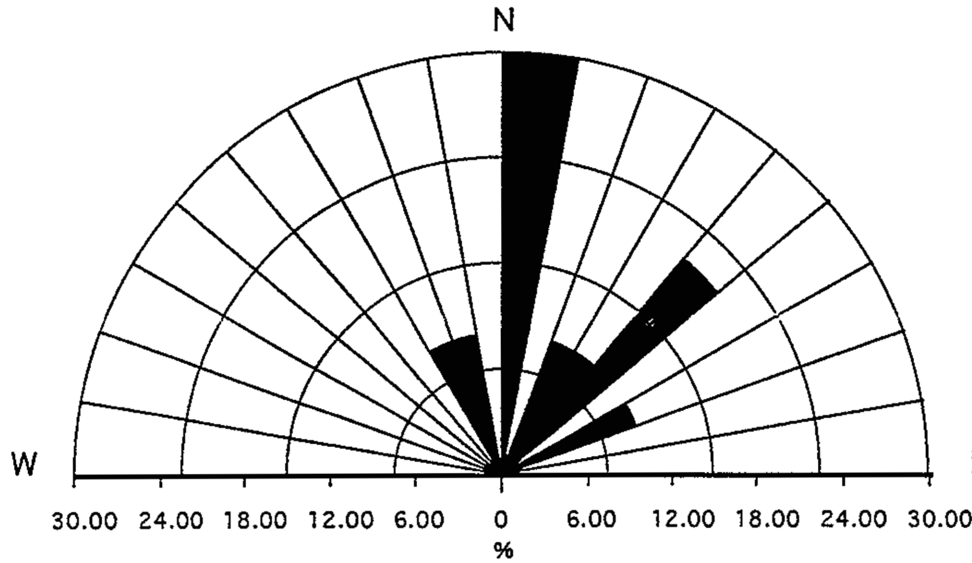

Mountain-front segments and subsegments
1
2ab
3a
3b
3c
4ab
4c
5a
5b
IVE
RR
P-SFF
AS
dO
del Agua
Las Huertas
Juan Tabo
DB
P
Mountain front-piedmont transition
Bear
Ebo
Eb
Tijeras
N
SCALE
0
15 km

Figure 48. Projection range-crests, mountain-piedmont junction, major canyons, salients and selected geomorphic features. The northern mountain-front is distinguished by a series of north-trending salients that include the Crest of Montezuma (CM), Cuchilla Lupe (CL) and Cuchilla de San Francisco (CSF). Mountain-front segments are distinguished by shifts in mountain front-piedmont position. Selected drainages include: Bear (BC), del Agua (dA), Domingo Baca (DB), Embudo (Eb), Embudito (Ebo), Juan Tabo Canyon (JT), La Cueva (LC), Las Huertas (LH), Pino (PC), Piedra Lisa (PL), and Strip Mine (SM) Creeks.



North
South
Topgraphic Divide
Major Drainage
Segment
Elevation (m)
3500
3000
2500
2000
1500
0
10,000
20,000
30,000
40,000
Distance along Rio Grande (m)
Sandia Mountains
Tijeras Canyon
Rincon Ridge
CL
CM
CSF
LH
SM
dA
JT
LC
DB
P
B
Ebo
PL
Eb
1
2
3ab
3c
4ab
4c
5

Figure 49. Mountain-front orientation and sinuosity. Top: orientation of ten mountain-front segments illustrating dominant north-trending salients, typically juxtaposed by shorter, northeast-trending re-entrant segments of the mountain front. Bottom: mountain-front sinuosity ratios for various segments. Segments are generally linear or slightly sinuous. Higher sinuosity values are measured along northern and southern margins of range.


N
W
E
30.00 24.00 18.00 12.00 6.00 0 6.00 12.00 18.00 24.00 30.00
%

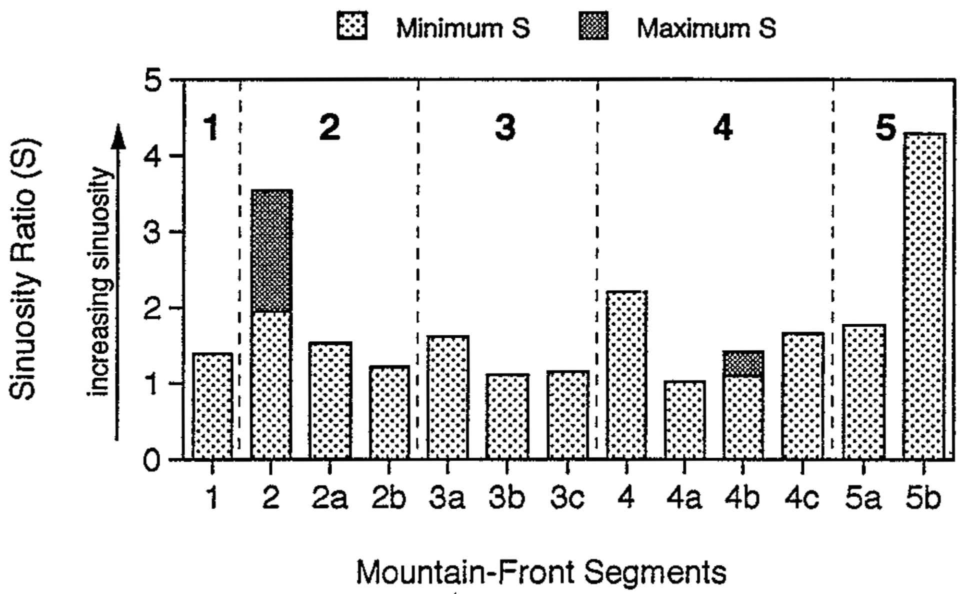
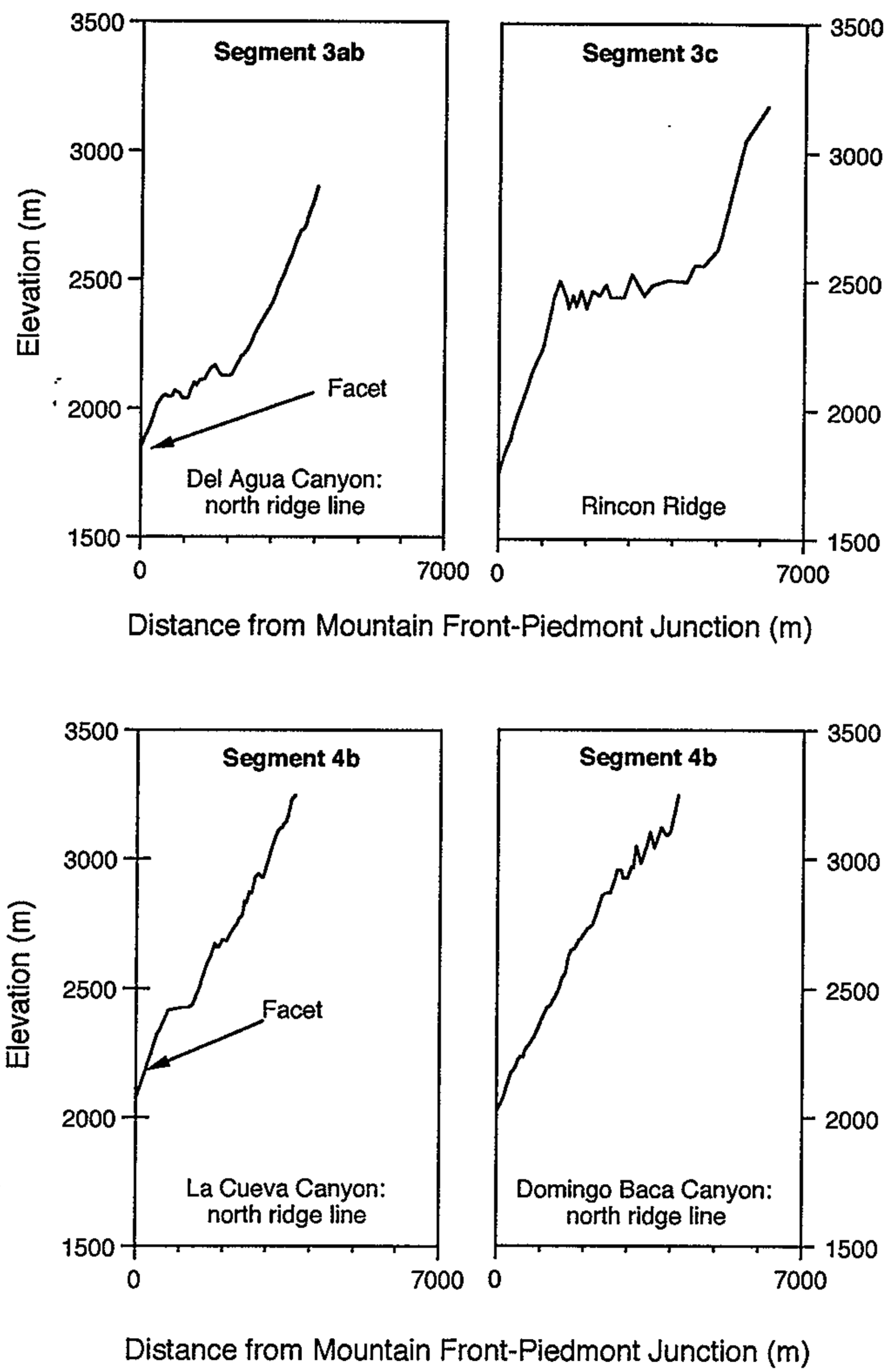

Minimum S
Maximum S
Sinuosity Ratio (S)
increasing sinuosity
0
1
2
3
4
5
1
2
3
4
5
1 2 2a 2b 3a 3b 3c 4 4a 4b 4c 5a 5b
Mountain-Front Segments

Figure 50. Full mountain-front escarpment profiles along spur-ridges measured from mountain-piedmont junction to range crest along segments 3, 4 and 5. Vertical exaggeration is 6.0. Profiles illustrate positions of large basal facets and mid-escarpment benches.



Segment 3ab
Facet
Del Agua Canyon: north ridge line
Segment 3c
Rincon Ridge
Elevation (m)
3500
3000
2500
2000
1500
0
7000
Distance from Mountain Front-Piedmont Junction (m)
Segment 4b
Facet
La Cueva Canyon: north ridge line
Segment 4b
Domingo Baca Canyon: north ridge line
Elevation (m)
Distance from Mountain Front-Piedmont Junction (m)

Figure 50 (contiuned).

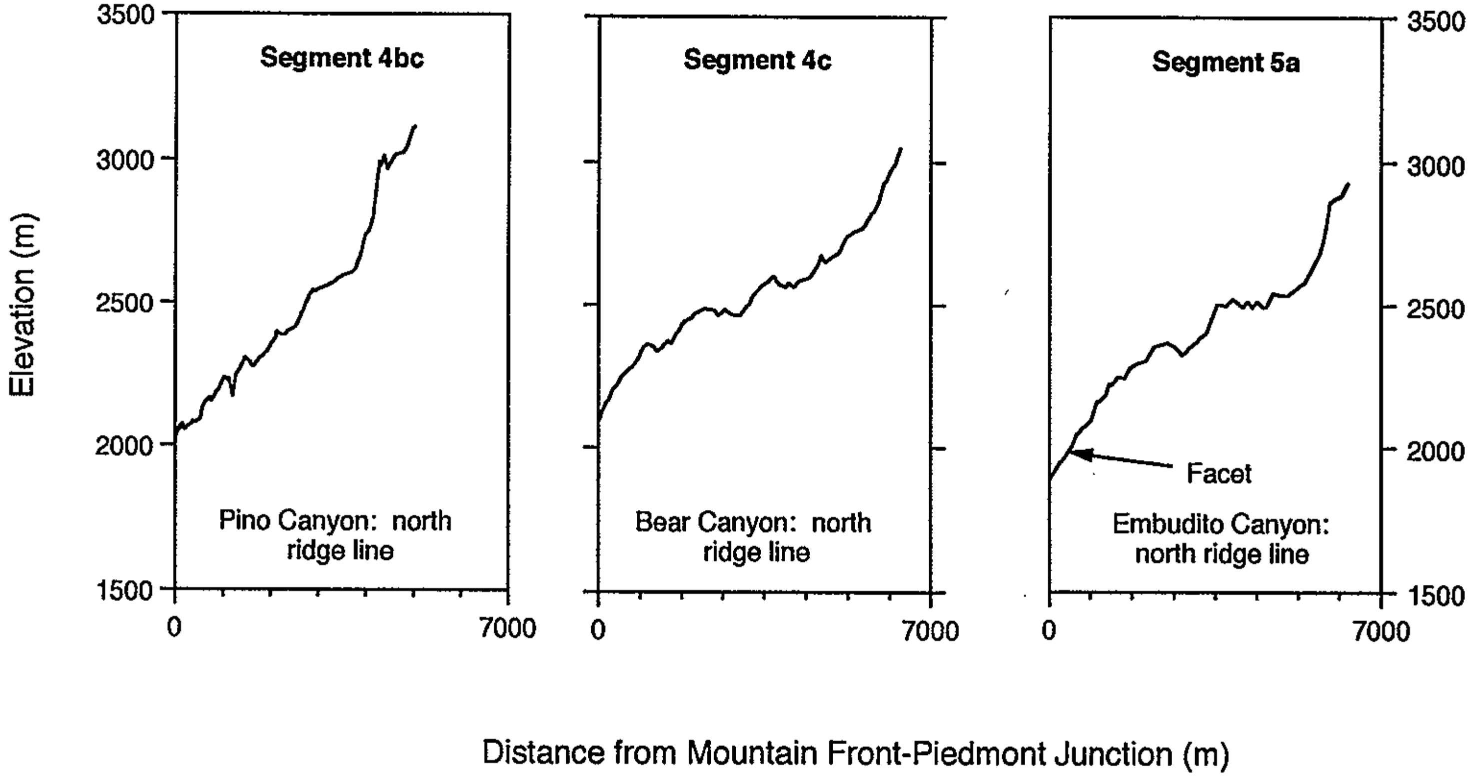


Figure 51. Distribution of cumulative elevation and percent-area (Strahler, 1952) along mountain-front segments 3, 4 and 5. The central portion of the range (segments 3 and 4) exhibits highest relief and greatest drainage area.

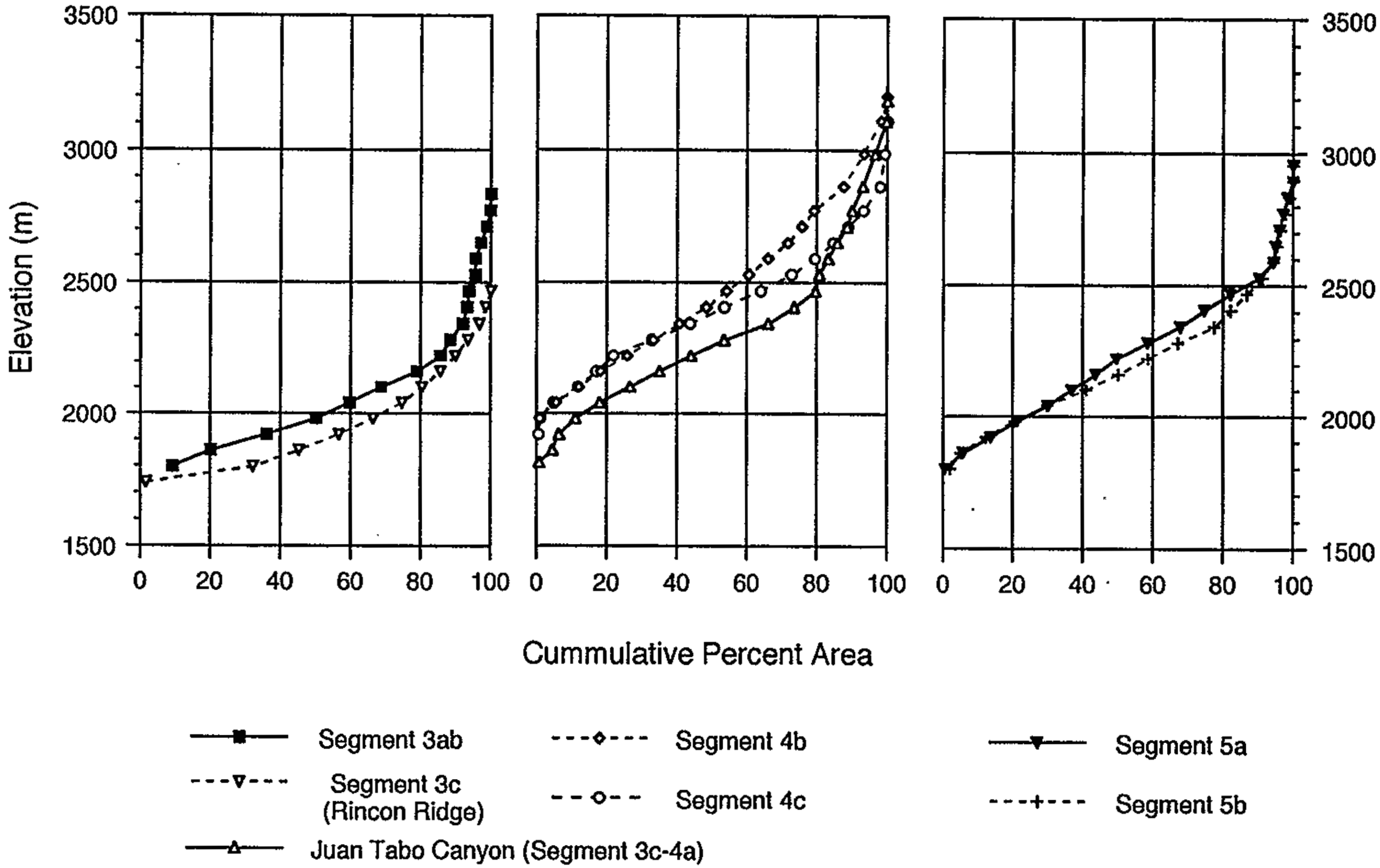

Elevation (m)
3500
3000
2500
2000
1500
0
20
40
60
80
100
Cummulative Percent Area
Segment 3ab
Segment 3c
(Rincon Ridge)
Juan Tabo Canyon (Segment 3c-4a)
Segment 4b
Segment 4c
Segment 5a
Segment 5b

Table 6. Summary of mountain-front morphology illustrated in Figures 47 through 51. Mountain-front faults include the, Escala (EF), Lomos (LF), Rincon (RF), Sandia (SF) and Valley View (VVF) faults. Incised piedmonts are dominated by pediment landforms. Aggradational piedmonts are dominated by typically constructional landforms (e.g., alluvial fans). Major geographic features include: Cuchilla de Escala (CE); Domingo Baca Creek (DB); Las Huertas Creek (LHC); Juan Tabo Creek (JTC); Sandia fault (SF); and Rincon Ridge (RR) are noted on table. Lithologic types are denoted as: Paleozoic through Mesozoic (PzMzu); Mesozoic (Mzu); Santa Fe Group (lower = Tsfl; upper = QTsfu); Precambrian (Rincon Ridge metamorphic = Xm; Sandia granite = Xg).

Segment	**1**
Lithology	S
Orientation	N25E±5°
Length (km)	3.0
Sinuosity	1.39
Divide distance (km)	14.0 (LHC)
Drainage-basin form	elongate
Faceted spurs	Yes / No
single / compound	
height (m)	24 - 43
dissected	Yes
Mountain-front fault	EF
offset deposits	QTpf1(?)
fault scarps	No
Piedmont character	erosional - dissected
landforms	pediment
slope direction	NW

Table 6 (continued).

Segment	2	2a	2b
Lithology	S	S	S
Orientation	N15-80W	N80W	N15W±5°
Length (km)	---	5.0	4.5
Sinuosity	1.95 - 3.53	1.53	1.22
Divide distance (km)	---	---	7.0
Drainage-basin form	elongate	---	elongate-equant
Faceted spurs single / compound	---	No/ No	No / No
height (m)	---	---	---
dissected	---	---	---
Mountain-front fault	---	---	VVF
offset deposits	---	---	QTpf1 & Qpf2
fault scarps	---	No	No
Piedmont character	erosional	erosional - dissected	erosional - aggradational
landforms	pediment	pediment	pediment - fan
slope direction		---	NW
valley floor ratio (Vf)	LHC: 4.43 at CE	---	---

Segment	3a	3b	3c
Lithology	M & G	M	M
Orientation	N40E±10°	N30E±10°	N0E±10°
Length (km)	2.0	3.2	
Sinuosity	1.62	1.11	1.15
Divide distance (km)	5.1 (dAC)	2.3 (dAC) 1.5 (RR)	5.8 (JTC) 1.5 (RR)
Drainage-basin form	low-order elongate	low-order elongate	low-order elongate (JTC is equant)
Faceted spurs single / compound	Yes /No	Yes / Yes	Yes / Yes
height (m)	24 - 43	37 - 244	24 - 33
dissected	No	Yes	No
Mountain-front fault	RF	RF	RF
offset deposits	Qp2-3	Qf7-8.r	Qf7-8.r
fault scarps	No	Yes	Yes
Piedmont character	aggradational	aggradational	aggradational
landforms	fan	fan	fan
slope direction	NW	W - NW	W-SW
valley floor ratio (Vf)	---	---	JTC: 0.77

Table 6 (continued).

Segment	4a	4b	4c
Lithology	G	G	G
Orientation	N60E±5°	N25W±10°	N45E±10°
Length (km)	2.5	5.5	4.0
Sinuosity	1.02 **Segment 4abc** **S = 2.20**	1.09 - 1.42	1.66
Divide distance (km)	1.5	3.6	4.9
Drainage-basin form	low-order elongate	high-order elongate	high-order equant
Faceted spurs single / compound	No / No	Yes / No	No /No
height (m)	---	146 - 354	---
dissected	---	Yes	---
Mountain-front fault	SF	SF	not observed
offset deposits	Mzu	Qp2-3(?)	not observed
fault scarps	No	No	No
Piedmont character	erosional	erosional - aggradational	aggradational
landforms	pediment	pediment - fan	fan
slope direction	SW	W - SW	W-SW
valley floor ratio (Vf)	---	La Cueva: 0.11 DB: 0.57	Pino Cyn: 1.77 Bear Cyn: 0.25

Table 6 (continued).

Segment	5a	5b
Lithology	G	G
Orientation	N0E±5°	N0E±5°
Length (km)	3.5	4.6
Sinuosity	1.77	4.29
Divide distance (km)	5.4	4.9
Drainage-basin form	high-order elongate	high-order equant
Faceted spurs single / compound	Yes / Yes	No /No
height (m)	73 220	---
dissected	Yes	---
Mountain-front fault	SF	SF
offset deposits	not observed	PzMzu & QTsf
fault scarps	No	No
Piedmont character	aggradational	erosional - aggradational
landforms	fan	pediment - fan
slope direction	W	W
valley floor ratio (Vf)	Piedra Lisa: 0.59	Embudo: 1.62

Segment 3 forms the mountain-front associated with Rincon Ridge and the Rincon fault. This segment is characterized by a linear, north- to northeast-trending mountain-front with numerous faceted spurs, fault scarps and elongated drainage basins. Less than 20 percent of the mountain front lies above 2100 m (Figs. 50 and 51) and drainage originates on Rincon Ridge and the Sandia Mountains. The Juan Tabo and del Agua drainages extend to the crest of the Sandia Mountains at 3184 to 3243 m.

Segment morphology is strongly influenced by Rincon Ridge, a prominent range-front salient located west of the crest of the Sandia Mountains rising about 720 m above the piedmont-mountain junction. The Rincon fault marks a narrow zone that is coincident with the base of the mountain front. The piedmont is dominated by alluvial fans and isolated, topographically high ridges of Sierra Ladrones Formation. The segment is divided into sub-segments 3a, 3b and 3c. Juan Tabo and del Agua Canyons cut through the northern and southern margins of Rincon Ridge and form laterally extensive fans that merge on the piedmont and restrict development of fans within segments 3b and 3c (Plate I).

Segment 3a forms a slightly sinuous (S = 1.62) mountain-front along the northern margin of Rincon Ridge and contains well developed, approximately 24-to 43-m high, relatively undissected basal facets and u-shaped canyons. Segments 3b and 3c form a linear mountain front with highly elongated drainage basins. The mountain-front is cut by large drainages of the Juan Tabo and del Agua Creek drainages, which enter the piedmont near sub-segment margins (i.e., 3a-3b and 3c-4a transitions). Segment 3b forms a linear (S = 1.11) mountain front that exhibits fault scarps and numerous, 37- to 244-m high, slightly dissected basal and composite facets. Drainage basins are typically elongate and very small and drainage is generally restricted to the western divide of Rincon Ridge. Segment 3c forms a linear (S = 1.15), north-trending mountain-front exhibiting several low (24- to 33-m high) undissected faceted spurs and well expressed fault scarps that displace Qf6-7, Qf7-8.r and Qpfy (Fig. 49; Table 6).

Segment 4 displays v-shaped valleys that distinctly widen near mid-escarpment benches. The piedmont is characterized by entrenched fans and local range-front pediments. The mountain-front associated with segment 4 sits east of Rincon Ridge and forms a steep escarpment rising approximately 840 to 1180 m above the base. The escarpment is broken by a series of benches between 2200 and 2400 m (Fig. 50). The benches may be formed by intra-range tectonic fault activity or may represent remnants of formerly extensive erosional surfaces (pediments or exhumed sub-alluvial benches). Less than 20 percent of the mountain front is higher than 2600 m. Fans are generally elongated, but become somewhat equant at sub-segment boundaries. A series of buried faults associated with the Rincon and Sandia faults marks the base of segment 4, which has a sinuous front (S = 2.20) and is divided into three generally linear sub-segments. Several high dissected faceted spurs are recognized between La Cueva and Domingo Baca Canyons (Kelley and Northrop, 1975). This segment contains drainages that originate at the highest parts of the range and may be capable of producing the greatest amount of runoff (Fig. 51). Segment 4a forms a northeast-trending mountain-front re-entrant that links the base of Rincon Ridge to the main front. Segment 4b forms a northwest-trending linear (S = 1.09 to 1.42) front associated with high, dissected faceted spurs. Segment 4c forms a slightly sinuous (S = 1.77), northeast-trending mountain-front re-entrant between Bear and Embudito Canyons (Fig. 49). Sub-segment 4c is transitional to 4b and 5a.

Segment 5 is north of Tijeras Canyon and marks the southern margin of the range. Range-crest elevations range from 2992 m at South Sandia Peak to about 1800 m in Tijeras Creek (Fig. 50). Less than 20 percent of the mountain-front is higher than 2300 m, resulting in a maximum relief of 1153 m between the crest and base of mountain front (Fig. 51). Segment 5 is separated into two sub-segments. Segment 5a segment forms a slightly sinuous (S = 1.77) mountain front with high dissected composite faceted spurs (Figs. 47 and 49). Segment 5b forms an embayed mountain front (S = 4.6) containing isolated hills of Paleozoic limestone on the piedmont (Table 6; Plates II and III).

<u>Summary</u>

Range-crests of the Sandia Mountains and Rincon Ridge have similar profile forms: a deeply dissected southern bench that abruptly rises to a narrow summit area (Figs. 47 and 48). Patterns in mountain-front morphology expressed across dissimilar rock-types along the Sandia Mountains (Figs. 8 and 47, Table 6) suggests that tectonics, not lithology, may strongly influence mountain-front form. Segmentation patterns also suggest that the Sandia Mountains are divided into separate tectonic blocks that experienced various amounts of uplift during the late Cenozoic. Sinuosity is fairly low along the mountain front, but it increases slightly at segment boundaries (Fig. 49, bottom) where drainage basins become slightly larger and somewhat equant in plan view (Fig. 47).

Strong similarities between the geometry of Las Huertas-Tijeras and del Agua-Juan Tabo drainages indicate drainages are influenced by mountain-front segmentation patterns. Aggradational piedmonts are commonly associated with linear mountain fronts and incised piedmonts are typically associated with embayed (re-entrant) mountain fronts. A short, northwest-trending mountain-front segment forms a minor eastward-step in the mountain front-piedmont junction south of Juan Tabo Canyon. This segment is sinuous (S = 2.20) and contains smaller, linear sub-segments exhibiting local range-front pediments and faceted spur ridges. Aggradational piedmonts are generally associated with higher range-crest elevations and incised piedmonts are generally associated with lower elevations. Incised piedmonts are common along segment boundaries, notably along the northern range-front margin where the Placitas fault forms a large-scale transfer structure along the southwestern margin of the Santo Domingo sub-basin.

Sandia Piedmont Soil Chronosequence

Semi-quantitative assessments of soil-profile development were made using the profile-development index (Harden, 1982; Harden and Taylor, 1983; Birkeland and others, 1989). Individual properties were described, in this study, using a soil-property index that allows for semi-quantitative evaluations of soil morphology derived from field data. The soil-property index was not weighted for horizon thickness because soil-profiles typically increase in thickness through time (Birkeland, 1984). Parent-material characteristics were measured, where possible, within soil profiles or substitute characteristics were recorded within alluvium from nearby modern streams (Appendix C-1). Variations of soil properties were evaluated by comparisons of soil-property indices calculated from suitable soil profiles. Incompletely described soils and those described in geomorphically unstable or unsuitable landscape settings, such as those exhibiting significant surface alteration, gully bed cementation or parent material differences, were not used to develop the study area chronosequence (Appendix B and C; P-3, P-4, P-11, P-12, P-16, P-20, P-21, P-24 through 31 and P-33).

Geomorphic surfaces were arbitrarily scaled to allow for semi-quantitative comparisons of soil-properties (Appendix C-3). Geomorphic surfaces were assigned integer values, intermediate surfaces were assigned fractional values. Comparisons of soil-property data against arbitrarily scaled geomorphic-surface data presents some difficulties in determining distributions among variables. Nonparametric Spearman's rank tests (Davis, 1986) were applied to the data to minimize this problem. For this test, soil-property and geomorphic-surface data were ranked and Spearman's rank correlation coefficients were determined (Figs. 52 and 53). These coefficients were then used to determine the correlation (association) among soil properties and geomorphic surfaces. Use of the Spearman's rank correlation coefficient assumes that geomorphic-surface differentiation did not solely rely upon these particular soil properties. This condition has been generally fulfilled because many geomorphic surfaces were differentiated by inset relations and surface character. A two-tailed test of correlation was employed to evaluate the significance of correlation among soil properties and geomorphic-surface position (Davis, 1986). The null hypothesis assumes that no association (i.e., data is randomly distributed) exists among the data.

The tests indicate that melanization, color lightening, consistence, soil structure and carbonate development are statistically distinct at a 95-percent level of significance for geomorphic surfaces QT1 through Q9 (Fig. 52); therefore, distributions of several soil properties are related to geomorphic-surface position. Rubification, paling, total texture and clay films were not distinct (Fig. 52), probably because of the strongly calcic nature of older piedmont soils.

Younger geomorphic surfaces (Q5 through Q9) exhibit slightly better correlation values (Fig. 53). Tests on these surfaces indicate that rubification, color lightening, total texture, consistence, clay films soil structure and carbonate development are statistically distinct at a 95-percent level of significance for geomorphic surfaces Q5 through Q9 (Fig. 53), whereas, paling and melanization are not distinct. The lower correlation coefficients for older geomorphic surfaces may be the result of significant ground-surface modification by streams developed on abandoned surfaces.

Carbonate and color-lightening exhibit the strongest trends for QT1-Q9; however, the color component is already factored into the carbonate parameter. Consistence exhibits the next highest correlation related to cohesion of sediments. Clay-film development is weakly correlated to geomorphic surface, especially in the older (Q4 through QT1) soils, and therefore, may not provide a consistent indicator of geomorphic surfaces within areas dominated by calcic soil development.

Soils developed on the Sandia piedmont generally exhibit progressive soil development on progressively older geomorphic surfaces and therefore, defines a chronosequence. Soil properties that progressively increase on older geomorphic surfaces include carbonate accumulation, coloration, structure, consistence and texture (Figs. 52 and 53; Table 4; Appendix C-3). Carbonate morphology generally shows progressive development on higher, dissected geomorphic surfaces (Fig. 37). Soils developed on piedmont deposits are used to distinguish geomorphic surfaces that allow for correlation to deposits that lack clearly defined stratigraphic (i.e., cross-cutting) relations.

Overall, piedmont soils are distinguished by the development of argillic and calcic horizons on geomorphic surfaces Q9 through Q5. Older surfaces are dominated by development of calcic and petrocalcic horizons. Variations in morphologic parameters between piedmont fans and pediment gravels are interpreted to be significant enough to form soil-stratigraphic units that demonstrate the occurrence of nine major geomorphic events resulting in the development of several pediments and fans.

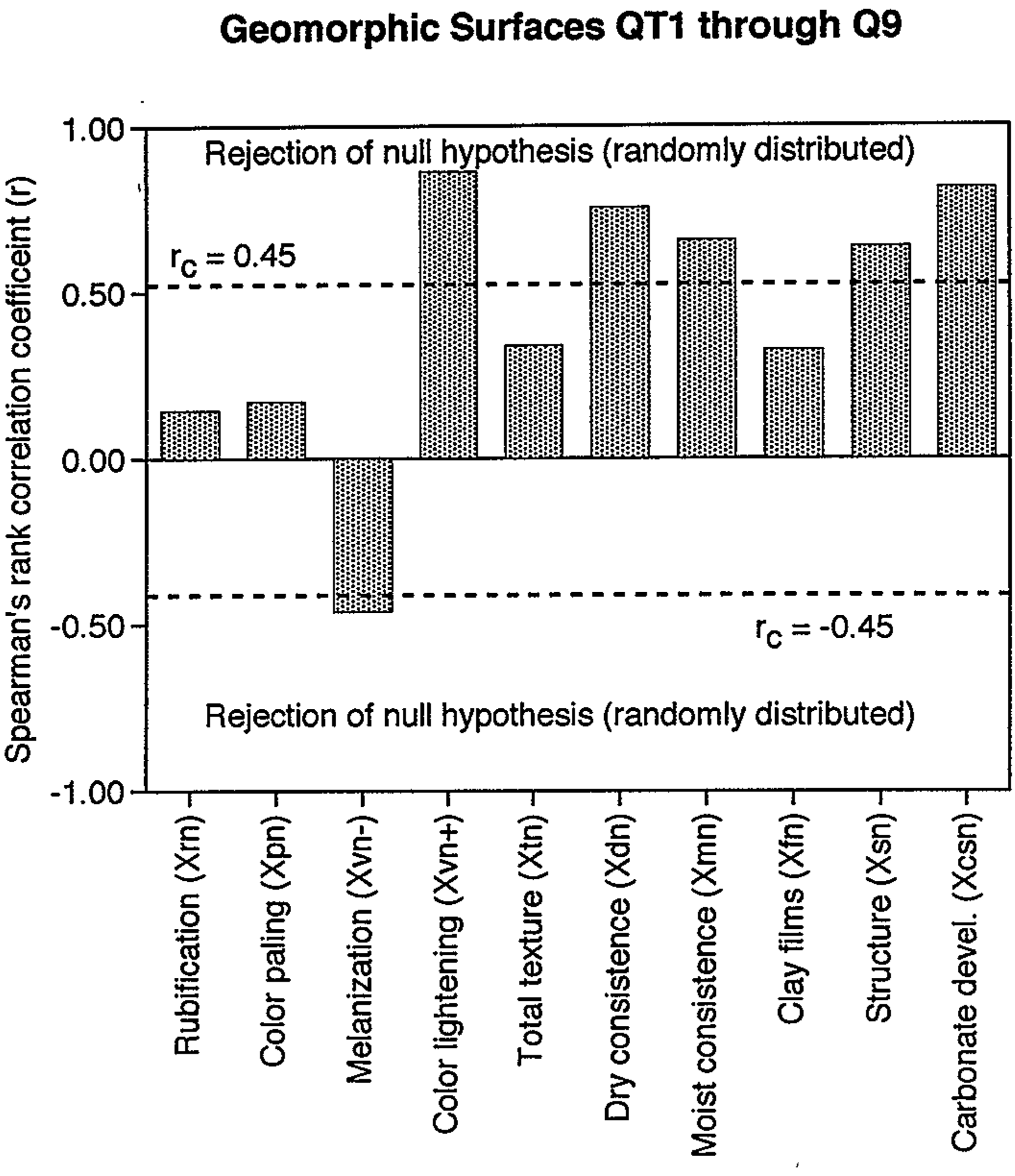


Figure 52. Nonparametric Spearman's rank correlation coefficients for normalized soil properties on geomorphic surfaces QT1 through Q9 (Appendix C-3). A two-tailed test of the null hypothesis (values are independent) indicates that melanization, color lightening, dry and moist consistence, soil structure and carbonate development are statistically distinct at the 95-percent significance level ($-0.45 \leq r_c \leq 0.45$; n=20).

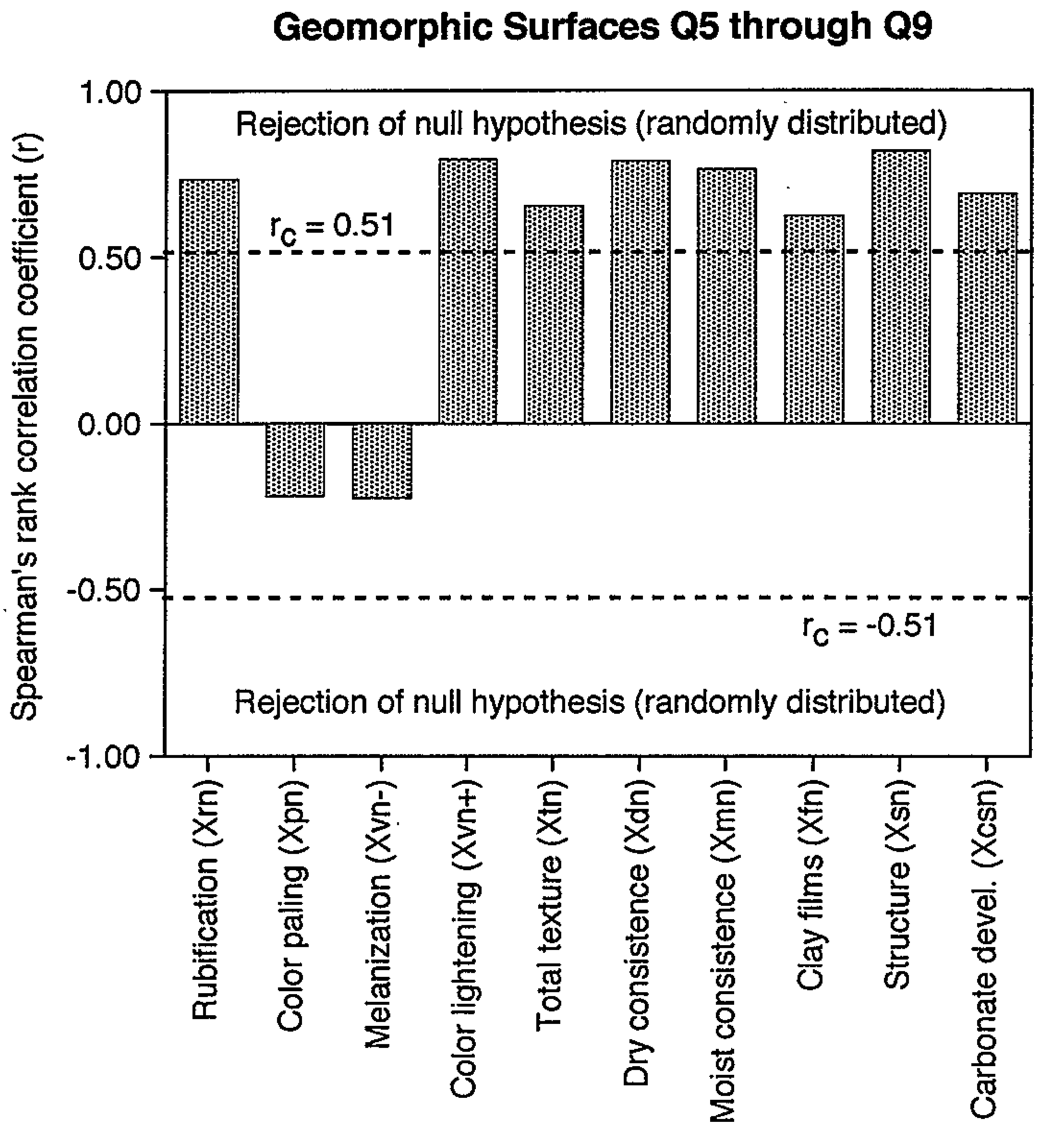


Figure 53. Nonparametric Spearman's rank correlation coefficients for normalized soil properties on geomorphic surfaces Q5 through Q9 (Appendix C-3). A two-tailed test of the null hypothesis (values are independent) indicates that rubification, color lightening, total texture, dry and moist consistence, clay film, soil structure and carbonate development are statistically distinct at the 95-percent significance level ($-0.51 \leq r_c \leq 0.51$; n=16).

DISCUSSION

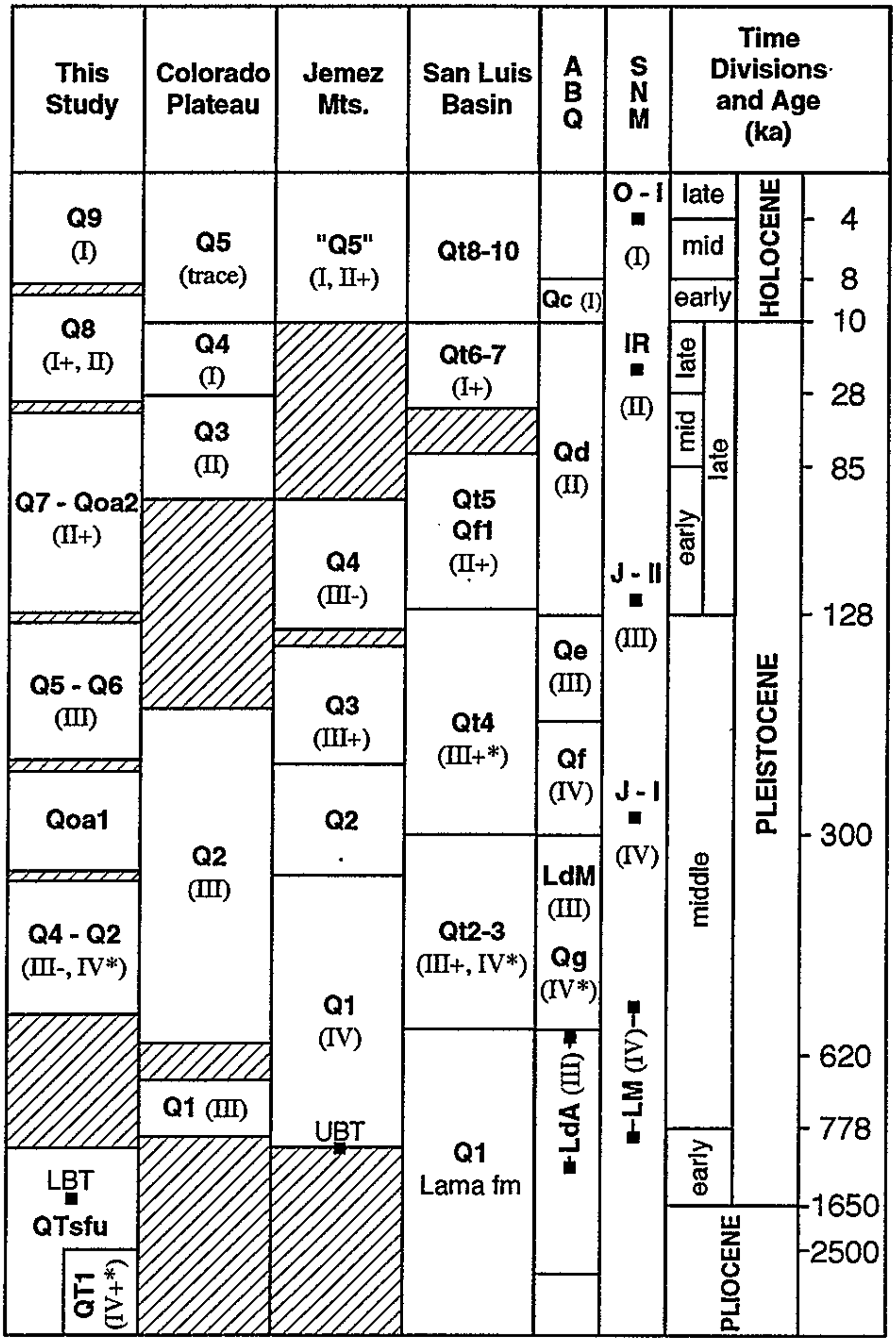
Age of Sandia Piedmont Deposits

Correlation of Piedmont Deposits

Age estimates of post-Santa Fe Group piedmont and axial-river deposits are based on cross-cutting relations (Table 2), landscape (topographic) position (Table 3) and correlation (Table 4) to soil chronosequences (Fig. 54) developed in similar physiographic settings (Fig. 13; Table 1). Although numerical age control was not established in this study, age-estimates based on soil development provides minimum estimates for the deposits. Several workers (Grimm, 1985; Drake and others, 1991; and Wells and others, 1990), in the eastern Colorado Plateau, provided age-constraints on alluvial deposits on the basis of inset relations among geomorphic surfaces to radiometrically dated (K-Ar method) basalt flows of the Zuni-Bandera and Mount Taylor volcanic fields (Fig. 13); however, soils in western New Mexico are generally non-gravelly and strongly influenced by eolian processes (Wells and others, 1990). Workers in the Jemez Mountains and Española basin (Dethier and Demsey, 1984; Dethier and others, 1988; Gonzalez, 1995) provided age-constraints of alluvial deposits from stratigraphic relations, amino-acid racemization of mollusks, cation-ratio dating and tephrochronology.

Ages of fans and terraces described in the southern San Luis basin of northern New Mexico (Kelson, 1986; Pazzaglia, 1989; Pazzaglia and Wells, 1990) were established on the basis of inset and stratigraphic relations, radiometric (^{14}C) dating, and correlation to glacial sequences in the Sangre de Cristo Mountains (Pazzaglia, 1989).

Figure 54. Estimated ages of geomorphic surfaces and deposits within the Sandia Mountains piedmont. Tentative correlation of alluvial stratigraphy is made to deposits described in the eastern Colorado Plateau (Drake and others, 1991; Wells and others, 1990), Jemez Mountains (Dethier and others, 1988); Albuquerque (ABQ) basin (Machette, 1978b, 1985), San Luis basin of northern New Mexico (Pazzaglia and Wells, 1990), and southern New Mexico (SNM) (Gile and others, 1981). Asterisks (*) indicate stripped soils, common on older geomorphic surfaces. Carbonate-morphological stages are given in parenthesis. Abbreviations of geomorphic surfaces and deposits include: Organ (O-I), Issacks Ranch (IR), Jornada (J-I and J-II) and La Mesa (LM) alluvium (Gile and others, 1981), the Llano de Albuquerque (LdA) and Llano de Manzano (LdM) surfaces, and the Sierra Ladrones Formation (QTsfu). Occurrences of lower (LBT) and upper Bandelier (UBT) Tuff indicate early Pleistocene ages (Dethier and others, 1988; Drake and others, 1991). Time scale is modified from Morrison (1991) and Sibrava and others (1986).


This Study
Colorado Plateau
Jemez Mts.
San Luis Basin
ABQ
SNM
Time Divisions and Age (ka)
Q9
(I)
Q8
(I+, II)
Q7 - Qoa2
(II+)
Q5 - Q6
(III)
Qoa1
Q4 - Q2
(III-, IV*)
LBT
QTsfu
QT1
(IV+*)
Q5
(trace)
Q4
(I)
Q3
(II)
Q2
(III)
Q1 (III)
"Q5"
(I, II+)
Q4
(III-)
Q3
(III+)
Q2
Q1
(IV)
UBT
Qt8-10
Qt6-7
(I+)
Qt5
Qf1
(II+)
Qt4
(III+*)
Qt2-3
(III+, IV*)
Q1
Lama fm
Qc (I)
Qd
(II)
Qe
(III)
Qf
(IV)
LdM
(III)
Qg
(IV*)
LdA (III)
O - I
(I)
IR
(II)
J - II
(III)
J - I
(IV)
LM (IV)
late
mid
early
HOLOCENE
late
mid
early
late
middle
early
PLEISTOCENE
PLIOCENE
4
8
10
28
85
128
300
620
778
1650
2500

Tephrochronology provided age control on basin-fill deposits of the Lama formation (Wells and others, 1987a; Pazzaglia and Wells, 1990). Several soils, however, are noncalcic and strongly influenced by loess deposition because of their proximity to glacial outwash deposits (Kelson, 1986; Pazzaglia, 1989). Ages of alluvial sequences described in the more arid environment of southern New Mexico (Table 1) (Gile and others, 1981) are constrained by tephrochronology in deposits underlying the La Mesa surface and by radiometric (^{14}C) dating of younger (Holocene and late Pleistocene) deposits (Fig. 54). Estimates of intermediate geomorphic surfaces were accomplished using isotopic (Gile and others, 1981) and pedogenic-carbonate accumulation methods (Harden and Taylor, 1983).

Ages of deposits described in the Albuquerque basin were determined from studies pedogenic-carbonate accumulation rates in soils of southwestern North America (Fig. 54) (Machette, 1978a and 1985). Radiometric (K-Ar method) and paleomagnetic dating of basalt provides numerical age-constraints on older geomorphic surfaces and deposits (e.g., Tercero Alto terrace, Llano de Albuquerque and Sierra Ladrones Formation) (Lipman and Mehnert, 1975; Bachman and Mehnert, 1978; and Geissman and others, 1990).

Soil-based correlation was somewhat hampered by slight variations of parent-material, eolian processes and climate; however, comparisons made to several alluvial chronologies in New Mexico should provide reasonable age-estimates of soils developed in aridic soil-moisture regimes (Table 1). Geomorphic surfaces QT1 through Q4 typically possess well developed, pale (7.5YR to 2.5Y) calcic and petrocalcic horizons with stage III- to IV+ carbonate morphology (Table 4). Argillic-horizon development progressively decreases on older geomorphic surfaces (QT1 through Q4), which generally become modified by local erosion or deposition. Geomorphic surfaces Q5 through Q7 typically possess well-developed, darker (7.5 to 10YR) argillic horizons developed over calcic horizons with stage II to III morphology (Table 4). Geomorphic surfaces Q8 and Q9 typically possess weakly developed calcic soils with little clay-film development (Table 4).

The Sierra Ladrones Formation (QTsfu) is a widespread basin-fill deposit underlying most of the study area. It typically is buried by post-Santa Fe Group piedmont and ancestral Rio Grande sediments. The occurrence of *Glyptotherium* (Lucas and others, 1993) and clasts of lower Bandelier Tuff constrains deposition to at least the early Pleistocene. Deposition of QTsfu may have ceased between 500 ka and 1.1 Ma (Hawley and others, 1976; Machette, 1978b; and Gile and others, 1981); however, entrenchment of the Rio Grande into the Santa Fe Group probably did not begin until the middle Pleistocene, about 500 ka (Hawley and others, 1976; Gile and others, 1981; and Machette, 1985).

Unit QTpf1 forms the highest preserved pediment in the study area and occurs as coarse-grained alluvium that unconformably overlies moderately tilted proximal-piedmont facies of the Santa Fe Group (Tsfl and QTsfup) along the northern range front. QTpf1 is recognized on the footwall of the Escala, Lomos Ranchos and Valley View faults and is buried within the Sierra Ladrones Formation; therefore, QTpf1 is temporally correlative to the Sierra Ladrones Formation.

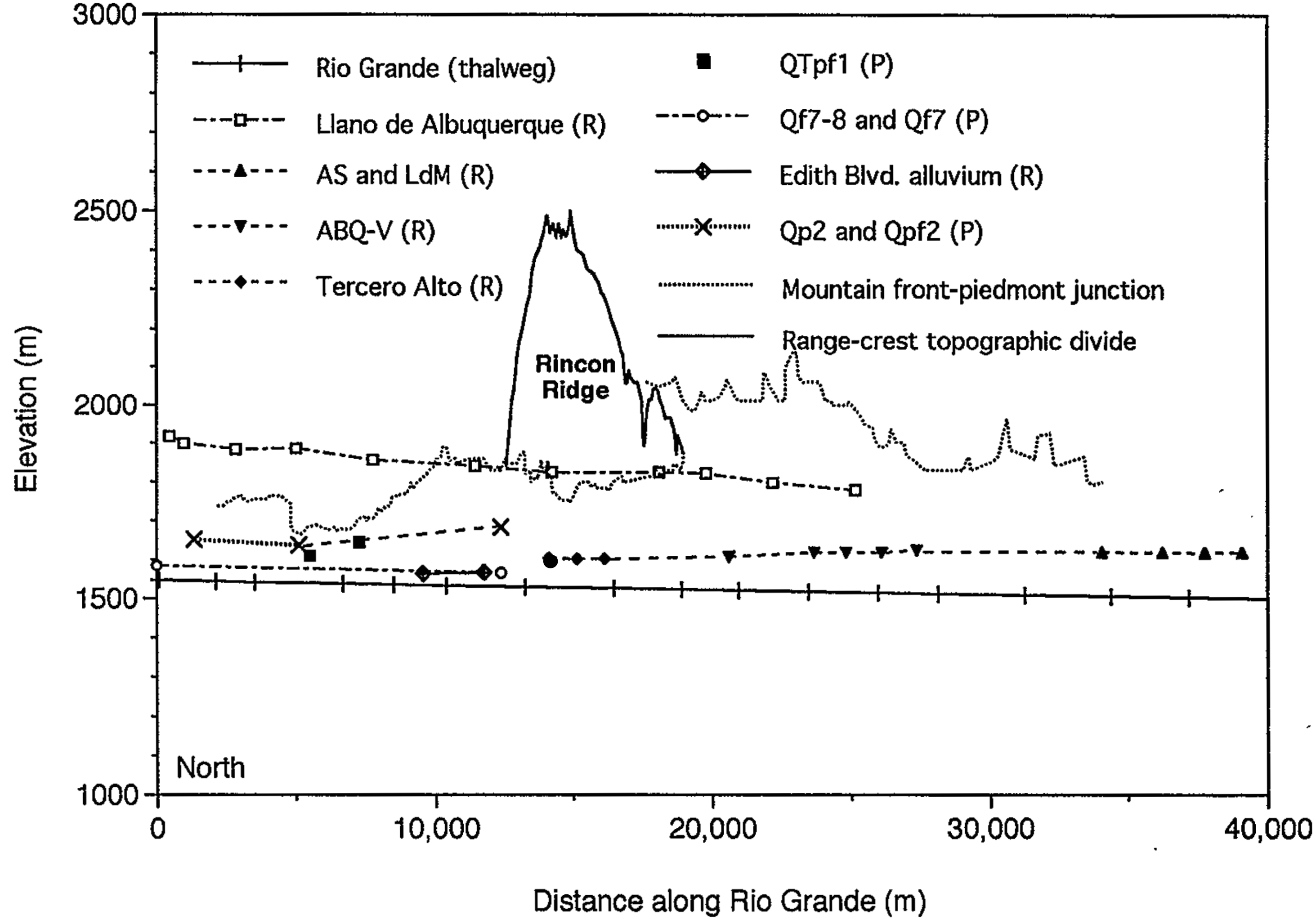
Age-estimates of geomorphic surface QT1 are determined by stratigraphic, soil-stratigraphic and landscape-topographic relations (Tables 2, 3 and 4). Soils formed on QTpf1 possess strongly developed petrocalcic horizons with stage IV+ carbonate morphology (Table 4). These strongly developed soils resemble those of the early Pleistocene La Mesa surface of southern New Mexico (Gile and others, 1981); however, QTpf1 occurs at a similar elevation to the Ortiz pediment (Picha, 1982) and is restricted to the footwall of the Lomos and Valley View faults. Therefore, QTpf1 may be associated with the Tuerto gravels (Stearns, 1953) of the Ortiz pediment, a topographically high surface of erosion originating from the Ortiz Mountains to the northeast. The age of the Tuerto gravels is overlain by basalt of the Cerros del Rio (north of the study area) and the Santa Ana (or San Felipe) Mesa, radiometrically dated at about 2.5 to 3.0 Ma (Bachman and Mehnert, 1978); however, Stearns (1979) indicates that the Ortiz pediment comprises more than one surface and the Tuerto gravels and Ancha Formation interfinger with the basalts. Bachman and Mehnert (1978) mention a strongly developed calcic soil underneath the basalt. The basalt constrains the age of the Tuerto gravels and geomorphic surface QT1 to the late Pliocene (about 2.5 to 3.0 Ma).

Geomorphic surface Q2 forms a laterally extensive pediment inset below QTpf1. Soils possess well-developed petrocalcic horizons with stage III- carbonate morphology (Table 4). Deposits of Qpf2 overlie sub-horizontal strata of the Sierra Ladrones Formation (QTsfu) with a slight angular unconformity indicating Qpf2 was laid down after deposition of QTsfu. Graphical projections (Fig. 55) indicate that geomorphic surface Q2 is below the Llano de Albuquerque, a relation that is consistent with the unconformable contact with QTsfu.

The Airport surface (Sunport surface of Lambert, 1968) and Llano de Manzano (LdM) occur at similar elevations relative to the Tercero Alto terrace, west of the Rio Grande; however, graphical projections do not account for tectonic deformation (Fig. 55), which would shift surface elevations across the piedmont. Paleomagnetic (secular variation) data and soil-profile development of basalt from the Albuquerque volcanoes provide maximum age-constraints of 150 to 250 ka (Geissman and others, 1990), suggesting that the Tercero Alto terrace is older than 150 to 250 ka. Graphical projections across the Rio Grande (Fig. 55) indicate the Airport and LdM surfaces are older than 150 to 250 ka. This relation is consistent with the stratigraphic position of the basalt of the Albuquerque volcanoes and age-estimates based on carbonate accumulation studies (about 320 ka, Machette, 1985). On the basis of the unconformable contact with the Sierra Ladrones Formation and graphical projections of Q2 to the Tercero Alto terrace and Airport surface, geomorphic surface Q2 is middle Pleistocene in age (Fig. 54).

Fan and pediment alluvium of Qf4, Qf4-5 and Qp4-5 are recognized as topographically high inliers of deeply dissected fans developed on the hanging wall of the Rincon and Sandia faults. Geomorphic surface Q4 is inset below Q2 and Q3 and may be inset by the alluvium of Edith Boulevard (Table 2). Pediment alluvium of Qp4-5 is inset below Qp2-3 along the mountain-front south of Rincon Ridge. Soils developed on geomorphic surface Q4 are stripped but locally display reddish colors on the ground, an indicator of rubified (argillic?) soils. Q4 possesses strongly developed petrocalcic horizons with stage IV carbonate morphology

Figure 55. Projections of the topographic divide on Rincon Ridge, mountain front-piedmont junction and selected geomorphic surfaces. The projection is oriented parallel to the range-crest of the Sandia Mountains (see Fig. 48). Explanation of projection methods are described in the methods section. Projections of geomorphic surfaces QT1 and Q2 are made using trigonometric projections to the eastern margin of the Rio Grande. All other surfaces are graphically projected into the profile (Table 3). Selected features are projected down-slope (P) are roughly parallel to the direction of flow along the Rio Grande (R). The Llano de Albuquerque (LdA) forms the topographically highest surface west of the Rio Grande. The LdA represents the constructional surface defining the "top" of the Sierra Ladrones Formation (Machette, 1985; Hawley, 1978). The topographic position of the Albuquerque volcanoes basalt (ABQ-V), Tercero Alto terrace, Airport surface (AS) (320 ka, Machette, 1985) and Llano de Manzano surface (LdM) lie at similar elevations and may represent geomorphically correlative surfaces; however, variations in elevation may be the result of differential movement across major faults (e.g., Lomos, Rio Grande Rincon and Valley View faults). Geomorphic surfaces Q7 and Q8 lie below the Airport and Llano de Manzano surfaces and represent younger surfaces. Pediments of Qp2-3 and Qp4-5 lie near the mountain front-piedmont junction south of Rincon Ridge.



Rio Grande (thalweg)
Llano de Albuquerque (R)
AS and LdM (R)
ABQ-V (R)
Tercero Alto (R)
QTpf1 (P)
Qf7-8 and Qf7 (P)
Edith Blvd. alluvium (R)
Qp2 and Qpf2 (P)
Mountain front-piedmont junction
Range-crest topographic divide
Rincon Ridge
North
Elevation (m)
3000
2500
2000
1500
1000
0
10,000
20,000
30,000
40,000
Distance along Rio Grande (m)

and grussified granitoid clasts (Table 4). Age estimates made on the basis of inset relations and carbonate morphology suggest that geomorphic surface Q4 is middle Pleistocene in age (Fig. 54).

Alluvium of Qp2-3 forms topographically high pediments south of Rincon Ridge. Qp2-3 straddles the southern drainage divide of Juan Tabo Creek and formed a broad pediment prior to entrenchment of Juan Tabo Creek. Unit Qp2-3 is inset by Qp4-5 and sits at elevations similar to the Llano de Albuquerque (LdA) surface (Fig. 55); however, tectonic deformation may have shifted surface elevations. Unit Qp2-3 is tentatively correlated to geomorphic surfaces Q2 or Q3 on the basis of inset relations with Qf6 and Qp4-5; however, Qp2-3 could be correlative to the Llano de Albuquerque (about 500 ka, Machette, 1985) or even to QT1. Qp2-3 consists of slightly weathered and pitted granitoid boulders. In contrast, QTpf1 contains grussified granitoid clasts; however, the clasts of Qp2-3 may be weakly weathered because of their large size. Soils were not described on Qp2-3 because of the bouldery nature of deposits and lack of accessible locations. On the basis of inset relations with Qp4-5, Qp2-3 is at least middle Pleistocene in age.

Soils developed on the Qt3 terrace in Las Huertas Creek (Plate I) possess weakly developed calcic horizons with stage II carbonate morphology (Table 4). Estimates of Qt3 are inconclusive because of parent-material variability and ambiguous physical correlation to surfaces of Qp3 (Fig. 20; Table 3). Perhaps, carbonate morphology on Qt3 may be lower because of the generally fine-grain nature of the deposit, increased precipitation or decreased dust-flux within the range; however, the causes of apparently low carbonate morphology was not resolved in this study. Soils on pediment alluvium (Qp3) were not described because of poor exposures and the coarse-grained nature of deposits. Age estimates of geomorphic surface Q3 are therefore, constrained by inset relations between Qpf2 and Qpf5 (Table 2) to the middle Pleistocene (Fig. 54).

Geomorphic surfaces Q5 and Q6 occur at similar landscape-topographic positions and possess similarly developed soils (Table 4). Unit Qpf5 closely resembles Qf6 except that the surface of Qpf5 exhibits less dissection by streams originating on the piedmont. Geomorphic surface Q5 forms extensive pediments and strath-terraces inset below Q2 and Q3. Qf7a is inset below Qpf5 (Table 2). Outcrop patterns (Plate I) suggest that the alluvium of Edith Boulevard is inset below Qpf5, which is younger than the Edith alluvium because soil-profile development more closely resembles Qf6 than Qf4 (Table 4). Unit Qf6 buries Edith alluvium and forms laterally extensive fans inset below the Llano de Manzano surface. Soils formed on geomorphic surface Q6 possess well-developed argillic and calcic horizons with stage III carbonate morphology. On the basis of on carbonate and clay-film development and inset relationship with the Llano de Manzano, geomorphic surface Q6 is at least late-middle Pleistocene in age (Fig. 54).

The alluvium of Edith Boulevard (Qoa1) forms the earliest post-Santa Fe Group axial Rio Grande deposits within the study area. Outcrop patterns suggest that Qoa1 is inset below the Llano de Manzano (about 320 ka, Machette, 1985), Q2 and Q4 (Plates I and II; Lambert, 1968, geologic map). Constraints on the age of Qoa1 is not well established. Distinctive clasts of densely welded tuff derived from the Jemez Mountains (Valles Caldera) first appear in terraces of the Jemez River, which enters the

Rio Grande just northwest of the study area. First occurrences of this clast are tentatively constrained amino-acid racemization dates of mollusk shells between 350 and 450 ka (J.B. Rogers, 1994, personal communication), potentially providing a maximum constraint on the timing of deposition. Better understanding of geomorphic and stratigraphic relations among deposits west of the Rio Grande could resolve age-estimates of the Edith alluvium. Outcrop patterns of basalt of the Albuquerque volcanoes (Lambert, 1968, geologic map) suggests that the basalt stratigraphically overlies the alluvium of Los Duranes Boulevard; however, Lambert interprets the Los Duranes alluvium to be inset below (i.e., younger than) the Albuquerque volcanoes. Lambert (1968) interprets these fluvial deposits to form a progressively inset sequence of cut-and-fill fluvial (ancestral Rio Grande) terrace-deposits comprising the alluvium of Los Duranes, Edith and Menaul Boulevards. Recent studies of water-well data on the West Mesa suggest that these deposits may comprise a fairly thick aggradational package of sediment (J.W. Hawley, 1995, personal communication) rather than a series of distinct cut-fill events (Lambert, 1968); however, stripped soils bounding the tops of the alluvium of Edith and Menaul Boulevards suggests that deposition occurred as distinct aggradational episodes followed by periods of landscape stability and soil formation.

Coarse-grained deposits of the Edith alluvium are characterized by rounded, quartzite-rich, conglomerate derived from northern New Mexico and southern Colorado during "degrading" glacial climatic conditions (Lambert, 1968). The occurrence of *Bison* (Rancholabrean), stratigraphic position between geomorphic surfaces Q4 and Q6, and inset position below the Llano de Manzano indicates a middle-Pleistocene age of deposition for the alluvium of Edith Boulevard (Fig. 54) (Lambert, 1968).

According to Lambert (1968), deposition of the alluvium of Menaul Boulevard (Qoa2) occurred during a glacial period. Qoa2 buries Qf6 and is buried by early late Pleistocene deposits of Qf7 (Figs. 30 and 45; stratigraphic section S-4, Appendix D) and may have been deposited during the early to middle-late Pleistocene (Fig. 54). Alluvium of Edith and Menaul Boulevards possess stripped soils that display remnants of cambic and argillic horizons, which suggests deposition was punctuated by periods of relative surface stability for at least several thousand years between depositional events (soil profiles P-24 and P-25, Appendix B; stratigraphic section S-4, Appendix D). The alluvium of Menaul Boulevard is interpreted to represent a late Pleistocene depositional terrace formed by the ancestral Rio Grande during a glacial period (perhaps, early Pinedale or Bull Lake stages).

Deposits associated with geomorphic surface Q7 are divided into two sub-units based on inset relations and soil-profile development. Both sub-units are inset below Qf6. Soils possess moderately developed argillic and calcic horizons that are similar to early late Pleistocene geomorphic surfaces described in northern and western New Mexico (Drake and others, 1991; Pazzaglia and Wells, 1990); therefore, geomorphic surface Q7 is interpreted to be early late Pleistocene in age (Fig. 54).

A wedge of coarse-grained fan alluvium derived from Rincon Ridge (Qf7-8.r) possesses moderately developed clay films with weakly developed calcic horizons (Table 4). Inset relations indicate that Qf7-8.r is younger than geomorphic surface Q6 and may be correlative to Q7 or Q8. On the basis of soil development and comparisons to other soil chronosequences (Fig. 54), Qf7-8.r is interpreted to be latest Pleistocene or early Holocene in age.

Deposits associated with geomorphic surface Q8 are about 18 to 36 m above the modern floodplain of the Rio Grande (Table 3). The deposits are truncated by the inner valley escarpment of the Rio Grande, which may have formed when the Rio Grande incised into the piedmont during the latest Pleistocene at about 17 ka (Lambert, 1968; Hawley and Hasse, 1992); however, this escarpment could have also formed by lateral migration of the Rio Grande during the Holocene after the river had aggraded to near its present level. Qf8 contains coarse-grained debris-flow alluvium suggesting deposition during a time of greater effective precipitation or during a large-magnitude storm event. Soils are weakly developed and exhibit thin clay films and stage I+ to II carbonate morphology (Table 4). On the basis of soil development, geomorphic surface Q8 is interpreted to have formed during the latest Pleistocene or early Holocene (Fig. 54).

Geomorphic surface Q9 comprises fan and stream alluvium associated with modern drainages established after abandonment of Q8 during the latest Pleistocene. Soils are weakly developed and exhibit slight accumulations of pedogenic carbonate (Table 4), suggesting deposition of Q9 during the middle to late Holocene (Fig. 54).

Influence of Climatic Change on the Sandia Piedmont

Climatic changes during the Quaternary typically vary from cooler and wetter glacial conditions, to warmer and drier interglacial conditions (Barry, 1983; Imbrie and others, 1984). Preliminary correlations to other alluvial sequences in New Mexico suggest that regional climatic variations may have influenced piedmont deposition (Fig. 54) (Dethier and others, 1988); however, older (pediment) units are preferentially preserved along the northern mountain flank, suggesting tectonic influences on landform preservation (Dohrenwend, 1987).

Climatic influences on piedmont deposition may be the result of enhanced physical and chemical weathering within the Sandia Mountains during periods of enhanced effective moisture during glacial "climates" or during transitions between glacial and interglacial periods where vegetative cover is reduced and sediment load increases (Bull and Schick, 1979; Bull, 1991). Deposits of the Sandia Mountains were probably not directly associated with mountainous glaciation. The crest of the Sandia Mountains is slightly lower than the highest peaks (>4270 m) of the Sangre de Cristo Range of northern New Mexico. References to glacial features on the Sandia Mountains were not recognized in my review of the geologic literature. Features consistent with mountainous glaciation (e.g., cirques, moraines or rock glaciers) were not recognized in the Sandia Mountains.

Piedmont deposits are generally coarse-grained, suggesting that they were laid down during times of greater effective moisture. The piedmont is incised by Holocene deposits and arroyos, suggesting that much of the piedmont became abandoned during the latest Pleistocene when the Rio Grande incised about 37 m (Hawley and Hasse, 1992) below present base level.

According to Lambert (1968), coarse-grained axial-river deposits associated with the ancestral Rio Grande (alluvium of Edith and Menaul Boulevards) were presumably laid down during the end of a glacial period when the river could transport a coarse-grained bedload south from the Sangre de Cristo and Tusas Mountains. Likewise, fan deposition may have occurred during transitions to interglacial times when removal of vegetation resulted in destabilization of hill slopes, which increased sediment availability for the transport of debris from the mountain front (Bull and Schick, 1979). Deposition of coarse-grained fill-terraces of the alluvium of Edith and Menaul Boulevards suggests climatic influences on deposition by the ancestral Rio Grande. Qf7 and Qf8 may be temporally equivalent to the Pinedale glaciation of the Rocky Mountains during the late Pleistocene (Wisconsinan). Geomorphic surfaces Q6 and Q7(?) may be temporally equivalent to the Bull Lake glaciation (perhaps, the Illinoisan stage) during the early late to late-middle Pleistocene.

Evaluation of the climatic control on piedmont deposition was difficult in this study because of the lack of numerical age control. Another problem was in comparisons to alluvial sections developed under by climatic mechanisms. For example, Quaternary deposits in northern New Mexico are strongly influenced by Pleistocene periglacial environments (Kelson, 1986; Pazzaglia, 1989), whereas, the stratigraphy of the eastern Colorado Plateau (Wells and others, 1990; Drake and others, 1991) and southern New Mexico (Gile and others, 1981) were influenced by climatic changes or increases in effective precipitation.

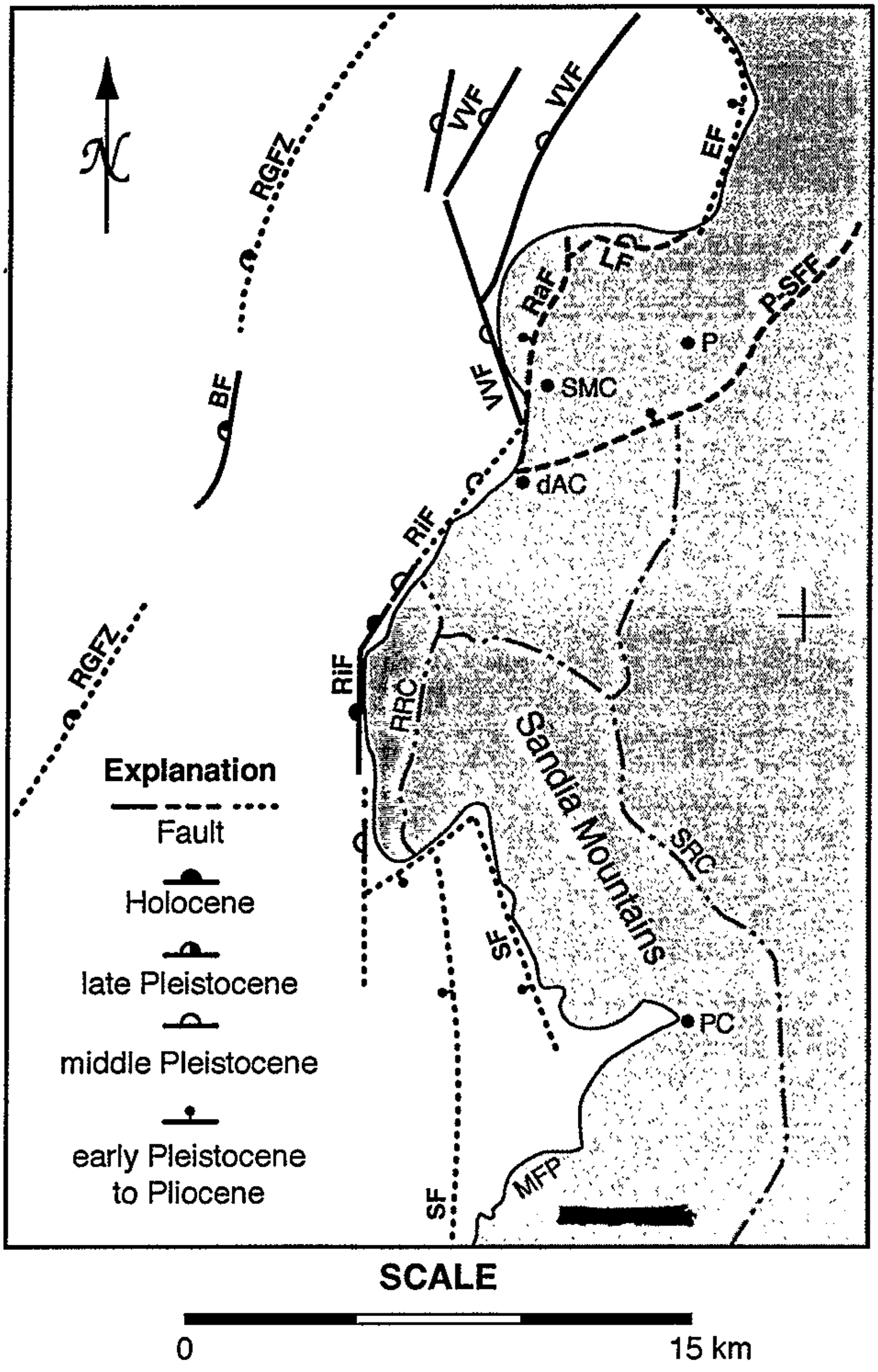
History of late Pliocene and Quaternary Faulting

Age and Distribution of Faults

Quaternary deposits can constrain ages of major tectonic events resulting in seismogenic rupture of the ground surface. Timing of fault activity is constrained by cross-cutting relations among stratigraphic units (Fig. 54) and fault-scarp degradation models (Bucknam and Anderson, 1979; Machette, 1982 and 1989). Ages of ground-rupture events on major faults were placed into four categories on the basis of latest ground-rupture activity: Holocene, late Pleistocene, middle Pleistocene, and early Pleistocene through Pliocene (Fig. 56). Faults exhibiting displacement of pre-middle Pleistocene deposits (Sierra Ladrones Formation and QTpf1) include the Placitas, San Francisco, Escala, Ranchos and Sandia faults. Faults that displace middle-Pleistocene geomorphic surfaces (Q2 through Q4) include the Valley View and Lomos faults. Although the Rio Grande fault zone (RGFZ; Russell and Snelson, 1990 and 1994) is generally obscured by the position of the Rio Grande, the Bernalillo fault (a related structure) displaces middle-to-late Pleistocene deposits (Fig. 56). The Rincon fault displaces middle-to late-Pleistocene deposits, but movement last occurred during the middle Holocene (Table 5; Figs. 43 and 56).

The Placitas and San Francisco faults form master basin-margin faults (May and others, 1994; Russell and Snelson, 1994) along the northern flank of the Sandia Mountains (Fig. 56). These structures juxtapose Santa Fe Group against pre-Cenozoic rock, but are buried by Quaternary deposits. A stepped sequence of pediments developed on the northern flank of the Sandia Mountains spans the Lomos and Valley

Figure 56. Generalized fault-activity map of Sandia Piedmont study area. Solid lines indicate well-expressed movement. Dashed lines indicate inferred activity and dotted lines denote the approximate location of buried structures. Shaded semi-circles denote faults that display evidence activity of ground-rupture during the Holocene. Half-shaded semi-circles denote late Pleistocene activity; open semi-circles denote middle Pleistocene activity. The ball-and-bar denotes ground-rupture during the early Pleistocene or Pliocene. Major faults include, the Rio Grande fault zone (RGFZ), Bernalillo (BF), Escala (EF), Lomos (LF), Placitas and San Francisco (P-SFF), Rincon (RiF), Ranchos (RaF), Sandia (SF), and Valley View (VVF) faults. Selected drainage features include Strip Mine Canyon (SMC), del Agua Canyon (dAC), Pino Canyon (PC) and Rincon Ridge (RRC) and Sandia Crest (SRC) drainage divides. Upland areas (shaded) include the mountain-front and deeply dissected foothills along the northern flank. Selected features include the Sandia Mountains (SRC) and Rincon Ridge (RRC) range crests, and the mountain front-piedmont junction (MFP). The Escala fault presumably displaces QTpf1 but may be buried by Qpf2.


N
RGFZ
VVF
VVF
EF
LF
RaF
P-SFF
P
SMC
VVF
BF
dAC
RiF
RiF
RRC
RGFZ
Sandia Mountains
SRC
Explanation
Fault
Holocene
late Pleistocene
middle Pleistocene
early Pleistocene
to Pliocene
SF
SF
PC
MFP
SCALE
0
15 km

View faults and record deep dissection of the piedmont resulting from incision of streams across the hanging wall of the Placitas and San Francisco master faults (Plate I; Fig. 56). Deposits of the lower Santa Fe Group are recognized along the hanging wall of the Placitas and San Francisco faults, suggesting coeval movement and deposition during the Miocene.

Tectonic activity along the Placitas fault may have ceased since the formation of geomorphic surfaces QT1 and Q2 (Figs. 56; Table 5). Qp2 buries the Placitas fault, but QTpf1 does not cross the fault. If the Placitas fault was active during the early or middle Pleistocene, then remnants of QTpf1 should be recognized on the footwall. The San Francisco fault offsets deposits of the Ortiz surface (Tuerto gravels) north of the study area (Picha, 1982). Correlative deposits (QTpf1) at similar elevations on the hanging wall of the San Francisco and Placitas fault indicates that significant dip-slip movement has not occurred since the late Pliocene. Absence of Quaternary movement along the Placitas and San Francisco faults suggests that these structures form old, possibly inactive, rift-margin structures within the study area (Fig. 56) (Gonzalez, 1993 and 1995).

The Lomos (LF) and Escala faults (EF) developed on the hanging wall of the Placitas and San Francisco faults. The LF and EF displace Plio-Pleistocene deposits, but are buried by middle Pleistocene strata. The Valley View faults (VVF) displace upper Santa Fe Group and middle Pleistocene geomorphic surfaces. On the basis of on topographic profiles drawn from the Bernalillo 7.5-minute quadrangle, a scarp formed by the VVF has a maximum slope angle of approximately 11° and height of about 18 m (locality L-4, Appendix A-2), which is consistent with scarps older than 100 ka (see Fig. 43) (Bucknam and Anderson, 1979; Machette, 1982 and 1989).

The Sandia fault is recognized by vegetation lineaments along the mountain front. Quaternary deposits bury the fault, but the Santa Fe Group is offset to the south (Kelley and Northrop, 1975), therefore, movement along the Sandia fault occurred prior to the middle Pleistocene.

The trace of the Bernalillo fault segment of the Rio Grande fault zone is obscured by the position of the (modern) Rio Grande. Several north-striking normal-oblique faults cut basalts of Santa Ana (San Felipe) Mesa to the north (Fig. 3). The direction of normal displacement generally shifts to the northwest across a series of volcanic cones (Kelley, 1977, geologic map; Cather, 1992; May and others, 1994). The intersection between faults of opposing structural polarity represents the Santa Ana accommodation zone (Fig. 2) (Cather, 1992). The dominant structural trend in the study area is marked by northeast-trending traces of the Valley View faults (Figs. 3 and 38). This pattern suggests that the northeast extension of the (buried) Rio Grande fault zone may accommodate apparent variations in fault orientation across the Rio Grande. Axial facies of the Sierra Ladrones Formation extend across the Valley View fault but are restricted to the hanging wall of the Escala, Ranchos and Lomos faults, suggesting that the Rio Grande flowed through a relatively broad valley during the Pliocene. The present position of the Rio Grande is constrained to a relatively narrow channel along the base of Santa Ana Mesa, suggesting possible structural influence of river position by the Rio Grande fault.

A prominent erosional bench recognized midway up the mountain front suggests that a long period of relative pre-Quaternary tectonic quiescence was followed by resumption of uplift of the Sandia Mountains (Fig. 50). The bench is topographically higher than QTpf1 and may represent a Miocene or Pliocene surface of erosion or an exhumed sub-alluvial bench. Episodic uplift of the Sandia Mountains is consistent with results of apatite-fission track studies, which documents two periods of uplift (S.A. Kelley and others, 1992).

Fault-scarp morphological dating provides minimum age-estimates of ground rupture along the Rincon fault (Fig. 43). The latest ground-rupture on the Rincon fault occurred during the middle Holocene (Fig. 56). The penultimate ground-rupture event occurred during the late Pleistocene (about 100 ka), suggesting that this fault has a fairly long recurrence time. Examination of mountain-front projections (Fig. 48) indicates that Rincon Ridge experienced long-term uplift along the fault. Rincon Ridge and the Sandia Crest mark the highest segments of the mountain indicating that present mountain-front physiography resulted from tectonic linkage between Rincon Ridge and the Sandia Mountains. Inliers of deformed Mesozoic strata recognized on the hanging-wall of the Rincon fault (Plate III) support the occurrence of buried normal faults west of the basin margin, such as the Rio Grande and unnamed faults.

Spatial and Temporal Distribution of Strain

The activity and distribution of faults reveal patterns of ground rupture and provide information on the distribution of strain through the study area. Spatial and temporal patterns of faulting indicate that a general narrowing of the rift has occurred during the Quaternary (Fig. 56). This phenomenon is recognized elsewhere in the rift (Chapin and Cather, 1994; Gonzalez, 1995), especially along the Hubbell bench (Kelley, 1982b). Narrowing of the rift may be the result of removal of basin-margin irregularities (i.e., re-entrant structure) and transfer of strain across the footwall of basin-margin master faults (Ellis and Prexler, 1994) along the prominent eastward-step in the Albuquerque physiographic basin. Numerous late Quaternary fault scarps, recognized on the Llano de Albuquerque (Machette, 1982), supports the idea of continued transfer of strain across the footwall of other major basin structures (e.g., Rio Grande fault zone). Geophysical and bore-hole studies document significant normal displacement of the Santa Fe Group by the Rio Grande fault zone (Russell and Snelson, 1994; Hawley and others, 1995), indicating that it has been a temporally persistent inner-graben (basin) structure.

Basinward transfer of strain is well expressed along the northern range flank where it may be associated with the prominent east-step in the rift basin (Fig. 56). Unit QTpf1 is restricted to the footwall of Valley View, Ranchos and Lomos fault. The position and thickness of QTpf1 suggest coeval deposition and activity, suggesting that the margin of the Santo Domingo basin had transferred westward from the San Francisco fault by the beginning of QTpf1 deposition. The decrease in stratigraphic throw (Fig. 8) and age of displaced strata (Fig. 54) decrease northwestward into the basin, suggesting transfer of strain across the Placitas and San Francisco faults during the Pliocene (May and others, 1994; Russell and Snelson, 1994).

Mountain-Front Influence on Piedmont and Drainage-Basin Development

Fault-segmentation patterns along the front of the Sandia Mountains may influence the distribution and preservation of Quaternary landforms and deposits of the piedmont. Aggradational (fan) landforms predominantly occur along the western mountain-front. Pediments are common along the northern flank and along a narrow stretch of the range-front between Juan Tabo and Bear Canyons. Bedrock pediments of the Basin and Range are commonly located in tectonically stable regions, where erosional and depositional processes are approximately balanced for long periods of time (Bull, 1979; Dohrenwend, 1987). Tectonically active mountain-fronts are typically dominated by alluvial-fans and have linear mountain-fronts with major range-bounding faults along the base of the range.

Range-front faults along the Sandia Mountains typically display two deformational styles. A narrow, linear zone of well-defined faults forms along the base of the mountain. A wider, more diffuse zone of faults are commonly associated with sinuous mountain fronts. Similar patterns are described in the Sangre de Cristo Mountains of northern New Mexico where well-defined fault zones and linear mountain-fronts occur within a given fault-segments, whereas, wider zones occur at segment boundaries (Menges, 1988, 1990ab; Pazzaglia, 1989).

The relative lack of widespread correlation of geomorphic surfaces (QT1 through Q7) across the piedmont suggests that other, non-climatic factors may influence piedmont morphology, such as tectonic (Menges, 1988; Pazzaglia, 1989; Gonzalez, 1993) or hydrologic influences (Kelson and Wells, 1989). Tectonic or lithologic controls on piedmont morphology may be associated with the restriction of certain types of landforms to specific parts of the piedmont. Variations in landform and deposit character may also result from lithologic differences within the Sandia Mountains. Bull and Schick (1979) note that slopes underlain by weathering-limited slopes (e.g., granite) are generally more sensitive to climatic changes, can weather more rapidly and therefore, can yield more sediment than drainage-basins underlain by transport-limited slopes (e.g., metamorphic). Several geomorphic surfaces (Q5 through Q9) typically bury basin-margin structures, implying that tectonic control on deposition may be modified by climatic influences. Older deposits and landforms are typically preserved along the northern and southern margins of the range and along major segment boundaries. In particular, older landforms are preferentially preserved along the northern flank of the Sandia Mountains and southern margin of the Santo Domingo sub-basin, where several pediments bury major basin-margin structures. The piedmont associated with the northern Albuquerque basin, in contrast, generally contains younger deposits that bury Santa Fe Group deposits. This may be due to the lack of active mountain-front tectonic activity during the Quaternary. In contrast, relatively younger landforms are preserved to the south. Tectonic influences on piedmont morphology may thus, be expressed by landform type and preservation.

Mountain-front segmentation patterns and their relation to rift-margin fault structure is also complicated by the progressive basinward propagation of basin-margin faults; however, some general trends are recognized. The northern and southern margins of the Sandia Mountains are associated with broad zones of multiple faults and generally more sinuous mountain-fronts associated with the Sandia fault to the south, and the Escala, Lomos, Ranchos, Placitas-San Francisco and Valley View faults to the north. The segment along Rincon Ridge displays a relatively narrow zone of deformation associated with the Rincon fault.

The embayed mountain-front between La Cueva and Bear Canyons may result from the juxtaposition of several short range-front structures developed along a small left step between the Sandia and Rincon faults. Faulting presumably shifted into the basin beneath Albuquerque where faults are buried by late Quaternary piedmont deposits along the high western escarpment of the Sandia Mountains.

The northern piedmont (Figs. 4, 47, 48 and 56) forms a large ramp structure (Kelley, 1977, 1978 and 1982) where drainages have dissected the hanging wall of the uplifted range margin (i.e., Placitas and San Francisco faults). Las Huertas Creek enters the piedmont along a short re-entrant structure between the Placitas and San Francisco faults. Interactions between piedmont landforms and fault activity are well expressed along the northern mountain front. Larger drainage-basins typically develop near segment boundaries and enter the piedmont along transfer (hinge) zones where faulting is distributed across a wider zone of faulting (Menges, 1988). This en-echelon pattern of mountain-front segments may be separated by transverse structures within the range that create zones of weakness exploited by drainages. Intra-range (e.g., La Cueva and Groundwater faults, Kelley and Northrop, 1975) and Sandia faults illustrate this pattern (Fig. 8).

Mountain-front segment boundaries associated with acute re-entrant-salient angles typically contain large drainage basins and fans that strongly influence piedmont morphology. Geometric similarities between Rincon Ridge, Juan Tabo and del Agua drainages, and the much larger Las Huertas and Tijeras drainages, mountain-front fault-segmentation patterns persist at different spatial scales.

Much of the structural offset becomes distributed over several faults along diffuse zones of faulting (Menges, 1988; Pazzaglia, 1989) where drainage basins can readily adjust to local base level conditions and maintain integration with the Rio Grande. Uplift along narrow mountain-front fault zones (e.g., Rincon fault) can disturb mountain-front streams, which must readjust their base-level. This generally results in the formation of linear bedrock range-fronts containing relatively short, elongate, low-order drainage basins. In contrast, larger drainage-basins incise Rincon Ridge near segment boundaries where they are relatively less disturbed by faulting (Figs. 47 and 48). Tectonic influence on drainage-basin and piedmont development is well expressed along Rincon fault. Fans associated with drainage-basins of the del Agua and Juan Tabo Canyons merge west of Rincon Ridge to accommodate basin subsidence along the hanging wall of the Rincon fault. These fans also may have influenced the position of Sandia Wash, which developed when the Rio Grande abandoned geomorphic surface Q7 during the late Pleistocene.

Pliocene and Quaternary Evolution of the Sandia Piedmont

Deposits on the Sandia piedmont record late Pliocene through early Pleistocene basin aggradation followed by extensive incision primarily driven by entrenchment of the Rio Grande and local mountain-front uplift (Table 3; Figs. 17, 20, 22, 26, 27 and 29). Periods of relative base-level stability and basin aggradation were punctuated by a series of incisional events followed by subsequent phases of aggradation (Fig. 57). The tectonic evolution of the Sandia Mountains may have its origins during the Laramide orogeny (early Tertiary) when older basin-margin structures displaying Precambrian through Quaternary recurrent movement (Lisenbee and others, 1979; Abbott and Goodwin, 1995) may have influenced the position of Neogene rift-margin structures, such as the Tijeras, Placitas and San Francisco faults (Figs. 8 and 23) (Cather, 1992; Chapin and Cather, 1994).

Uplift of the Sandia Mountains began during the Miocene when alluvial fans developed along the margin of the rising block of the Sandia Mountains (Picha, 1982; Menne, 1989; Ingersoll and others, 1990). The Placitas, San Francisco and western margin faults formed the dominant basin structure at the northern flank during the Miocene and Pliocene. The Sandia Mountains formed a prominent topographic feature by at least the late Pliocene when a broad surface of erosion associated with the Ortiz pediment (Tuerto gravels) spanned the Placitas and San Francisco faults. Basalt (about 2.5 to 3.0 Ma) then buried parts of this surface within the basin. Large-scale segmentation of the mountain-front probably formed during the Pliocene with the development of drainages in Las Huertas and Tijeras Creeks. Basin filling continued through the end of the Pliocene when the basin margin shifted to the Lomos and Escala faults (Fig. 58a).

The Rio Grande deposited coarse-grained alluvium within a broad valley that extended across much of the basin by the middle Pleistocene. Entrenchment of the upper Rio Grande began in the early to middle Pleistocene (Hawley and others, 1976; Gile and others, 1981; Personius and Machette, 1984; and Wells and others, 1987a). Tectonic activity shifted across the piedmont to the Valley View faults, which resulted in dissection of the hanging wall of the Placitas and San Francisco faults (Fig. 58ab). Subsidence of the Santo Domingo sub-basin decreased during the early to middle Pleistocene when strain transferred west to the Rio Grande fault zone (Fig. 58bc). Subsidence along the Rincon and Rio Grande faults continued south of Strip Mine Canyon; however, significant movement along range-front segments of the Sandia fault ceased during this time (Figs. 58ab).

Incision of Juan Tabo Creek into Rincon Ridge probably occurred during the late Pliocene to early or middle Pleistocene (between QT1 and Q2-3 time) when mountain-front streams incised into pediment alluvium of Qp2-3. The Rio Grande fault probably became the dominant basin-margin structure during the early or middle Pleistocene, which may have restricted eastward migration of the Rio Grande (Fig. 58bc).

Movement along the Valley View and northern Rincon fault ceased by middle-Pleistocene (Q5) time. A significant incisional event along the Rio Grande occurred prior to middle-Pleistocene deposition of the alluvium of Edith Boulevard (Fig. 58c), followed by the formation of Q5, Q6 and Q7 and the Menaul Boulevard alluvium during the late-middle and late Pleistocene (Fig. 58d). Movement along the northern part of the Rincon fault ceased prior to formation of geomorphic surface Q5 in the late-middle Pleistocene (Fig. 58c). Tectonic subsidence became concentrated along the Rincon and Rio Grande faults during the middle Pleistocene (Fig. 58d). Fans of geomorphic surface Q8 developed along the piedmont during the latest Pleistocene (Fig. 58e) prior to incision of the Rio Grande during the end of glacial conditions at the latest Pleistocene. Tributary (piedmont) alluvium then filled stream valleys during the Holocene.

Figure 57. Schematic diagram of geomorphic surfaces and activity of selected faults showing overall pattern of post-early Pleistocene basin incision. Diagram represents the compilation of spatial and temporal patterns of various geomorphic and tectonic events along the mountain front.

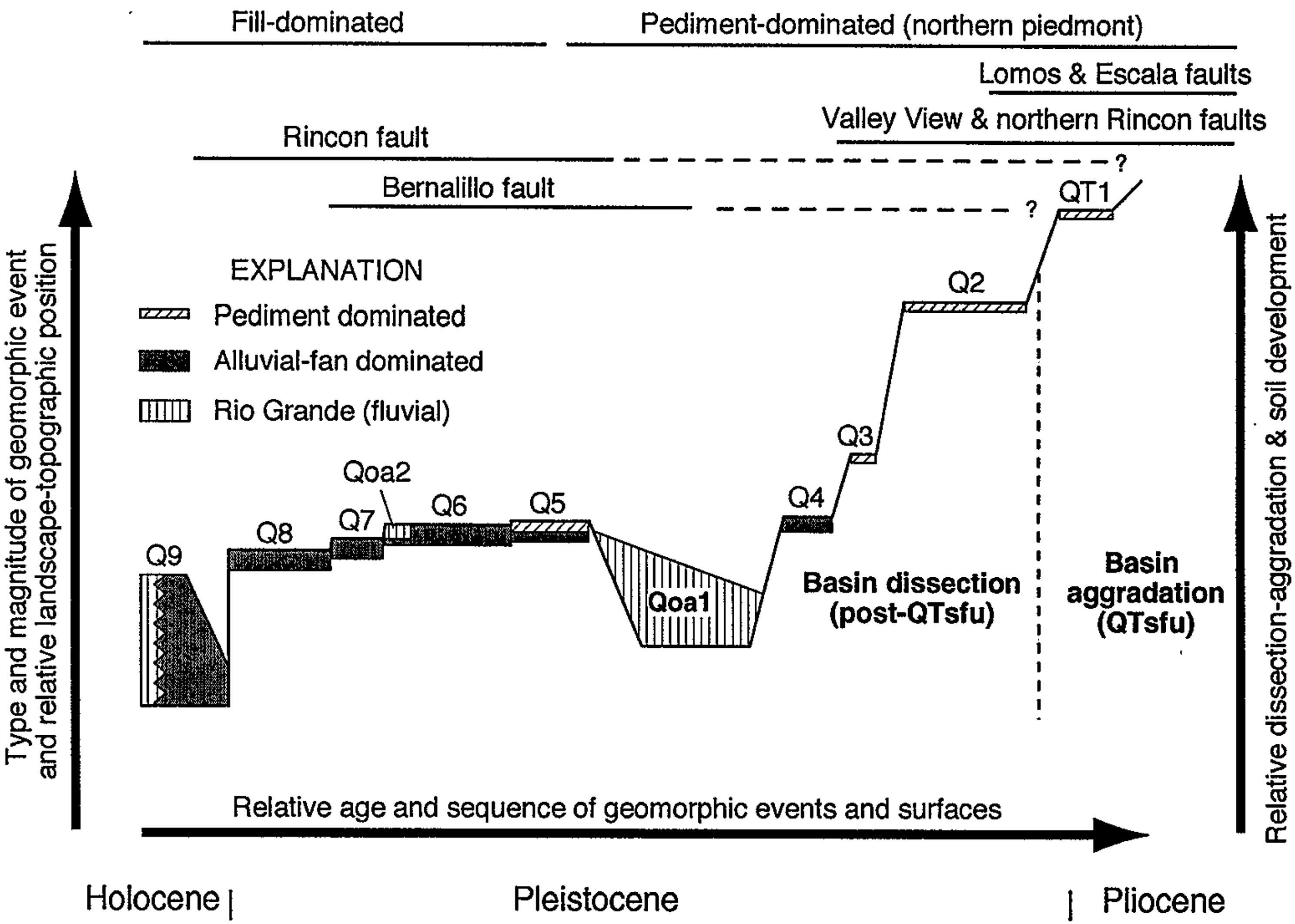
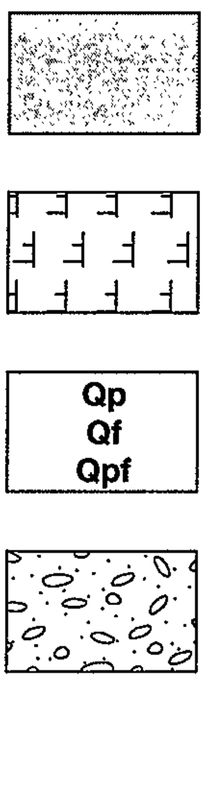

Fill-dominated
Pediment-dominated (northern piedmont)
Lomos & Escala faults
Valley View & northern Rincon faults
Rincon fault
?
Bernalillo fault
?
QT1
EXPLANATION
Pediment dominated
Alluvial-fan dominated
Rio Grande (fluvial)
Q2
Q3
Qoa2
Q4
Q7
Q6
Q5
Q8
Q9
Qoa1
Basin dissection (post-QTsfu)
Basin aggradation (QTsfu)
Type and magnitude of geomorphic event and relative landscape-topographic position
Relative dissection-aggradation & soil development
Relative age and sequence of geomorphic events and surfaces
Holocene
Pleistocene
Pliocene

Figure 58a through e. Schematic map illustrating interpretations of piedmont and mountain-front paleogeography of the Sandia Mountains during the late Cenozoic: a) late Pliocene; b) early middle Pleistocene; c) middle Pleistocene; d) late-middle to early late Pleistocene; and e) latest Pleistocene. Selected major features include: the mountain-front (MF), Sandia range-crest (SRC), Cuchilla de Escala (CE), Strip Mine Creek (SMC), del Agua Creek (dAC), Las Huertas Creek (LHC), Pino Creek (PC) and Juan Tabo Creek (JC). Faults are noted by bold lines: solid where activity is well constrained; dashed where activity is uncertain, dotted where inactive. Major faults include the Bernalillo (BF), Escala (EF), Lomos (LF), Placitas-San Francisco (P-SFF), Ranchos (RaF), Rincon (RiF), Rio Grande, Sandia (SF) and Valley View (VVF) faults. Arrows indicate approximate direction of sediment transport.

Explanation of patterns



Upland areas

Abandoned geomorphic surfaces

Piedmont deposition:
pediment (Qp)
alluvial fan (Qf)
pediment and fan (Qpf)

Axial-river facies (Rio Grande)

Fault activity:
solid where well constrained;
dashed where uncertain;
dotted where buried

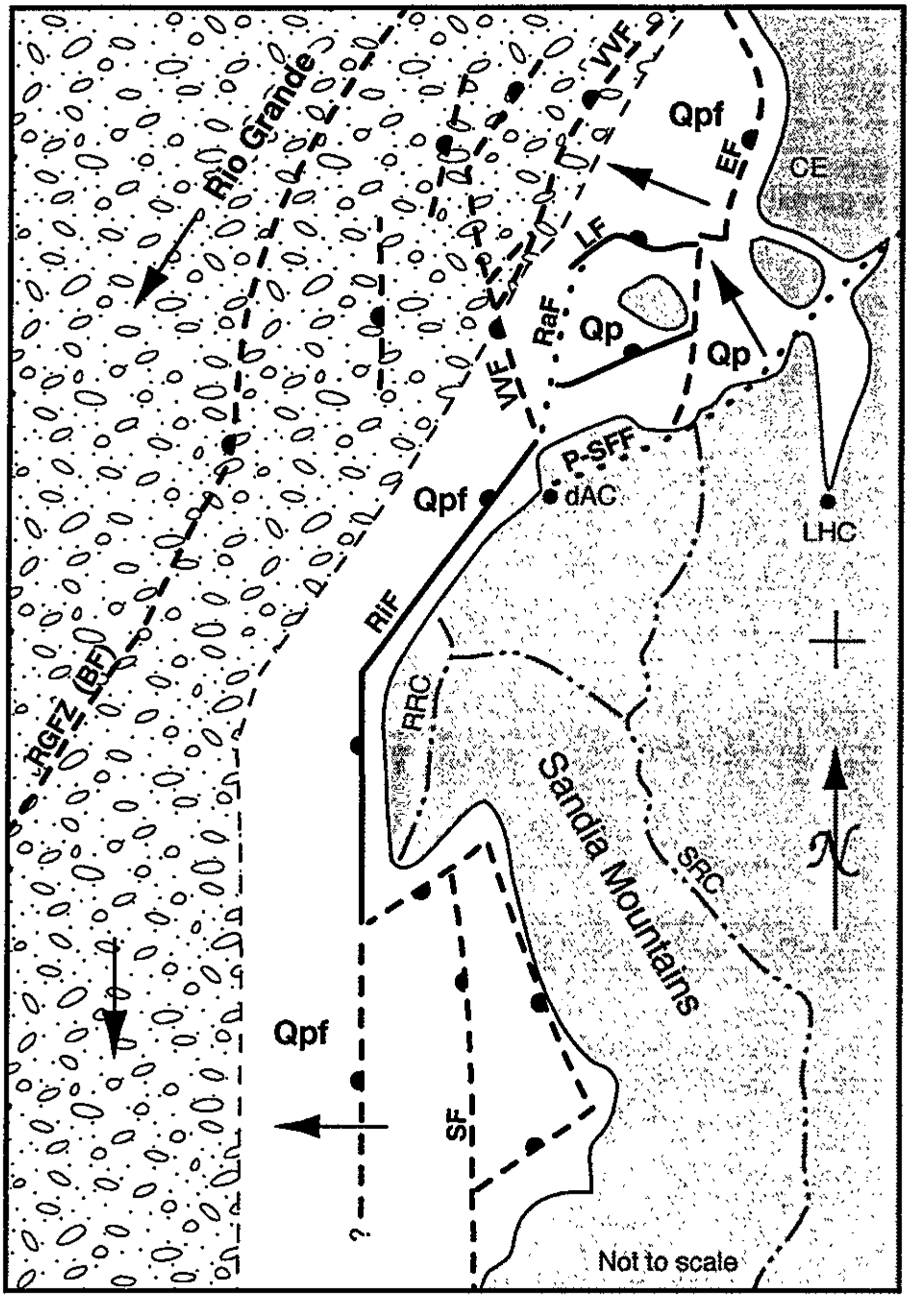


Figure 58a. Schematic map illustrating interpretations of piedmont and mountain-front paleogeography during late Pliocene (Sierra Ladrones and geomorphic surface QT1) time. Activity of faults (dashed) south of Rincon Ridge is uncertain.

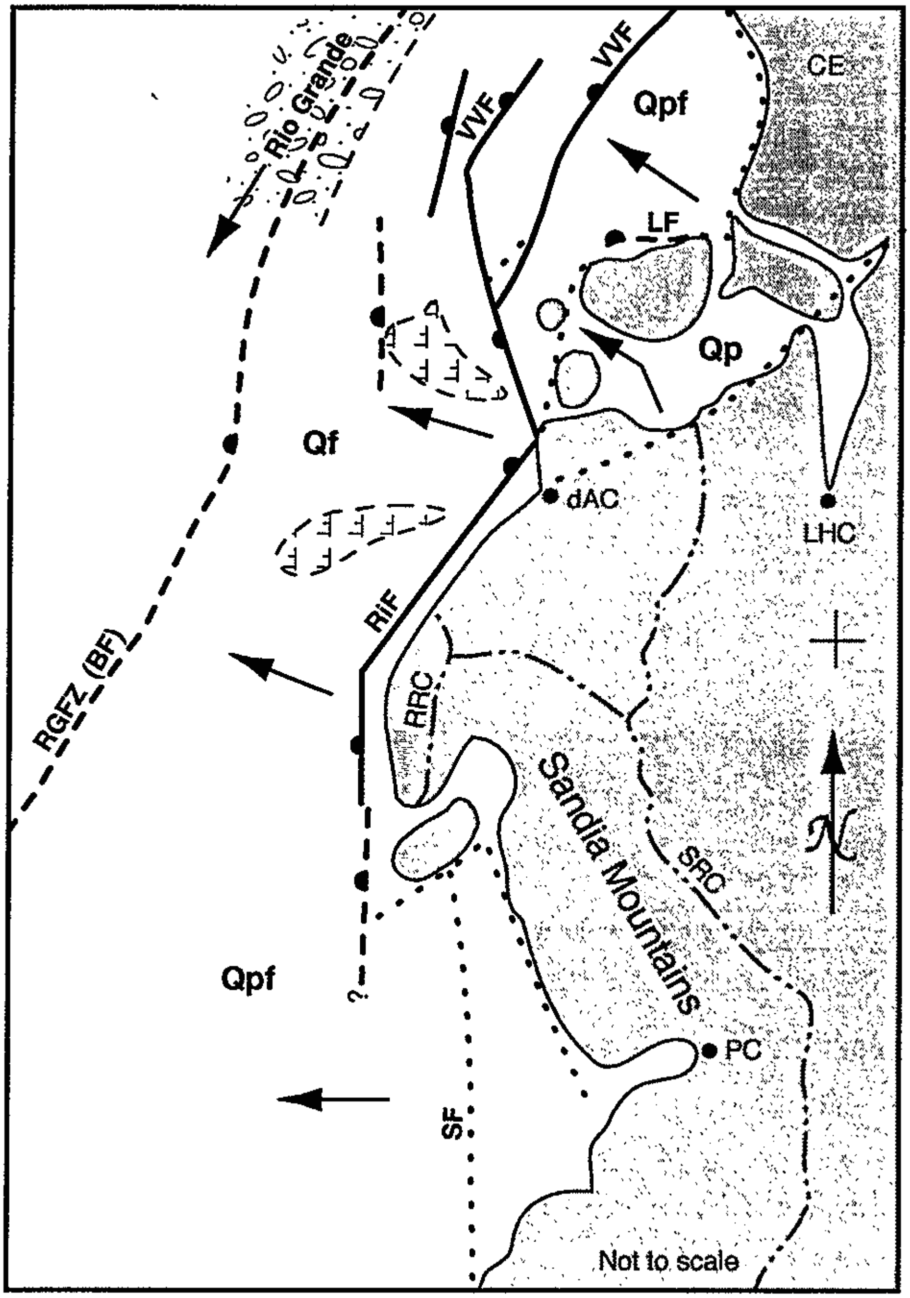


Figure 58b. Schematic map illustrating interpretations of piedmont and mountain-front paleogeography during early middle Pleistocene (geomorphic surface Q2 and Q3) time. Faults along base of Rincon Ridge and northern piedmont are active. The Sandia fault (SF) is buried by piedmont deposits.

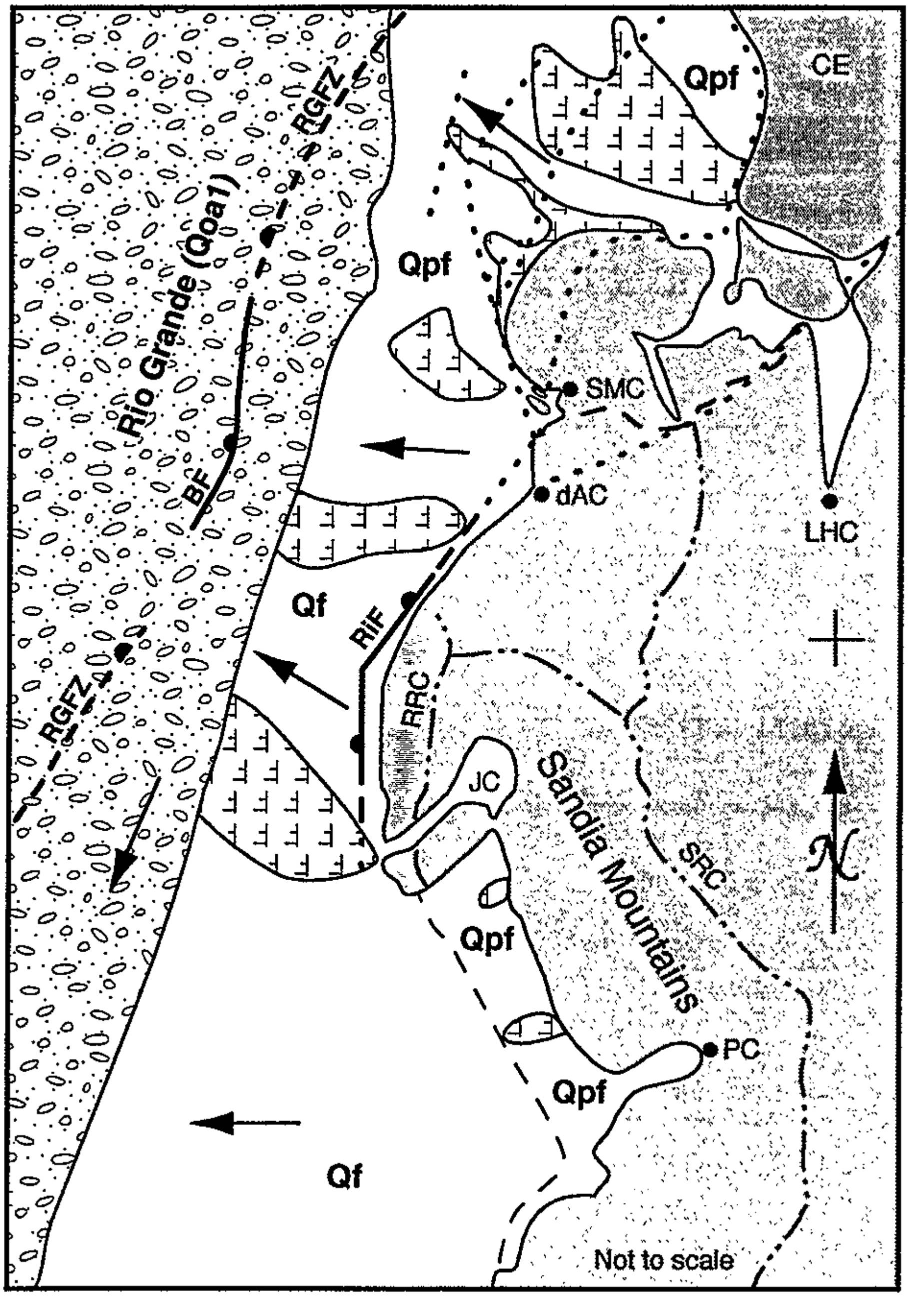


Figure 58c. Schematic map illustrating interpretations of piedmont and mountain-front paleogeography during middle Pleistocene (alluvium of Edith Boulevard and geomorphic surface Q5) time. The alluvium of Edith Boulevard (Qoa1), deposited by the Rio Grande, is inset below geomorphic surfaces Q2 through Q4. Bernalillo (BF) and central portion of Rincon (RiF) faults were active.

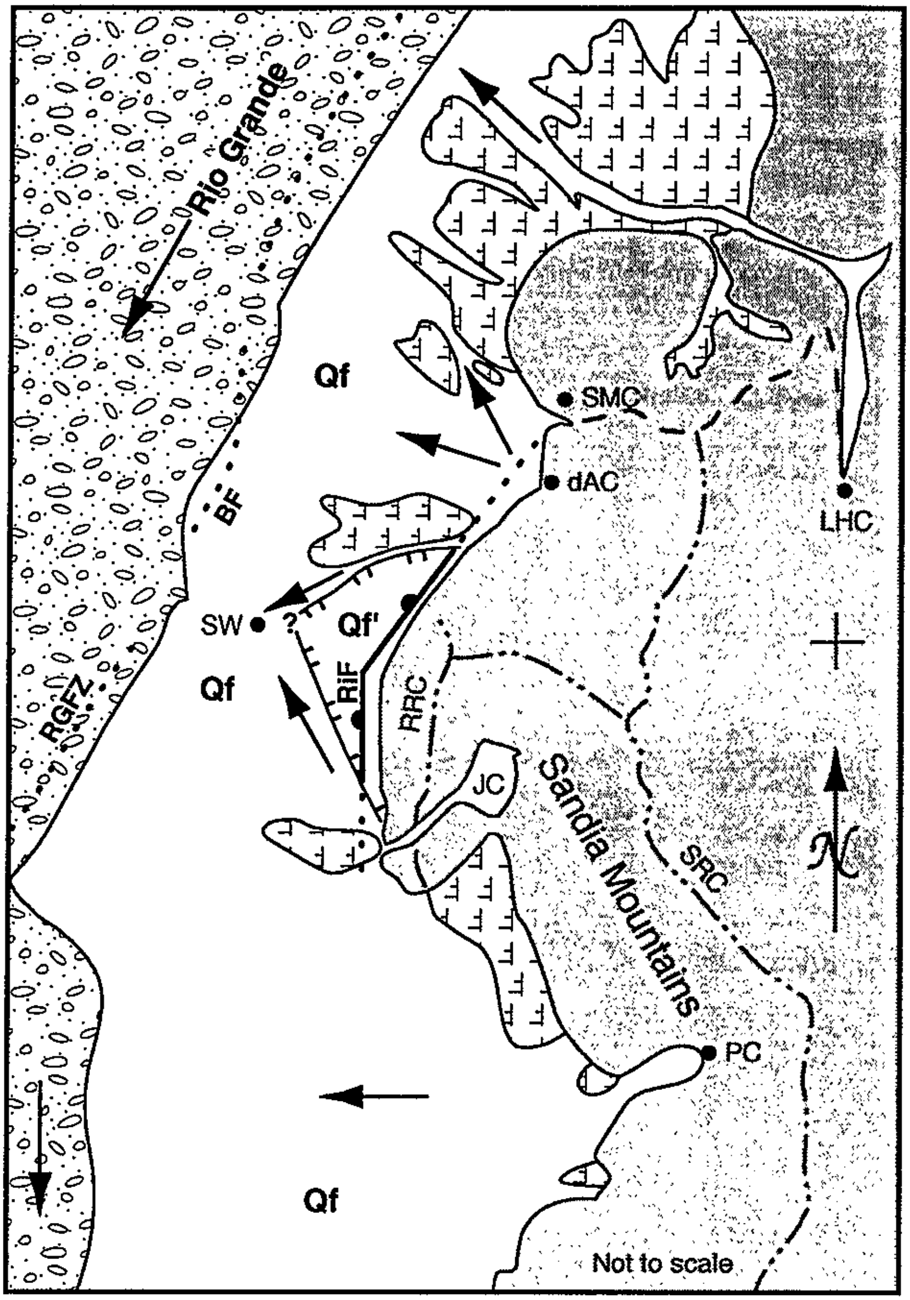


Figure 58d. Schematic map illustrating interpretations of piedmont and mountain-front paleogeography during late-middle to early late Pleistocene (geomorphic surface Q6 and Q7) time. Alluvial fans from the del Agua and Juan Tabo (JC) Canyons shift deposition to area of the modern Sandia Wash (SW) to accomodate tectonic subsidence along the Rincon fault (RiF), which cut off Qf7-8.r (Qf') from the Rio Grande.

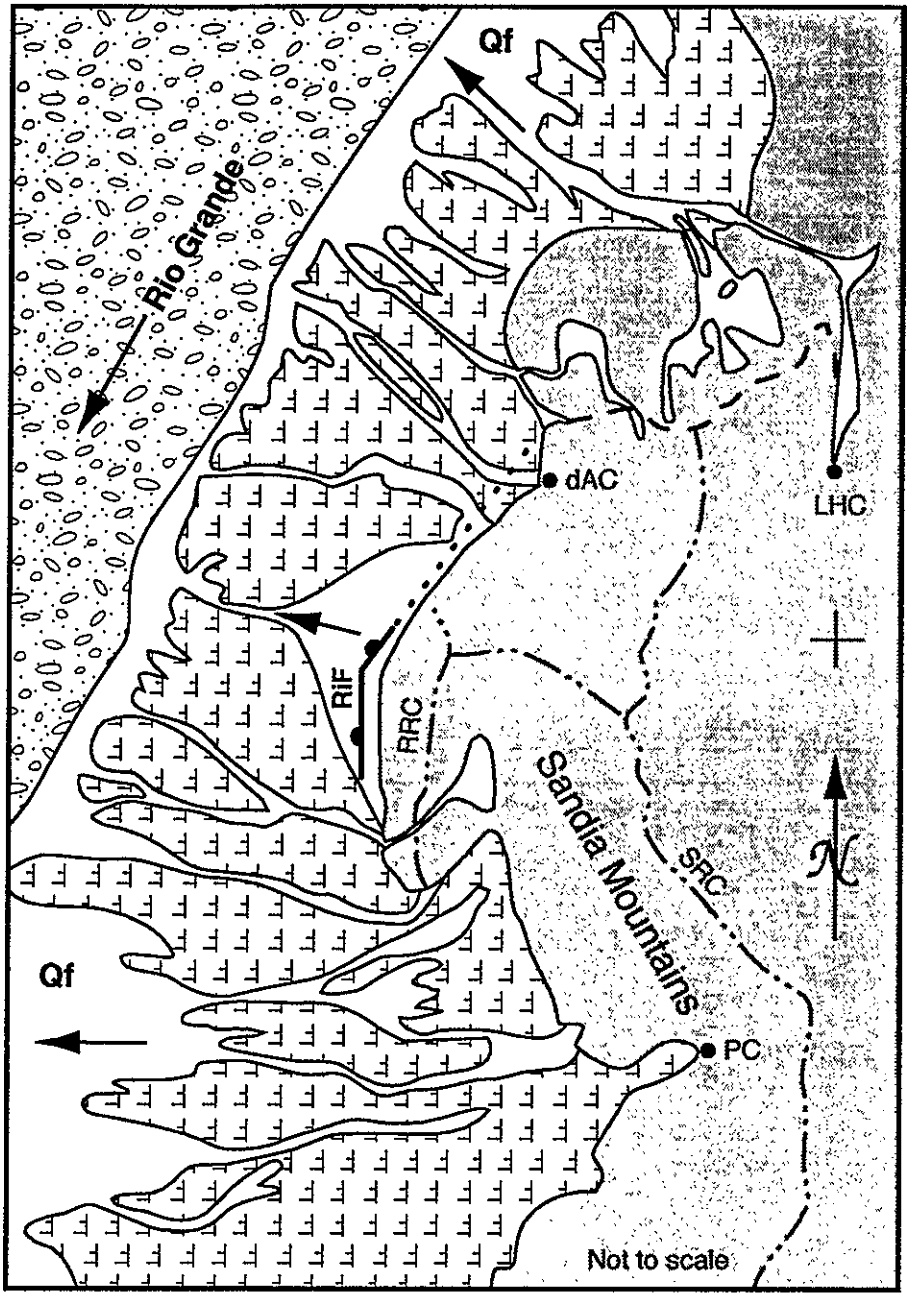


Figure 58e. Schematic map illustrating interpretations of piedmont and mountain-front paleogeography during latest Pleistocene and early Holocene (geomorphic surface Q7 and Q8) time.

CONCLUSIONS

This study provides a detailed framework of the late Pliocene and Quaternary stratigraphy, structural geology, geomorphology and geomorphic evolution of the piedmont developed along the western and northern flanks of the Sandia Mountains (Tables 2 through 6; Plates I, II and III). The piedmont of the Sandia Mountains crosses the northern Albuquerque and Santo Domingo sub-basins (Fig. 2) and records a complex history late Cenozoic piedmont evolution (Figs. 54, 56 and 57). The boundary between sub-basins coincides with the intersection of the Placitas, Rincon and Valley View faults at a prominent east (right) step in the basin margin. Relatively minor tectonic subsidence has occurred along the southwestern margin of the Santo Domingo sub-basin since the middle Pleistocene. In contrast, the northern Albuquerque sub-basin has experienced significant tectonic subsidence since the middle Pleistocene.

The study area is dominated by late Pliocene and Quaternary deposits and landforms: basin fill, alluvial fans, pediments and stream terraces (Fig. 54). Basin fill (Sierra Ladrones Formation) underlies much of the piedmont and is commonly buried south of NM 165. Pediments and strath terraces are common along the northern piedmont and locally along the mountain-front south of Rincon Ridge. Alluvial fans predominantly occur south of NM 165. Axial-stream alluvium of the ancestral Rio Grande is recognized along the western margin.

A soil chronosequence described for Quaternary deposits is used to correlate the alluvial stratigraphy across the piedmont and to provide estimates of deposit age on the basis of soil development and inset relations (Fig. 54). Several geomorphic surfaces exhibit divergent longitudinal profiles, suggesting base-level influence by an incising Rio Grande (Table 3; Figs. 17, 20, 22, 26, 27 and 29). Five major pediments and strath-terraces are recognized along the northern mountain-front flank and locally along the mountain front south of Rincon Ridge (Plates I and II). Pediments of the northern piedmont locally span the mountain front-piedmont junction and cross major range-bounding and intra-basin faults (Fig. 56). To the south, alluvial fans of geomorphic surfaces Q4 through Q9 form laterally extensive Holocene and middle Pleistocene fans unconformably overlying Sierra Ladrones Formation. Fan deposits of Qf4, Qf6 and Qf7 are common south of highway NM 165. Piedmont deposits record a series of aggradational and incisional episodes, occasionally punctuated by relatively deep incisional events where the Rio Grande cuts down into the Santa Fe Group (Figs. 30 and 45).

The influence of Quaternary tectonics on landform development and preservation is expressed in the distribution of erosional (pediment) landforms (Figs. 47, 48 and 56). The transition between aggradational (fan) and erosionally dominated piedmonts coincides with the intersection of the Placitas, Rincon and Valley View faults, geomorphically defining the transition between the Santo Domingo and northern Albuquerque sub-basins (Figs. 45, 47, 48 and 56).

The mountain-front is tectonically segmented into independent structural blocks that influence the distribution and type of landforms and deposits. Mountain-front segments are delineated on the basis of qualitative estimates of mountain-front morphology (Figs. 47 through 51; Table 6). The mountain front is typically associated with distinctive fault segments that are recognized by narrow or diffuse segments that generally alternate along the base of the mountain front. Drainage basins developed at segment margins are typically larger and generally equant (Fig. 47). Basins developed within segments typically are small, elongated and influenced by drainages associated basins developed along segment boundaries (Fig. 47). The distribution and ages of landforms suggests that tectonics constitute the most dominant influence on the piedmont; however, correlations to several soil-based alluvial chronologies in New Mexico suggests that deposition of units are, in part, modulated by climatic changes.

The Valley View, Ranchos, Lomos and Escala faults developed on the hanging wall of the San Francisco and Placitas faults, which merge into the Rio Grande fault at depth (Figs. 3 and 7; Table 5; Plate I). The San Francisco and Placitas faults mark the northern flank of the Sandia Mountains during the Miocene and Pliocene (Fig. 58a). The margin migrated westward to the Lomos and Escala faults during the late Pliocene and early Pleistocene (Figs. 58ab). The northern study area is dominated by broad, north and northwest-sloping, gravel-mantled pediments and strath terraces that extend from the range-front into the basin, suggesting that only minor basin subsidence has occurred during the Quaternary (Fig. 58bcd; Plate I).

The Sandia Mountains was a prominent topographic feature during the late Pliocene (Fig. 58a). The Santo Domingo sub-basin experienced long-term dissection of the hanging wall by broad pediments. Tectonic subsidence along the southeastern-margin of the Santo Domingo sub-basin slowed by the early or middle(?) Pleistocene (Fig. 58a). The northern Albuquerque basin, in contrast, was active and influenced by the Rio Grande and Rincon faults. Pediments along the northern flank formed the dominant landform during the early and middle Pleistocene followed by deposition of fill-terraces during latest Pleistocene or Holocene (Figs. 58de). The central and southern portions of the study area are generally dominated by a relatively thick sequence of middle Pleistocene through Holocene alluvial-fan and fluvial deposits, suggesting a period of fairly rapid and long-term basin subsidence. Pediments developed within faulted blocks of the northern range flank suggest that relatively little subsidence has occurred since middle Pleistocene (Figs. 56 and 57). Westward transfer of strain on the footwall of the Placitas and San Francisco faults is expressed in timing of movement along the Valley View fault, which has not been active since the late-middle Pleistocene (Figs. 56 and 58bc).

The predominance of broad pediments along the northern flank of the Sandia Mountains suggests that strain may have transferred to the Rio Grande fault or possibly to the San Felipe graben and Ziana anticline (Fig. 3) since the early Pleistocene (Figs. 56 and 58). Late Pleistocene and Holocene activity along the Bernalillo and Rincon faults suggesting continued subsidence within the northern Albuquerque sub-basin (Fig. 52). Lack of Holocene fault activity along other basin faults suggests that transfer of strain may be accommodated by buried structures within the basin (Figs. 54 and 56).

On the basis of cross-cutting relations, the Bernalillo fault (Rio Grande fault zone) last moved during the late Pleistocene (Fig. 56; Table 5). Geophysical and bore-hole data indicate that the Rio Grande fault, a prominent inner-graben structure, exhibits about 4 to 6 km of late Cenozoic displacement (Russell and Snelson, 1994; Hawley and others, 1995) and has been a geologically persistent structural feature not directly associated with range-front uplift. Fault activity along the range front generally ceased or slowed since the middle Pleistocene, except along the Rincon fault (Fig. 56), which has undergone recurrent late Quaternary (including Holocene) ground-rupture. Scarp-morphologic dating indicates that the southern segment of the Rincon fault last moved during the middle to late Holocene and also moved at least two times during the late Pleistocene (Figs. 43 and 56). Ridge-crest profiles also suggest that the Rincon fault has been a long-lived basin margin structure (Fig. 48; Table 5).

Activity along basin-interior faults since at least the middle Pleistocene suggests footwall transfer of strain into the basin. Basinward transfer of strain is well expressed along the northern flank of the Sandia Mountains (Santo Domingo sub-basins) and may be associated with a prominent step in the Albuquerque basin (Fig. 56). In the northern Albuquerque sub-basin the Rincon fault and Rio Grande fault zone complicate this pattern.

Implications for Rift-Margin Evolution and Earthquake Hazards

Recognition of recurrent Holocene and late Pleistocene movement along the Rincon and Bernalillo faults indicate the need to assess the impacts of future seismic (ground acceleration) response and liquefaction potential on local building codes and public awareness of the potential for moderate earthquakes in the greater Albuquerque metropolitan area. The Rincon fault last moved during the middle or late Holocene and experienced recurrent ground-rupture since the Pliocene. On the basis of rupture length measured on the lowest scarps (Bonilla and others, 1984), the Rincon fault could be capable of producing a significant (about 6.5 Ms) earthquake in the future; however, relations between rupture length and slip on this fault are not consistent with magnitude

(Bonilla and others, 1984), suggesting these empirical relations may not be appropriate here. Explanations for the discrepancy are not clear and should be evaluated in future studies. Perhaps, strain is transferred to buried structures, or the "characteristic earthquake" concept (Schwartz and others, 1981; dePolo and Slemmons, 1990), implicitly used to predict earthquake magnitude (Bonilla and others, 1984), requires a better understanding of the local fault-segment patterns, rheologic conditions and tectonic-regimes.

The Bernalillo fault exhibits late Pleistocene movement and represents the surface expression of the Rio Grande fault north of Tijeras Creek (Fig. 56; Table 5). This fault is commonly buried beneath the floodplain of the Rio Grande under Albuquerque (Hawley and others, 1995). The Bernalillo fault also presents interesting implications regarding predictions of fault location based on the use of tectonic geomorphology because it is not generally recognizable by surface morphology (no fault scarps or associated upland or graben areas).

Directions for Future Studies

The scope of mapping should be expanded to include the piedmont south to Tijeras Creek, and west of the Rio Grande. A better understanding of the stratigraphy west of the Rio Grande could resolve age estimates of alluvial stratigraphy on the Sandia piedmont and possibly constrain estimates of late Quaternary movement on the Rio Grande fault zone. Amino-acid racemization studies of fresh-water mollusks in the Edith Boulevard alluvium supplemented by comparisons to the amino-acid stratigraphy of the Jemez Mountains could provide age-control for this axial-river deposit.

Differentiation of piedmont stratigraphy, in this study, resulted in grouping of smaller geomorphic surfaces because of project scope and scale of mapping. Detailed soil-geomorphic studies of Quaternary deposits could further refine piedmont stratigraphy. Quantitative evaluation of mountain-front morphometry could be used to assess variations in drainage-basin and mountain-front form and hydrologic parameters along mountain-front segments to test the applicability fault-segmentation models (Menges, 1988 and 1990ab; Leeder and Jackson, 1993; Gonzalez, 1993 and 1995).

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QUATERNARY GEOLOGY AND GEOMORPHOLOGY OF THE SANDIA MOUNTAINS PIEDMONT, CENTRAL NEW MEXICO

Sean D. Connell
New Mexico Bureau of Mines and Mineral Resources
Socorro, New Mexico 87801

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FOREWORD

This report presents the results of M.S. thesis research conducted along the piedmont of the northern and western flanks of the Sandia Mountains, near Albuquerque, New Mexico. This research was submitted (December 1995) in partial satisfaction of the requirements for the degree of Master of Science in the Geological Sciences at the University of California at Riverside (UCR), where it is on file in the original thesis format. The thesis committee consisted of Drs. Stephen G. Wells (chairperson), David A. Osleger, Peter M. Sadler, and Leslie D. McFadden. The primary purpose of this research was to develop a detailed late Cenozoic stratigraphy for deposits associated with the western and northern flanks of the Sandia Mountains in the Albuquerque basin (see **INTRODUCTION** section). The study area, located within parts of the greater Albuquerque metropolitan area and vicinity, comprises portions of the Alameda, Bernalillo, Los Griegos, Placitas, Sandia Crest and Tijeras 7.5-minute quadrangles. The nominal scale of mapping was 1:24,000; however, selected areas were mapped at larger scales. The geologic maps emphasize Pliocene and Quaternary basin-fill, piedmont and valley fill deposits. Differentiation of major bedrock units is complied from previous studies (Kelley and Northrop, 1975; Menne, 1988).

This report is arranged into three volumes. Volume I contains the main text, figures, tables and references. Volume II contains supporting appendices (Appendix A through E) and includes soil-profile and stratigraphic descriptions. Volume III contains the geologic and geomorphic maps (Plates I through III) and description of map units (Appendix F).

Quadrangle maps, which form the basis for this report, will be placed on Open-File as individual geologic maps as they are completed, revised and integrated with current mapping studies of the bedrock and basin fill. *The contents of this report should not be considered final and complete until they are published as Bulletins or Geologic Maps by the New Mexico Bureau of Mines and Mineral Resources.*

Note: Page 255 is not included.

Appendix A

Appendix A-1. Aerial Photographs Used in Study. Sources include U.S. Department of Agriculture, (USDA), Soil Conservation Service (SCS), Forest Service (F) and U.S. Geological Survey (USGS).

Photograph	Year	Type	Scale	Source
NM 145 41 to 45	1935	Black & White	1:32,500	Fairchild Surveys
VVBE M45 AMS 5895 to 5896 5924 to 5926 5985 to 5989 6032 to 6033	1952	Black & White	1:51,100	Unkown
GS-VJ 3-108 to 3-110 3-143 to 3-145	1952	Black & White	1:17,000	USGS
GS-RT 1-63 to 1-72	1951	Black & White	1:37,400	USGS
GS-RU 1-157 to 1-168 1-208 to 1-216 2-6 to 2-14 2-114 to 2-122 2-37 to 2-43	1951	Black & White	1:23,600	USGS

Appendix A-1 (continued).

Photograph	Year	Type	Scale	Source
EXG 1-05 to 1-13 1-31 to 1-40	1971	Color	1:17,600	USDA-SCS
173 190 to 193 100 to 104 159 to 169 **273** 242 to 249	1973	Black & White	1:20,600	USDA-SCS
GS-VBUG 2-59 to 2-66 2-88 to 2-95	1967	Black & White	1:13,000	USGS
1382 121 to 123 190 to 202	1983	Color	1:26,200	USDA-F

Appendix A-2. Descriptions of Selected Localities in Study Area (USGS Bernalillo 7.5-minute quadrangle). Township and range coordinates are relative to the New Mexico Principal Meridian (NMPM).

Locality	Location (plate)	Remarks
L-1	**I**	SW1/4, NE1/4, Section 20, T12N., R04E., NMPM: outcrop of piedmont facies of Sierra Ladrones Formation along southern margin of Sandia Wash. Clasts are dominated by highly weathered and split schist. Soil possess a well developed petrocalcic horizon with stage III+ carbonate morphology. Minor constituent clasts of granitoid rocks exhibit variably degrees of grussification.
L-2	**I**	SE1/4, NE1/4, Section 34, T12N., R04E., NMPMM: outcrop of rounded pumice clasts belonging to the lower Bandelier tuff (Cather and others, in preparation) near small water tank along housing-tract access road, north of highway NM 165.
L-3	**I**	NE1/4, SW1/4, Section 34, T12N., R04E, NMPM, access road south of highway NM 165: rounded pebble to cobble conglomerate of axial-facies Sierra Ladrones Formation. Deposits are tilted to the east and cut by faults.
L-4	**I**	SE1/4, SE1/4, Section 13, T12N., R04E., NMPM: northwest-facing (18-m high) fault scarp of Valley View fault, which offsets deposits of geomorphic surface Q2; maximum scarp-slope angle is about 11°; fault-scarp morphology is measured from topographic map having a contour interval of 10 feet.

Appendix B

Soil-Profile Descriptions

B-1 Explanation of Soil-Profile Nomenclature and Abbreviations

B-2 Location of Soil Profiles

B-3 Descriptions of Soil-Profiles P-1 through P-35

Appendix B-1. Explanation of Soil-Profile Nomenclature and Abbreviations (SCS, 1975 and 1992; Gile and others, 1966; Birkeland, 1984).

General / **Roots and pores**

General		*Size*		*Abundance*	
n.o.	not observed	1	few	vf	very fine
nd	not described	2	common	f	fine
na	not applicable	3	many	m	medium
				c	coarse

Clay films

Abundance		*Thickness*		*Type*	
v1	very few: <5%	n	thin	co	colloidal stains
1	few: 2 to 25%	mk	medium	po	pores
2	common: 25 to 50%	k	thick	br	bridges
3	many: 50 to 90%			pf	ped faces
4	continuous: >90%				

Structure

Grade		*Size*		*Type*	
sg	single grain	f	fine	gr	granular
1	weak	m	medium	sbk	subangular blocky
2	moderate	c	coarse	abk	angular blocky
3	strong	vc	very coarse	pl	platy

Appendix B-1. (continued).

Texture		Effervescence		Carbonate morphology	
S	sand	eo	no effervescence	dissem.	no morphology
LS	loamy sand	ev	slightly effervescent	I ±(f)	stage 1 (filamentous)
SL	sandy loam	e	effervescent	II±	stage 2
SiL	silt loam	es	strongly effervescent	III±	stage 3
CL	clay loam	ve	violently effervescent	IV±	stage 4
SCL	sandy clay loam				
SiCL	silty clay loam				

Appendix B-2. Location of Soil-Profiles. Summaries of soil-profile locations, including, unit designation (e.g., Qf6), and location on geologic maps (Plates I and II).

Profile	Unit	Location	Profile	Unit	Location
P-1	Qf6	II	P-19	Qf8	II
P-2	Qa9	II	P-20	Qf7b	I
P-3	Qf7b	I	P-21	Qf7-8/QTsfup	II
P-4	Qt3	I	P-22	Qf7b	II
P-5	QTpf1	I	P-23	Qf6	II
P-6	Qa8	I	P-24	Qoa1	I
P-7	Qpf5	I	P-25	Qoa2	I
P-8	Qf7a	I	P-26	Qf7a	I
P-9	Qf8	I	P-27	Qf7a	I
P-10	Qf7-8Qf4	I	P-28	Qf7b	I
P-11	QTsfup	I	P-29	Qf8-9	I
P-12	QTsfup	I	P-30	QTpf1	I
P-13	Qp5	I	P-31	Qp5	I
P-14	Qa9	I	P-32	Qpf2	I
P-15	Qf6	II	P-33	Qf8-9	I
P-16	Qf6	II	P-34	Qt7-8	I
P-17	Qf7-8.r	II	P-35	Qf8-9/Qf4	I
P-18	Qf7-8.r	II			

Appendix B-3. Descriptions of Soil Profiles P-1 through P-35.

Soil-Profile Description

General

Soil-profile number: **P-1** Geomorphic Surface: **Q6** Map unit: **Qf6**

Location: Near northwest corner of Tramway Blvd. and San Bernardino Ave., Elena Gallegos Grant, Sandia Crest 7.5-minute Quadrangle

Landform: Alluvial fan Described by: Sean D. Connell Date: July 04, 1994

Deposit: Alluvium and debris flow Dominant clast lithology: Granitoid

Parent material characteristics: 10YR 5/4 (d), 10YR 4/3 (m), Sand

Surface elevation (m/feet): 1853±3 / 6080±10 Aspect: West-facing cut-slope

Base level (m): 9 to 10 Dissection class: 2 to 3 Slope (%): nd

Vegetation: Juniper, Pinyon, grasses and minor Cholla and Beavertail cactus.

Comments: Described along retaining-wall backcut. Surface disturbed by construction activities. Top of Bkm1 is bioturbated (krotovina); Bkm2 horizon exhibits a ≤1-to 2-cm thick wavy, laminar carbonate layer. Bk5 horizon contains highly weathered (grussified) granitoid clasts.

Soil-profile summary

PDI (8/4): 23.33 / 47.34 Thickness-normalized PDI (8/4): 0.34 / 0.17

Maximum B-horizon development and thickness

Hue: 7.5YR Bk (cm): ≥137 Bt (cm): 19 Btk (cm): 0 Max. clay films: 2mkcobrpf

Carbonate morphology/thickness (cm): IV- / 20 Max. structure: 2cabk

Horizon	Depth (cm)	Color dry *(ped)* moist	Texture (≤2 mm)	Structure	Consist. d m w pl	Clay films	Gravel % volume	Roots	Pore	Carbonate	Base
A	0 - 4	10YR 5-6/4 10YR 4/3	LS	1f-mgr	so vfr so po	n.o.	15	2f	n.o.	eo	vas
Bt	4 - 23	7.5YR 4/4 7.5YR 4/4 *(7.5YR 4/4)*	SiC	2m-cabk	sh fr s mp	2mkbrcopf	50	2vf	1vf	eo	as
Bw	23 - 33	10YR 5/4-6 10YR 4/3-4 *(10YR 5/4-6)*	SL	2m-csbk	sh fr so po	v1ncobr	40	1vf	1vf	e dissem.	vai
Bkm1	33 - 52	10YR 6/3 10YR 5/3	LS	1m-csbk	h fr so po	1nco	50 - 60	1vf	2vf	ev III	gi
Bkm2	52 - 72	2.5Y 7/2 2.5Y 6/3	LS	2m-cabk	eh fi so po	1npf	30 - 40	1vf	1vf	ev IV-	ai
Bkm3	72 - 82	2.5Y 4/3 2.5Y 6/3	S	2mabk	eh fi so po	n.o.	40	n.o.	2vf	ev III	aw
Bk1	82 - 125	10YR 6/3 10YR 5/3-4	S	2m-cabk	h vfr so po	n.o.	45	1vf	1vf	ev II+	as
Bk2	125-139+	10YR 6/3 10YR 5/3	S	1fsbk	sh vfr so po	v1nco	35	n.o.	n.o.	e dissem.	n.o.

Soil-Profile Description

General

Soil-profile number: **P-2** Geomorphic surface: **Q9** Map unit: **Qa9**

Location: Near retention dam along Bear Creek, Elena Gallegos Grant, Sandia Crest 7.5-minute Quadrangle

Landform: Floodplain Described by: Sean D. Connell Date: July 06, 1994

Deposit: Sandy alluvium Dominant clast lithology: Granitoid

Parent material characteristics: 10YR 6/2-3 (d), 10YR 5/3 (m), Sand

Surface elevation (m/ feet): 1923±3 / 6310±10 Aspect: West-facing stream cut

Base level (m): ≤0.5 Dissection class: 2 Slope (%): flat

Vegetation: Grasses, Cholla, sage-brush and phreatophytes

Soil-profile summary

PDI (8/4): 6.01 / 11.96 Thickness-normalized PDI (8/4): 0.05 / 0.10

Maximum B-horizon development and thickness

Hue: 10YR Bk (cm): 0 Bt (cm): 0 Btk (cm): 0 Max. clay films: n.o.

Carbonate morphology/thickness (cm): dissem./ ≥30 Max. structure: 1csbk

Horizon	Depth (cm)	Color dry moist	Texture (≤2 mm)	Structure	Consist. d m w pl	Clay films	Gravel % volume	Roots	Pores	Carbonate	Base
A	0 - 1	2.5Y 5/3 2.5Y 4/2	S	1mgr	lo lo so po	n.o.	60	N.O.	n.o.	eo	vas
C1	1 - 4	10YR 6/3 10YR 5-4/3	S	sg	lo lo so po	n.o.	85	1vf	n.o.	eo	vas
C2	4 - 37	10YR 5/2-3 10YR 4/2	S	1f-mgr	lo lo so po	n.o.	60	2vf	n.o.	eo	as
2Ab	37 - 52	10YR 4/1 10YR 3/1	SiL	1f-csbk	sh vfr so po	n.o.	10	2m1vf	n.o.	eo	as
2C1b	52 - 93	10YR 5/3 10YR 5/4-3	S	sg	lo lo so po	n.o.	30 - 40	1vf	n.o.	ve dissem.	as
2C2b	93 - 123+	10YR 6/2-3 10YR 5/3	S	1vf-fgr	lo so so po	v1nco	80	n.o.	n.o.	ve dissem	n.o.

Soil-Profile Description

General

Soil-profile number: **P-3** Geomorphic surface: **Q7b** Map unit: **Qf7b**

Location: SW1/4, NE1/4, Section 10, T12N., R04E., NMPM, Bernalillo Quadrangle

Landform: Alluvial fan

Described by: Sean D. Connell Date: August 03, 1994

Deposit: Gravelly and sandy alluvium

Dominant clast lithology: Granitoid, minor metamorphic and limestone

Parent material characteristics: 10YR 5/4 (d), 10YR 4/3 (m), Sand

Surface elevation (m/feet): 1719±3 / 5640±10 Aspect: West-facing stream cut

Base level (m): 3.4 Dissection class: 2 Slope (%): Shallow

Vegetation: Juniper, grasses, Cholla and sage-brush

Comments: Described on east wall of deep, steep-walled stream cut.

Soil-profile summary

PDI (8/4)*: 9.74 / 18.80 Thickness-normalized PDI (8/4)*: 0.03 / 0.06

Maximum B-horizon development and thickness

Hue: 7.5YR Bk (cm): ≥124 Bt (cm): 0 Btk (cm): 11 Max. clay films: 2mkcobr

Carbonate morphology/thickness (cm)*: II+ / 40 Max. structure: 2cabk & 1cpl

* Depth for PDI, thickness-normalized PDI and carbonate morphology calculated to Bk6 horizon (148 cm).

Horizon	Depth (cm)	Color dry moist	Texture (≤2 mm)	Structure	Consist. d w	m pl	Clay films	Gravel % volume	Roots	Pores	Carbonate	Base
A	0 - 4	10YR 5/4 10YR 4/3	SL	1fgr-sbk	so so	lo ps	n.o.	5 - 10	1fvf	1f	e dissem.	as
AB	4 - 13	10YR 4/3 10YR 4/3	SiCL	1f-msbk	so	vfr	v1nco	10 - 15	1fvf	1f 2vf	ve dissem.	aw
Btk1	13 - 24	7.5YR 4/4 7.5YR 4/4	SiCL - C	2m-cabk	sh s	vfr p	2n-mkcobr	25	1vf	1vf	es I	vas
Bk1	24 - 37	10YR 7/3 10YR 6/3	SL	1msbk	so so	vfr po	n.o.	35	1f 2vf	1vf	ev II	aw
Bk2	37 - 54	10YR 7/3 10YR 6/3	LS	1m-cabk	sh so	fr po	v1nco	80	1vf	2vf	ev II+	cw
Bk3	54 - 77	10YR 6/3 10YR 5/3	S	sg	lo so	lo po	n.o.	60	1fvf	1vf	ev II+	cw
Bk4	77 - 111	10YR 5/4 10YR 4/3-4	S	n.o.	lo so	lo po	n.o.	80	2f	n.o.	es - ev I+	as
Bk5	111 - 119	10YR 7/2 10YR 6/3	S	1m-cabk	sh so	fr po	n.o.	95	n.o.	n.o.	ev I+	as
Bk6	119 - 148	10YR 5/3 10YR 4/3	S	sg	lo so	lo po	n.o.	60	n.o.	n.o.	e - es I	gw

Horizon	Depth (cm)	Color dry moist	Texture (≤2 mm)	Structure	Consist. d w	Consist. m pl	Clay films	Gravel % volume	Roots	Pores	Carbonate	Base
Btk1b	148 - 177	10YR 5/4 10YR 5/3	S	sg	lo so	lo po	1n-mkcobr	90	n.o.	n.o.	es I	cw
Btk2b	177 - 208	10YR 5/4 10YR 5/3	S	1m-cabk	sh so	lo po	1n-mkcobr	80	n.o.	n.o.	e dissem.	cw
Bk1b	208 - 229	10YR 5/3-4 10YR 4/3	S	1f-msbk & 1cpl	so so	lo po	n.o.	20	n.o.	n.o.	ve dissem.	as
Bk2b	229 - 305	10YR 5/4 10YR 4/3	S	1c-vcpl & 1msbk	sh so	lo po	1ncobr	60	n.o.	n.o.	eo - e dissem.to I	cw
Bk3b	305 - 325	10YR 5/4 10YR 4/3	S	sg	lo so	lo po	n.o.	10	n.o.	n.o.	eo - e dissem.	cw
Bk4b	325 - 335+	2.5Y 6/3 2.5Y 6/3	S	sg	lo so	lo po	n.o.	60	n.o.	n.o.	eo - e dissem.	n.o.

Soil-Profile Description

General

Soil-profile number: **P-4** Geomorphic surface: **Q3** Map unit: **Qt3**

Location: NE1/4, NE1/4, Section 4, T12N., R05E., NMPM, Placitas Quadrangle

Landform: Terrace Described by: Sean D. Connell Date: October 11, 1994

Deposit: Gravelly and clayey alluvium Dominant clast lithology: Limestone and reddish-brown siltstone

Parent material characteristics: 7.5YR 5/4 (d), 7.5YR 4/3 (m), SiCL and 10YR 6/3 (d & m), Sandy Clay Loam

Surface elevation (m/feet): 1929±3 / 6330±10 Aspect: Northwest-facing stream cut

Base level (m): 55 Dissection class: 2 to 4 Slope (%): 4

Vegetation: Juniper, grasses and Cholla

Comments: Carbonate covers clay films.
Parent material for horizons A through Btk3 derived from Paleozoic-Mesozoic sedimentary units.

Soil-profile summary

PDI (8/4): 23.27 / 24.24 Thickness normalized PDI (8/4): 0.17 / 0.18

Maximum B-horizon development and thickness

Hue: 7.5YR Bk (cm): 0 Bt (cm): 0 Btk (cm): ≥137 Max. clay films: 3mkpf

Carbonate morphology/thickness (cm): II+ / 30 Max. structure: 2mabk

Horizon	Depth (cm)	Color dry *(ped)* moist	Texture (≤2 mm)	Structure	Consist. d w	 m pl	Clay films	Gravel % volume	Roots	Pores	Carbonate	Base
A	0 - 7	10YR 4/3 10YR 4/3	SiC	sg	lo s	lo vp	n.o.	≤5	1f	n.o.	es dissem.	as
Btk1	7 - 20	7.5YR 4/2 7.5YR 4/2	SiC	2f-mabk	sh s	fr vp	2npf	≤5	1f	1vf	e If	cs
Btk2	20 - 32	7.5YR 4/3 7.4YR 4/2	SiC	2m-cabk	sh vs	fr vp	3mkpf	≤5	1f	1fvf	e If	cs
Btk3	32 - 59	7.5YR 5/3 7.5YR 4/3 *(7.5YR 4/3)*	SiC	2m-cabk	sh s	fr p	2npopf	≤5	1f	1vf	es I+ to II	cw
2Btk4	59 - 79	7.5YR 6/3 7.5YR 5/3 *(7.5YR 4/3)*	SiCL	2m-cabk	sh s	vfr mp	1mkpopf	5	1fvf	1vf	e - es II+	cw

Horizon	Depth (cm)	Color dry *(ped)* moist	Texture (≤2 mm)	Structure	Consist. d m w pl	Clay films	Gravel % volume	Roots	Pores	Carbonate	Base
2Btk5	79 - 89	7.5YR 6/3 7.5YR 5/3	SiCL	2cabk	sh vfr ss ps	1ncobrpf	7	1vf	1vf	es - ev II+	cw
2Btk6	89 - 107	7.5YR 5/3 7.5YR 5/3	SCL	1mabk	sh vfr s mp	1npf	75	1fvf	1fvf	ev II	cw
2Btk7	107 - 117	7.5YR 6/3 7.5YR 6/3	SCL	sg	lo lo ss mp	1ncobrpf	60	1f	n.o.	ev II	cw
2Btk8	117 - 137+	10YR 6/3 10YR 6/3	SCL	sg	lo lo ss ps	1ncobr	80	1f	n.o.	ev II+	n.o.

Soil-Profile Description

General

Soil-profile number: **P-5** Geomorphic surface: **QT1** Map unit: **QTpf1**

Location: NE1/4, NE1/4, Section 1, T12N., R04E., NMPM, Placitas Quadrangle

Landform: Gravel-mantled pediment Described by: Sean D. Connell Date: October 14, 1994

Deposit: Gravel Dominant clast lithology: Limestone & minor metamorphic

Parent material characteristics: 10YR 5/4 (d), 10YR 4/3 (m), Sand

Surface elevation (m/feet): 1820±3 / 5970±10 Aspect: Northwest-sloping surface

Base level (m): 73 Dissection class: 2 to 4 Slope (%): 4

Vegetation: Juniper, Pinyon, grasses and Beavertail cactus.

Comments: Described along road cut; Surface is dissected and stripped and is on hanging wall of unnamed fault.
Platy structure indicates Stage IV carbonate morphology.
Approximate thickness of horizons Bkm2b and Bkm3b.
Silica recognized by yellowish hue and does not slake in dilute hydrochloric acid.

Soil-profile summary

PDI (8/4)*: 107.63 / 40.10 Thickness normalized PDI (8/4)*: 0.10 / 0.27

Maximum B-horizon development and thickness

Hue: 2.5Y Bk (cm): ≥250 Bt (cm): 0 Btk (cm): 21 Max. clay films: 1nco

Carbonate morphology/thickness (cm)*: IV+ / 55 Max. structure: 3vcpl & 3cabk

* Depth for PDI and thickness-normalized PDI calculated to Bkm2b horizon (258 cm).

Horizon	Depth (cm)	Color dry moist	Texture (≤2 mm)	Structure	Consist. d m w pl	Clay films	Gravel % volume	Roots	Pores	Carbonate	Base
A	0 to 12	10YR 4/3 10YR 4/3	SiCL	sg	lo lo so ps	n.o.	30	2f	n.o.	ev dissem.	as
Btk	12 to 33	10YR 6/3 10YR 5/4	CL	1m-csbk	h vfr ss ps	1nco	50	2cf	1f	ev I	aw
Bkmb	33 to 73	10YR 8/2 10YR 7/3	SCL	3cabkpl	eh vfi so po	n.o.	20	2f 1c	1vf	ev IV+	aw
Bkqmb	73 to 88	2.5Y 8/1 2.5Y 8/3	nd	3c-vcpl	eh vfi so po	n.o.	10	2c	n.o.	ev IV+	aw
Bkm1b	88 to 258	10YR 8/2-3 10YR 7/3	SL	1csbk	sh fr ss po	n.o.	30	N.O.	n.o.	ev IV	gw
Bkm2b	258 to 393	10YR 8/2 10YR 7/3-4	SL	2m-csbk	vh vfi so ps	v1nco	20	N.O.	n.o.	ev IV	as

Soil-Profile Description

General

Soil-profile number: **P-6** Geomorphic surface: **Q8** Map unit: **Qa8**

Location: NE1/4, NE1/4, Section 1, T12N., R04E., NMPM, Placitas Quadrangle

Landform: Valley floor

Deposit: Alluvium and debris flow

Described by: Sean D. Connell Date: October 14, 1994

Dominant clast lithology: Metamorphic and minor limestone, granitoid and sandstone

Parent material characteristics: 10YR 6/3 (d), 10YR 5/3 (m), Sand

Surface elevation (m/feet): 1783±3 / 5850±10 Aspect: Northwest-facing stream cut

Base level (m): 2.5 Dissection class: 2 Slope (%): 2

Vegetation: Pinyon, Juniper, Cholla and grasses

Comments: Btk1 and Btk2 horizons exhibit clay films on clasts.

Soil-profile summary

PDI (8/4): 13.75 / 9.83 Thickness-normalized PDI (8/4): 0.06 / 0.04

Maximum B-horizon development and thickness

Hue: 7.5YR Bk (cm): ≥100 Bt (cm): 0 Btk (cm): 80 Max. clay films: 1ncobr

Carbonate morphology/thickness (cm): I+ / 32 Max. structure: 1csbk

Horizon	Depth (cm)	Color dry moist	Texture (≤2 mm)	Structure	Consist. d m w pl	Clay films	Gravel % volume	Roots	Pores	Carbonate	Base
A	0 - 7	10YR 4/2 10YR 3/2	L	sg	lo lo so ps	n.o.	40	2f	1vf	es dissem.	cs
Bk1	7 - 18	10YR 4/3 10YR 4/3	SL	1msbk	lo vfr so po	n.o.	50	2fvf	2vf	ev I	cs
Bk2	18 - 50	10YR 5/3 10YR 4/3	LS	sg	lo lo so po	v1nco	75	2vf	n.o.	ev I+	cw
Btk1	50 - 90	7.5YR 6/3 7.5YR 4/3	LS	sg	lo lo so po	1ncobr	50	2f	n.o.	ev I	gi
Btk2	90 - 130	7.5YR 6/3 7.5YR 4/3	S	sg	lo lo so po	1nco	20 - 30	2cf	n.o.	es - ev I	cw
Bk3	130 - 230+	7.5YR 6/3 7.5YR 4/3	S	1f-csbk	lo lo so po	v1nco	65	2cf	n.o.	es - ev I	n.o.

Soil-Profile Description

General

Soil-profile number: **P-7** Geomorphic surface: **Q5** Map unit: **Qpf5**

Location: NE1/4, NE1/4, Section 2, T12N., R04E., NMPM, Placitas Quadrangle

Landform: Pediment-fan complex Described by: Sean D. Connell Date: October 22, 1994

Deposit: Gravel and gravelly sand Dominant clast lithology: Metamorphic, limestone, granitoid and minor sandstone

Parent material characteristics: 10YR 5/4 (d), 10YR 4/3 (m), Sand

Surface elevation (m/feet): 1716±3 / 5630±10 Aspect: Northwest-sloping surface

Base level (m): 7.6 Dissection class: 2 Slope (%): 4

Vegetation: Grasses, sage-brush, Juniper, Cholla and Yucca

Comments: Soil Pit described after rainstorm; moist surface and shallow subsoil.
Horizons Btk1 and Btk2 exhibit clay films on clasts.
Scattered krotovina indicate that profile has been slightly biotrubated.

Soil-profile summary

PDI (8/4): 34.76 / 27.53 Thickness-normalized PDI (8/4): 0.22 / 0.28

Maximum B-horizon development and thickness

Hue: 7.5YR Bk (cm): ≥71 Bt (cm): 11 Btk (cm): 28 Max. clay films: 2mkbrpf

Carbonate morphology/thickness (cm): III- / 20 Max. structure: 3cabk

Horizon	Depth (cm)	Color dry *(ped)* moist	Texture (≤2 mm)	Structure	Consist. d m w pl	Clay films	Gravel % volume	Roots	Pores	Carbonate	Base
A	0 - 6	10YR 5/3 10YR 4/3	CL	1csbk	so vfr ss mp	n.o.	5	1f	n.o.	eo	vas
B	6 - 11	10YR 6-5/3 10YR 4/3	CL	1csbk	sh vfr s mp	v1npo	≤5	1f	1vf	eo	vas
Bt	11 - 22	7.5YR 4-3/4 7.5YR 4/4 *(7.5YR 3/3-4)*	SiC	3mcabk	so vfr vs mp	4kpfbr	5	1vf	1vf	eo	as
Btk1	22 - 31	7.5YR 5/4 7.5YR 5/4 *(7.5YR 4/4)*	C	3m-cabk	h vfr vs p	2mkpfbr	7	1vf	2vf	es II	as

Horizon	Depth (cm)	Color dry (*ped*) moist	Texture (≤2 mm)	Structure	Consist. d m w pl	Clay films	Gravel % volume	Roots	Pores	Carbonate	Base
Btk2	31 - 50	7.5YR 6/4 7.5YR 5/4	SiCL	2cabk & sbk	sh vfr s p	1npf	25	1vf	2vf	es II	cw
Bk1	50 - 80	10YR 7/4 10YR 7/3	SCL	1cabk	sh fr ss ps	1npo	70	n.o.	n.o.	ev II+ to III-	cw
Bk2	80 - 92	10YR 7/4 10YR 7/3-4	SCL	1mabk	sh vfr so po	n.o.	50 - 60	n.o.	n.o.	ev II+	cw
Bk3	92 - 112	10YR 7/4 10YR 7/4	CL	1cabk	sh fr ss mp	v1npf	40	n.o.	n.o.	ev II+ to III-	vas
Bk4	112 - 121+	10YR 5/4 10YR 4/3	SL	sg	lo lo so ps	n.o.	20	n.o.	n.o.	es dissem. to I+	n.o.

Soil-Profile Description

General

Soil-profile number: **P-8** Geomorphic surface: **Q7a** Map unit: **Qf7a**

Location: SE1/4, NW1/4,, Section 2, T12N., R04E., NMPM, Placitas Quadrangle

Landform: Alluvial fan Described by: Sean D. Connell Date: October 21, 1994

Deposit: Sandy and gravelly alluvium Dominant clast lithology: Metamorphic, limestone, granitoid and minor sandstone

Parent material characteristics: 10YR 5/4 (d), 10YR 4/3 (m), Sand or Sandy Clay Loam

Surface elevation (m/feet): 1707±3 / 5600±10 Aspect: West-northwest sloping surface

Base level (m): 3.1 Dissection class: 2 Slope (%): 4

Vegetation: Grasses, sage-brush, Juniper and Yucca

Comments: Soil pit described after rainstorm; moist surface and shallow subsoil

Soil-profile summary

PDI (8/4): 15.83 / 19.21 Thickness-normalized PDI (8/4): 0.16 / 0.19

Maximum B-horizon development and thickness

Hue: 7.5YR Bk (cm): ≥54 Bt (cm): 0 Btk (cm): 29 Max. clay films: 2nbrpo

Carbonate morphology/thickness (cm): II / 44 Max. structure: 2cabk

Horizon	Depth (cm)	Color dry moist	Texture (≤2 mm)	Structure	Consist. d m w pl	Clay films	Gravel % volume	Roots	Pores	Carbonate	Base
A1	0 - 2	10YR 5/4 10YR 4/3	L	sg	lo lo so ps	n.o.	30	1vf	n.o.	eo	vas
A2	2 - 7	10YR 4/3 10YR 4/2	SiC	sg	lo lo ss mp	n.o.	10	1vf	1vf	eo	cs
Bk1	7 - 16	10YR 4/3-4 7.5YR 4/3	CL	1f-csbk	so vfr ss mp	n.o.	10	1vf	1vf	ve dissem.	cs
Btk1	16 - 25	7.5YR 4/6 7.5YR 4/3	C	1m-cabk	so vfr s p	1nbr	5	1vf	1vf	ve dissem. to I-	cs
Btk2	25 - 45	7.5YR 4/6 7.5YR 4/6	SiC	2cabk	sh vfr s p	2nbrpo	20	1fvfm	1vf	ve I	sw
Bk2	45 - 89	10YR 6/4 10YR 5/3	SCL	1cabk	sh fr so po	n.o.	70	1vf	n.o.	es - ev II	aw
Bk3	89 - 99+	10YR 5/4 10YR 4/3	SiC	1m-cabk	so vfr s p	v1nco	40	1vf	n.o.	es - ev I+	n.o.

Soil-Profile Description

General

Soil-profile number: **P-9** Geomorphic surface: **Q8** Map unit: **Qf8**

Location: NW1/4, SE1/4, Section 11, T12N., R04E., NMPM, Placitas Quadrangle

Landform: Alluvial fan

Deposit: Sandy and gravelly alluvium

Described by: Sean D. Connell Date: October 21, 1994

Dominant clast lithology: Metamorphic, limestone, granitoid and minor sandstone

Parent material characteristics: 10YR 5/4 (d), 10YR 4/3 (m), Sand

Surface elevation (m/feet): 1801±3 / 5910±10 Aspect: West-northwest sloping surface

Base level (m): ≤1 Dissection class: 2 Slope (%): 5

Vegetation: Grasses, Cholla and minor sage-brush, Yucca and Juniper

Comments: Soil Pit

Soil-profile summary

PDI (8/4): 21.00 / 14.52 Thickness-normalized PDI (8/4): 0.15 / 0.22

Maximum B-horizon development and thickness

Hue: 7.5YR Bk (cm): ≥91 Bt (cm): 0 Btk (cm): 0 Max. clay films: 1nbr

Carbonate morphology/thickness (cm): I / 91 Max. structure: 2cabk

Horizon	Depth (cm)	Color dry moist	Texture (≤2 mm)	Structure	Consist. d m w pl	Clay films	Gravel % volume	Roots	Pores	Carbonate	Base
A	0 - 3	10YR 5/3 10YR 4/2	L	1msbk	lo lo so po	n.o.	10	2f	n.o.	eo	vas
Bk1	3 - 19	10YR 4/3 10YR 3/2	SCL	1fsbk	so lo so po	1nco	60	1vf	1f	es dissem. to I	as
Btk	19 - 45	10YR 3/3 10YR 4/2	SL - SCL	1m-csbk	so lo ss mp	1nbr	25	2vf	1f	ve If	gw
Bk2	45 - 87	10YR 4/3 10YR 4/2	L	2m-cabk	so lo ss ps	n.o.	50	2vf	1f	ve If	gw
Bk3	87 - 94+	10YR 5/3-4 10YR 4/3	SL	1fsbk	so lo ss po	n.o.	40	n.o.	1fvf	es If	n.o.

Soil-Profile Description

General

Soil-profile number: **P-10** Geomorphic surface: **Q4** Map unit: **Qf7-8/Qf4**

Location: W1/2, NW1/4, Section 12, T12N., R04E., NMPM, Placitas Quadrangle

Landform: Alluvial fan
Deposit: Sandy and gravelly alluvium

Described by: Sean D. Connell Date: October 23, 1994
Dominant clast lithology: Metamorphic, granitoid and minor limestone

Parent material characteristics: 10YR 5/4 (d), 10YR 4/3 (m), Sand

Surface elevation (m/feet): 1817±3 / 5960±10 Aspect: West-northwest sloping surface

Base level (m): 9 to 12 Dissection class: 3 Slope (%): nd

Vegetation: Grasses, Juniper and Yucca

Comments: Soil pit described in younger fan alluvium Qf7 or Qf8.

Soil-profile summary

PDI (8/4): 16.98 / 22.33 Thickness-normalized PDI (8/4): 0.13 / 0.17

Maximum B-horizon development and thickness

Hue: 7.5YR Bk (cm): ≥100 Bt (cm): 23 Btk (cm): 13 Max. clay films: 2mkpocobr

Carbonate morphology/thickness (cm): II+ / 17 Max. structure: 3cabk

Horizon	Depth (cm)	Color dry *(ped)* moist	Texture (≤2 mm)	Structure	Consist. d m w pl	Clay films	Gravel % volume	Roots	Pores	Carbonate	Base
AB	0 - 8	10YR 5/4 10YR 4/3	SCL	1m-csbk	so lo so ps	n.o.	25	2f	1f	eo	as
Bt	8 - 31	7.5YR 4/4 7.5YR 4/3 *(7.5YR 4/4)*	SiC	2m-cabk	sh vfr s mp	2mkpocobr	15	1fm	n.o.	eo	cs
Btk	31 - 44	10YR 5/4 10YR 4/3	SiC	1m-cabk	so vfr ss mp	1nbr & v1nco	30	1f	1vf	es I & If	cw
Bk1	44 - 53	10YR 6/3-4 10YR 5/3	SiCL	1cabk	sh vfr ss mp	n.o.	70	n.o.	1vf	ev II	cw
Bk2	53 - 70	10YR 7/3 10YR 6/3	SCL-SC	1m-cabk	sh fr so ps	n.o.	30	n.o.	1vf	es II+	gw
Btk1b	70 - 83	10YR 6/3 10YR 5/4	SiL	1m-cabk	h vfr ss po	2ncopobr	40	n.o.	1fvf	es II	gw
Btk2b	83 - 97	10YR 6/3 10YR 4/3	SL	1m-cabk	lo lo so po	1nco	60	n.o.	2vf	ev II	aw
Bkb	97 - 131+	10YR 5/4 10YR 4/3	SL	sg	lo lo so po	n.o.	15	1f	n.o.	es I	n.o.

Soil-Profile Description

General

Soil-profile number: **P-11** Unit: **QTsfup**

Location: SE1/4, NE1/4, Section 2, T12N., R04E., NMPM, Placitas Quadrangle

Landform: Piedmont alluvial fan
Deposit: Sandy and gravelly alluvium

Described by: Sean D. Connell Date: October 23, 1994
Dominant clast lithology: Metamorphic, granitoid and sandstone

Surface elevation (m/feet): 1722±3 / 5650±10 Aspect: Northwest-sloping surface

Base level (m): 6 to 9 Dissection class: 4 to 5 Slope (%): 7

Vegetation: Pinyon, Juniper, Cholla and grasses

Comments: Soil pit on rounded and modified surface and partially stripped soil.
Buried soil noted by occurrence of highly weathered granitoid and sandstone clasts and abrupt color change.
Btk1 through Btk1b horizons exhibit carbonate coatings on clasts.
Unit is at elevation similar to geomorphic surface Q2.

Soil-profile summary

Maximum B-horizon development and thickness

Hue: 7.5YR Bk (cm): 0 Bt (cm): 0 Btk (cm): ≥65 Max. clay films: 2mkcobr

Carbonate morphology/thickness (cm): II / ≥35 Max. structure: 2cabk & 1vcpl

Horizon	Depth (cm)	Color dry moist	Texture (≤2 mm)	Structure	Consist. d m w pl	Clay films	Gravel % volume	Roots	Pores	Carbonate	Base
Ak	0 - 1	10YR 5/4 10YR 5/3	SL	sg	lo lo so ps	n.o.	35	1f	n.o.	ve dissem.	vas
Btk1	1 - 8	10YR 4/3 10YR 4/3	SCL	1msbk	so lo so mp	1ncobr	50	1f	n.o.	ve dissem. to I	cs
Btk2	8 - 19	10YR 5/4 10YR 4/3	CL	1m-csbk	so lo ss mp	1ncobr	20	2fm	1vf	ve dissem. to I	cs
Btk1b	19 - 31	7.5YR 5/4 7.5YR 6/4	SCL	1m-cabk	so lo ss mp	2n-mkcobr	70	1f2m	1vf	ve I	cw
Btk2b	31 - 51	7.5YR 6/4 7.5YR 7-6/4	SCL	2cabk	so lo ss mp	2mkcobr	80	1fm	n.o.	ve II	aw
Btk3b	51 - 66+	7.5YR 5/4 7.5YR 5/4	SCL	1c-vcpl	h fr so ps	1ncobr	80	n.o.	n.o.	ve II	n.o.

Soil-Profile Description

General

Soil-profile number: **P-12** Unit: **QTsfup**

Location: SW1/4, NW1/4, Section 2, T12N., R04E., NMPM, Placitas Quadrangle

Landform: Piedmont alluvial fan

Deposit: Sandy and gravelly alluvium

Described by: Sean D. Connell Date: October 23, 1994

Dominant clast lithology: Metamorphic, granitoid and sandstone

Surface elevation (m/feet): 1695±3 / 5660±10

Aspect: `North-northwest-sloping surface

Base level (m): 9 Dissection class: 4 to 5 Slope (%): 14

Vegetation: Grasses, Yucca, Juniper and Cholla

Comments: Soil pit described on rounded slope.
Unit is at similar elevation as geomorphic surface Q2.

Soil-profile summary

Maximum B-horizon development and thickness

Hue: 10YR Bk (cm): ≥50 Bt (cm): 0 Btk (cm): 18 Max. clay films: 1ncobr

Carbonate morphology/thickness (cm): I / ≥68 Max. structure: 1cabk

Horizon	Depth (cm)	Color dry moist	Texture (≤2 mm)	Structure	Consist. d m w pl	Clay films	Gravel % volume	Roots	Pores	Carbonate	Base
A	0 - 3	10YR 5/4 10YR 4/3	CL	sg	lo lo so ps	N.O.	20	2f	n.o.	eo	as
B	3 - 21	10YR 5/4 10YR 4/2	SiC	1m-csbk	so lo ss mp	v1nco	20	1m2f	n.o.	ve dissem. to I-	cs
Btk	21 - 39	10YR 5/4 10YR 5/4	SC	1m-cabk	so vfr so mp	1ncobr	40	1f	n.o.	ve I	cw
Bk1	39 - 74	10YR 6/4 10YR 5/4	SCL	1cabk	h vfr ss mp	v1ncobr	50	1f	n.o.	ve I	cw
Bk2	74 - 89+	10YR 5/4 10YR 4/4	SL	sg	lo lo so po	1nco	70	n.o.	n.o.	es I	n.o.

Soil-Profile Description

General

Soil-profile number: **P-13**   Geomorphic surface: **Q5**   Map unit: **Qp5**

Location: SW1/4, NW1/4, Section 1, T12N., R05E., NMPM, Placitas Quadrangle

Landform: Pediment   Described by: Sean D. Connell   Date: October 25, 1994

Deposit: Sandy and gravelly alluvium   Dominant clast lithology: Metamorphic with minor granitoid and limestone

Parent material characteristics: 10YR 5/4 (d), 10YR 4/3 (m), Sandy Clay Loam

Surface elevation (m/feet): 1740±3 / 5710±10   Aspect: Northwest-sloping surface

Base level (m): 3 to 6   Dissection class: 2 to 3   Slope (%): 5

Vegetation: Grasses, Cholla, Juniper and Yucca

Comments: Soil pit. Buried soil noted by color change and illuvial clay increase. Bk and Btkb horizons exhibit weak cementation.

Soil-profile summary

PDI (8/4): 30.94 / 38.11   Thickness-normalized PDI (8/4): 0.23 / 0.28

Maximum B-horizon development and thickness

Hue: 7.5YR   Bk (cm): ≥77   Bt (cm): 14   Btk (cm): 38   Max. clay films: 3kbrpf

Carbonate morphology/thickness (cm): II / 67   Max. structure: 3vcabk

Horizon	Depth (cm)	Color dry moist	Texture (≤2 mm)	Structure	Consist. d m w pl	Clay films	Gravel % volume	Roots	Pores	Carbonate	Base
A	0 - 2	10YR 5/4 10YR 4/3	SiCL	sg	lo lo ss mp	n.o.	40	n.o.	n.o.	eo	vas
Bw	2 - 7	8.75YR 5/4 7.5YR 4/3	SiC	1f-msbk	so lo ss vp	n.o.	60	2f	n.o.	eo	as
Bt	7 - 21	7.5YR 4/4 7.5YR 4-3/4	SiC	3m-cabk	so vfr vs vp	3kbrpf & 2mkcopo	10	1fm	1fvf	eo	cs
Btk1	21 - 41	7.5YR 5/4 7.5YR 4/4	SiC	3c-vcabk	h fr vs vp	3mkpf copobr	25	1f	1vf	es dissem.to I+	cw
Btk2	41 - 59	10YR 7/4 10YR 6/4	SiCL	1mabk	sh fr so ps	1ncobr	80	1vf	n.o.	es I+	cw
Bk	59 - 98	10YR 7/3 10YR 6/3-4	SL	1m-cabk	sh lo ss ps	v1ncobr	40 - 45	1vf	1fvf	ev II	cw
Btkb	98 - 126	7.5YR 7/4 7.5YR 6/4	L - CL	1m-cabk	h vfr so mp	2ncobr	60	1vf	n.o.	es II	cw
Bkb	126 - 136+	7.5YR 7/4 7.5YR 4/4	SCL	sg	lo lo ss ps	v1nco	35	n.o.	n.o.	ev dissem. to I	n.o.

Soil-Profile Description

General

Soil-profile number: **P-14** Geomorphic surface: **Q9** Map unit: **Qa9**

Location: SE1/4, SE1/4, Section 3, T12N., R04E., NMPM, Placitas Quadrangle

Landform: Floodplain Described by: Sean D. Connell Date: October 25, 1994

Deposit: Sandy and gravelly alluvium Dominant clast lithology: Granitoid and metamorphic

Parent material characteristics: 10YR 5/4 (d), 10YR 4/3 (m), Loamy Sand

Surface elevation (m/feet): 1689±3 / 5540±10 Aspect: West-sloping surface

Base level (m): ≤0.5 Dissection class: 1 to 2 Slope (%): 4

Vegetation: Grasses, Cholla, sage-brush and Yucca

Comments: Soil pit excavated into riser of low terrace within arroyo.

Soil-profile summary

PDI (8/4): 11.37 / 16.85 Thickness-normalized PDI (8/4): 0.11 / 0.17

Maximum B-horizon development and thickness

Hue: 10YR Bk (cm): ≥85 Bt (cm): 0 Btk (cm): 0 Max. clay films: n.o.

Carbonate morphology/thickness (cm): I / 68 Max. structure: 1csbk

Horizon	Depth (cm)	Color dry moist	Texture (≤2 mm)	Structure	Consist. d w	Consist. m pl	Clay films	Gravel % volume	Roots	Pores	Carbonate	Base
A	0 - 3	10YR 4/3 10YR 3/2	L	sg	lo so	lo ps	n.o.	5	2f	n.o.	eo	vas
AB	3 - 10	10YR 5/4 10YR 4-3/3	L	sg to 1fmsbk	so so	lo po	n.o.	5	2f	n.o.	eo	vas
Bw	10 - 17	10YR 4/3 10YR 3/2	L	sg to 1fsbk	so so	lo po	n.o.	10	1fm	n.o.	eo	as
Bk1	17 - 34	10YR 4/3 10YR 4/2	SL	1m-csbk	so so	lo ps	vlncobr	50	1fc	n.o.	ve dissem.to I-	as
Bk2	34 - 52	10YR 4/3 10YR 4/2-3	SCL	1mcsbk	so so	lo ps	vlnco	50	1f	n.o.	es If	as
Bk3	52 - 102+	10YR 5/4 10YR 4/3	L	1m-csbk	sh ss	lo po	vlnco	40	1f	n.o.	es I	n.o.

Soil-Profile Description

General

Soil-profile number: **P-15** Geomorphic surface: **Q6** Map unit: **Qf6**

Location: SW1/4, SW1/4, Section 33, T12N., R04E., NMPM, Alameda Quadrangle

Landform: Alluvial fan

Described by: Sean D. Connell Date: November 05, 1994

Deposit: Sandy and gravelly alluvium

Dominant clast lithology: Granitoid with minor metamorphic and limestone

Parent material characteristics: 10YR 6/3 (d), Sand (taken from nearby stream alluvium)

Surface elevation (m/feet): 1693±3 / 5555±10

Aspect: Northwest-sloping surface; southwest-facing stream cut

Base level (m): 3.5 Dissection class: 2 to 3 Slope (%): 7

Vegetation: Grasses, sage-brush, Cholla, Yucca and Juniper

Comments: Stream-cut exposure; partially stripped surface and soil.
Bkm horizon is laterally variable and exhibits Stage II to III+ carbonate morphology.

Soil-profile summary

PDI (8/4): 24.82 / 30.80

Thickness-normalized PDI (8/4): 0.21 / 0.26

Maximum B-horizon development and thickness

Hue: 7.5YR Bk (cm): ≥80 Bt (cm): 0 Btk (cm): 36 Max. clay films: 3mkbrpo & 2npf

Carbonate morphology/thickness (cm): III+ / 40 Max. structure: 3mpr & 3cabk

Horizon	Depth (cm)	Color dry moist	Texture (≤2 mm)	Structure	Consist. d w	m pl	Clay films	Gravel % volume	Roots	Pores	Carbonate	Base
Ak	0 - 1	10YR 5/4 10YR 4/3	SC	sg	lo ss	lo ps	n.o.	45 - 55	2m	n.o.	es dissem.	vas
Btk1	1 - 17	7.5YR 4/6 7.5YR 4/4	SiC - C	3mpr & 3m-cabk	sh s	vfr p	3n-mkbrpo & 2npf	10 - 15	2f	1f2vf	es I+	cw
Btk2	17 - 37	7.5YR 6/4 7.5YR 5/4	SiC	3mpr & 3m-cabk	h ss	vfr mp	2nbrpopf & 1mkprbr	10 - 15	1f	1f2vf	ev II	cw
Bk	37 - 47	10YR 7/4 10YR 6/4	CL	1csbk	h ss	fr mp	v1nco	55	n.o.	1vf	es - ev II	cw
Bkm	47 - 87	10YR 8/3 10YR 7/3	SiCL	1m- cabkpl	sh s	vfr mp	n.o.	70	n.o.	n.o.	es II+ to III-	cw
Bk	87 - 127+	10YR 6/4 10YR 5/4	SL - SCL	1vf-fsbk	so so	lo po	n.o.	15 - 20	n.o.	n.o.	ev I	n.o.

Soil-Profile Description

General

Soil-profile number: **P-16** Geomorphic surface: **Q6** Map unit: **Qf6**

Location: NE1/4, SW1/4, Section 33, T12N., R04E., NMPM, Alameda Quadrangle

Landform: Alluvial fan Described by: Sean D. Connell Date: November 06, 1994

Deposit: Sandy and gravelly alluvium Dominant clast lithology: Granitoid and minor limestone and metamorphic

Parent material characteristics: 10YR 6/3 (d), 10YR 5/3 (m), Sandy Loam

Surface elevation (m/feet): 1739±3 / 5705±10 Aspect: Northeast-facing stream cut

Base level (m): 2 Dissection class: 2 to 3 Slope (%): nd Vegetation: nd

Comments: Described along stream cut of Juan Tabo Creek. Upper 50-cm is part of undifferentiated Qf7-8.
Soil exhibits multiple, thin laminar platy carbonate in Bkm horizons, suggesting gully bed cementation.
Bk horizon exhibits carbonate rinds reworked from older(?) soils.
Bkmqb horizon exhibits 0.5-mm thick laminar carbonate over platy carbonate.
Horizons A-Bk-Btk-Bk are associated with unit Qf8.
Silica films recognized by yellowish hue and does not slake in dilute hydrochloric acid.
†Horizon exhibits minor soil-structure except for carbonate accumulation.

Soil-profile summary (buried soil)

PDI (8/4): 17.87 / 29.54 Thickness-normalized PDI (8/4): 0.12 / 0.20

Maximum B-horizon development and thickness

Hue: 7.5YR Bk (cm): ≥95 Bt (cm): 7 Btk (cm): 0 Max. clay films: 3mkcobr

Carbonate morphology/thickness (cm): IV (28) Max. structure: 3vcpl

Horizon	Depth (cm)	Color dry moist	Texture (≤2 mm)	Structure	Consist. d m w pl	Clay films *silica films*	Gravel % volume	Roots	Pores	Carbonate	Base
A	0 - 2	10YR 5/4 10YR 4/2	SCL	sg	lo lo so ps	n.o.	10	1f	2vf	eo	vas
Bk	2 - 6	10YR 5/4 10YR 4/2	SCL	1fsbk	so lo so mp	v1nco	10	2vf	1f	es dissem.	as
Btk	6 - 33	10YR 7-6/4 8.75YR 6-5/4	SiL - SiCL	1csbk	sh vfr ss mp	lncobr	15 - 20	2vf 1f	2vf	es I+	cw
Bk†	33 - 43	10YR 6-5/4 10YR 4/3-4	S	1f-msbk	sh lo so po	vlnco	60	2vf	n.o.	ev dissem.	as
Btb	43 - 50	7.5YR 5/6 7.5YR 5/4-6	C	3cabk	h lo ss p	3n-mkcobr	40	2fvf	2vf	eo	ai
Bkqb	50 - 57	10YR 7/4 10YR 7/4	SC - SCL	1m-csbk	so lo so p	n.o. *v1nco*	10 - 20	1f	2vf	ev III	aw
Bkmqb	57 - 85	10YR 8/1&8/2 10YR 8/1&7/3	S	3c-vcpl	vh fi so po	n.o. *lnco*	20 - 30	2mc	n.o.	ev IV	gi
Bk1b	85 - 110	10YR 7/3-4 10YR 5/3	LS	sg	lo lo so po	n.o.	40	n.o.	n.o.	ev I	gw
Bk2b	110 - 145+	10YR 6/4 10YR 5/4	SL	1fsbk	so lo so po	vlncobr	60	n.o.	n.o.	ev I	n.o.

Soil-Profile Description

General

Soil-profile number: **P-17** Geomorphic surface: **Q7-8** Map unit: **Qf7-8.r**

Location: SW1/4, NW1/4, Section 27, T12N., R04E., NMPM, Alameda Quadrangle

Landform: Alluvial fan Described by: Sean D. Connell Date: November 07, 1994

Deposit: Sandy and gravelly alluvium Dominant clast lithology: Metamorphic

Parent material characteristics: 10YR 5/4 (d), 10YR 4/4 (m), Silty Clay

Surface elevation (m/feet): 1704±3 / 5590±10 Aspect: Southwest-facing stream cut

Base level (m): 2 Dissection class: 2 Slope (%): 18

Vegetation: Grasses, sage-brush, Juniper, Cholla and beavertail cactus; very minor Oak

Comments: Described along stream cut under poor lighting conditions.
Piedmont alluvium along Rincon Ridge range-front.

Soil-profile summary

PDI (8/4): 43.90 / 39.36 Thickness-normalized PDI (8/4): 0.24 / 0.22

Maximum B-horizon development and thickness

Hue: 7.5YR Bk (cm): ≥70 Bt (cm): 81 Btk (cm): 25 Max. clay films: 2mkbr

Carbonate morphology/thickness (cm): I / 25 Max. structure: 2cabk

Horizon	Depth (cm)	Color dry moist	Texture (≤2 mm)	Structure	Consist. d m w pl	Clay films	Gravel % volume	Roots	Pores	Carbonate	Base
A	0 - 4	10YR 5/3 10YR 4/3	L	sg to 1fsbk	so lo so ps	n.o.	15	1fvf	n.o.	eo	vas
Bt1	4 - 30	7.5YR 4/3-4 7.5YR 4/3	SiC	2m-cabk	sh fr ss p	2ncobr	50	1fvf	1vf	eo	cw
Bt2	30 - 45	10YR 5/4 10YR 4/3	SiCL	2m-cabk	sh fr ss mp	1ncobr	10	1fm	2fvf	eo	cw
Bt3	45 - 59	10YR 5/4 10YR 4/3	SiCL	1mabk	sh fr ss mp	v1ncobr	15	2m	2fvf	eo	cw
Bt4	59 - 85	8.75YR 5/4 8.75YR 5/4	SiC - C	2m-cabk	h fi s mp	2mkbr	20	1m	n.o.	eo	gw
Btk	85 - 110	10YR 5/4 10YR 4/4	SiC	2m-cabk	sh fr s mp	1nbr	30 - 40	2m1f	n.o.	e dissem. to I	cw
Bk	110 - 180+	10YR 5/4 10YR 4/4	SiC-C	1mabk	sh vfr ss p	v1nco	60	1f	n.o.	ve dissem. to I-	n.o.

Soil-Profile Description

General

Soil-profile number: **P-18** Geomorphic surface: **Q7-8** Map unit: **Qf7-8.r**

Location: NE1/4, NE1/4, Section 4, T12N., R04E., NMPM, Alameda Quadrangle

Landform: Alluvial fan Described by: Sean D. Connell Date: November 08, 1994

Deposit: Sandy and gravelly alluvium Dominant clast lithology: Metamorphic

Parent material characteristics: 10YR 5/4 (d), 10YR 4/4 (m), Sandy Loam

Surface elevation (m/feet): 1810±3 / 5940±10 Aspect: North-facing stream cut

Base level (m): ≤1.5 Dissection class: 2 Slope (%): 9

Vegetation: Grasses, sage-brush, Cholla and Yucca

Comments: Bt3 horizon exhibits scattered thick clay films.
Piedmont alluvium along Rincon Ridge range front.

Soil-profile summary

PDI (8/4): 31.73 / 27.62 Thickness-normalized PDI (8/4): 0.29 / 0.25

Maximum B-horizon development and thickness

Hue: 7.5YR Bk (cm): 0 Bt (cm): 36 & 40 Btk (cm): 25 Max. clay films: 4kbrpf

Carbonate morphology/thickness (cm): II / 25 Max. structure: 3cabk & 3mpr

Horizon	Depth (cm)	Color dry moist	Texture (≤2 mm)	Structure	Consist. d m w pl	Clay films	Gravel % volume	Roots	Pores	Carbonate	Base
A	0 - 8	10YR 5-4/4 10YR 4/3	SCL	sg	lo lo ss p	n.o.	10	2m 1f	n.o.	eo	aw
Bt1	8 - 19	7.5YR 4/4 7.5YR 4/4	SiC	1f-mabk	so fr s p	3mkbrco	40 - 50	2f	n.o.	eo	aw
Bt2	19 - 44	7.5YR 4/4-6 7.5YR 4/6	SiC - C	3cabk	sh fr s p	4mk-kbrpf	50 - 60	1f	2fvf	eo	aw
Btk	44 - 69	8.75YR 5/4 8.75YR 5/3	C	3cabk & 3mpr	h fr vs p	1nbrco	15	2fvf	2fvf	es IIf	gi
Btb	69 - 109+	10YR 5/4 10YR 4/4	SiC	2m-cabk	so vfr ss mp	1mk- kbrcopf	10	1vf	1f	eo	n.o.

Soil-Profile Description

General

Soil-profile number: **P-19** Geomorphic surface: **Q8** Map unit: **Qf8**

Location: SE1/4, NW1/4, Section 32, T12N., R04E., NMPM, Alameda Quadrangle

Landform: Alluvial fan Described by: Sean D. Connell Date: November 08, 1994

Deposit: Sandy and gravelly alluvium Dominant clast lithology: Granitoid with minor limestone and metamorphic

Parent material characteristics: 10YR 5/4 (d), 10YR 4/3 (m), Sand

Surface elevation (m/feet): 1664±3 / 5460±10 Aspect: West-facing surface

Base level (m): 3.5 to 4 Dissection class: 2 Slope (%): 7

Vegetation: Grasses, sage-brush and Cholla

Comments: Described in deep gully; surface is dissected and slightly modified.
Approximate thickness measured for Bk3 through Cox horizons.
Bk4 horizon exhibits thick discontinuous pedogenic-carbonate coatings.

Soil-profile summary

PDI (8/4)*: 43.34 / 69.08 Thickness-normalized PDI (8/4)*: 0.12 / 0.19

Maximum B-horizon development and thickness

Hue: 10YR Bk (cm): 298 Bt (cm): 0 Btk (cm): 0 Max. clay films: vlnco

Carbonate morphology/thickness (cm): II / 138 Max. structure: 1cabk

* Depth for PDI and thickness-normalized PDI calculated to Bk3 horizon (278 cm).

Horizon	Depth (cm)	Color dry moist	Texture (≤2 mm)	Structure	Consist. d m w pl	Clay films	Gravel % volume	Roots	Pores	Carbonate	Base
Ak	0 - 3	10YR 5/3 10YR 4/2	SL	sg	lo lo so po	n.o.	15	2fvf	n.o.	es dissem.	as
Bk1	3 - 17	10YR 4/3-4 10YR 4/2-3	SL - SCL	1fsbk	so lo so ps	n.o.	20 - 30	2vf	n.o.	es dissem.	cs
Bk2	17 - 140	10YR 4/3 10YR 4/2-3	SL	1m-csbk	so lo so po	n.o.	35	1vf	n.o.	es dissem. to I	cs
Bk3	140 - 278	10YR 7/4 10YR 7/4	SiCL	1cabk	sh fr ss mp	v1nco	15 - 20	2vf 1m	2vf	es II	cw
Bk4	278 - 298	10YR 6/4 10YR 6/4	LS - S	sg	lo lo so po	n.o.	50	2vf	n.o.	e dissem.	aw
Cox	298 - 358+	10YR 5/4 10YR 4/3	S	sg	lo lo so po	n.o.	70	n.o.	n.o.	eo	n.o.

Soil-Profile Description

General

Soil-profile number: **P-20** Geomorphic surface: **Q7** Map unit: **Qf7b** over **Qoa2**

Location: NE1/4, NE1/4, Section 19, T12N., R04E., NMPM, Bernalillo Quadrangle

Landform: Alluvial fan Described by: Sean D. Connell Date: November 06, 1994

Deposit: Sandy and gravelly alluvium Dominant clast lithology: Granitoid, metamorphic and limestone

Parent material characteristics: 10YR 5/4 (d), 10YR 4/3 (m), Sandy Loam

Surface elevation (m/feet): 1582±3 / 5190±10 Aspect: North-northwest-facing stream cut

Base level (m): 12 Dissection class: 2 Slope (%): na Vegetation: na

Comments: Described in stream cut along southern margin of Sandia Wash.
Bk3b horizon is within Bk3 horizon and may be gully bed cementation.
Surface soil described on strath cut into Qf7; buried soil forms top of unit Qoa2.
Refer to Stratigraphic Section 5 for details.

Soil-profile summary

PDI (8/4)*: 6.00 / 20.76 Thickness-normalized PDI (8/4)*: 0.05 / 0.17

Maximum B-horizon development and thickness

Hue: 10YR Bk (cm): 98 Bt (cm): 0 Btk (cm): 0 Max. clay films: n.o.

Carbonate morphology/thickness (cm): II / 37 Max. structure: 1cabk

*Depth for PDI, thickness-normalized PDI and carbonate morphology calculated to C horizon (122 cm).

Horizon	Depth (cm)	Color dry moist	Texture (≤2 mm)	Structure	Consist. d m w pl	Clay films	Gravel % volume	Roots	Pores	Carbonate	Base
Ak	0 - 6	10YR 6/4 10YR 4/3	L	sg	lo lo so po	n.o.	10	2m	n.o.	es dissem.	as
Bk1	6 - 43	10YR 7/4 10YR 5/3-4	SL	1fsbk	so lo so po	n.o.	50	1f	n.o.	ev II	cw
Bk2	43 - 62	10YR 5/4 10YR 4/4	LS	sg	lo lo so po	n.o.	60	1vf	n.o.	e I+	aw
Bk3a	62 - 104	10YR 6/4 10YR 5/4	SiL	1f-msbk	so lo so po	n.o.	10	1fvf	n.o.	e dissem.	cs
[Bk3b]	(62 - 104)	10YR 8-7/3 10YR 7/3	SiCL	1f-mabk	so lo ss ps	n.o.	0	n.o.	n.o.	es II	na
C	104 - 122	10YR 6/4 10YR 5/3-4	SL - LS	sg	lo lo so po	n.o.	0	n.o.	n.o.	eo	aw

Horizon	Depth (cm)	Color dry moist	Texture (≤2 mm)	Structure	Consist. d m w pl	Clay films	Gravel % volume	Roots	Pores.	Carbonate	Base
Bwb	122 - 157	7.5YR 6/6 7.5YR 5/4	SL - SCL	1m-csbk	so lo so po	n.o.	0	1vf	n.o.	eo	cw
Bwk1b	157 - 164	10YR 7/4 8.75YR 6/4	SL	1m-cabk	h vfr so po	n.o.	0	n.o.	n.o.	es dissem. to II	cw
Bk1b	164 - 215	10YR 7-6/4 10YR 6/4	SL	1m-cabk	vh lo so po	n.o.	0	n.o.	n.o.	e dissem. to II	gw
Bk2b	215 - 305+	10YR 6/4 10YR 6/3	SiL	1msbk	so lo so po	N.O.	3	2m 1vf	n.o.	es dissem.to I+	n.o.

Soil-Profile Description

General

Soil-profile number: **P-21** Geomorphic surface: **Q7-8** Map unit: **Qf7-8/QTsfup**

Location: SE1/4, SW1/4, Section 21, T12N., R04E., NMPM, Alameda 7.5-minute Quadrangle

Landform: Alluvial fan overlying QTsfup Described by: Sean D. Connell Date: November 09, 1994

Deposit: Sandy alluvium Dominant clast lithology: Granitoid

Parent material characteristics: nd

Surface elevation (m/feet): 1641±3 / 5385±10 Aspect: West-facing surface; north-facing stream cut

Base level (m): ≤3 Dissection class: 2 Slope (%): nd

Vegetation: Grasses, sage-brush and Cholla

Comments: Fine-grained alluvial fan overlying surface cut on unit QTsfup described in stream cut.
2Bkqmb through 3Bk2b developed within QTsfup
Upper 12 cm of horizon 2Bkm1b exhibits 3mpl structure.
Cemented carbonate within horizon 2Bkqmb may be gully bed cementation

Soil-profile summary (buried soil)

PDI (8/4): 51.38 / 80.34 Thickness-normalized PDI (8/4): 0.16 / 0.25

Maximum B-horizon development and thickness

Hue: 10YR Bk (cm): ≥320 Bt (cm): 0 Btk (cm): 58 Max. clay films: 1ncobr

Carbonate morphology/thickness (cm): IV & IV+ / 35 Max. structure: 3mpl

Horizon	Depth (cm)	Color dry moist	Texture (≤2 mm)	Structure	Consist. d m w pl	Clay films *silica films*	Gravel % volume	Roots	Pores	Carbonate	Base
A & Bk	0 - 60	nd	nd	nd	nd nd so lo	nd	10	2mf	n.o.	e dissem.	cs
Bkb	60 - 77	10YR 7/4 10YR 5/4	SL	1cabk	vh fr so po	v1ncobr	15 - 20	2mf	n.o.	es II+	cs
2Bkqmb	77 - 112	10YR 8/2 10YR 7/4	SL	3mpl & 2mpl	vh fi so po	n.o. *1ncobr*	10	n.o.	n.o.	ev IV to IV+	cw
2Btkb	112 - 150	10YR 6/3 10YR 6/4	SCL	2cabk	h fr so po	1ncobr	70	2vf	n.o.	es II	ci
3Btkb	150 - 170	10YR 5/4 10YR 4/4	C	2cabk	vh fr s p	1nbr	≤3	n.o.	2fvf	ev I	cw
3Bkb	170 - 320+	10YR 6/6 10YR 4/4	SC	1m-cabk	sh fi s p	n.o.	0	n.o.	n.o.	es II	n.o.

Soil-Profile Description

General

Soil-profile number: **P-22** Geomorphic surface: **Q7b** Map unit: **Qf7b**

Location: NW1/4, SE1/4, Section 16, T12N., R04E., NMPM, Alameda 7.5-minute Quadrangle

Landform: Alluvial fan Described by: Sean D. Connell Date: November 10, 1994

Deposit: Sandy alluvium Dominant clast lithology: Granitoid and minor metamorphic and limestone

Parent material characteristics: 10YR 5/4 (d), 10YR 4/3 (m), Sandy Loam

Surface elevation (m/feet): 1669±3 / 5475±10 Aspect: West-southwest-sloping surface

Base level (m): 3 Dissection class: 2 Slope (%): nd

Vegetation: Grasses, sage-brush, Juniper and Cholla

Comments: Described in steep-walled gully cut.

Soil-profile summary

PDI (8/4): 22.27 / 24.02 Thickness-normalized PDI (8/4): 0.22 / 0.24

Maximum B-horizon development and thickness

Hue: 7.5YR Bk (cm): ≥70 Bt (cm): 0 Btk (cm): 35 Max. clay films: 2mkbrpf

Carbonate morphology/thickness (cm): II+ / 32 Max. structure: 2cabk

Horizon	Depth (cm)	Color dry moist	Texture (≤2 mm)	Structure	Consist. d m w pl	Clay films	Gravel % volume	Roots	Pores	Carbonate	Base
Ak	0 - 3	7.5YR 5/6 7.5YR 4/4	SC	sg	lo lo s p	n.o.	10	1fvf	n.o.	e dissem.	as
Btk1	3 - 27	7.5YR 4/4 7.5YR 4/3	SC	2cabk	sh fr s vp	2n-mk cobrpf	≤5	1fvf	2vf	ve If	cs
Btk2	27 - 38	7.5YR 4/4 7.5YR 4/4	C	2cabk	sh fr s vp	2mkbrpf	0	1vf 2c	2fvf	es IIf	as
Bk1b	38 -70	7.5YR 6/4 8.75YR 6/3	SiC	2f-mabk	h vfr s p	n.o.	0	1m2vf	2fvf	ve II+	gw
Bk2b	70 - 98	7.5YR 4/6 7.5YR 5/3-4	SiC - C	1m-cabk	sh vfr ss mp	n.o.	0	2cf	n.o.	es If	cw
2Bkmb	98 - 108+	10YR 5/4-6 10YR 5/4	SL	1msbk	sh vfr so po	n.o.	50 - 70	N.O.	n.o.	es II to II+	n.o.

Soil-Profile Description

General

Soil-profile number: **P-23** Geomorphic surface: **Q6** Map unit: **Qf6**

Location: Spain Ave., immediately north of Tramway Blvd., Sandia Crest 7.5-minute Quadrangle

Landform: Alluvial fan Described by: Sean D. Connell Date: November 10, 1994

Deposit: Sandy alluvium Dominant clast lithology: Granitoid and very minor limestone

Parent material characteristics: 10YR 5/4 (d), 10YR 4/3 (m), Sand

Surface elevation (m/feet): 1832±3 / 6010±10 Aspect: West-sloping surface

Base level (m): 9 Dissection class: 2 to 3 Slope (%): nd

Vegetation: Grasses with minor Cholla and Yucca

Comments: Described along road-cut on Spain Ave.

Soil-profile summary

PDI (8/4): 49.11 / 27.17 Thickness-normalized PDI (8/4): 0.14 / 0.26

Maximum B-horizon development and thickness

Hue: 7.5YR Bk (cm): ≥138 Bt (cm): 0 Btk (cm): 42 Max. clay films: 2mkpf

Carbonate morphology/thickness (cm): III / 75 Max. structure: 3cabk & 3mpr

Horizon	Depth (cm)	Color dry *(ped)* moist (ped)	Texture (≤2 mm)	Structure	Consist. d m w pl	Clay films	Gravel % volume	Roots	Pores	Carbonate	Base
Ap	0 - 8	10YR 5/3-4 10YR 4/3	SL	1f-msbk	sh vfr so ps	1nco	10 - 15	2f	n.o.	eo	cw
Btk1	8 - 14	7.5YR 4/4 7.5YR 4/4	SiCL	2f-csbk	sh vfr s mp	2mkco & 1nco	7	2fc	1vf	ev dissem.	gs
Btk2	14 - 36	7.5YR 5/4 7.5YR 5/4 *(7.5YR 4/4)* (7.5YR 4/4)	SiC	3m-cabk	h fr s mp	1mkbr & 2nco	10	2vf	1vf	es - ev dissem. to If	cw
Btk3	36 - 50	10YR 6/2 10YR 5/4	CL	3m-cabk & 3mpr	sh vfr s mp	2mkpf, 1nco & 1mkbr	10 - 15	1fvf	2vf	ev II to II+	ci
2Bkm1	50 - 125	10YR 7/3 10YR 7/3	LS	1cabk	so vfr so po	1ncobr	50 - 60	2vf	1f 2vf	ev III	gw
2Bkm2	125 - 147	10YR 6/3-4 10YR 5&4/3	S	1f-c sbk&abk	lo vfr so po	v1nco	70	1vf	n.o.	ev I and II+	gw
2Bk	147 - 188+	10YR 6/3-4 10YR 5/4	S	sg	lo vfr so po	N.O.	35	1vf	n.o.	e dissem.	n.o.

Soil-Profile Description

General

Soil-profile number: **P-24** Map unit: **Qoa1** (Edith Blvd. alluvium) (buried)

Location: NE1/4, SE1/4, Section 18, T12N., R04E., NMPM, Bernalillo 7.5-minute Quadrangle

Landform: na Described by: Sean D. Connell Date: November 04, 1994

Deposit: Sandy alluvium Dominant clast lithology: nd

Parent material characteristics: nd

Elevation (m/feet): 1574±3 / 5165±10 Aspect: na

Base level (m): na Dissection class: na Slope (%): na

Vegetation: nd

Comments: Described along northern margin of Sandia Wash.
Buried and stripped soil forming top of unit Edith Boulevard alluvium (Qoa1).
Refer to Stratigraphic Section 4 for details.

Soil-profile summary

Maximum B-horizon development and thickness

Hue: 7.5YR Bk (cm): 0 Bt (cm): 0 Btk (cm): 0 Max. clay films: n.o.

Carbonate morphology/thickness (cm): n.o. Max. structure: 2mprsbk

Horizon	Depth (cm)	Color dry moist	Texture (≤2 mm)	Structure	Consist. d m w pl	Clay films	Gravel % volume	Roots	Pores	Carbonate	Base
Bw1b	0 - 33	7.5YR 5/6 7.5YR 5/4	SiL	2mprsbk	sh vfr so po	n.o.	0	1vf	n.o.	eo	gs
Bw2b	33 - 54	7.5YR 5/6 7.5YR 5/4	SiL	sg & 1m-csbk	so lo so po	n.o.	0	n.o.	n.o.	eo	dw
Bw3b	54 - 84	8.75YR 5/6 10YR 5/4	SiL	1msbk	so lo so po	n.o.	0	n.o.	n.o.	eo	dw
Coxb	84 - 184+	10YR 5/4 10YR 5/4	SiL	1f-msbk	so lo so po	n.o.	0	n.o.	n.o.	eo	n.o.

Soil-Profile Description

General

Soil-profile number: **P-25** Map unit: **Qoa2** (Buried: Menaul Blvd. alluvium or Qf6?)

Location: NE1/4, SE1/4, Section 18, T12N., R04E., NMPM, Bernalillo 7.5-minute Quadrangle

Landform: na Described by: Sean D. Connell Date: November 02, 1994

Deposit: Sandy alluvium Dominant clast lithology: nd

Parent material characteristics: nd

Elevation (m/feet): 1587±3 / 5205±10 Aspect: na

Base level (m): na Dissection class: na Slope (%): na

Vegetation: nd

Comments: Buried soil described along partially exposed stream cut along northern margin of Sandia Wash. Top of buried soil is approximately 3 m above quartzite conglomerate of alluvium of Menaul Blvd. (Qoa2). Refer to Stratigraphic Section 4 for details.

Soil-profile summary

Maximum B-horizon development and thickness

Hue: 7.5YR Bk (cm): 40 Bt (cm): 0 Btk (cm): 30 Max. clay films: n.o.

Carbonate morphology/thickness (cm): I / 30 Max. structure: 2cabk

Horizon	Depth (cm)	Color dry moist	Texture (≤2 mm)	Structure	Consist. d m w pl	Clay films	Gravel % volume	Roots	Pores	Carbonate	Base
gravel	0 - 37	nd nd	nd	nd	nd nd nd nd	nd	nd	nd	nd	nd	nd
sand	37 - 102	nd nd	nd	nd	nd nd nd nd	nd	nd	nd	nd	nd	nd
Bwkb	102 - 142	7.5YR 5/4 10YR 5/4	SiC	1f-msbk	so lo ss ps	n.o.	0	1f	n.o.	es dissem.	gw
Btkb	142 - 172+	10YR 5/4 7.5YR 5/4	C	2m-cabk	sh vfr s mp	1n-mk brpopf	0	1vf	1f 2vf	e If	n.o.

Soil-Profile Description

General

Soil-profile number: **P-26** Geomorphic surface: **Q7a** Map unit: **Qf7a**

Location: NW1/4, SW1/4, Section 2, T12N., R04E., Placitas 7.5-minute Quadrangle

Landform: Alluvial fan Described by: JBR and JA Date: Fall, 1991

Deposit: Sandy and gravelly alluvium Dominant clast lithology: nd

Parent material characteristics: 10YR 4/4 (d), 10YR 6/3 (m), Loamy Sand

Surface elevation (m/feet): 1710±3 / 5610±10 Aspect: West-northwest-facing surface

Base level (m): ≤7 Dissection class: 2 Slope (%): nd

Vegetation: Grasses, sage-brush, Juniper, and minor Oak, Cholla and Beavertail cactus

Comments: Stream-cut exposure described by John Rogers and John Appel (University of New Mexico)

Clay-film explanation*: f = faint; d = distinct; p = prominent

Soil-profile summary

Maximum B-horizon development and thickness

Hue: 7.5YR Bk (cm): nd Bt (cm): nd Btk (cm): nd Max. clay films: 1dpfcobr

Carbonate morphology/thickness (cm): ≥II / nd Max. structure: 2vcsbk & 2cabk

Horizon	Depth (cm)	Color dry moist	Texture (≤2 mm)	Structure	Consist. d m w pl	Clay films *	Gravel % volume	Carbonate % volume	Base
Bk1	0 - 9	10YR 4/2 10YR 6/3	SL	1mgr	lo ss ps	n.o.	10	12.4	cs
Bk2	9 - 19	10YR 5/4 10YR 7/3	SL	2csbk	sh so po	n.o.	25	16.9	gs
Bk3	19 - 53	10YR 4/3 10YR 6/3	LS	1msbk	so so po	n.o.	50	10.3	gw
BC	53 - 92	10YR 4/4 10YR 6/3	LS	1csbk	so so po	v1fcopo	25	7.1	as
2Bw1b	92 - 110	10YR 4/4 10YR 6/4	SL	1msbk	so ss ps	n.o.	25	3.8	cs
2Bt1b	110 - 119	7.5YR 3/4 7.5YR 5/5	L - SL	2cabk	sh s ps	1fpocobr	10	0.7	as
2Bt2b	119 - 122	10YR 4/4 10YR 5/4	SL	1msbk	sh ss ps	v1fco	40	1.4	aw
2Bkb	122 - 124	10YR 4/4 10YR 5/4	SL	1msbk	sh ss ps	1dpfcobr	40	7	aw
2Bw2b	124 - 185	10YR 4/3 10YR 6/4	SL	2csbk	sh ss ps	n.o.	15	3.2	gw

Horizon	Depth (cm)	Color dry moist	Texture (≤2 mm)	Structure	Consist. d w	 pl	Clay films *	Gravel % volume	Carbonate % volume	Base
2BCb	185 - 250	10YR 4/4 10YR 6/3	LS	1msbk	sh ss	 ps	n.o.	40	2.7	cs
2Cb	250 - 370	10YR 4/3 10YR 6/3	S	sg gr	so so	 po	n.o.	75	1.4	as
3Bwb	370 - 400	10YR 4/4 10YR 5/4	SL	1msbk	so so	 po	n.o.	60	2.5	gw
3Cb	400 - 465	10YR 4/4 10YR 5/4	S	sg gr	lo so	 po	n.o.	75	0.8	as
4Bw1b	465 - 495	10YR 4/4 10YR 6/4	SL	1csbk	sh ss	 ps	n.o.	35	2.4	cs
4Bw2b	495 - 557	7.5YR 4/4 7.5YR 6/4	SL	2vc sbk	h ss	 ps	n.o.	50	5.5	as
4Bw3b	557 - 635	7.5YR 4/4 7.5YR 6/4	SL	2csbk	sh s	 ps	n.o.	35	1.8	as
4Cb	635 - 654	7.5YR 4/4 7.5YR 5/4	LS	sg gr	lo ss	 po	n.o.	75	1.8	cs
5Btb	654 - 670	7.5YR 4/4 7.5YR 5/4	SL	2vc sbk	sh s	 ps	v1fpobr	25	4.9	as

Horizon	Depth (cm)	Color dry moist	Texture (≤2 mm)	Structure	Consist. d w pl	Clay films *	Gravel % volume	Carbonate % volume	Base
5Bk1b	670 - 743	7.5YR 6/3 7.5YR 7/3	SL	2vc sbk	so s ps	n.o.	10	19.7	cs
5Bk2b	≥ 743	7.5YR 4/4 7.5YR 6/4	SL	2csbk	sh s ps	n.o.	≤10	9.2	n.o.

Soil-Profile Description

General

Soil-profile number: **P-27** Geomorphic surface: **Q7a** Map unit: **Qf7a**

Location: NW1/4, SW1/4, Section 2, T12N., R04E., Placitas 7.5-minute Quadrangle

Landform: Alluvial fan Described by: JBR & JA Date: Fall, 1991

Deposit: Sandy and gravelly alluvium Dominant clast lithology: nd

Parent material characteristics: 10YR 4/4 (d), 10YR 6/3 (m), Loamy Sand

Surface elevation (m/feet): 1710±3 / 5610±10 Aspect: West-northwest-facing surface

Base level (m): ≤7 Dissection class: 2 Slope (%): nd

Vegetation: Grasses, sage-brush, Juniper, and minor Oak, Cholla and Beavertail cactus

Comments: Soil pit described by John Rogers and John Appel (University of New Mexico) near stream-cut exposure of P-26.

Clay-film explanation*: f = faint; d = distinct; p = prominent

Soil-profile summary

Maximum B-horizon development and thickness

Hue: 10YR Bk (cm): 85 Bt (cm): 0 Btk (cm): 0 Max. clay films: n.o.

Carbonate morphology/thickness (cm): ≥II /nd Max. structure: 1csbk

Horizon	Depth (cm)	Color dry moist	Texture (≤2 mm)	Structure	Consist. d w pl	Clay films *	Gravel % volume	Carbonate % volume	Base
Bk1	0 - 19	10YR 3/3 10YR 4/3	SL	1msbk	so ss ps	n.o.	≤10	7.6	cs
Bk2	19 - 65	10YR 6/3 10YR 8/2	SL	1csbk	so ss ps	n.o.	10	42	cs
Bk3	65 - 85	10YR 5/3 10YR 7/3	SL	1csbk	sh ss po	n.o.	25	28.1	gs
BC	≥ 85	10YR 5/3 10YR 6/3	SL	1csbk	so ss ps	n.o.	≤5	14.8	n.o.

Soil-Profile Description

General

Soil-profile number: **P-28** Geomorphic surface: **Q7b** Map unit: **Qf7b**

Location: NW1/4, SW1/4, Section 2, T12N., R04E., Placitas 7.5-minute Quadrangle

Landform: Alluvial fan Described by: JBR & JA Date: Fall, 1991

Deposit: Sandy and gravelly alluvium Dominant clast lithology: nd

Parent material characteristics: 10YR 5/4 (d), 10YR 4/3 (m), Sand

Surface elevation (m/feet): 5590±3 / 1704±10 Aspect: West-northwest-facing slope

Base level (m): ≤3 Dissection class: 2 Slope (%): nd

Vegetation: nd

Comments: Described by John Rogers and John Appel (University of New Mexico).

Clay-film explanation*: f = faint; d = distinct; p = prominent

Soil-profile summary

Maximum B-horizon development and thickness

Hue: 7.5YR Bk (cm): 68 Bt (cm): 0 Btk (cm): 0 Max. clay films: v1fco

Carbonate morphology/thickness (cm): ≥ II / nd Max. structure: 2vcsbk

Horizon	Depth (cm)	Color dry moist	Texture (≤2 mm)	Structure	Consist. d m w pl	Clay films *	Gravel % volume	Carbonate % volume	Base
A1	0 - 2	10YR 4/4 10YR 6/4	L	1csbk	nd vs ps	n.o.	≤10	0.2	as
A2	2 - 17	7.5YR 3/4 7.5YR 4/4	L	1csbk	sh s p	v1fco	≤10	0.1	as
Bk	17 - 85	10YR 4/3 7.5YR 6/4	L	2vcsbk	sh ss po	n.o.	25	11.6	cw
BC	≥85	7.5YR 3/4 7.5YR 6/4	SL	1csbk	so ss ps	n.o.	50	3.9	n.o.

Soil-Profile Description

General

Soil-profile number: **P-29** Geomorphic surface: **Q8-9** Map unit: **Qa9**

Location: NW1/4, SW1/4, Section 2, T12N., R04E., Placitas 7.5-minute Quadrangle

Landform: Terrace Described by: JBR & JA Date: Fall, 1991

Deposit: Sandy and gravelly alluvium Dominant clast lithology: ns

Parent material characteristics: 10YR 5/4 (d), 10YR 4/3 (m), Sand

Surface elevation (m/feet): 5585±3 / 1702±10 Aspect: West-northwest-facing slope

Base level (m): Dissection class: 2 Slope (%): nd

Vegetation: nd

Comments: Described by John Rogers and John Appel

Soil-profile summary

Maximum B-horizon development and thickness

Hue: 10YR Bk (cm): 25 Bt (cm): 0 Btk (cm): 0 Max. clay films: n.o.

Carbonate morphology/thickness (cm): ≤I / nd Max. structure: 1csbk

Horizon	Depth (cm)	Color dry moist	Texture (≤2 mm)	Structure	Consist. d w pl	Clay films	Gravel % volume	Carbonate % volume	Base
A	0 - 15	10YR 3/2 10YR 4/3	SL	sg	lo ss ps	n.o.	≤10	0.0	cs
AB	15 - 35	10YR 3/2 10YR 4/3	SL	1csbk	sh ss ps	n.o.	15	0.8	gs
Bk	35 - 60	10YR 4/3 10YR 5/3	SL	1csbk	so ss po	n.o.	20	4.8	cs
C	≥60	10YR 4/3 10YR 5/3	S	sg	lo so po	n.o.	75	1.4	n.o.

Soil-Profile Description

General

Soil-profile number: **P-30** Geomorphic surface: **QT1** Map unit: **QTpf1**

Location: NE1/4, SE1/4, Section 5, T12N., R05E, NMPM, Placitas 7.5-minute Quadrangle

Landform: Gravel-mantled pediment Described by: Sean D. Connell Date: October 10, 1994

Deposit: Gravel Dominant clast lithology: Limestone

Parent material characteristics: 10YR 5/4 (d), 10YR 4/3 (m), Sand

Surface elevation (m/feet): 1914±3 / 6280±10 Aspect: North-facing surface

Base level (m): nd Dissection class: 2 to 4 Slope (%): 36

Vegetation: Pinyon, Juniper and grasses

Comments: Described in abandoned mining prospect.

Soil-profile summary

PDI (8/4): 39.31 / 15.64 Thickness-normalized PDI (8/4): 0.15 / 0.06

Maximum B-horizon development and thickness

Hue: 2.5Y Bk (cm): 158 Bt (cm): 0 Btk (cm): ≥100 Max. clay films: 2npf

Carbonate morphology/thickness (cm): III+ / 110 Max. structure: 2cabk

Horizon	Depth (cm)	Color dry moist	Texture (≤2 mm)	Structure	Consist. d w	m pl	Clay films	Gravel % volume	Roots	Pores	Carbonate	Base
Ak	0 - 20	10YR 4/3 10YR 4/2	SL	1fsbk	lo so	lo po	n.o.	20	2fvfco	nd	es dissem.	aw
Bk1	20 - 38	10YR 5/3 10YR 4/3	CL	1fsbk	lo ss	lo ps	n.o.	20	2vfco & 1f	2vf	es dissem.	cw
Bk2	38 - 68	10YR 7/2 10YR 6/2	SL	1f-mabk	so ss	lo ps	v1nco	50	2fco	2fvf	ev I+	gi
Bkm	68 - 178	10YR 8/2 10YR 7/3	SL	1fabk	so ss	lo ps	n.o.	25	2co & 1m	1f & 2m	ev III & III+	gw
Btkb	178 - 268+	2.5Y 7/3 2.5Y 7/4	SL	2m-cabk	sh ss	vfr ps	2npf	35	1co & 2vf	n.o.	ev II	n.o.

Soil-Profile Description

General

Soil-profile number: **P-31** Geomorphic surface: **Q5** Map unit: **Qp5**

Location: SE1/4, SW1/4, Section 1, T12N., R04E., Placitas 7.5-minute Quadrangle

Landform: Pediment Described by: Sean D. Connell Date: September 03, 1994

Deposit: Gravel Dominant clast lithology: nd

Surface elevation (m/feet): 1780 ±3 / 5840 ±10 Aspect: South-facing stream cut

Base level (m): ≤8 Dissection class: 2 Slope (%): 65

Vegetation: Juniper, grasses and Cholla

Comments: Described on modified near rounded margin of stream cut.
Carbonate coatings on clasts.

Soil-profile summary

Maximum B-horizon development and thickness

Hue: 7.5YR Bk (cm): ≥211 Bt (cm): 0 Btk (cm): 0 Max. clay films: 2nco

Carbonate morphology/thickness (cm): I+ / 40 Max. structure: sg

Horizon	Depth (cm)	Color dry moist	Texture (≤2 mm)	Structure	Consist. d m w pl	Clay films	Gravel % volume	Roots	Pores	Carbonate	Base
Bk1	0 - 10	10YR 6/3-4 10YR 5/4	SL	sg	lo lo so po	2nco	60	2fvf	nd	ev I+	cw
Bk2	10 - 20	7.5YR 6/4 7.5YR 5/3	LS	sg	lo lo so po	1nco	40	2vf	1vf	ev I	gw
Bk3	20 - 38	7.5YR 6/3 7.5YR 5/4	SL	sg	lo lo so po	n.o.	30	1vf	1vf	ev I	ci
Bk4	38 - 78	7.5YR 6/3 7.5YR 4/4	LS	sg	lo lo so po	v1nco	60	2fvf	N.O.	ev I to I+	gw
Bk5	78 - 211+	5YR 5/4 5YR 4/4	S	sg	lo lo so po	n.o.	60	2fvf	N.O.	ev I	cw

Soil-Profile Description

General

Soil-profile number: **P-32** Geomorphic surface: **Q2** Map unit: **Qpf2**

Location: SE1/4, SW1/4, Section 20, T13N., R05E., Placitas 7.5-minute Quadrangle

Landform: Pediment Described by: Sean D. Connell Date: April 11, 1995

Deposit: Gravelly alluvium Dominant clast lithology: nd

Parent material characteristics: 7.5YR 5/4 (d), 7.5YR 4/4 (m), Sand

Surface elevation (m/feet): 1740 ±3 / 5710 ±10 Aspect: Northwest-facing surface

Base level (m): 30.5 Dissection class: 2 Slope (%): ≤10

Vegetation: Juniper, grasses and minor Cholla

Comments: Described in foundation excavation.
Surface is smooth, broad with few (≤10%) pebbles.
Surface is partially modified by construction activity.

Soil-profile summary

PDI (8/4): 21.99 / 13.33 Thickness-normalized PDI (8/4): 0.12 / 0.07

Maximum B-horizon development and thickness

Hue: 10YR Bk (cm): ≥184 Bt (cm): 0 Btk (cm): 0 Max. clay films: lncobr

Carbonate morphology/thickness (cm): III+ / 163 Max. structure: 2cabk & 2vcpl

Horizon	Depth (cm)	Color dry *(ped)* moist (ped)	Texture (≤2 mm)	Structure	Consist. d m w pl	Clay films *silica Films*	Gravel % volume	Roots	Pores	Carbonate	Base
Bwk	0 - 20	10YR 5/4 10YR 4/3	Sil - SiCL	1mcabk	sh vfr ss ps	v1nco	7	1m2f	1fvf	es I	ci
Bk	20 - 31	10YR 6/4 10YR 5/4	L	sg	lo lo so ps	n.o.	20	2cvf1f	n.o.	es dissem. to I	ai
Bkmq1b	31 - 60	10YR 7/3 10YR 7/2 *(2.5Y 8/1)* (10YR 8/2-3)	SL	1mplabk & 1vfgr	vh vfi so po	v1ncobr *v1mkcobr*	30	1mvf	n.o.	ev III+	gw
Bkmq2b	60 - 94	10YR 7/2-3 10YR 6/4 *(10YR 8/1&2)* (10YR 7/3)	SL	2m-cabk 2f-m & vcpl	sh vfr so po	v1ncobr *lncobr*	45 - 50	1f	n.o.	es - ev III+	cw
Bk1b	94 - 137	10YR 7/4 10YR 6/4	SL	1vf-fgr	so lo so po	n.o.	40	1f	n.o.	es II	gw
Bk2b	137 - 164	8.75YR 6/4 8.75YR 5-4/4	SL	sg	lo lo so po	v1ncobr	45 - 55	1f	n.o.	es I	cw
Bk3b	164 - 184+	7.5YR 5/4 7.5YR 4/4	S	sg	lo lo so po	n.o.	50	n.o.	n.o.	e dissem. to I	n.o.

Soil-Profile Description

General

Soil-profile number: **P-33** Geomorphic surface: **Q8-9** Map unit: **Qf8-9**

Location: SE1/4, SW1/4, Section 20, T13N., R05E., Placitas 7.5-minute Quadrangle

Landform: Colluvial fan Described by: Sean D. Connell Date: April 11, 1995

Deposit: Fine-grained alluvium and colluvium Dominant clast lithology: nd

Parent material characteristics: 10YR 6/4 (d & m), Sandy Clay Loam

Surface elevation (m/feet): 1740 ±3 / 5710 ±10 Aspect: Northwest-facing surface

Base level (m): ≤5 Dissection class: 2 Slope (%): ≤10

Vegetation: Juniper, grasses and minor Cholla

Comments: Described approximately 20 m east of P-32 in foundation excavation, near distal margin of fine-grained colluvial fan that unconformably overlies Qp2 (see P-32 for description of underlying gravels). Surface partially modified by construction activities.

Soil-profile summary

PDI (8/4): 20.72 / 7.28 Thickness-normalized PDI (8/4): 0.12 / 0.04

Maximum B-horizon development and thickness

Hue: 8.75YR Bk (cm): ≥166 Bt (cm): 0 Btk (cm): 0 Max. clay films: n.o.

Carbonate morphology/thickness (cm): I+ / 23 Max. structure: 1cabk

Horizon	Depth (cm)	Color dry moist	Texture (≤2 mm)	Structure	Consist. d m w pl	Clay films	Gravel % volume	Roots	Pores	Carbonate	Base
Ap	0 - 3	10YR 6/3 10YR 5/4	SiCL	1f-csbk	sh vfr s mp	n.o.	10	n.o.	n.o.	es dissem.	vas
Bk1	3 - 15	10YR 5/3 10YR 4/3	SiCL	1f-csbk	so vfr s mp	n.o.	≤5	1f	n.o.	es dissem.	as
Bk2	15 - 30	10YR 5/4 10YR 4/4	SiCL	1m-cabk	sh fr ss mp	n.o.	≤5	1fm	n.o.	es I	aw
2Bk1b	30 - 53	10YR 6/4 10YR 6/4	CL	1m-cabk	sh vfr ss mp	n.o.	25	1fm	1vf	es I+	cw
2Bk2b	53 - 159	8.75YR 6/4 8.75YR 6/4	SiCL	1m-cabk	sh vfr ss ps	n.o.	10	1f	2fvf	es I	gw
2Bk3b	159 - 169	8.75YR 6/4 8.75YR 5/4	SCL	sg	lo lo so ps	n.o.	≤5	1f	n.o.	es dissem.	gw
3Bkb	≥169	Not described									

Soil-Profile Description

General

Soil-profile number: **P-34** Geomorphic surface: **Q7-8** Map unit: **Qt7-8**
Location: NE1/4, NW1/4, Section 29, T12N., R05E., Placitas 7.5-minute Quadrangle
Landform: Terrace Described by: Sean D. Connell Date: April 11, 1995
Deposit: Gravelly alluvium Dominant clast lithology: Limestone and sandstone
Parent material characteristics: 8.75YR 5/4 (d), 8.75YR 4/4 (m), Sand
Surface elevation (m/feet): 1713 ±3 / 5620 ±10 Aspect: North-facing stream cut
Base level (m): nd Dissection class: nd Slope (%): nd
Vegetation: Juniper, grasses and minor Cholla
Comments: Described along steep-walled ≥5.6-m thick outcrop along southern margin of Las Huertas Creek. Surface is modified by small strath terraces.

Soil-profile summary

PDI (8/4): 6.31 / 1.80 Thickness-normalized PDI (8/4): 0.06 / 0.02

Maximum B-horizon development and thickness

Hue: 8.75YR Bk (cm): ≥72 Bt (cm): 0 Btk (cm): 17 Max. clay films: 1nco
Carbonate morphology/thickness (cm): I+ / 43 Max. structure: 1csbk

Horizon	Depth (cm)	Color dry moist	Texture (≤2 mm)	Structure	Consist. d m w pl	Clay films	Gravel % volume	Roots	Pores	Carbonate	Base
Ak	0 - 6	8.75YR 5-4/4 8.75 4/3	L	1vf-fgr	so lo s ps	n.o.	≤5	2fvf	n.o.	es dissem.	as
Bk	6 - 14	8.75YR 5/4 8.75YR 4/3	L	1f-msbk	so lo s ps	v1nco	5	2f	1fvf	es dissem. to I-	cs
Btk	14 - 31	8.75YR 4/4 8.75YR 4/3	CL	1f-csbk	sh vfr s mp	1nco	10	2fmco	1fvf	e I	aw
2Bk1b	31 - 74	8.75YR 5/3-4 8.75YR 4/3-4	SL	sg	lo lo so po	n.o.	60	1f2m	n.o.	es I+	aw
2Bk2b	74 - 103	8.75YR 5/4 8.75YR 4/3-4	SL	sg	lo lo so po	vlnco	70	1f	n.o.	e I	aw
Section continues	103 - 560+	Not described									

Soil-Profile Description

General

Soil-profile number: **P-35** Geomorphic surface: **Q4** Map unit: **Qf8-9/Qf4**

Location: NW1/4, SW1/4, Section 12, T12N., R04E., Placitas 7.5-minute Quadrangle

Landform: Alluvial fan Described by: Sean D. Connell Date: April 13, 1995

Deposit: Sandy and gravelly alluvium Dominant clast lithology: Granitoid and metamorphic

Parent material characteristics: 10YR 5/4 (d), 10YR 4/3 (m), Sand

Surface elevation (m/feet): 1719 ±3 / 5640 ±10 Aspect: North-facing stream cut

Base level (m): ≤3 Dissection class: 2 to 3 Slope (%): 15

Vegetation: Juniper, grasses and minor Cholla

Comments: Described along stream cut.
Surface of Qf5 modified by debris flow and alluvium inset into Qf5.
Bkm2b and Bkm3b horizons contain grussified granitoid clasts and partially split metamorphic clasts.

Soil-profile summary

PDI (8/4)*: Qf8-9: 4.89 / 0.84 Thickness-normalized PDI (8/4)*: Qf8-9: 0.09 / 0.02

Qf4: 24.81 / 17.60 Qf4: 0.18 / 0.13

Maximum B-horizon development and thickness (buried soil)

Hue: 10YR Bk (cm): ≥132 Bt (cm): 0 Btk (cm): 0 Max. clay films: 1nco

Carbonate morphology/thickness (cm): IV / 20 Max. structure: 2cabk & 2vcpl

Horizon	Depth (cm)	Color dry moist	Texture (≤2 mm)	Structure	Consist. d w	m pl	Clay films *silica films*	Gravel % volume	Roots	Pore	Carbonate	Base
Ak	0 - 3	10YR 5/4 10YR 4/2	SCL	1mgr & 1fsbk	so ss	lo ps	n.o.	10	1vf	n.o.	e dissem.	vas
Bk1	3 - 9	10YR 6/4 10YR 5/4	SCL	1f-msbk	so ss	lo ps	n.o.	25	2fvf	n.o.	es I+	as
Bk2	9 - 18	10YR 6/4 10YR 5/4	SL-SCL	1m-csbk	sh ss	vfr po	n.o.	15	1cm 2fvf	2vf	ev II	cs
Bk3	18 - 38	10YR 5/4 10YR 4/3	SCL	sg	lo ss	lo po	n.o.	5 - 10	1mf	n.o.	ev I	cw
Bk4	38 - 54	10YR 5/4 10YR 5/4	SCL	1f-msbk & abk	so ss	vfr mp	n.o.	25	1f 2vf	n.o.	ev I+ to II	gw
Bk1b	54 - 87	10YR 7/3 10YR 6/3	SC-SCL	1f-cabk	sh ss	vfr mp	v1nco	25 - 30	2fvf	2fvf	ev III	aw
Bkm1b	87 - 107	10YR 8/3 10YR 7/3	SL	2m-vcpl	h so	fr po	n.o. *1nco*	25	1mf	n.o.	ev IV	cw
Bkm2b	107 - 172	10YR 8/2-3 10YR 7/3	SL	1vfgr & 2f-cabk	vh so	vfi po	v1nco *1nco*	40	n.o.	n.o.	ev III	cw
Bk2b	172 - 186+	10YR 6/6 10YR 5/4	SL	sg	lo so	lo po	1nco	30	n.o.	n.o.	es dissem.	n.o.

Appendix C

Parent-Material Characteristics and Soil Properties

C-1 Summary of Parent-Material Characteristics for Selected Soil Profiles.

C-2 Summary of Normalized Soil-Property Indices for Geomorphic Surfaces QT1 through Q9.

C-3 Graphs of Soil-Profile Properties Recorded on Geomorphic Surfaces QT1 through Q9.

Appendix C-1. Summary of Parent-Material Properties for Selected Soil Profiles.

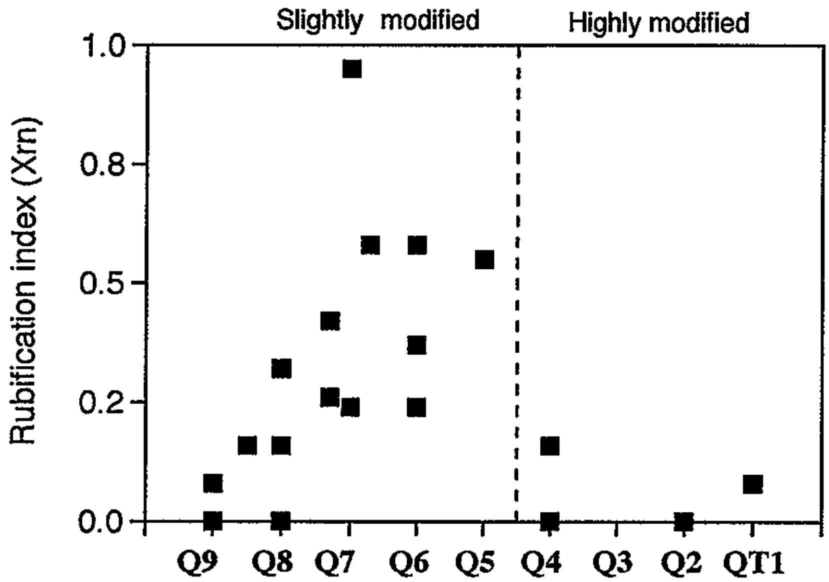
Soil profiles (Appendix B)	Color dry (d) moist (m)	Texture (SCS, 1992)	Structure	Consist. dry / wet	Consist. moist / plasticity	Clay films	Carbonate
P-1, P-3, P-5, P-7, P-8, P-9, P-10, P-19, P-20, P-22, P-23, P-28, P-29, P-30 and P-35	10YR 5/4 (d) 10YR 4/3 (m)	S, LS, SL, SCL	sg	lo so-ss	lo po-ps	n.o.	n.o.
P-2, P-6, and P-16	10YR 6/3 (d) 10YR 5/3 (m)	S, SL	sg	lo lo	lo lo	n.o.	n.o.
P-26 and P-27	10YR 4/4 (d) 10YR 6/3 (m)	LS	sg	lo lo	lo lo	n.o.	n.o.
P-4 and P-32	7.5YR 5/4 (d) 10YR 6/3 (d) 7.5YR 4/3&4 (m) 10YR 6/3 (m)	S, SCL	sg	lo so-ss	lo po-ps	n.o.	n.o.
P-33	10YR 6/4 (d) 10YR 6/4 (m)	SCL	sg	lo lo	lo lo	n.o.	n.o.
P-34	8.75YR 5/4 (d) 8.75YR (m)	S	sg	lo lo	lo lo	n.o.	n.o.

Appendix C-2. Summary of Normalized Soil-Property Indices for Geomorphic Surfaces QT1-Q9.

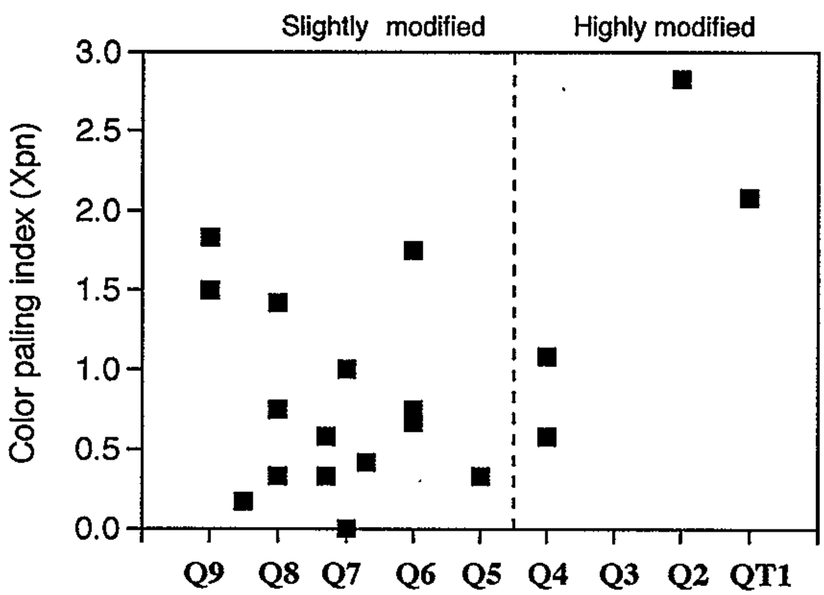
Soil Profile	Geomorphic Surface	Xrn	Xpn	Xvn-	Xvn+	Xtn	Xdn	Xmn	Xfn	Xsn	Xcsn
P-1	Q6	0.24	1.75	0.12	1.81	1.61	2.20	1.50	0.54	4.17	2.20
P-2	Q9	0.08	1.50	1.12	0.00	0.44	0.20	0.20	0.00	1.33	0.01
P-3	Q7b	0.24	1.00	0.24	1.56	2.67	0.80	0.70	0.00	2.67	1.11
P-5	QT1	0.08	2.08	0.12	3.38	2.67	1.90	1.50	0.00	3.00	4.86
P-6	Q8	0.32	0.33	1.06	0.00	0.89	0.00	0.10	0.23	0.67	0.03
P-7	Q5	0.55	0.33	0.29	2.31	6.00	1.40	1.00	1.15	4.75	1.36
P-8	Q7a	0.58	0.42	0.47	0.25	3.33	0.70	0.60	0.00	2.50	0.13
P-9	Q8	0.00	1.42	0.59	0.00	2.11	0.40	0.00	0.00	2.00	0.20
P-10	Q4	0.16	0.58	0.12	1.13	3.17	1.00	0.60	0.50	3.50	0.86
P-14	Q9	0.00	1.83	0.82	0.00	1.67	0.60	0.00	0.00	1.67	0.11
P-15	Q6	0.58	0.67	0.59	0.75	4.72	1.00	0.50	0.58	3.83	0.77
P-17	Q7-8.r	0.26	0.58	0.12	0.13	4.67	1.40	1.20	1.23	4.00	0.00
P-18	Q7-8.r	0.42	0.33	0.29	0.13	3.83	0.70	0.70	1.38	3.25	0.13
P-19 [to Bk3]	Q8	0.16	0.75	0.24	0.63	1.72	0.40	0.20	0.00	1.17	0.41
P-22	Q7b	0.95	0.00	0.35	0.63	3.94	1.10	0.70	0.15	2.83	0.34
P-23	Q6	0.37	0.75	0.12	1.44	3.28	0.90	0.80	1.58	4.08	1.10
P-32	Q2	0.00	2.83	0.00	2.06	2.06	0.90	0.55	0.08	2.50	2.95
P-34	Q8	0.00	0.75	0.06	0.00	2.61	0.40	0.10	0.00	1.00	0.13
P-35T [to Bk4]	Q8-9	0.16	0.17	0.00	0.63	2.22	0.50	0.20	0.00	1.50	0.30
P-35B [Bk4b]	Q4	0.00	1.08	0.00	2.25	1.00	0.90	0.65	0.00	2.08	2.13

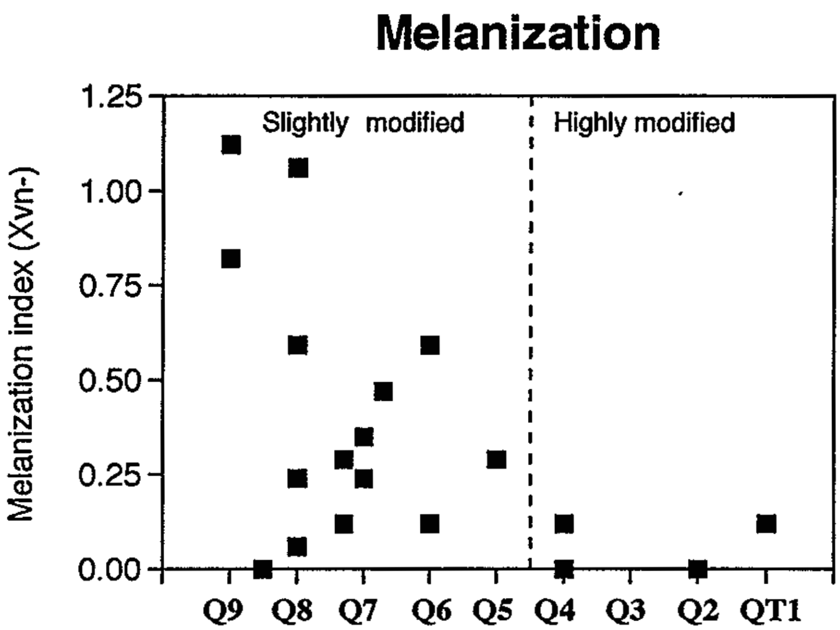
Appendix C-3. Graphs of Soil-Profile Properties Recorded on Geomorphic Surfaces QT1 through Q9. Geomorphic surfaces are arbitrarily scaled from youngest (left) to oldest (right) to allow for comparisons to be made for soil properties (n=20). Dashed vertical line separates surfaces exhibiting significant surface modification. Properties include: rubification (Xrn), color paling (Xpn), melanization (Xvn-), color lightening (Xvn+), total texture (Xtn), dry consistence (Xdn), moist consistence (Xmn), clay films (Xfn), soil structure (Xsn) and carbonate development (Xcsn).

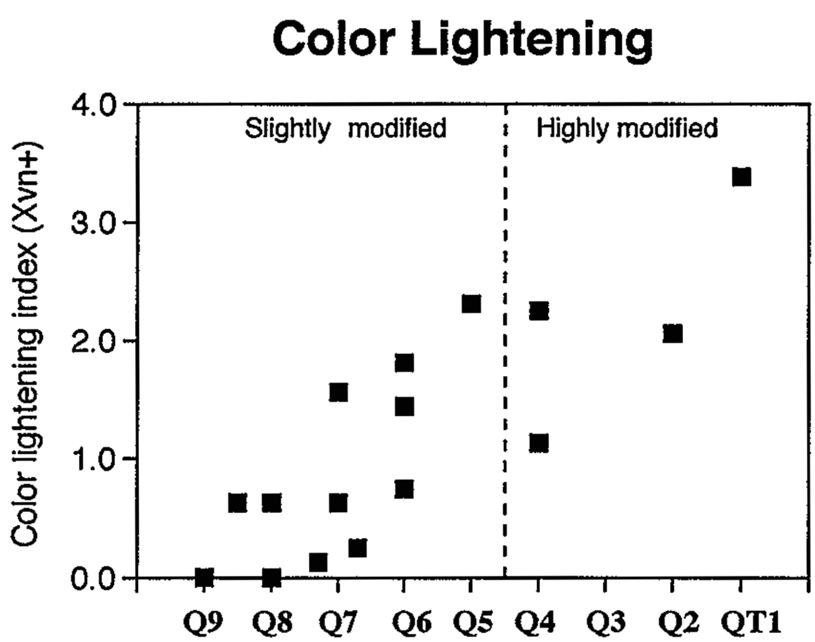
Rubification



Color Paling




Melanization
Slightly modified
Highly modified
Melanization index (Xvn-)
1.25
1.00
0.75
0.50
0.25
0.00
Q9
Q8
Q7
Q6
Q5
Q4
Q3
Q2
QT1


Color Lightening
Slightly modified
Highly modified
Color lightening index (Xvn+)
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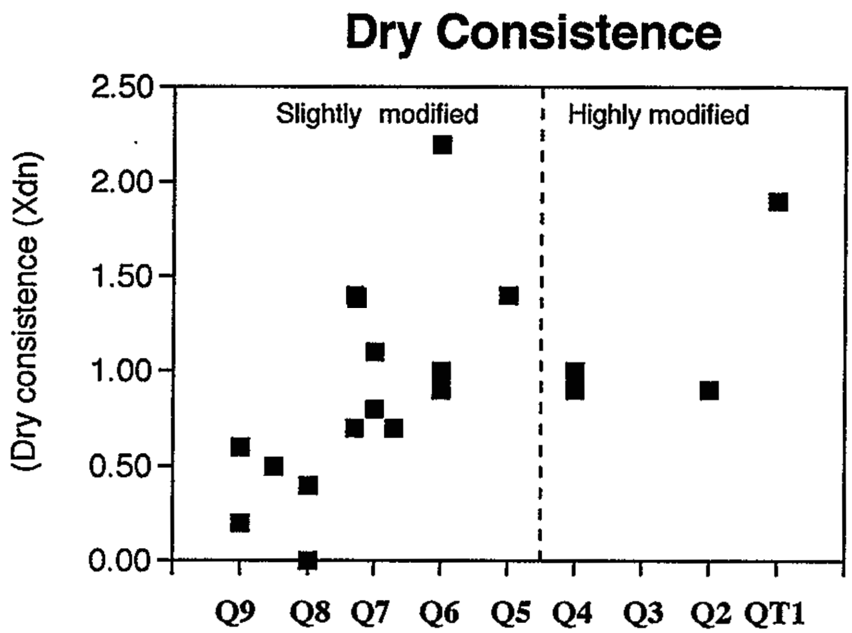
3.0
2.0
1.0
0.0
Q9
Q8
Q7
Q6
Q5
Q4
Q3
Q2
QT1


Dry Consistence
(Dry consistence (Xdn)
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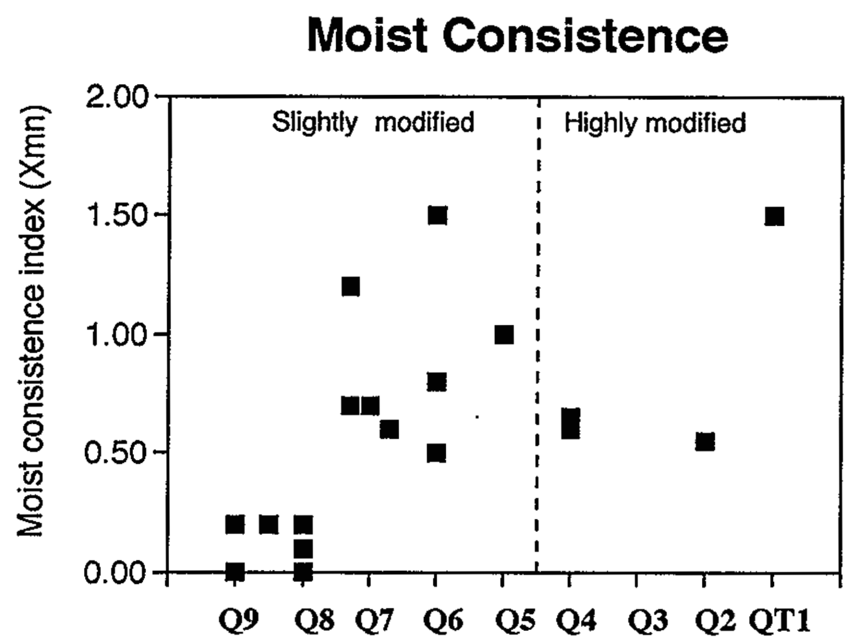
2.00
1.50
1.00
0.50
0.00
Slightly modified
Highly modified
Q9
Q8
Q7
Q6
Q5
Q4
Q3
Q2
QT1


Moist Consistence
Moist consistence index (Xmn)
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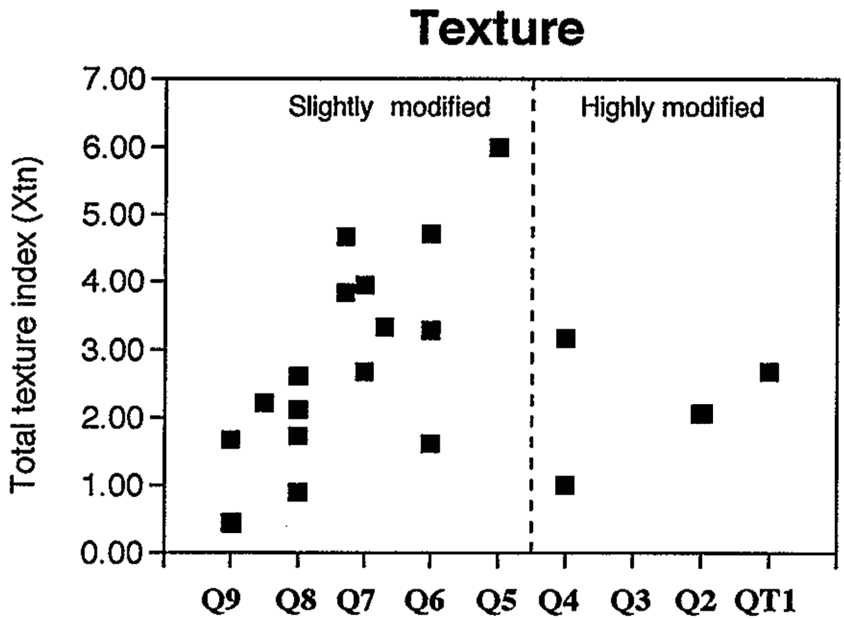
1.50
1.00
0.50
0.00
Slightly modified
Highly modified
Q9
Q8
Q7
Q6
Q5
Q4
Q3
Q2
QT1


Texture
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Highly modified
Total texture index (Xtn)
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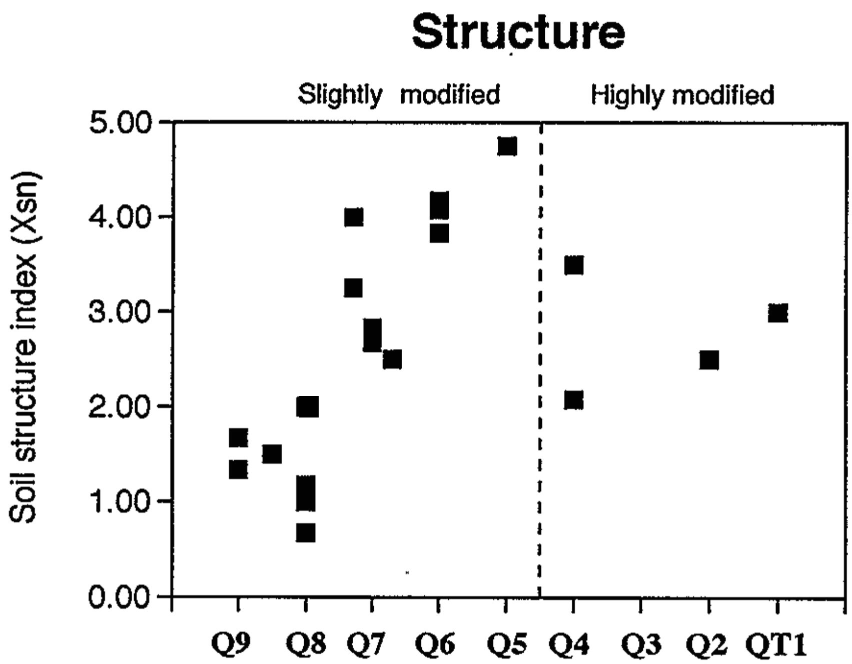
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Q9 Q8 Q7 Q6 Q5 Q4 Q3 Q2 QT1


Structure
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Highly modified
Soil structure index (Xsn)
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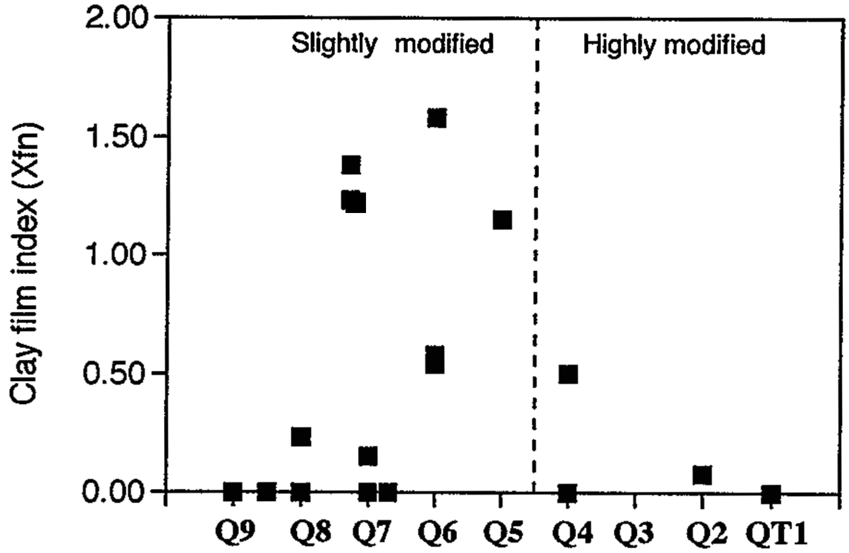
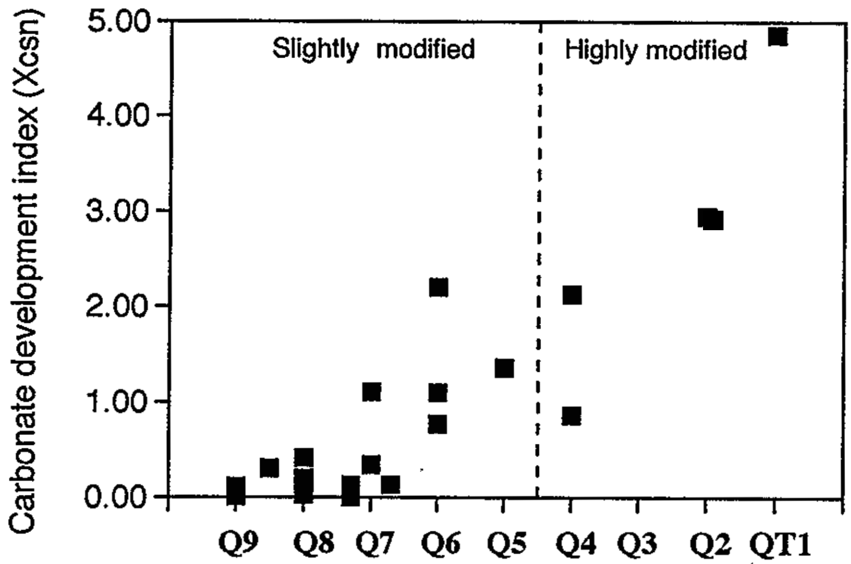
4.00
3.00
2.00
1.00
0.00
Q9 Q8 Q7 Q6 Q5 Q4 Q3 Q2 QT1

Clay Films



Carbonate Development



Appendix D

Stratigraphic and Clast Descriptions

Appendix D-1. Descriptions of Clasts.

Unit: QTpf1

Location: NE1/4, SE1/4, NE1/4, Section 1 T.12N., R.04E., NMPM, Placitas 7.5-minute quadrangle, Sandoval County, New Mexico.

Limestone	Metamorphic	Granitoid
36	4	0

Unit Qp2

Location: NE1/4, NW1/4, NE1/4, Section 11, T.12N., R.04E., NMPM, Placitas 7.5-minute quadrangle, Sandoval County, New Mexico.

Limestone	Metamorphic	Granitoid
50	0	0

Unit QTsfua (Sierra Ladrones Formation, axial-stream facies)

Location: NE1/4, SE1/4, NW1/4, Section 16 T.12N., R.04E., NMPM, Bernalillo 7.5-minute quadrangle, Sandoval County, New Mexico.

Aphanitic	4	**Metamorphic**	3
Phaneritic	6	**Granitoid**	4
Quartzite	13	**Sandstone**	0
Limestone	3	**Other**	7

Unit QTsfua (Sierra Ladrones Formation, axial-stream facies)

Location: See stratigraphic section 2.

Aphanitic	2	**Metamorphic**	31
Phaneritic	0	**Granitoid**	2
Quartzite	25	**Sandstone**	0
Limestone	3	**Vesicular Basalt**	2

Unit Qoa1 (alluvium of Edith Boulevard)

Location: See stratigraphic section 3.

Aphanitic	2	**Metamorphic**	3
Phaneritic	14	**Granitoid**	8
Quartzite	25	**Sandstone**	4
Vesicular Basalt	2	**Other**	1

Unit Qf8

Location: NE1/4, NE1/4, SW1/4, Section 32, T.12N., R.04E., NMPM, Bernalillo 7.5-minute quadrangle, Sandoval County, New Mexico.

Limestone	**Metamorphic**	**Granitoid**
2	5	32

Unit Qp5

Location: See stratigraphic section 10.

Limestone	**Metamorphic**	**Granitoid**	**Sandstone**	**Aplite**
12	21	0	11	1

Unit Qp5

Location: NE1/4, SW1/4, Section 1, T.12N., R.04E., NMPM, Placitas 7.5-minute quadrangle, Sandoval County, New Mexico.

Limestone	**Metamorphic**	**Granitoid**	**Sandstone**
11	9	0	0

Unit Qp3

Location: See stratigraphic section 12.

Limestone	**Metamorphic**	**Granitoid**	**Sandstone**
16	12	0	2

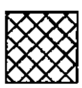
Unit Qp3

Location: See stratigraphic section 13.

Limestone	**Metamorphic**	**Granitoid**	**Sandstone**
19	11	0	0

Appendix D-2. Descriptions of Stratigraphic Sections (S-1 through S-13)

Graphic Column Explanation

Graphic Notation	Description
	Piedmont conglomerate
	Fluvial (Rio Grande) conglomerate
	Sandstone
	Cross bedded sandstone
	Sandstone, silty to clayey
	Diatomite
	Soil profile
	Covered; not described

Description of Stratigraphic Section S-1

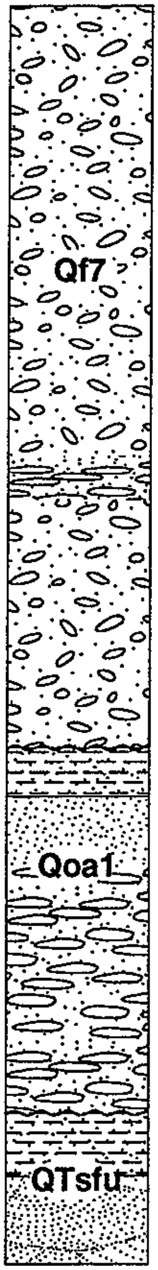
Location: Section measured in canyon, east of I-25; SW1/4, SE1/4, Section 32 and SW1/4, SW1/4, Section 33, T.13N., R.04E., New Mexico Principal Meridian, Bernalillo quadrangle, Sandoval County, New Mexico. Section measured using Jacob Staff and compass.

Unit	Description	Thickness (cm) Unit	Total
	Sierra Ladrones Formation (QTsfu) axial facies (not differentiated on map)	≥495	---
1a	SAND (arenite): very pale brown, 10YR 8/2 (d), well sorted, subrounded, subdiscoidal, very coarse-to coarse-grained sand; no clasts; non indurated and non effervescent; forms partly covered slopes; lower 206 cm of unit is massive to finely (2-to 5-cm thick beds) bedded; upper 89 cm of unit is well indurated, effervescent and interbedded with 5-to 29-cm thick, poorly indurated beds; top of unit is conformable and recognized by lowest occurrence of clasts and increased reddening; base not observed.	295	---
1b	SAND (arenite): reddish brown, 5YR 5/4 (d), moderately sorted, rounded-to subrounded, very fine-to fine-grained sand; ≤5% clasts; well indurated, forms ledges; 4-to 6-cm thick scattered interbeds of unit 1a (comprising ≤5% of unit); top of unit is unconformable and recognized by lowest occurrence of pebble to cobble clasts of unit 2; upper 63 cm exhibits angular blocky structure and clay films.	200	495
	Alluvium of Edith Boulevard (Qoa1a)	1200	---
2	QUARTZITE PEBBLE CONGLOMERATE: pale brown, 10YR 6/3 (d), moderately sorted, subrounded to rounded, subprismoidal, pebble to cobble conglomerate; 40% gravel, 60% sand; massive to imbricated bedding; gravel consists of 70% pebbles, 25% cobbles and ≤5% boulders; clasts of quartzite, welded tuff and granitoid; ≤3% of clasts are densely welded tuff containing chatoyant sanidine crystals; matrix is coarse-grained, moderately sorted, subrounded to subangular, subdiscoidal sand; non indurated, strongly effervescent; top is conformable and recognized by abrupt decrease in clasts.	810	1305

Unit	Description	Thickness (cm)	
	(Qoa1b)		
3a	SAND (arenite): pale brown, 10YR 6/3 (d), well sorted, subrounded to subangular, fine-grained sand; no clasts; well indurated; effervescent; forms ledges; top is conformable, gradational and recognized by decrease in grain size; very pale brown 10YR 8/2 (d), carbonate-cemented sand nodules form thin, discontinuous beds at 69 cm, 96 cm and 146 cm above base.	220	1525
3b	SANDY CLAY (mudstone): pale brown, 10YR 6/3 (d), with streaks of reddish brown, 5YR 5/3 (d), along base, moderately well sorted, subrounded to subangular, very fine-grained silt to very fine-grained sand; no clasts; well indurated and effervescent; forms ledges; very pale brown, 10YR 8/2 (d), 5- to 26-mm diameter, carbonate-cemented nodules scattered in unit; top is gradational and recognized by lowest occurrence of subangular gravels composed of schist and gneiss, limestone and granitoid.	170	1695
	Fan alluvium (Qf7)	2457	---
4	SAND (arenite) and PEBBLY SAND: light yellowish brown, 10YR 6/4 (d), poorly sorted, subangular to subrounded, subdiscoidal and subprismoidal medium-grained and very coarse-grained sand and pebbly sand; ≤10% clasts; poorly to moderately indurated; forms slopes; well indurated lenses of pebble conglomerate near base; crystalline (sparry) calcite cement in pebble conglomerate; top is unconformable, sharp, wavy and recognized by lowest occurrence of quartzite-rich, subrounded to rounded clasts.	510	2205

Unit	Description	Thickness (cm)	
5	PEBBLY SAND AND PEBBLE CONGLOMERATE: yellowish brown, 10YR 5/4 (d), poorly to moderately sorted, subrounded to rounded, subdiscoidal, very coarse-and medium-grained pebbly sand; 60% clasts; 40% sand; poorly indurated; forms slopes with minor benches; 60-cm thick conglomerate bed along base and a 170-cm thick conglomerate bed at 380 cm above base; gravel consists of 15% subrounded to rounded quartzite-rich clasts and 85% subrounded to subangular, subdiscoidal to subprismoidal clasts composed of 70% pebbles and 30% cobbles and boulders (composed of, in order of decreasing abundance: schist and gneiss, limestone, granitoid and aplite); matrix is light yellowish brown 10YR 6/4 (d), subrounded to subangular, very coarse-to medium-grained sand.	1570	3775
6	PEBBLE CONGLOMERATE: light yellowish brown, 10YR 6/4 (d), moderately sorted, subrounded, subdiscoidal and subprismoidal, very coarse-and medium-grained sand and gravel; 60% clasts, 40% sand; massive; poorly indurated; clasts are subrounded to subangular, subprismoidal to subdiscoidal and consist of 70% cobbles and 30% cobbles and boulders; clast composition, in decreasing order of abundance: schist and gneiss, granitoid, limestone, minor (≤5%) sedimentary; section ends on ridge top, surface is highly dissected; clasts exhibit stage I carbonate morphology; granitoid clasts exhibit stage 2 cobble weathering.	377	4152

Graphic Stratigraphic Section S-1



Unit Number	Stratigraphic Section	Thickness (cm)	Summary Description
6		377	**Fan alluvium (Qf7)** Light yellowish-brown and yellowish brown pebbly sand and pebble conglomerate.
5		1570	
4		510	
3b		170	**Alluvium of Edith Blvd. (Qoa1)** Pale-brown pebble to cobble conglomerate, sand and sandy clay.
3a		220	
2		810	
1b		200	**Sierra Ladrones Fm. (QTsfu)** Pale-brown pebble to cobble conglomerate, sand and sandy clay.
1a		295	

(Elev: 1575 m)
base not observed

approximate scale = 1:245

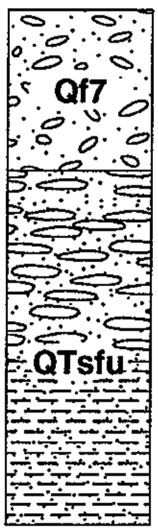
Description of Stratigraphic Section S-2

Location: Section measured in canyon, east of I-25; SW1/4, NE1/4, Section 4, T.12N., R.04E., New Mexico Principal Meridian, Bernalillo quadrangle, Sandoval County, New Mexico. Section measured using Jacob Staff and compass.

Unit	Description	Thickness (cm) Unit	Total
	Sierra Ladrones Formation (QTsfu) axial facies (not differentiated on map)	≥430	---
1a	CLAYSTONE with interbedded SAND (arenite): reddish brown, 2.5YR 5/4 (d), claystone and light-brown, 7.5YR 6/4 (d), fine-grained sand; no clasts; well indurated; forms ledges; top of unit is sharp, unconformable and recognized by lowest occurrence of rounded quartziteclasts; base not observed.	430	430
2	QUARTZITE PEBBLE CONGLOMERATE: pale-brown, 10YR 6/3 (d), moderately sorted, subrounded to rounded, subprismoidal, pebble to cobble conglomerate; 70% gravel, 30% sand; massive to imbricated bedding; matrix is fine- to very coarse-grained, poorly to moderately sorted, subrounded to rounded, subdiscoidal and subprismoidal sand; poorly indurated; top is unconformable and recognized by decrease in rounded clasts.	520	950
	Fan alluvium (Qf7)	720	1670
3a	SAND (arenite) and interbedded CONGLOMERATE: light-brown, 10YR 6/4 (d), moderately sorted, subrounded to subangular, subdiscoidsl and subprismoidal, medium- to coarse-grained sand and pebble to cobble conglomerate; grantioid and metamorphic clasts are moderately weathered (stage 2 cobble weathering stage); poorly indurated; forms partly covered slopes; basal 50 cm contain rounded quartzite and volcanic clasts; section continues.	720	1670

Graphic Stratigraphic Section S-2

Unit Number	Stratigraphic Section	Thickness (cm)	Summary Description
	section continues		
3	Qf7	720	**Fan alluvium (Qf7)** Light-brown sand and pebble conglomerate.
2	QTsfu	520	**Sierra Ladrones Fm. (QTsfu)** Pale-brown quartzite conglomerate and reddish-brown to light-brown claystone and sandstone.
1		430	



(Elev: 1612 m)

base not observed

approximate scale = 1:200

Description of Stratigraphic Section S-3

Location: Section measured in canyon east of I-25; NE1/4, NE1/4, Section 8, T.12N., R.04E, New Mexico Principal Meridian, Bernalillo quadrangle, Sandoval County, New Mexico. Section measured using Jacob Staff and compass.

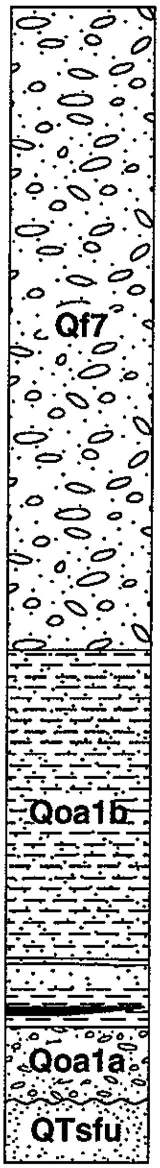
Unit	Description	Thickness (cm) Unit	Thickness (cm) Total
	Sierra Ladrones Formation (QTsfu) axial facies (not differentiated on map)	≥150	---
1a	SAND (lithic arenite): light gray, 10YR 7/2 (d), moderately sorted, rounded, spherical to subprismoidal, fine-and coarse-grained sand; no clasts; poorly indurated, non-to violently effervescent; forms mostly covered slopes; base not observed.	55	---
1b	SAND (lithic arenite): light gray, 10YR 7/2 (d), and white, 10YR 8/1 (d), moderately sorted, rounded-to subrounded, medium-and coarse-grained sand; no clasts; moderately well indurated, forms ledge, strongly effervescent.	65	120
1c	SAND (lithic arenite): white, 10YR 8/1 (d), well sorted, rounded-to subrounded, medium-grained sand; no clasts; well indurated, forms ledge, strongly effervescent; top is unconformable, sharp, wavy and recognized by lowest occurrence of quartzite-rich pebble conglomerate.	22	150
	Alluvium of Edith Boulevard (Qoa1a)	1195	---
2	QUARTZITE PEBBLE CONGLOMERATE: pale brown, 10YR 6/3 (d), and very pale brown, 10YR 7/3 (d), moderately sorted, subrounded to rounded, subprismoidal to subdiscoidal, pebble to cobble conglomerate; 50 to 60% gravel, 40 to 50% sand; massive to imbricated bedding; poorly indurated, strongly effervescent; top is conformable, sharp and recognized by abrupt decrease in clasts.	200	350
	(Qoa1b)		
3a	SANDY SILTSTONE (wacke): pale yellow, 5Y 8/3 (d), well sorted, siltstone with medium-grained sand; no clasts; well indurated; forms ledge and partly covered slopes; top is conformable, sharp, wavy and recognized by lowest occurrence of crystalline (sparry) calcite-cemented pebbly sand lenses.	103	453

Unit	Description	Thickness (cm) Unit	Total
3b	DIATOMITE: white, 5Y 8/1 (d), diatomite with reddish brown, 5YR 5/3 (d), silty clay streaks along base; very low density and variable thickness. Unit forms three distinct beds within unit 3a: 5-cm thick bed at 23 cm above base; 8-cm thick bed at 68 cm above base; and 4-cm thick bed at 75 cm above base. Merges into a single bed to west.	---	---
4a	SANDY CLAYSTONE (mudstone): pale brown, 10YR 6/3 (d), with dark grayish brown, 10YR 4/2 (d), mottles; sand is subrounded and medium-grained; no clasts; poorly to moderately indurated; forms slopes; well indurated lenses of sparry calcite-cemented pebbly sand; lenses of unit 4b present.	70	523
4b	SAND (lithic arenite): light brownish gray to light yellowish brown, 10YR 6/4-2 (d), moderately sorted, subrounded to subangular, fine-grained sand; no clasts; well indurated; violently effervescent; contains plant fragments and small concretions and cemented root casts.	22	545
5a	SANDY CLAYSTONE (mudstone): pale brown, 10YR 6/3 (d); sand is subrounded and medium-grained; no clasts; poorly to moderately indurated; forms slopes; irregular and discontinuous 2- to 5-cm thick, light gray, 10YR 7/2 (d), carbonate cemented sand interbeds; sand is dark yellowish brown, 10YR 4/4 (d) after treatment with dilute hydrochloric acid solution. Unit truncated by 5-cm wide clastic dike composed of gravels from unit 2.	140	685
5b	SAND (lithic arenite): light yellowish brown, 10YR 6/4 (d), well sorted, subangular to subrounded, subdiscoidal and subprismoidal, fine-grained sand and gravel; no clasts; poorly indurated; forms slopes; irregular and discontinuous lenses of calcite-cemented sand and root casts that die out upward within 1 m above base. Top of unit is poorly exposed, unconformable (?), gradational (range: approximately 2 m) and recognized by increase in cobbles and small boulders on slope.	660	1345

Unit	Description	Thickness (cm) Unit	Total
	Fan alluvium (Qf7)		
6	GRAVELY SAND: yellowish brown, 10YR 5/4 (d), poorly to moderately sorted, subangular to subrounded, discoidal and subprismoidal, medium-grained sand and gravel; 35% clasts; poorly indurated; forms partly covered slopes; clasts are subrounded to rounded and composed of approximately 80% metamorphic, 10% limestone, 7% granitoid and 3% sandstone; top of unit not observed; description ends at ridge top.	1690	3035

Graphic Stratigraphic Section S-3

ground surface



base not observed

Unit Number	Stratigraphic Section	Thickness (cm)	Summary Description
6	Qf7	1690	**Fan alluvium (Qf7)** Light yellowish-brown and yellowish-brown pebbly sand and pebble conglomerate.
5	Qoa1b	800	**Alluvium of Edith Blvd. (Qoa1)** Pale-brown quartzite pebble conglomerate (Qoa1a); grades upwards into sand, sandy clay and silty sand (Qoa1b). Diatomite in unit 3.
4		92	
3		103	
2	Qoa1a	200	
1	QTsfu	150	**Sierra Ladrones Fm. (QTsfu)** Pale-brown pebble to cobble conglomerate, sand and sandy clay.

approximate scale = 1:200

Description of Stratigraphic Section S-4

Location: Unit measured along northern side of Sandia Wash; SW1/4, Section 10, T.10N., R.04E, New Mexico Principal Meridian, Bernalillo quadrangle. Unit measured using Jacob Staff and compass.

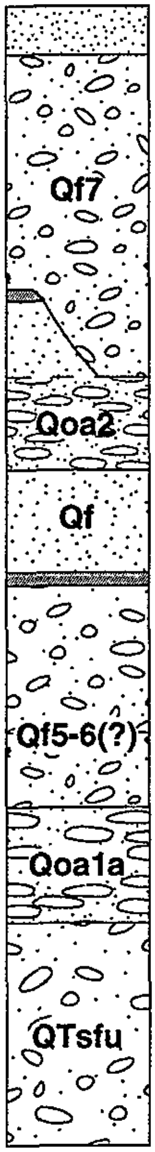
Unit	Description	Thickness (cm) Unit	Thickness (cm) Total
	Sierra Ladrones Formation (QTsfu)	≥570	---
1	PEBBLE CONGLOMERATE: light yellowish brown, 10YR 6/4 (d), and yellowish brown, 10YR 5/4 (d); subrounded, fine-to coarse-grained pebble conglomerate and sand; 75% pebbles; unit is poorly indurated, poorly exposed and partly covered by colluvium; upper contact is sharp, unconformable and recognized by an abrupt increase in rounded quartzite cobbles.	570	570
	Alluvium of Edith Boulevard (Qoala)	330	---
2	PEBBLE CONGLOMERATE: yellowish-brown, 10YR 5/4(d), moderately sorted, subrounded to rounded, subdiscoidal and subprismoidal, coarse-grained conglomerate; matrix is feldspathic arenite 70% clasts in unit; poorly to indurated, but supports relatively steep, poorly vegetated slopes and benches; upper contact is sharp, unconformable and recognized by abrupt decrease in rounded quartzite clasts.	330	900
	Fan alluvium (Qf5-6(?))	610	---
3a	SAND (arenite): yellowish brown, 10YR 5/4(d), poorly sorted, subangular to subrounded, fine-to coarse-grained feldspathic arenite; ≤10% clasts; upper contact is sharp, conformable and recognized by abrupt increase in clasts.	180	1080
3b	PEBBLE CONGLOMERATE: subrounded to subangular pebbles of quartzite, and phaneritic and aphanitic intrusive rocks; 60% clasts; minor, scattered lenses of white, 10YR 8/1(d), diatomite; upper contact is sharp, conformable (?) and recognized by abrupt decrease in subrounded pebbles; unit locally forms bench.	---	---

Unit	Description	Thickness (cm) Unit	Total
4	PEBBLY SAND: light yellowish-brown, 10YR 6/4 (d), moderately to poorly sorted, subangular to subrounded conglomerate; upper contact is sharp, unconformable and recognized by abrupt color change; clasts predominantly composed of metamorphic rocks with minor limestone and granitoid and rounded quartzite-rich clasts; refer to **Pedon Description Number 24.**	430	1510
	Fan alluvium, undivided (Qf)	275	---
5	SAND: yellowish brown, 10YR 5/4 (d), moderately sorted, medium-to coarse-grained and very coarse-grained sand; scattered angular to subangular pebbles of carbonate and diatomite (?) in basal 50 cm; upper contact is sharp, unconformable and recognized by lowest occurrence rounded pebbles; forms poorly vegetated slopes	275	1785
	Alluvium of Menaul Boulevard (Qoa2)	265	---
6	PEBBLY SAND: yellowish-brown, 10YR 5/4 (d), poorly to moderately sorted, medium- to very coarse-grained feldspathic arenite; ≤40% clasts; upper contact is sharp, possibly unconformable and recognized by the highest occurrence of rounded pebbles; forms poorly vegetated slopes and topographic benches. **Pedon Description Number 25** described near section (approximately 2.4 m above top of unit 6).	265	2050
7	**Fan alluvium (Qf7)**	852	---
	SAND (arenite): yellowish brown, 10YR 5/4(d), well sorted, subrounded, fine-to coarse-grained sand; 10% subrounded to subangular pebbles and cobbles; metamorphic and minor limestone clasts; upper contact is gradational and recognized by highest occurrence of clasts; poorly to moderately indurated.	852	2902
	Eolian sand (not differentiated on map)	140	---
8	SAND (arenite): yellowish brown, 10YR 5/4 and 8.75YR 5/4 (d), well sorted, fine-to medium-grained sand; areally limited and forms small mound on dissected fan surface.	140	3043

Graphic Stratigraphic Section S-4

Unit Number | Stratigraphic Section | Thickness (cm) | Summary Description

ground surface



Unit Number	Thickness (cm)	Summary Description
8	140	**Eolian sand** Yellowish-brown well sorted, fine-to medium-grained sand.
7	852	**Fan alluvium (Qf7)** Yellowish-brown sand.
P-25		
6	265	**Alluvium of Menaul Blvd. (Qoa2)** Pale-brown pebble conglomerate.
5	275	**Fan alluvium, undivided (Qf)** Yellowish-brown sand.
P-24		
4	430	**Fan alluvium (Qf5-6(?))** Yellowish-brown sand and pebble conglomerate.
3	180	
2	330	**Alluvium of Edith Blvd. (Qoa1a)** Pale-brown pebble conglomerate.
1	570	**Sierra Ladrones Fm. (QTsfu)** Pale brown pebble to cobble conglomerate, sand and sandy clay.

(Elev: 1558 m)
base not observed

approximate scale = 1:200

Description of Stratigraphic Section S-5

Location: Section measured in canyon, east of I-25; SW1/4, NE1/4, NE1/4, Section 19, T.12N., R.04E., New Mexico Principal Meridian, Bernalillo quadrangle, Sandoval County, New Mexico. Section measured using Jacob Staff and compass.

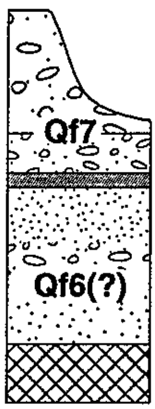
Unit No.	Description	Thickness (cm) Unit	Total
1	**Covered Section**: not described	≥160	---
	Fan alluvium (Qf6(?))	463	---
2a	SAND (arenite): light yellowish-brown, 10YR 6/4 (d), well sorted, subrounded to subangular, fine-to coarse-grained sand; ≤10% clasts; poorly indurated; carbonate cemented; top is sharp, wavy, unconformable and recognized by abrupt increase in clasts; base note observed.	160	320
2b	CONGLOMERATE: light olive-brown, 2.5Y 5/3 (d), to brownish-yellow, 10YR 6/6 (d), poorly sorted, subangular to rounded, pebble conglomerate; 65% clasts; ≤5% rounded quartzite clasts (not derived from Sandia Mountains); matrix is fine-to very coarse-grained sand; clasts locally imbricated (tilted) to east; poorly indurated; forms slopes; top is smooth conformable and recognized by decrease in clasts.	120	440
3	SAND (arenite) TO SILTY SAND (wacke): description summarized from ***Pedon Description Number 20***, horizons Bwb-Bwkb1-Bwkb2-Bwkb3. Reddish-yellow, 7.5YR 6/6 (d), to light yellowish-brown, 10YR 6/3 to 4 and 5/4 (d), sandy loam, loamy sand, silt loam and loamy sand; ≤3% clasts; top contact is sharp, smooth, unconformable and recognized by color change.	183	623

Unit No.	Description	Thickness (cm)	
	<u>Fan alluvium (Qf7)</u>	450	---
4	SAND (arenite) TO SILTY SAND (wacke): description summarized from ***Pedon Description Number 20*** for horizons A-Bk1-Bk2-Bk3-C. Very pale-brown to yellowish brown, 10YR 7/4 to 5/4 (d), loamy sand to silty clay loam; 10 to 60% clasts; deposit continues up section; soil description ends at strath.	122	---
5	CONGLOMERATE: yellowish-brown to dark yellowish-brown, 10YR 5 to 4/4 (d), poorly sorted, subangular, fine-to coarse-grained pebble to cobble conglomerate; section ends at dissected ground surface.	328	450

Graphic Stratigraphic Section S-5

Unit Number | Stratigraphic Section | Thickness (cm) | Summary Description

ground surface



Unit Number	Thickness (cm)	Summary Description
4	328	**Fan alluvium (Qf7)** Very pale-brown to dark yellowish-brown sand and conglomerate
	122	
3	183	**Fan alluvium (Qf6(?))** Light olive-brown to reddish-yellow sand and conglomerate
	120	
2	160	
1	160	

(Elev: 1573 m)

base not observed

approximate scale = 1:200

Description of Stratigraphic Section S-6

Location: unit measured in canyon, east of I-25; SE1/4, SW1/4, Section 5, T.12N., R.04E., New Mexico Principal Meridian, Bernalillo quadrangle, Sandoval County, New Mexico. Section measured using Jacob Staff and compass.

Unit	Description	Thickness (cm) Unit	Thickness (cm) Total
	Sierra Ladrones Formation (QTsfu)	≥433	---
1a	SAND: (arenite) reddish brown, 5YR 5/4 (d), moderately sorted, subangular, fine-to medium-grained arenite; no clasts; moderately indurated and slightly effervescent; forms partly covered slopes; grains exhibit reddish brown stains; top of unit is conformable and recognized by increase in grain size and decrease in induration; base not observed.	211	---
1b	SAND (arenite): reddish brown, 5YR 5/4 (d), moderately sorted, subangular, fine-grained arenite; no clasts; slightly indurated and strongly effervescent; forms slopes; top of unit is conformable and recognized by decrease in reddening and increase in effervescence.	181	392
1c	SAND (arenite): white, 10YR 8/1 (d), moderately sorted, rounded-to subrounded, very fine-to fine-grained arenite; no clasts; poorly indurated and violently effervescent; forms slopes; lensoidal geometry; color is light gray, 10YR 7/2 (d), after treatment with dilute hydrochloric acid solution; top of unit is unconformable, sharp, wavy and recognized by lowest occurrence of subrounded quartzite-rich conglomerate.	41	433
	Alluvium of Edith Boulevard (Qoal)	---	---
2	QUARTZITE PEBBLE CONGLOMERATE: Not described.	---	---

Description of Stratigraphic Section and Weathering Profile S-7

Location: Stratigraphic section and weathering-profile measured along road-cut; NE1/4, NE1/4, Section 1, T.12N., R.04E., New Mexico Principal Meridian, Placitas quadrangle, Sandoval County, New Mexico. Section measured using Jacob Staff and compass. Refer to P-5 for soil-profile description. Cobble weathering stages are from Bull (1991).

Unit	Description	Thickness (cm) Unit	Total
	Undifferentiated sedimentary bedrock (PzMzu) (not described)		
	Lower Santa Fe Group (Tsfl(?))		
1	PEBBLE CONGLOMERATE AND PEBBLY SAND: 85% limestone, 7% granitoid, 5% metamorphic, and 3% sandstone clasts; metamorphic clasts exhibit cobble weathering stage 3 and granitoid clasts exhibit cobble weathering stage 4; unit is fractured, faulted and tilted; unit subdivided into 3 subunits based on carbonate morphology and clast abundance; base is sharp, unconformable and recognized by lowest occurrence of limestone clasts.	---	330
1a	PEBBLE CONGLOMERATE: Stage II carbonate morphology.	85	85
1b	PEBBLE CONGLOMERATE: Stage I to I+ carbonate morphology.	78	163
1c	PEBBLY SAND: pebbly sand with interbedded pebble conglomerate lenses; unit is fractured; upper 60 cm is pink, 7.5YR 7/3 (d), silty sand.	400	563

Unit	Description	Thickness (cm)	
	<u>Pediment alluvium (QTpf1)</u>		
2	SAND: very pale brown, 10YR 8/2 to 3 (d), sandy loam; ≤30% clasts; limestone is dominant clast type; bedding is sub parallel to ground surface; stage IV to IV+ carbonate morphology; description summarized in **Pedon Description Number 5.**	418	981
3	SAND (arenite) and SILTY SAND (wacke): pale-brown to brown, 10YR 6 to 4/3 (d), silty clay loam and clay loam; ≤50% clasts; limestone is dominant clast type; description summarized in **Pedon Description Number 5.**	25	1006

Description of Stratigraphic Sections and Weathering Profile S-8

Location: Stratigraphic section and weathering profile measured near steep gully and slope along power line road; SW1/4, NW1/4, Section 6, T.12N., R.05E., New Mexico Principal Meridian, Placitas quadrangle, Sandoval County, New Mexico. Section measured using Jacob Staff and compass.

Unit	Description	Thickness (cm) Unit	Total
	Undifferentiated sedimentary bedrock (PzMzu): (not described)	---	---
	Lower Santa Fe Group (Tsfl)	344	---
1a	COBBLE CONGLOMERATE and SILTY SANDSTONE: 60-cm thick basal cobble conglomerate composed of 10% limestone and 90% sandstone and shale clasts; 35% clasts; upper 43 cm consists of reddish brown silty sandstone; basal contact is sharp, unconformable and recognized by lowest occurrence of limestone clasts.	108	108
2b	SILTY SAND (wacke): fine-grained silty sand; 10% clasts composed of sandstone and limestone; moderately well indurated; forms partly covered slopes.	236	344
	Pediment alluvium (Qp2)		
3	PEBBLE CONGLOMERATE: Poorly sorted pebble conglomerate; 75% pebbles, cobbles and boulders; 80% limestone, 18% sandstone and 2% metamorphic clast composition; Stage I+ to II carbonate in upper 25 cm of section; at least Stage II carbonate in lower 435 cm of section; section ends at top of dissected geomorphic surface.	460	804

Description of Stratigraphic Section and Weathering Profile S-9

Location: Stratigraphic section and weathering profile measured; NW1/4, NW1/4, Section 5, T.12N., R.05E., New Mexico Principal Meridian, Placitas quadrangle, Sandoval County, New Mexico.

Unit	Description	Thickness (cm) Unit	Total
	Pediment alluvium (Qp2)	330	---
1	CONGLOMERATE: pale-brown to brown, 10YR 6-5/3 (d), cobble to boulder conglomerate; 35% clasts; base is poorly exposed, unconformable and recognized by lowest occurrence of limestone clasts.	150	150
2	CONGLOMERATE: light-brown, 7.5YR 6/4 (d), conglomerate; ≥Stage II carbonate morphology; section ends on edge of dissected geomorphic surface.	180	330

Description of Stratigraphic Section S-10

Location: Section measured south of Strip Mine Canyon trail; SE1/4, SW1/4, Section 1, T.12N., R.04E., New Mexico Principal Meridian, Placitas quadrangle, Sandoval County, New Mexico. Section measured using Jacob Staff and compass.

Unit	Description	Thickness (cm) Unit	Thickness (cm) Total
	Pediment alluvium (Qp5)		
1	COBBLE TO BOULDER CONGLOMERATE: brown, 7.5YR 5/4 (d), poorly sorted, subrounded, cobble to boulder conglomerate; 55% clasts; matrix (≤2 mm fraction) is fine-to very coarse-grained sand; poorly indurated; forms partly covered slopes; base is poorly exposed, sharp and exhibits angular unconformity recognized by lowest occurrence of limestone and metamorphic clasts; dissected surface. Clasts (n=45) were measured in intervals along a 30-m long transect on surface. Intermediate (b)-axis clast diameter along transect range from 4 to 28 cm (average: 8.43±4.49 cm); clasts composed of 49% metamorphic (schist and gneiss), 27% limestone and 24% sandstone; average of the b-axis diameter of the 5 largest clasts, ranging from 33 to 44-cm, on surface is 34±6 cm.	330	330

Description of Clasts S-11

Location: Section measured south of strip-mine trail; NW1/4, Section 1, T.12N., R.04E., New Mexico Principal Meridian, Placitas quadrangle, Sandoval County, New Mexico.

Pediment alluvium (Qp5)

Clasts (n=29) measured in 1-m intervals along a 30-m long transect on surface; Intermediate (b)-axis clast diameter along transect range from 6 to 12.5 cm (average: 7.75±4.50 cm); subrounded to subangular, subdiscoidal to subprismoidal clasts composed of 38% limestone, 31% metamorphic (schist and gneiss) and 31% sandstone; average of the b-axis diameter, ranging from 23 to 38 cm, of the 5 largest clasts on surface is 30±6.6 cm.

Description of Stratigraphic Section S-12

Location: Section measured south of strip-mine trail; SW1/4, Section 1, T.12N., R.04E., New Mexico Principal Meridian, Placitas quadrangle, Sandoval County, New Mexico. Section measured using Jacob Staff and compass.

Unit	Description	Thickness (cm) Unit	Thickness (cm) Total
	Pediment alluvium (Qp3)		
1	COBBLE TO BOULDER CONGLOMERATE: brown, 10YR 4/3 (d), poorly sorted, subangular to angular, cobble to boulder conglomerate; 40% clasts; matrix (≤2 mm fraction) is fine-to very coarse-grained sand; poorly indurated; forms partly covered slopes; base is poorly exposed, sharp and exhibits angular unconformity recognized by lowest occurrence of limestone clasts; dissected surface. Clasts (n=30) measured in 1-m intervals along a 30-m long transect on surface. Intermediate (b)-axis clast diameter along transect range from 7.2 to 185 cm; clasts composed of 57% limestone, 40% metamorphic (schist and gneiss) and 3% sandstone. 43% of clasts exhibit splitting and fracturing; 97% of limestone clasts exhibit surface dissolution; Average of the b-axis diameter of the 5 largest clasts on surface is 85±48 cm.	730	730

Description of Stratigraphic Section S-13

Location: Section measured south of strip-mine trail; NW1/4, Section 1, T.12N., R.04E., New Mexico Principal Meridian, Placitas quadrangle, Sandoval County, New Mexico. Section measured using Jacob Staff and compass.

Unit	Description	Thickness (cm) Unit	Total
	Pediment alluvium (Qp3)		
1	COBBLE TO BOULDER CONGLOMERATE: brown, 7.5YR 4/3 (d), poorly sorted, subangular to angular, cobble to boulder conglomerate; 35% clasts; poorly indurated; forms partly covered slopes; base is poorly exposed, sharp and exhibits angular unconformity recognized by lowest occurrence of limestone clasts; dissected surface. Clasts (n=30) measured in 1-m intervals along a 30-m long transect on surface. Intermediate (b)-axis clast diameter along transect range from 8 to 36 cm; clasts composed of 63% limestone, 36% metamorphic (schist and gneiss) and minor sandstone. 50% of clasts exhibit splitting and fracturing; 73% of limestone clasts exhibit surface dissolution; Average of the b-axis diameter of the 5 largest clasts on surface is 53±14 cm.	1360	1360

Appendix E

Rincon Fault - Scarp Data and Profiles

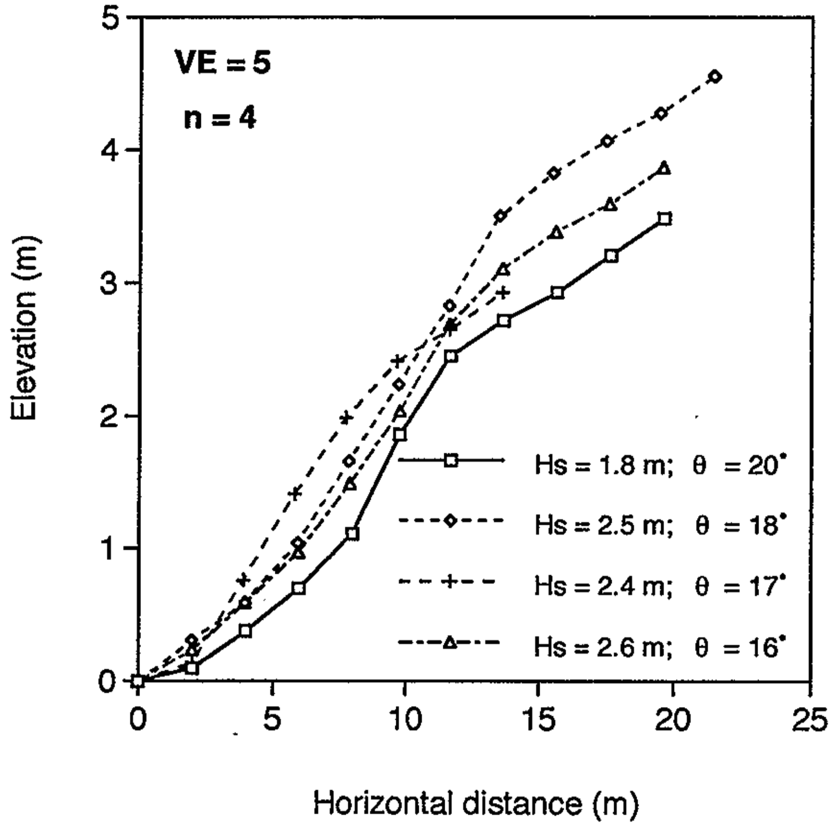
Appendix E-1. Summary of Fault-Scarp Morphometric Data Measured from Surveyed Topographic Profiles. Horizontal- and dip-slip vectors were trigonometrically determined using measurements of height and slopes of fault scarps. Slip is determined for simple (single-event) slopes (Xs and Ss) and compound (multiple-event) slopes (Xm and Sm).

Offset Deposit	θs / θm (degrees)	Hs / Hm (m)	Horizontal slip Xs / Xm (m)	Dip slip Ss / Sm (m)
Qf7-8.r	19.6 / ---	1.75 / ---	4.92 / ---	5.22 / ---
	17.98 / ---	2.47 / ---	7.61 / ---	8.00 / ---
	16.51 / ---	2.34 / ---	7.89 / ---	8.23 / ---
	15.63 / ---	2.60 / ---	9.29 / ---	9.65 / ---
Mean	*17.43±1.74 / ---*	*2.29±0.38 / ---*	*7.43± / ---*	*7.78± / ---*
Qf6-7	25.92 / 14.56	3.89 / 6.44	7.99 / 24.79	8.90 / 25.62
	21.59 / 16	3.68 / 7.98	9.30 / 27.83	10.00 / 28.95
	20.61 / 13.23	3.38 / 6.19	8.99 / 26.33	9.60 / 27.05
Mean	*22.71±2.83 / 14.60±1.39*	*3.65±0.26 / 6.87±0.97*	*8.76±0.68 / 26.32±1.52*	*9.50±0.56 / 27.21±1.67*
Qpfy	--- / 22	--- / 12.94	--- / 32.03	--- / 34.54

Scarp-height and maximum slope-angle

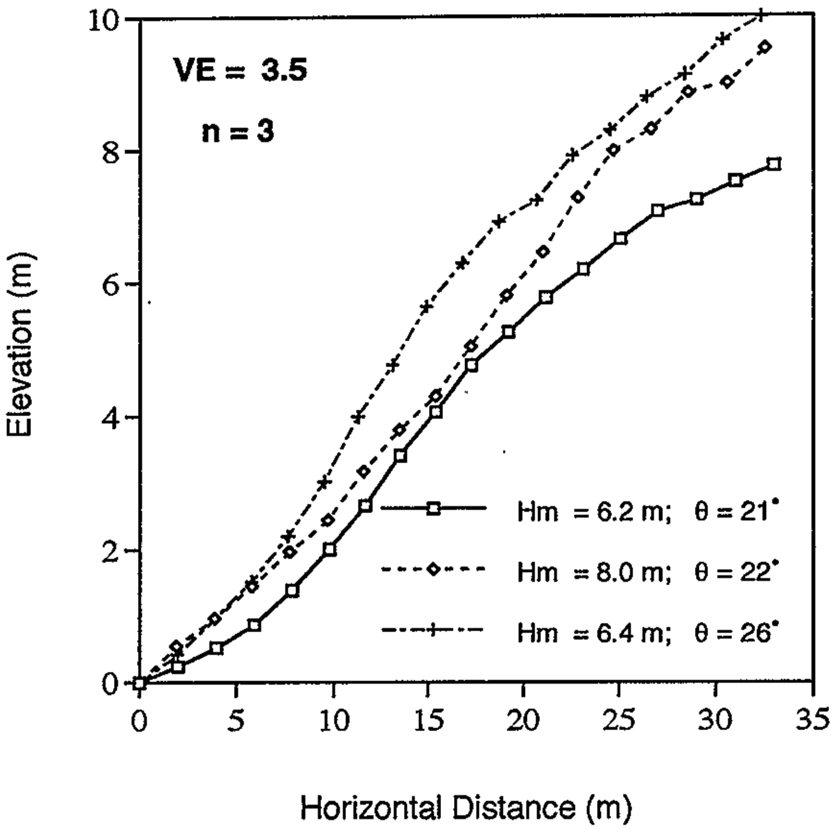
Offset Deposit	θm (degrees)	Hm (m)
Qf6-7(?)	5.6	24
Qpfy	21.2	22

Rincon fault topographic profiles, lowest scarps

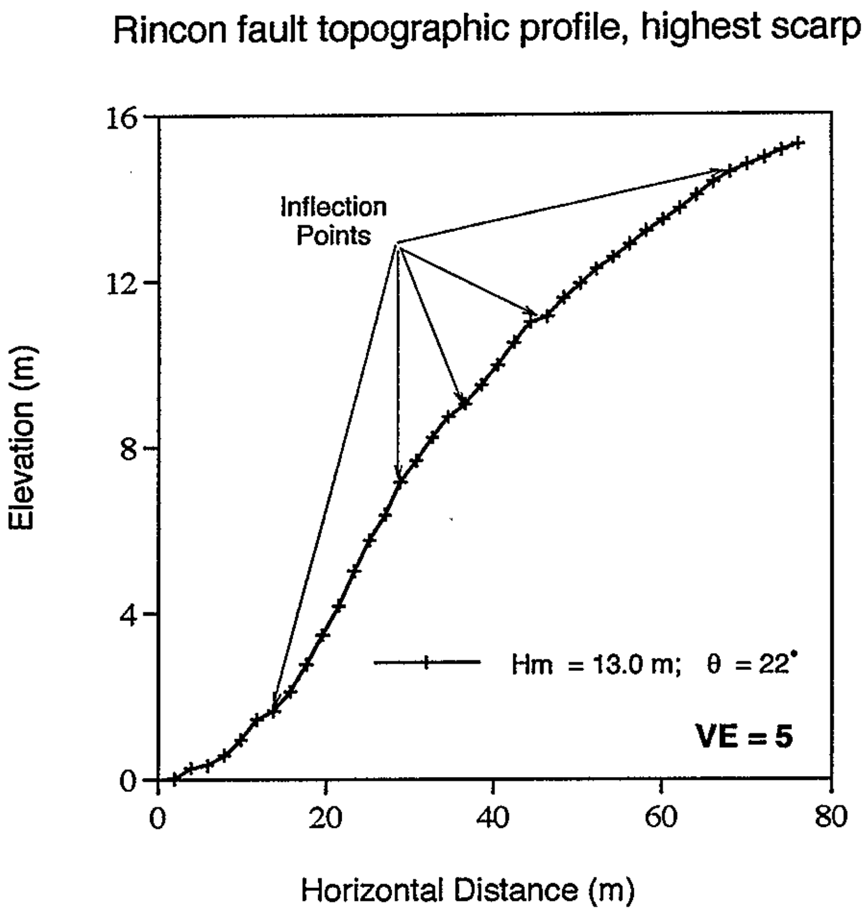


Topographic profiles of lowest scarps along Rincon fault, illustrating maximum fault displacement (Hs) and scarp angle (θ). Vertical exaggeration is 5. Mean vertical displacement is 2.3±0.4 m.

Rincon fault topographic profiles, intermediate-height scarps



Topographic profiles of intermediate-height scarps along Rincon fault, illustrating maximum fault displacement (Hm) and scarp angle (θ). Vertical exaggeration (VE) is 3.5. Total mean vertical displacment is 6.9 ± 1.0 m.



Topographic profile of high scarp along Rincon fault, illustrating maximum fault displacement (Hm) and scarp angle (θ). Bedrock is exposed along profile line. Vertical exaggeration (VE) is 5.

QUATERNARY GEOLOGY AND GEOMORPHOLOGY OF THE SANDIA MOUNTAINS PIEDMONT, CENTRAL NEW MEXICO

Sean D. Connell
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Open-File Report 425

VOLUME III

Quaternary Geologic and Geomorphic Maps (Plates I through III)
Description of Map Units (Appendix F)

May 1996

Open-File Report 425
Initial filing, May 1996

QUATERNARY GEOLOGY AND GEOMORPHOLOGY OF THE SANDIA MOUNTAINS PIEDMONT, CENTRAL NEW MEXICO

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FOREWORD

This report presents the results of M.S. thesis research conducted along the piedmont of the northern and western flanks of the Sandia Mountains, near Albuquerque, New Mexico. This research was submitted (December 1995) in partial satisfaction of the requirements for the degree of Master of Science in the Geological Sciences at the University of California at Riverside (UCR), where it is on file in the original thesis format. The thesis committee consisted of Drs. Stephen G. Wells (chairperson), David A. Osleger, Peter M. Sadler, and Leslie D. McFadden. The primary purpose of this research was to develop a detailed late Cenozoic stratigraphy for deposits associated with the western and northern flanks of the Sandia Mountains in the Albuquerque basin (see **INTRODUCTION** section). The study area, located within parts of the greater Albuquerque metropolitan area and vicinity, comprises portions of the Alameda, Bernalillo, Los Griegos, Placitas, Sandia Crest and Tijeras 7.5-minute quadrangles. The nominal scale of mapping was 1:24,000; however, selected areas were mapped at larger scales. The geologic maps emphasize Pliocene and Quaternary basin-fill, piedmont and valley fill deposits. Differentiation of major bedrock units is complied from previous studies (Kelley and Northrop, 1975; Menne, 1988).

This report is arranged into three volumes. Volume I contains the main text, figures, tables and references. Volume II contains supporting appendices (Appendix A through E) and includes soil-profile and stratigraphic descriptions. Volume III contains the geologic and geomorphic maps (Plates I through III) and description of map units (Appendix F).

Quadrangle maps, which form the basis for this report, will be placed on Open-File as individual geologic maps as they are completed, revised and integrated with current mapping studies of the bedrock and basin fill. *The contents of this report should not be considered final and complete until they are published as Bulletins or Geologic Maps by the New Mexico Bureau of Mines and Mineral Resources.*

Appendix F

Description of Map Units

ALLUVIAL DEPOSITS OF CONSTRUCTIONAL LANDFORMS

Consists of variable amounts of gravel, sand and silt, deposited by perennial, intermittent and ephemeral streams. Differentiation is based on surface morphology, degree of soil-profile development and sedimentary character. Map units are separated into stream (floodplain and terrace) and fan alluvium derived from the Rio Grande and tributary drainages from the Sandia Mountains. Stream deposits are mapped as deposits associated with floodplains, strath, fill-cut or fill terraces. Alluvial-fan deposits occur on the piedmont at the mouths of most mountain-front canyons. Deposits are composed a complex mixture of poorly sorted, poorly stratified, clast- and matrix-supported, debris- and hyperconcentrated-flow dominated alluvium. The western margin is dominated by primary and reworked deposits of the ancestral and modern Rio Grande fluvial system. Piedmont alluvium is derived from local upland basins of the Sandia Mountains, Tijeras and Las Huertas Creeks and unconformably overlie deposits of the Santa Fe Group. Fan deposits and associated geomorphic surfaces are differentiated using the following criteria: (1) their relationship to stream alluvium, alluvial fans and erosional surfaces, (2) their relationship to modern (local) stream level and surface preservation, and (3) differences in soil-profile development. Age estimates are based on comparisons of soil-profile development to soil chronosequences and soil-based alluvial chronologies described in southern New Mexico (Gile and others, 1981), eastern Colorado Plateau (Drake and others, 1991; Wells and others, 1990), northern New Mexico (Kelson, 1986; Dethier and others, 1988; Pazzaglia and Wells, 1990), and the Albuquerque basin (Machette, 1978b, 1985).

Axial-stream alluvium

Qafp9 Floodplain deposits of the Rio Grande (Holocene) — Unconsolidated deposits of fine-to coarse-grained sand and gravel. Forms the floodplain of the Rio Grande. Estimated thickness is less than 37 m (Hawley and Hasse, 1992).

Qoa2 Alluvium of Menaul Blvd. (lower-upper to upper-middle Pleistocene) — Poorly consolidated deposits of yellowish-brown (10YR) pebble conglomerate and pebbly sand derived from the ancestral Rio Grande. Clasts are dominated by rounded quartzite that are generally smaller than gravels of the alluvium of Edith Boulevard (Qoa1). The base unconformably overlies Qf6; top is unconformably overlain by Qf7 and locally recognized by a stripped soil. Forms discontinuous exposures east of the inner valley escarpment of the Rio Grande. The base is approximately 26 to 36 m above Rio Grande floodplain. An informal term for exposures near Menaul Blvd. (Lambert, 1968). Thickness is less than 2.65 m.

Qoa1 *Qoa1a* *Qoa1b* Alluvium of Edith Blvd. (middle Pleistocene) — Poorly consolidated, deposits of pale-brown to yellowish-brown (10YR) conglomerate, sand and sandy clay derived from the ancestral Rio Grande. Forms a fining-upwards sequence consisting of a basal quartzite-rich, cobble conglomerate (Qoa1a) that grades up-section into a yellowish-brown (10YR) sand, white diatomite (5Y) and reddish-brown (7.5YR) silty clay (Qoa1b). Unconformably overlies Sierra Ladrones Formation; buttress unconformity against the Sierra Ladrones Formation marks the eastern extent. Deposits are overlain by Qf4-5, Qf6 and Qf7. Forms extensive outcrops along the inner valley escarpment of the Rio Grande. The base is approximately 12 to 24 m above the floodplain of the Rio Grande. An informal term for exposures along Edith Boulevard (Lambert, 1968). Thickness is variable and ranges from 3.3 to 12 m.

Piedmont alluvium

Qf9 Fan alluvium of geomorphic surface Q9 (Holocene) — Unconsolidated deposits of brown, light gray-brown, and yellowish-brown (10YR) sand, sandy clay loam and gravel. Bouldery fans are common along range-front. Surface is generally not dissected and possesses well developed constructional bar-and-swale topography. Inset below Qf8 and grades to the floodplain of the Rio Grande. Thickness is generally less than 15 m.

Qa9 Undivided alluvium of geomorphic surface Q9 (Holocene) — Unconsolidated deposits of brown, light gray-brown, and yellowish-brown (10YR) sand, sandy clay loam and gravel. Bouldery fans are common along range-front. Inset below Qf8 and grades to the floodplain of the Rio Grande. Weakly developed soils exhibit trace accumulations of pedogenic carbonate and stage I carbonate morphology at depth. Thickness is generally less than 15 m.

Qf8-9 Undivided fan alluvium of geomorphic surfaces Q8 and Q9 (Holocene through uppermost Pleistocene) — Poorly consolidated deposits of brown to yellowish-brown (10YR) loam and sandy clay loam. Weakly developed soils exhibit trace accumulations of pedogenic carbonate to stage I+ carbonate morphology. Estimated thickness is at least 2 m.

Qf8 Fan alluvium of geomorphic surface Q8 (lower Holocene(?) through uppermost Pleistocene) — Poorly consolidated deposits of very pale-brown to light-brown (7.5-10YR) sand to sandy clay loam and gravel. Inset below Qf7. Distal margin is truncated by an erosional escarpment of the inner valley of the Rio Grande. Slightly dissected surface possesses well-developed constructional bar-and-swale topography. Weakly developed soils exhibit stage II carbonate morphology and minor clay film development. Estimated thickness is less than 21 m.

Qa8 Undivided alluvium of geomorphic surface Q8 (lower Holocene(?) through uppermost Pleistocene) — Poorly consolidated deposits of brown to light-brown (7.5-10YR) loamy sand and gravel. Inset below Qf7. Slightly dissected surface possesses well developed constructional bar-and-swale topography. Weakly developed soils exhibit stage I+ carbonate morphology and minor clay film development. Estimated thickness is less than 21 m.

Qt7-8 Terrace alluvium of geomorphic surfaces Q7 and Q8 (uppermost Pleistocene) — Poorly to moderately consolidated deposits of brown to yellowish-brown (8.75YR) loam, sand loam and minor clay loam exposed in walls of Las Huertas Creek, where it forms the primary fill of inner valley. Deposits are primarily rounded limestone and accessory sandstone derived from the eastern slope of the Sandia Mountains. Basal contact is irregular and overlain by stratified sand and gravel. Soils are weakly developed and exhibit stage I+ carbonate morphology. Terrace is 3 to 24 m above local base level and occupies a similar landscape position relative to Qf7 where Las Huertas Creek enters the floodplain of the Rio Grande. Surface is locally modified by fill-cut terraces. Estimated thickness is about 5 to 6 m.

Qf7-8.r Undivided fan alluvium of Rincon Ridge (lower Holocene(?) to upper Pleistocene) — Poorly consolidated deposits of yellowish-brown to brown (7.5-10YR) silty clay loam, silty clay and coarse-grained conglomerate derived from schist, gneiss and quartzite. Fans are restricted to the range-front between Juan Tabo and del Agua Canyons (Qf6 and Qf7). Deposits are offset by the Rincon fault, inset below Qf6 and locally buried by bouldery fans of Qf9. Weakly to moderately developed soil with stage I to II carbonate morphology and thin to moderately thick clay films. Estimated thickness is at least 6 m.

Qf7 Fan alluvium of geomorphic surface Q7 (uppermost to 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. Slightly to moderately dissected surface is approximately 18 to 36 m above local base level along Strip Mine Creek. Surface possesses subdued constructional bar-and-swale topography. Soils are moderately developed and characterized by stage II carbonate morphology. Alluvium unconformably overlies Qoa2 and forms buttress unconformity against deposits of the Sierra Ladrones Fm. Estimated thickness is 36 m. Divided into Qf7a and Qf7b on the basis of inset relationships.

Qf7a Sandy to silty clay with few to common, thin clay films; inset below Qpf5.

Qf7b Loamy sand to silty clay with few to common, thin to moderately thick clay films; inset below Qf7a.

Qpfy <u>Undivided pediment and fan alluvium (Pleistocene)</u> — Moderately consolidated deposits of poorly sorted, subangular to subrounded conglomerate discontinuously overlying mountain-front surface of erosion. Up to 5 m estimated thickness.

Qf6-7 <u>Undivided fan alluvium of geomorphic surfaces Q6 and Q7 (upper to middle Pleistocene)</u> — Discontinuous exposures of poorly sorted, coarse-grained sand and conglomerate along the base of Rincon Ridge. Deposits are inset below Qpfy and offset by the Rincon fault.

Qf6 <u>Fan alluvium of geomorphic surface Q6 (middle Pleistocene)</u> — Moderately consolidated deposits of light- to strong-brown (7.5YR) and very pale-brown to light-gray (7.5-10YR) sand to clay. Unconformably overlies alluvium of Menaul Boulevard; inset below Qf4-5. Forms dissected surface possessing subdued ridge-and-ravine topography. Subdued bar-and-swale constructional topography is locally preserved on stable interfluves. Moderately well developed soils with stage III-carbonate morphology and many moderately thick clay films. Estimated thickness is at least 15 m.

Qf4-5 <u>Undivided fan alluvium of geomorphic surfaces Q4 and Q5 (middle Pleistocene)</u> — Moderately consolidated deposits of yellowish-brown (10YR), poorly sorted, subangular to subrounded sand and conglomerate. Inset below Qp2 and unconformably overlies Sierra Ladrones Formation and alluvium of Edith Blvd. Inliers on proximal and medial piedmont segments along Rincon Ridge. Surface possesses dissectional ridge-and-ravine topography. Along the distal piedmont, the top is locally recognized by stripped soil. Estimated thickness is at least 9 m.

Qf4 <u>Fan alluvium of geomorphic surface Q4 (early-middle Pleistocene)</u> — Moderately consolidated deposits of very pale-brown (10YR) sandy clay loam. Inset below Qp3. Surface is highly dissected, exhibits ridge-and-ravine topography and is locally modified by deposits of Qf8 and Qa9. Soil is well developed and exhibits stage IV carbonate morphology and few thin colloidal clay films. Estimated thickness is at least 5 m.

EROSIONAL SURFACES AND ASSOCIATED ALLUVIAL DEPOSITS

Pediments are regional, low-relief surfaces of erosional cut by fluvial processes that typically have a concave up profile. Pediments locally span the mountain front-piedmont junction and are cut across bedrock and Santa Fe Group deposits. Surfaces are typically associated with an overlying alluvium that generally consists of poorly stratified, moderately to poorly sorted, subangular to subrounded conglomerate and sandy gravel. Deposits are differentiated using the following criteria: (1) surface morphology and characteristics of gravel remnants; (2) thickness of deposit; (3) their stratigraphic and geomorphic (inset) relationships to other units, (4) their relationship to local (modern) stream level and surface dissection; and (5) differences in soil-profile development. Pediments are differentiated for deposits having a thickness less than about 3 to 5 m. These are common south of highway NM 165 (formerly NM 44). Pediment-fan complexes are typically thicker than 3 m and common north of NM 165. Straths are thin terraces cut into bedrock and upper Santa Fe Group deposits and recognized along major drainages. The base of overlying alluvium is delineated on maps. Cross-hatched patterns depict bedrock-floored surfaces of erosion where overlying alluvium has been removed.

Pediments and pediment-fan complexes

Qp8 Pediment of geomorphic surface Q8 (uppermost Pleistocene) — Surface of erosion cut on crystalline rock and inset below units Qp4-5 and Qp6. Recognized as low sloping ridges without overlying gravel located within Juan Tabo Canyon.

Qp6 Pediment of geomorphic surface Q6 (middle Pleistocene) — Surface of erosion cut on crystalline rock and inset below units Qp4-5 and Qp2-3. Recognized as low sloping ridges approximately 6 to 18 m above Juan Tabo Creek. Locally overlain by granitic alluvium.

Qp5 Pediment and strath alluvium of geomorphic surface Q5 (lower-upper to upper-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. Forms broad, northwest-sloping surface covered by fairly thin veneer of conglomerate. Surface is slightly dissected and posses rare, subdued constructional bar-and-swale topography. Soils are moderately developed and exhibit stage III- carbonate morphology and many to continuous, thick clay films; inset below Qp3. Recognized along piedmont-foothills junction, near Strip Mine and Agua Sarca Canyons, and along the northern mountain front near Placitas. Divided into Qpf5 and Qt5 on the basis of unit thickness, morphology and location. Estimated thickness is about 2 to 5 m.

Qpf5 Forms laterally extensive surface north of highway NM 165 inset below Qp2. At least 6 m in thickness and grades up-slope into Qp5 near Strip Mine and Agua Sarca Creeks.

Qt5 Forms elongated strath terrace cut into deposits of the Sierra Ladrones Formation along Las Huertas Creek. Terrace is 6- to27-m above Las Huertas Creek.

Qp4-5 Undivided pediment alluvium of geomorphic surface Q4 and Q5 (middle Pleistocene) — Moderately consolidated deposits of strong brown (7.5YR) cobble to boulder conglomerate. Clasts primarily consist of weathered and pitted granitoid and minor (≤5%) limestone. Pediment is inset below Qp2-3 and is recognized along base of mountains south of Juan Tabo Canyon. Estimated thickness is at least 3.7 m.

Qp3 Pediment and strath alluvium of geomorphic surface Q3 (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-dominated cobble to boulder conglomerate. Locally overlies discontinuous remnants of formerly extensive pediment surface near the village of Placitas. Forms a north and northwest-sloping surface of erosion on the hanging wall of the Placitas fault. Pediment is overlain by 7 to 14 m of conglomerate and is about 9 to 32 m above local base level along del Ojo del Orno Creek. Deposits are poorly exposed and inset below Qp2. The surface is moderately dissected and eroded. Divided into strath terraces (Qt3) on the basis of surface morphology.

Qt3 Forms north-sloping bench and associated gravels (limestone conglomerate) about 9 to 32 m above Las Huertas Creek.

Qp2-3 Undivided pediment alluvium of geomorphic surfaces Q2 and Q3 (early to middle Pleistocene) — Cobbles to very large boulders of weathered and pitted Sandia granite. Discontinuously overlies a west-sloping surface of erosion along the mountain-front south of Rincon Ridge. Forms the highest preserved surface and deposits south of Strip Mine Canyon. Straddles the southern drainage divide of Juan Tabo Creek.

Qp2 <u>Pediment alluvium of geomorphic surface Q2 (middle Pleistocene)</u> — 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. Common along Las Huertas Creek. Dominated by clasts of limestone and accessory schist and micaceous quartzite. Inset below QTpf1 and approximately 34 to 50 m above local base level along Las Huertas Creek. The surface is modified by erosion and constructional bar-and-swale topography is generally absent. Accumulation of silt and fine-grained sand typically form smooth surfaces. Soils exhibit stage III+ carbonate morphology and very few thin clay films. Silica films occur on clasts and ped faces. Divided into pediment-fan complexes (Qpf2) and an intermediate pediment (Qp2a) on the basis of deposit thickness and location. Thickness is about 2 to 5 m.

Qpf2 Pediment alluvium thickens to about 12 m north and west of the piedmont-foothills junction at Lomos Altos and Cuchilla de Escala.

Qp2a Forms a locally preserved conglomerate discontinuously exposed on beveled ridge tops; approximately 12 m higher than Qp2.

QTpf1 <u>Pediment alluvium of geomorphic surface QT1 (upper Pliocene)</u> — 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 near the Sandia range front in Placitas. Forms highest preserved pediment in the study area. Unconformably overlies Santa Fe Group (Tsfl and QTsfup) deposits. Laterally extensive exposures on Lomos Altos are about 82 to 98 m above del Ojo del Orno Creek. Thickness is generally less than 12 m and ranges between 4 and 18 m. Surface is highly modified by erosion and re-deposition of pediment alluvium. Soils exhibit stage IV+ carbonate morphology. May be correlative to the Tuerto gravels (Stearns, 1953) and "Ortiz" pediment (Picha, 1982, geologic map).

Qpo <u>Qpo (middle(?) to lower Pleistocene)</u> — Erosional(?) surfaces or benches cut on crystalline rocks. Unit is preserved on mountain-front south of La Cueva Canyon and recognized as dissected benches less than 210 m above the mountain front-piedmont junction.

COLLUVIAL DEPOSITS

Consist of poorly sorted, gravity-generated, scree, talus colluvium. Delineated by surface morphology. Composition generally reflects local provenance. Locally differentiated where areally extensive.

Qsct Undivided scree and talus colluvium (Holocene through upper Pleistocene) - Colluvial apron formed on high hill slopes of the northern flank of the Sandia Mountains.

BASIN-FILL DEPOSITS

Deposits of the Santa Fe Group are separated into the Sierra Ladrones Formation (Plio-Pleistocene) and lower Santa Fe Group (Miocene?).

Basin-fill alluvium

QTsfu Sierra Ladrones Formation (late Pliocene to middle Pleistocene) — Poorly to moderately consolidated and indurated, poorly to well stratified deposits containing variable amounts of fine- to coarse-grained sand, pebbly to cobbly sand and pebble to cobble conglomerate. A *Glyptotherium* found north of highway NM 165 (N1/4, NE1/4, SW1/4, Section 27, T12N., R04E., NMPM, Bernalillo 7.5-minute quadrangle; Lucas and others, 1993) indicates an Irvingtonian age (late Pliocene to middle Pleistocene) for the unit. Rounded clasts of lower Bandelier Tuff indicate an early Pleistocene age. The base is not observed; deposits are at least 125 m in thickness and divided into axial and piedmont facies.

QTsfua *Axial-river facies* — Variable amounts of sandstone, mudstone and conglomerate deposited by the ancestral Rio Grande. Color varies from very pale-brown to light-gray to white (2.5YR - 10YR). Sandstone is poorly to moderately consolidated, moderately to well sorted, fine-to coarse-grained and calcium-carbonate cemented. Bedding is massive, laminated and cross bedded. Conglomerate contains moderately sorted, subrounded, locally imbricated cobbles and pebbles. Clasts are primarily composed of quartzite with lesser amounts of aphanitic and phaneritic volcanic and shallow intrusive rocks and pumice. Facies is dominant along the western half of study area and interfingers with piedmont facies to the east.

QTsfup *Piedmont facies* — Piedmont facies primarily contain conglomerate and sandstone derived from uplands of the Cuchilla de San Francisco, Sandia Mountains and Rincon Ridge. Deposits are poorly sorted, yellowish-brown to reddish-brown, subangular to subrounded, weakly bedded conglomerate, sand and minor mudstone. Deposits along NM 165 are dominated by reddish-brown sand and conglomerate derived from Mesozoic strata exposed in Strip Mine Canyon.

Tsfl Undivided lower Santa Fe Group (Miocene(?)) — Piedmont deposits consisting of very well consolidated conglomerate and sandstone. Clast composition varies. Volcanic clasts derived from the Espinaso Formation occur near the base. Paleozoic lithologies dominate up-section.

BEDROCK UNITS

Bedrock

PzMzu Undivided Paleozoic and Mesozoic strata (Mississippian through Mesozoic) — Very well consolidated Paleozoic and Mesozoic deposits. Includes the Sandia, Madera and Abo Formations and Chinle Group.

Mzu Undivided Mesozoic strata (Triassic and Jurassic) — Highly sheared, very well consolidated, reddish-brown and yellowish-brown mudstone and sandstone of the Mesozoic Chinle Group and Entrada Formation. Occurs southeast of Rincon Ridge.

Xg Sandia granite (Precambrian) — Pink, medium-to coarse-grained, orthoclase-rich porphyritic granite and granodiorite dated at about 1.4 Ga.

Xm Rincon Ridge metamorphic complex (Precambrian) — Schist, gneiss, micaceous quartzite and white aplite dikes (1.4 to 1.7 Ga).

Xgm Undivided crystalline rocks (Precambrian) — Undivided rocks of the Sandia granite and Rincon Ridge metamorphic complex.

PLATE I

Quaternary Geologic and Geomorphic Map of Portions of the Bernalillo and Placitas Quadrangles Sandoval County, New Mexico

Geology by S.D. Connell
University of California, Riverside
1995

GEOLOGIC SYMBOLS

DESCRIPTION

- Geologic contact, dashed where approximate; dotted where concealed; queried where inferred.
- Fault contact; dashed where approximate; dotted where concealed; queried where inferred.
- Geomorphic surface contact; approximate limit of selected, areally extensive surfaces.
- Diatomite bed of Edith Blvd alluvium (Qoa1).
- A / P: Approximate boundary between axial (A) and piedmont (P) facies of the Sierra Ladrones Fm (QTsfu).
- Pediment surface; no alluvium overlying erosional surface.
- Undifferentiated pre-Quaternary rock
- 83: Strike and dip of fault.
- 12: Strike and dip of bed.
- A——A': Cross section.
- 4: Selected stratigraphic section (Appendix D).
- 35: Soil-profile description.
- Boundary of detail maps (Plate III).

Major Geomorphic Surfaces and Deposits

HOLOCENE / upper Pleistocene / middle Pleistocene / PLEISTOCENE

- Qa9 Qf9 Qafp9
- *Unconformity*
- Qa8 Qf8 Qp8
- *Unconformity*
- Qf7 Qf7a Qf7b
- *Unconformity*
- Qoa2 (Menaul Blvd alluvium)
- *Unconformity*
- Qf6 Qp6
- *Unconformity*
- Qpf5 Qp5 Qt5
- *Unconformity*
- Qoa1 Qoa1a Qoa1b (Edith Blvd alluvium)
- *Unconformity*
- Qf4
- *Unconformity*
- Qp3 Qt3
- *Unconformity*
- Qpf2 Qp2
- *Angular Unconformity*

Grouped units: Qf8-9; Qf7-8.r; Qt7-8 Qt7-8; Qf4-5 Qp4-5; Qp2-3

lower PLEISTOCENE & upper PLIOCENE:

- QTsfu, QTsfua, QTsfup: Sierra Ladrones Fm.
- QTpf1: Pediment-fan complex
- *Angular Unconformity*

MIOCENE:

- Tsfl: Lower Santa Fe Grp.
- *Angular Unconformity*

PALEOZOIC & MESOZOIC:

- PzMzu, Mzu: Undivided sedimentary rocks
- *Nonconformity*

Crystalline Rocks

PRECAMBRIAN

- Xg: Sandia granite
- Xm: Rincon Ridge metamorphic complex
- Xgm: Undivided crystalline rocks

See Appendix F and text for explanation

SCALE 1:24 000

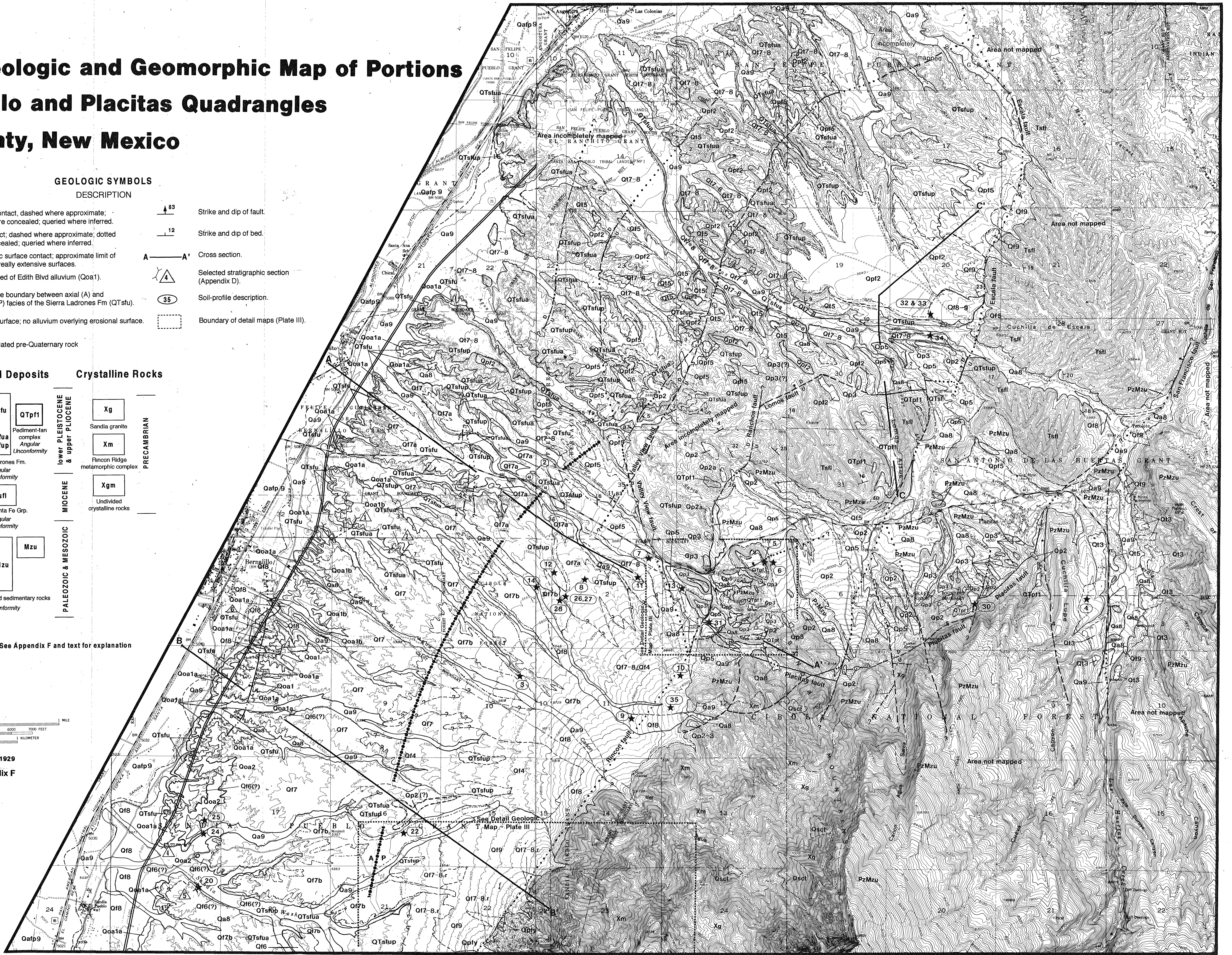
1 ½ 0 1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 .5 0 1 KILOMETER

National Geodetic Vertical Datum of 1929

Map Explanation: See Appendix F

N MN 13°

NEW MEXICO
QUADRANGLE LOCATION



Bernalillo Quadrangle: Contour Interval = 10 feet

Placitas Quadrangle: Contour Interval = 20 feet

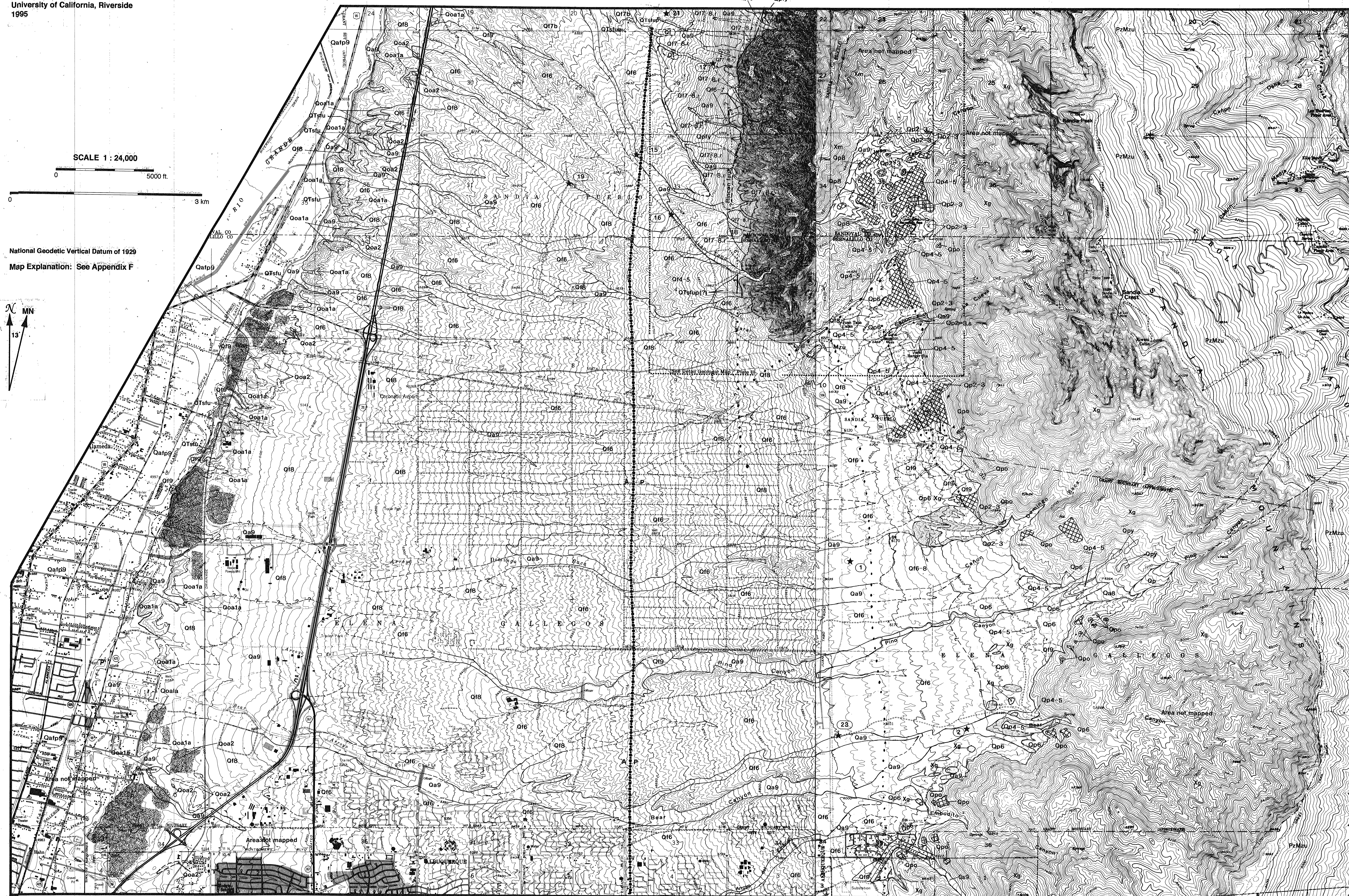
Quaternary Geologic and Geomorphic Map of Portions of the Alameda, Los Griegos and Sandia Crest Quadrangles, Sandoval and Bernalillo Counties, New Mexico

Geology by S.D. Connell
University of California, Riverside
1995

SCALE 1 : 24,000
0 5000 ft.
0 3 km

National Geodetic Vertical Datum of 1929

Map Explanation: See Appendix F

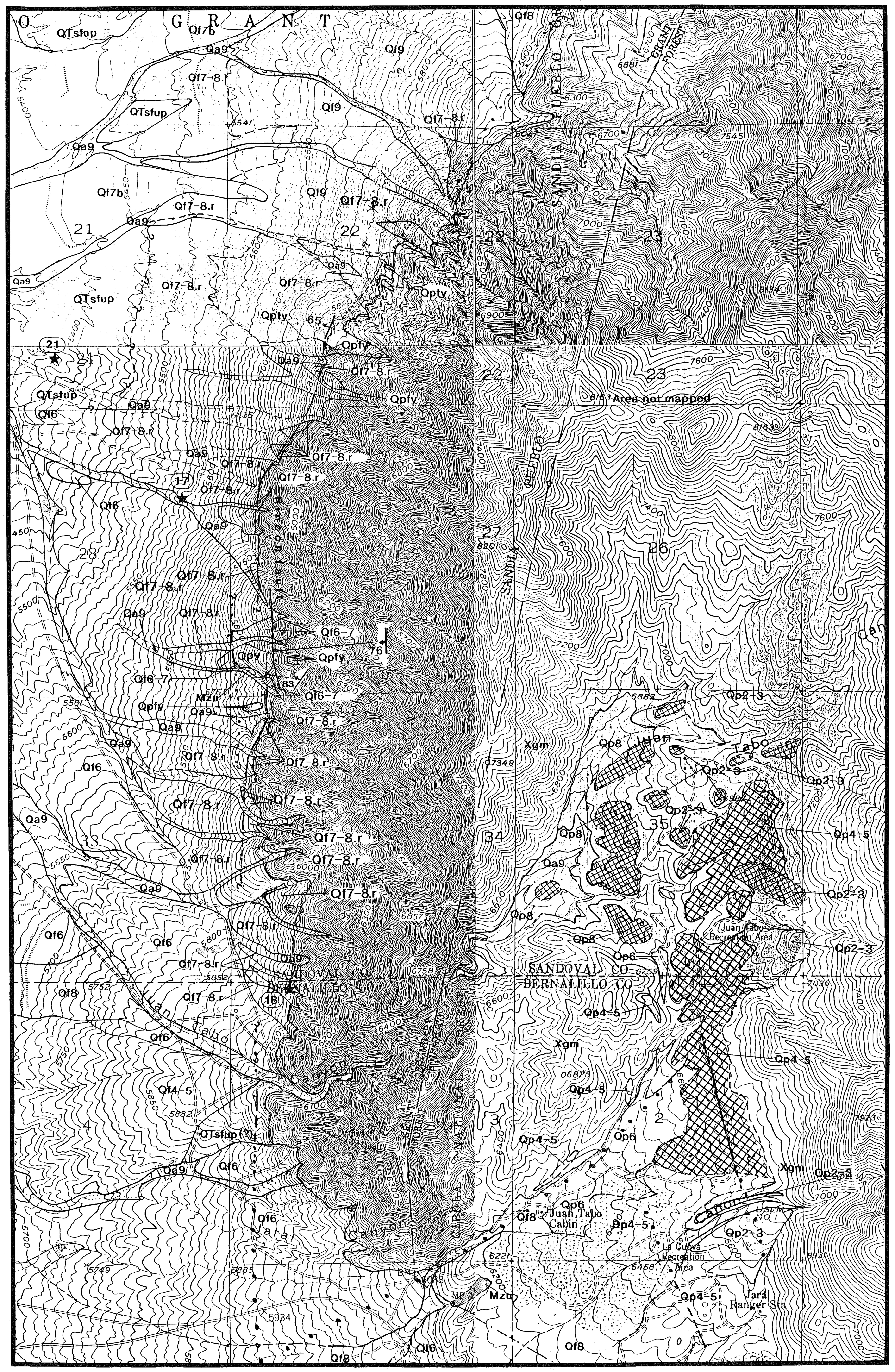


Alameda & Los Griegos Quadrangles: Contour Interval = 10 feet

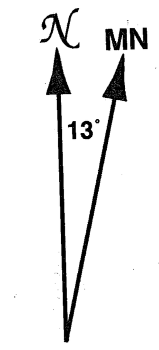
Sandia Crest Quadrangle: Contour Interval = 40 feet

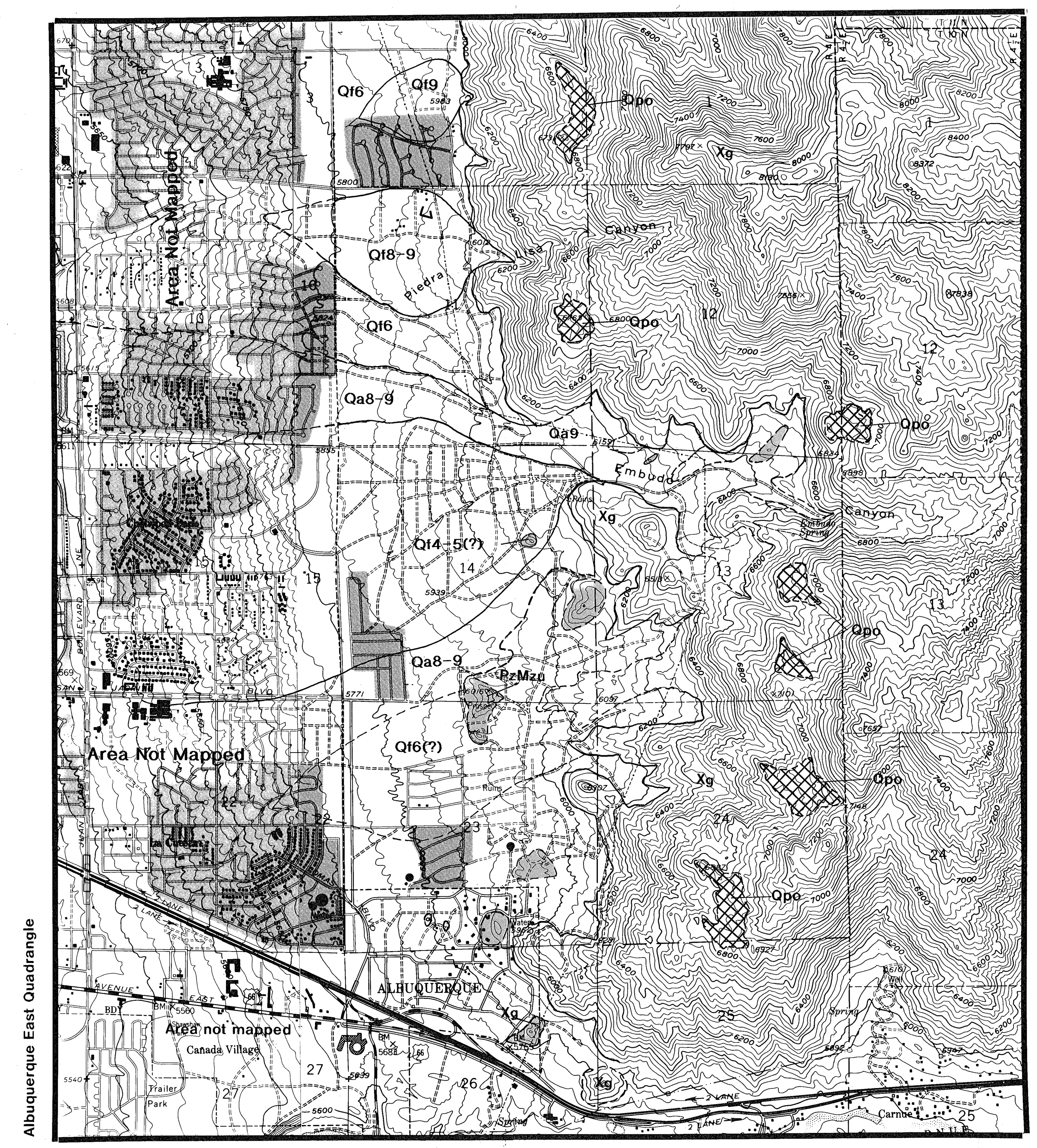
PLATE III

Quaternary Geologic Map Detail of Rincon Ridge Area



Quaternary Geologic and Geomorphic Map of Portions of the Tijeras and Albuquerque East Quadrangles, Bernalillo County, New Mexico





Contour Interval = 10 feet

Tijeras Quadrangle: Contour Interval = 40 feet

SCALE 1 : 24,000

0 5000 ft.

0 3 km

Geology by S.D. Connell
University of California, Riverside
1995

SCALE 1 : 15,480

0 5000 ft.

0 1500 m

SCALE 1 : 14,100

0 5000 ft.

0 1500 m

National Geodetic Vertical Datum of 1929

Map Explanation: See Appendix F

Quaternary Geologic Map Detail of Strip–Mine Canyon