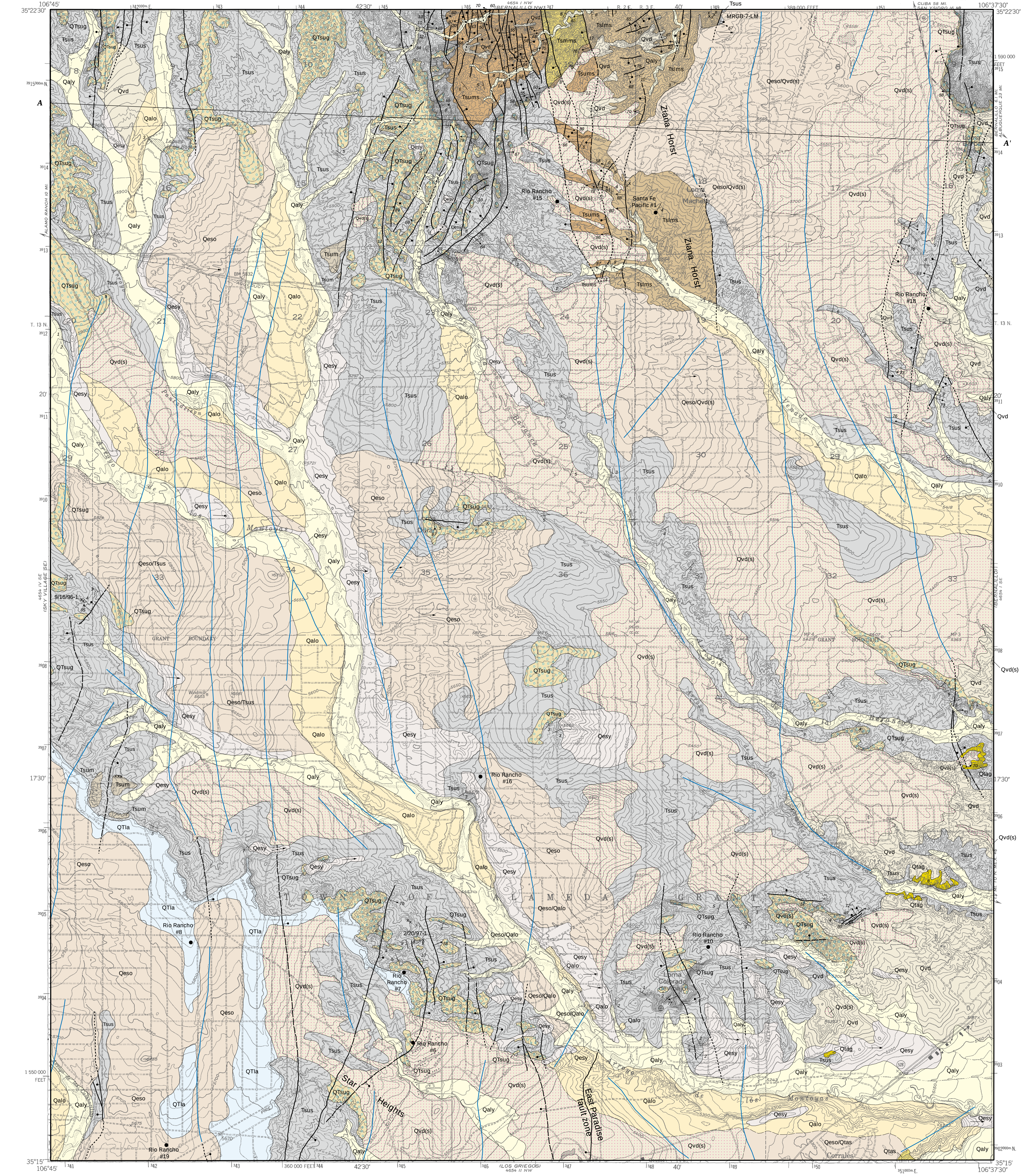
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

MISCELLANEOUS FIELD STUDIES MAP MF–2334
Version 1.0

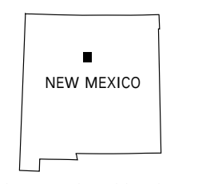


Base from U.S. Geological Survey, 1954. Photorevised 1972
Polyconic projection. 1927 North American datum
10,000-foot grid based on New Mexico coordinate system, central zone
1,000-meter Universal Transverse Mercator grid ticks, zone 13

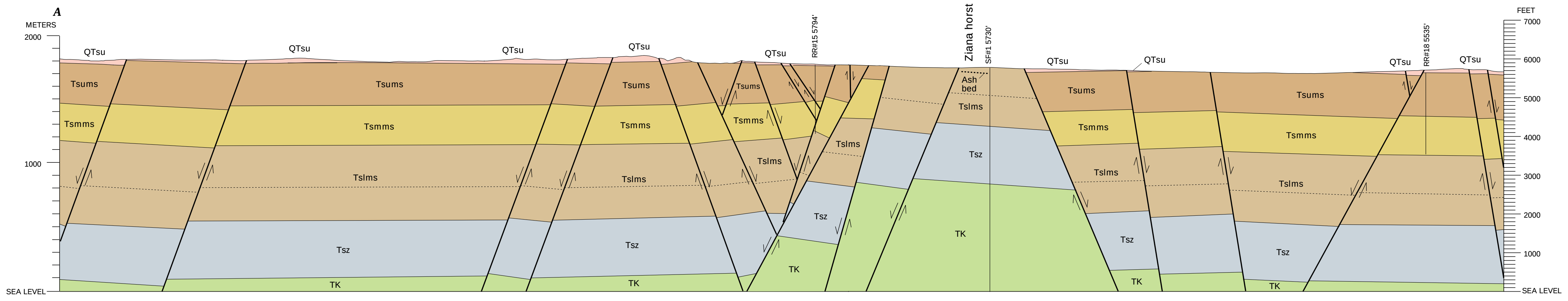
UTM GRID AND 1972 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24 000

CONTOUR INTERVAL 10 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929


QUADRANGLE LOCATION

Geology mapped 1996–1997
Manuscript approved for publication February 11, 2000



Surficial deposits omitted

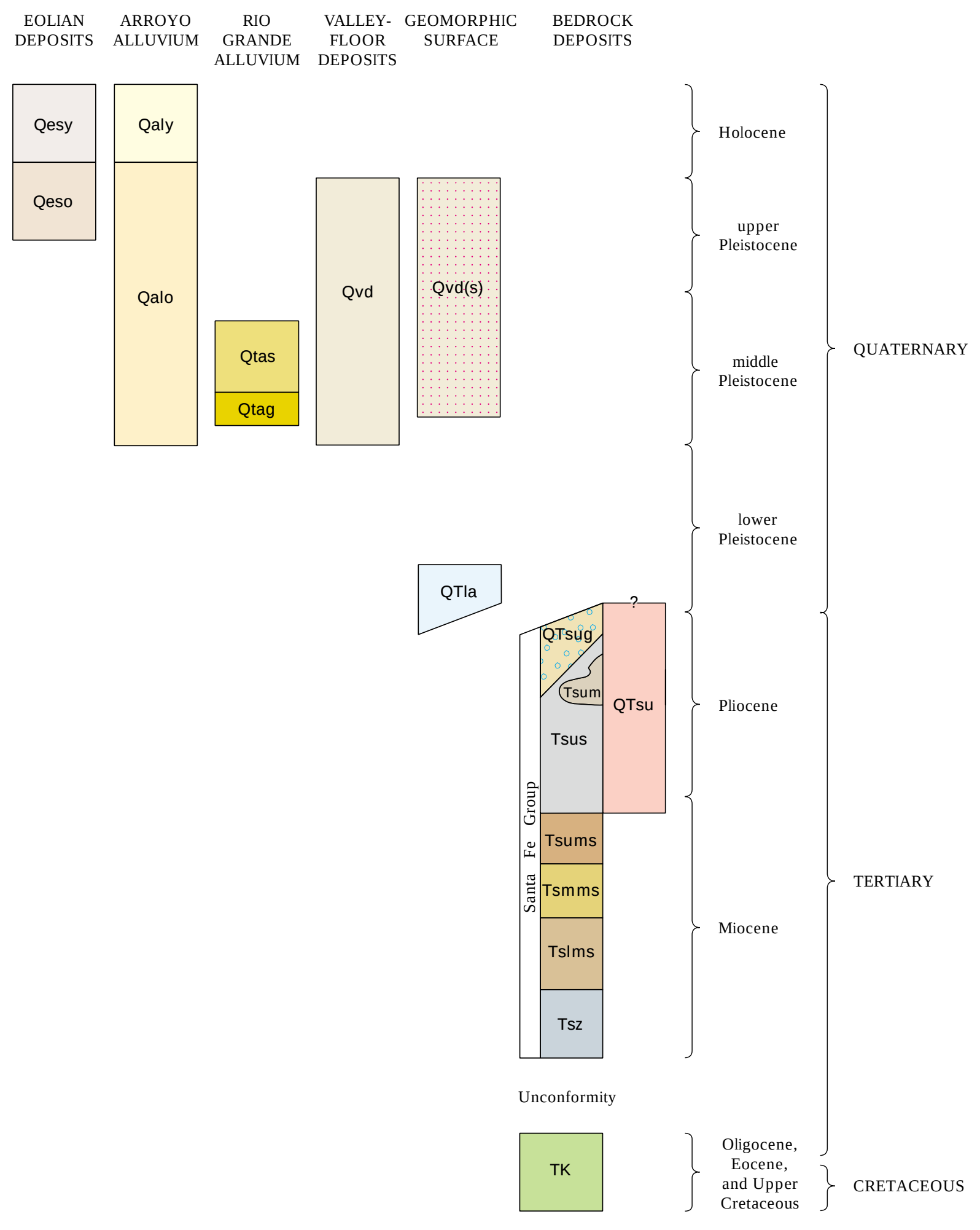
PRELIMINARY GEOLOGIC MAP OF THE LOMA MACHETE QUADRANGLE, SANDOVAL COUNTY, NEW MEXICO

By

Stephen F. Personius, Michael N. Machette, and Byron D. Stone

2000

CORRELATION OF MAP AND SUBSURFACE UNITS



DESCRIPTION OF MAP AND SUBSURFACE UNITS

Qesy **Young eolian sand (Holocene)**—Light-yellowish-brown, fine to coarse sand; moderately to well sorted; massive to crossbedded. Primarily deposited in narrow (100–500 m wide) zones along eastern and northeastern flanks of larger arroyos; forms sand sheets and minor transverse and incipient barchan dune complexes with closed depressions; sparsely vegetated to unvegetated. Minimal soil development. Thickness 1–10 m

Qeso **Older eolian sand (Holocene to upper Pleistocene)**—Light-brown, fine to coarse sand; moderately to well sorted; massive to crossbedded. Located downwind of younger sand deposits (Qesy); forms broad sand sheets and transverse-barchan dune complexes with numerous closed depressions; covers valley-floor surfaces [Qvd(s)] throughout much of map area; well vegetated. Soil development variable, but stable sites characterized by well-oxidized sands with stage I and stage II Bk horizons (soil terminology from Birkeland, 1984). Thickness 1–10 m

Qaly **Young arroyo alluvium (Holocene)**—Light-yellowish-brown, fine to coarse sand and pebbly sand, with some thin beds of sandy pebble gravel; moderately sorted; massive to well bedded, with occasional cross bedding. Deposited in arroyo channel bottoms and underlies low (<3 m) terraces flanking channels; unit commonly contains small areas of, or is capped by, eolian sand (Qesy); sparsely vegetated to unvegetated. Low terraces contain numerous charcoal-rich hearth sites that lie 20–100 cm below ground surface. Minimal soil development. Thickness 1–5 m

Qalo **Older arroyo alluvium (Holocene to middle Pleistocene)**—Light-brown, fine to coarse sand and pebbly sand, with some thin beds of sandy pebble gravel; moderately sorted; massive to well bedded, with occasional cross bedding. Preserved in terraces and eroded remnants 3–30 m above adjacent arroyo channels; underlies 5- to 30-m-high terraces along Arroyo de los Montoyas in west central part of map area and 3- to 5-m-high terraces along Arroyo Venada in northeastern part of map area. Commonly capped by 1–2 m of eolian sand (Qesy or Qeso); well vegetated. Where preserved, soils have ~50-cm-thick stage II to ~100-cm-thick stage III Bk horizons. Thickness 3–30 m

Qvd **Valley floor sand and gravel (upper and middle Pleistocene)**—Reddish-yellow-brown sand and sandy pebble and cobble gravel; poorly to moderately sorted; massive to poorly bedded. Gravel clasts subangular to subrounded and primarily consist of lithologies derived from northwestern New Mexico (Jemez River–Rio Salado) sources (Precambrian pink granitic rocks, Pedernal Chert Member of Abiquiu Formation, petrified wood, Paleozoic chert and limestone, Mesozoic sandstone); probably reworked from underlying upper Santa Fe Group deposits (QTsug). Forms broad fan surfaces (denoted by (s) symbol and dotted pattern) in interfluves between major arroyos and on hillslopes throughout much of map area; some surfaces may be remnants of old arroyo terraces. Unit contains both alluvium and thin eolian sand deposits. Commonly capped by 1–5 m of eolian sand (Qeso). Well vegetated. Soil development is variable, but stage I through stage III Bk horizons are common. Thickness 1–15 m. Deposits thicken dramatically in southeastern corner of quadrangle, where they apparently fill a main stem Rio Grande paleovalley formed during deposition of units Qtag and Qtas

Qvd(s) **Broad fan surfaces formed by unit** Qvd

Rio Grande alluvium

Qtas **Tercero Alto sand (middle Pleistocene)**—Light-brown sand and pebbly sand; moderately to well sorted; well bedded. Most clasts derived from northwestern New Mexico (Jemez River–Rio Salado) sources (Precambrian pink granitic rocks, Pedernal Chert Member of Abiquiu Formation, petrified wood, Paleozoic chert and limestone, Mesozoic sandstone). Underlies informally named Tercero Alto terrace (see description of Qtag below) and overlies unit Qtag (contact not exposed) in southeastern part of quadrangle. Commonly covered by 5- to 15-m-thick sequence of eolian sand (Qeso). Deposits are a mixture of axial channel and overbank facies of the ancestral Rio Grande, arroyo alluvium from Arroyo de los Montoyas (the source of northwestern New Mexico gravels), and eolian sand. Thickness poorly known, probably 10–20 m

Qtag **Tercero Alto gravel (middle Pleistocene)**—Sandy pebble and cobble gravel; moderately to well sorted; poorly bedded. Clasts well rounded and primarily consist of intermediate volcanics and quartzites derived from northern New Mexico and southern Colorado (Sangre de Cristo and San Juan Mountains) sources. Forms erosional remnants and lags on less resistant bedrock. Deposits are axial channel facies of the ancestral Rio Grande, deposited on strath cut into upper Santa Fe Group (Tsus) sedimentary rocks. Base of unit lies 70–75 m above the present channel of the Rio Grande. Most outcrops originally mapped by Spiegel (1961), who assigned them a late Pleistocene age, but these gravels more likely correlate with deposits underlying the middle Pleistocene Tercero Alto terrace (Bachman and Machette, 1977; Machette, 1985) of the Rio Grande. This informally named terrace is correlative with the surface underlying the Albuquerque volcanoes basalt mapped by Lambert (1968) in the adjoining Los Griegos quadrangle. Thickness <5 m

QTla **Llano de Albuquerque (lower Pleistocene to Pliocene)**—Extensive geomorphic surface formed in sand and gravel at the top of the Santa Fe Group (units QTsug and Tsus) in southwestern part of quadrangle. In places contains wedges of eolian sand and colluvium formed at the bases of large fault scarps that offset deposits of upper Santa Fe Group. Soil development consists of 5- to 20-cm-thick stage IV K horizons overlying 100- to 200-cm-thick stage III+ horizons (Machette and others, 1997). Commonly capped by 1–5 m of eolian sand (Qesy and Qeso)

Santa Fe Group (lower Pleistocene(?) to Miocene)

QTsug **Upper sandstone and conglomerate (lower Pleistocene(?) to Pliocene)**—Sandstone and sandy pebble, cobble, and boulder conglomerate; poorly indurated; poorly to moderately well sorted. Massive to moderately bedded. Clasts subangular to subrounded and primarily consist of lithologies derived from northwestern New Mexico (Jemez River–Rio Salado) sources (Precambrian pink granitic rocks, Pedernal Chert Member of Abiquiu Formation, Paleozoic chert and limestone, Mesozoic sandstone, vesicular basalt, intermediate volcanics, petrified wood). No clasts of lower Pleistocene Bandelier Tuff were found, so QTsug deposits may predate the 1.61 Ma maximum age (Izett and Obradovich, 1994) of these widespread volcanic rocks in most places. Largest basalt and sandstone clasts are 50–100 cm long, but conglomerate grain size decreases, and clasts become better sorted and more mature (less granitics, more chert), to south. Large clast size and poor sorting of some beds in northern part of quadrangle suggest part of unit is a fan deposit shed off Sierra Nacimiento and Jemez Mountains to north (Manley, 1978), prior to entrenchment of present Jemez River. However, most of unit is moderately well sorted sandstone and conglomerate deposited as channel facies by southward- and southeastward-flowing streams. Best exposed in Rincones de Zia along northern margin of quadrangle, and underlying Llano de Albuquerque (QTla) in southern part of quadrangle. Unit is occasionally mapped at lower stratigraphic positions where gravels form lags that armor less resistant deposits. Correlative with Upper Buff member of Santa Fe Formation of Bryan and McCann (1937), Ceja Member of Santa Fe Formation of Kelley (1977), Sierra Ladrones Formation of Machette (1978), upper unit of Cochiti Formation of Manley (1978), and proposed Ceja Member of Arroyo Ojito Formation of Connell and others (1999). Thickness 1–10 m

Tsus **Upper sandstone and siltstone (Pliocene to upper Miocene)**—Predominantly light-gray to pale-brown, fine- to medium-grained sandstone, with less common pebbly sandstone, sandy pebble conglomerate, and very pale brown to red sandstone, siltstone, and claystone; poorly indurated. Moderately to well sorted within beds; well bedded. Unit coarsens northward. Base of unit is commonly marked by a <1 m thick bed of pebble and cobble conglomerate. Contains some thin deposits of lacustrine silt (Tsum). Rounded pumice pebbles in beds 5- to 200-cm-thick found <5 m below the contact with unit QTsug and 10–15 m below the Llano de Albuquerque (QTla) in several locations (sample site 2/20/97-1) have chemical compositions inconsistent with chemical analyses of the Bandelier Tuff or any other Jemez Mountains volcanic tephra presently included in the USGS Tephrochronology Laboratory database (A.M. Sarna-Wojcicki, oral commun., 1999). Preliminary ^{40}Ar/^{39}Ar dating of this tephra was inconclusive, probably because the sample contained a mixture of feldspars of different ages (L.W. Snee, written commun., 1999). The Bandelier eruptions are the youngest possible source of widespread pumice deposits in map area, so the upper part of unit Tsus probably predates the 1.61 Ma maximum age (Izett and Obradovich, 1994) of these tephras. A second, less extensive pumice bed located 20–45 m below the Llano de Albuquerque (sample site 9/19/96-1) yielded a different chemical fingerprint that also has no local-source correlatives (A.M. Sarna-Wojcicki, oral commun., 1999). Pocket gopher fossils recently discovered about 30 m below the contact between units Tsus and QTsug at Loma Colorado de Abajo are Blancan in age (4.5–1.8 Ma), but are not diagnostic enough to be used for more precise age determinations (Morgan and Lucas, 1999). Mostly deposited as fluvial channel and overbank (flood plain) deposits in southward- and southeastward-flowing, low-gradient streams; also includes eolian sand deposits and buried argillic and calcic soils indicative of arid or semi-arid climates. Probably correlative with Upper Buff member of Santa Fe Formation of Bryan and McCann (1937), Ceja Member of Santa Fe Formation of Kelley (1977), Sierra Ladrones Formation of Machette (1978), middle unit of Cochiti Formation of Manley (1978), and upper part of proposed Loma Barbon Member of Arroyo Ojito Formation of Connell and others (1999). Thickness 60–75 m

Tsum **Upper siltstone (Pliocene)**—Light-gray siltstone; well bedded; diatomaceous; poorly indurated. Localized deposits of lacustrine siltstone and minor claystone, probably deposited in oxbow lakes and ephemeral springs, ponds, and marshes (cienaga). Most small deposits are included in unit Tsus, but deposits are mapped west of Picuda Peak and in southwestern part of quadrangle to show fault relations. Thickness <15 m

QTsu **Santa Fe Group, upper part, undivided (lower Pleistocene(?) to upper Miocene)**—Shown on cross section only. Only includes units QTsug, Tsus, and Tsum. Thickness <60 m

Tsums **Upper part of middle sandstone and siltstone (Miocene)**—Reddish-brown to reddish-yellow, fine- to medium-grained sandstone and silty sandstone, and grayish-red to reddish-brown siltstone and minor claystone; poorly indurated; sandstone contains uncommon, thin granule and fine pebble conglomerate beds. Sandstone is thin bedded to massive, some crossbedding. Mudstones are thin to thick, parallel bedded. Mostly deposited as fluvial overbank (flood plain) deposits by sluggish, southward- and southeastward-flowing streams. Apparently conformable with overlying unit Tsus and underlying unit Tsmms. Unit well exposed only in northern part of quadrangle along Rincones de Zia. Probably correlative with upper part of Middle Red member of Santa Fe Formation of Bryan and McCann (1937) and Kelley (1977), upper part of Red member of Santa Fe Group of Spiegel (1961), upper and middle parts of lower unit of Cochiti Formation of Manley (1978), and lower part of proposed Loma Barbon Member of Arroyo Ojito Formation of Connell and others (1999). Unit is highly faulted so thickness is uncertain; however, unit is at least 282 m thick in Rio Rancho #15 water well , 5 km west of Loma Machete

Tsmms **Middle part of middle sandstone and siltstone (Miocene)**—Pale-brown to yellowish-brown, fine- to medium-grained sandstone, and brown to yellowish-brown siltstone and claystone, with minor yellowish-red siltstone and claystone; poorly indurated. Sandstone is medium bedded to massive, some crossbedding. Mudstones are thin to thick, parallel bedded. Mostly deposited as fluvial overbank (flood plain) deposits by sluggish, southward- and southeastward-flowing streams. Unit well exposed only in a narrow fault block in northern part of quadrangle along Rincones de Zia. Apparently conformable with overlying unit Tsums; unit is in fault contact with underlying unit Tslms, but apparently conformably overlies Tslms about 750 m north of map area in Bernalillo NW quadrangle (Manley, 1978). Probably correlative with lower part of Middle Red member of Santa Fe Formation of Bryan and McCann (1937) and Kelley (1977), lower part of Red member of Santa Fe Group of Spiegel (1961), lowest part of lower unit of Cochiti Formation of Manley (1978), and upper sandy part of proposed Navajo Draw Member of Arroyo Ojito Formation of Connell and others (1999). Unit is in fault contact with underlying unit Tslms in map area, so thickness is poorly known; however, unit is >257 m thick in Rio Rancho #15 water well, 5 km west of Loma Machete

Tslms **Lower part of middle sandstone and siltstone (Miocene)**—Light-gray to very pale brown, fine- to coarse-grained sandstone, and brown and red siltstone and claystone; mostly weakly indurated; sandstone is moderately to well sorted; lithic rich. Lower part consists primarily of crossbedded eolian sandstone in large-scale (1–2 m thick) sets, with paleowind directions from west-northwest. Sandstone is weakly to strongly cemented by calcium carbonate, commonly into convoluted shapes and bedding. Discontinuous red siltstone and claystone beds 10–100 cm thick [intradune pond deposits(?)] are common in lower part. Upsection, unit fines and is dominated by fluvial overbank (flood plain) deposits—upper part is mostly parallel, thin- to thick-bedded, very pale brown to brown sandstone and siltstone and minor claystone, with minor light-gray to very pale brown crossbedded eolian sandstone. Unit contains at least two ash beds, 10–50 cm thick, one in the fluvial part of the unit and one in the eolian part of the unit. An ash sample from unit 2.2 km north of Loma Machete (sample site MRGB-7-LM) yielded a chemical fingerprint possibly correlative with 10.8 Ma tephras from Snake River Plain/Yellowstone hotspot in southern Idaho (A.M. Sarna-Wojcicki, written commun., 1997). Unit is everywhere in fault contact with overlying unit Tsmms, but may be conformable with this unit in the Bernalillo NW quadrangle to north (Manley, 1978); base of unit is not exposed. Presence of volcanic ashes and occurrence of both eolian and fluvial facies suggest that the exposed part of unit may be correlative with “Santa Fe Formation equivalent” beds of Galusha (1966), Zia Sand, upper part of Manley (1978), “Tesuque Formation equivalent” beds of Gawne (1981), unnamed member of Zia Formation of Tedford (1982) and Tedford and Barghoorn (1997), and ash-rich middle part of proposed Cerro Conejo Member of Zia Formation of Connell and others (1999). Lower part of unit (below dashed line in cross section) probably consists of Chamisa Mesa Member of Zia Sand Formation of Galusha (1966). Unit is extensively faulted so thickness is uncertain; exposed thickness about 50 m. A better estimate of actual thickness can be derived from the Shell Oil Company Santa Fe Pacific #1 test well, which was drilled 500 m southwest of Loma Machete in 1972. Analysis of drilling data indicates that the test well penetrated 454 m of fluvial sandstone, siltstone, and claystone before drilling into well-sorted eolian sandstone (Lozinsky, 1988); we correlate the eolian interval with the Piedra Parada Member of the Zia Sand Formation (our subsurface unit Tsz) of Galusha (1966). The exposed (~50 m) and subsurface (454 m) values yield a minimum thickness of 504 m

Tsz **Piedra Parada Member of Zia Formation (Miocene)**—Shown on cross section only. Moderately to well sorted, fine- to medium-grained sandstone and siltstone; very minor claystone interbeds; massive to thick bedded; predominantly eolian (Lozinsky, 1988). Probably correlative with Piedra Parada Member of Zia Sand Formation of Galusha (1966). Only penetrated in Shell Oil Company Santa Fe Pacific #1 test well, where thickness of interval is 451 m (Lozinsky, 1988)

TK **Lower Tertiary and Cretaceous rocks, undivided (Oligocene, Eocene, and Upper Cretaceous)**—Shown on cross section only. Sedimentary rocks of Oligocene and Eocene Galisteo Formation, Eocene San Jose Formation, and Upper Cretaceous Menefee Formation, Point Lookout Sandstone, Mancos Shale, Crevasse Canyon Formation, and Niobrara Formation. Only penetrated in Shell Oil Company Santa Fe Pacific #1 test well, where total thickness of interval is 747 m (Black and Hiss, 1974)

DISCUSSION

The Loma Machete quadrangle is located in the northern part of the Albuquerque basin, which is the largest basin or graben within the Rio Grande rift. All of the map area is underlain by rift-related, poorly consolidated sedimentary rocks of the Santa Fe Group. Prior to our studies, few details of the structure and stratigraphy of the quadrangle were known because only small-scale (1:190,000 to 1:275,000) reconnaissance mapping had been published for this part of the Albuquerque basin (Bryan and McCann, 1937; Spiegel, 1961; Kelley, 1977). In the following paragraphs, we briefly describe some of the highlights and potential problems with the geology of the Loma Machete quadrangle.

GEOMORPHOLOGY

Most of the map area is covered by large expanses of eolian sand and alluvium associated with several large arroyo systems that drain southeasterly into the Rio Grande. These deposits are especially prevalent in the central part of the quadrangle, where they nearly completely cover the underlying bedrock. Only a few low terraces along these arroyos are prominent enough to be shown at the map scale. A few deposits of main stem Rio Grande alluvium are present along the southeastern margin of the map area (Spiegel, 1961). These deposits probably correlate with alluvium underlying the middle Pleistocene Tercero Alto terrace (informal name) of Bachman and Machette (1977) and Machette (1985). Remnants of the oldest geomorphic surface in the map area, the Llano de Albuquerque (Ceja Mesa of Kelley, 1977), dominate the landscape in the southwestern part of the quadrangle. The age of this surface is poorly known, but most studies indicate that it formed at least 500 ka (Lambert, 1978; Bachman and Machette, 1977; Bachman and Mehnert, 1978; Machette, 1985). Both erosional and depositional processes have played a part in the origin of this surface (Bryan and McCann, 1938). In some places the extensive Llano de Albuquerque calcic soils are developed in windblown sand and gravelly alluvium that truncate deposits of the upper Santa Fe Group, and in other places the Llano soil is formed directly in upper Santa Fe Group sedimentary rocks. This polygenetic origin may explain variations in development of the calcic soils that characterize the Llano de Albuquerque throughout the region.

STRATIGRAPHY

Good exposures of Santa Fe Group sedimentary rocks are primarily restricted to the northeastern margin of the Llano de Albuquerque in the southwestern part of the quadrangle and in badlands of the Rincones de Zia at the northern end of the quadrangle. Outside of these two areas, the poor induration of most Santa Fe Group rocks restricts bedrock exposures to isolated outcrops in active arroyo channels. Bedrock outcrops in the southern part of the quadrangle are restricted to deposits of upper Santa Fe Group conglomerate, sandstone, and mudstone, but in the Rincones de Zia, deposits correlative with the middle and lower Santa Fe Group also are exposed. The correlation of these rocks throughout the Albuquerque basin is still uncertain, so we have chosen to describe Santa Fe Group rocks using a modified form of Santa Fe nomenclature described by Cather (1997) that does not rely on formal formation names. This nomenclature is very functional because it sidesteps problems with correlating Santa Fe Group rocks throughout the region (Tedford, 1982; Lozinsky, 1988; Hawley and Love, 1991) while still providing rock descriptions useful for hydrogeologic studies. Our rock unit names include age modifiers (for example, QT—Quaternary and Tertiary), formation or group name (for example, su—upper Santa Fe Group), and dominant lithology (for example, g—sandstone and conglomerate, s—sandstone and siltstone, m—siltstone and claystone). For example, Pliocene upper Santa Fe Group sandstone and siltstone is designated Tsus.

STRUCTURE

Our mapping has produced a detailed picture of the structural geology of this part of the northern Albuquerque basin. As expected, the structural geometry of the quadrangle is dominated by generally north-trending, east- and west-dipping normal faults that are consistent with Neogene east-west extension of the Rio Grande rift. These structures are especially well exposed in the northern part of the quadrangle, where we have extended southward the complex of north-trending normal faults mapped by Manley (1978) in the Bernalillo NW quadrangle. We have mapped a similar, though more widely spaced, pattern of faults in the southern part of the quadrangle along the north flank of the Llano de Albuquerque. We have observed no dominant dip direction in these faults, most of which have throws of a few tens of meters in upper Santa Fe Group rocks.

The central part of the quadrangle is mostly covered by surficial deposits that mask the underlying structural geology, but we were fortunate to have access to recently acquired high-resolution aeromagnetic data in the northern and central Albuquerque basin (Grauch and Millegan, 1998; U.S. Geological Survey and SIAL Geosciences, Inc., 1997). These data show numerous prominent linear magnetic anomalies that in many cases coincide with mapped faults in bedrock. We have shown the most clearly defined of these anomalies on the geologic map, and assume that most represent normal faults similar to those mapped in bedrock. Some anomalies are coincident with geomorphic features such as arroyos and steep escarpments; these may have a nonstructural origin, although fault control of some landforms is a distinct possibility. Stratigraphic relations can be used to determine assumed dip directions for some of our aeromagnetic “faults”, but in most cases their dip directions are unknown. Given the complexity of faults exposed in the northern and southern parts of the quadrangle, we infer that the faults inferred from magnetic anomalies are only a minimum approximation of the structural geology of the central part of the map area. However, the general fault patterns, such as the band of closely spaced faults along the western margin of the quadrangle and wider fault spacing to the east, probably are an accurate representation of the underlying structural fabric.

EASTERLY TRENDING FAULTS

Most normal faults in the Loma Machete quadrangle parallel the northerly trend of rift-related faults in the Albuquerque basin, but we also have mapped numerous short east-, northeast-, and northwest-trending normal faults in bedrock. The aeromagnetic data also indicate faults with these trends. Some authors believe that some of these structures represent basin-scale strike-slip transfer zones that accommodate differential movement between domains of opposing fault dip. These accommodation zones are best known in the East African rift system (for example, Rosendahl, 1987) where they exhibit a wide range of geometries and structural styles (Morley and others, 1990). The most prominent such zone mapped in the northern Albuquerque basin is the Loma Colorado transfer zone of Hawley (1996), which he believes is manifested at the surface by a northeast-trending zone of faults located about 2 km east-northeast of Loma Colorado de Abajo in the southeastern part of the quadrangle (J.W. Hawley, oral commun., 1996-1997). Hawley (1996) showed a right-lateral sense of displacement on this structure, but the 50°–70° N. dips on the faults east-northeast of Loma Colorado de Abajo may be more consistent with down-to-the-north normal displacement. The apparent lack of disruption of north-trending normal faults along strike to the southwest also suggests that the northeast-trending faults are not the large-scale, throughgoing structures envisioned by Hawley (1996). Our mapping and analysis of the aeromagnetic data show that almost all of the east-, northeast-, and northwest-trending faults in the quadrangle are short, have very small displacements, and in some rare cases expose slip indicators that show predominantly normal slip. We conclude that in most cases these faults are more likely to have inherited their geometry from older basement structures or are small-scale transfer zones that are manifested as connecting faults in relay ramps between en echelon normal faults (for example, Peacock and Sanderson, 1991, 1994).

ZIANA HORST

The most prominent structure shown on geologic maps encompassing the quadrangle since the 1970’s (Kelley, 1977) is the Ziana anticline, an approximately 20- to 30-km-long south-plunging fold that was apparently the target of the Shell Oil Company Santa Fe Pacific #1 test well in the northern part of the quadrangle. This structure was named by Black and Hiss (1974), who described it as a large high in regional gravity data (Joesting and others, 1961). Black and Hiss (1974) attributed the gravity high and apparent regional dip patterns to a north-trending fold they named the Ziana anticline. Our mapping of the well-exposed Santa Fe Group rocks in the Rincones de Zia shows a different structural pattern than that described by Black and Hiss (1974). We observed no consistent evidence of pervasive folding of Santa Fe Group rocks in this region. In contrast, we found numerous horsts and grabens and a series of tilted fault blocks that dip into these bounding faults. Our interpretation is that the prominent gravity high is caused by a large horst that faults a block of lowermost middle Santa Fe Group rocks against middle and upper Santa Fe Group rocks. Presumably the gravity anomaly results from the elevated structural position of high-density basement rocks in the Ziana horst. Thus our mapping and interpretations are consistent with the original interpretation of the gravity high in the area as an uplifted fault block (Joesting and others, 1961), herein referred to informally as the Ziana horst, rather than as a fold whose geometry is more difficult to explain in a rifting environment. Throws across the normal faults bounding the Ziana horst are unknown, but are probably at least several hundred meters. The southern extent of the Ziana horst must be limited, because bedrock outcrops along Arroyo Baranca are limited to upper Santa Fe Group rocks. We explained this pattern with the help of the aeromagnetic data, which shows prominent north-trending linear anomalies that are the extensions of the faults bounding the horst, but also a prominent northeast-trending anomaly that must bring lowermost middle Santa Fe Group rocks up along a southeast-dipping normal fault. To the north, the Ziana horst becomes one of several similar north-trending fault-bounded structures mapped by Manley (1978) in the Bernalillo NW quadrangle.

QUATERNARY FAULTS

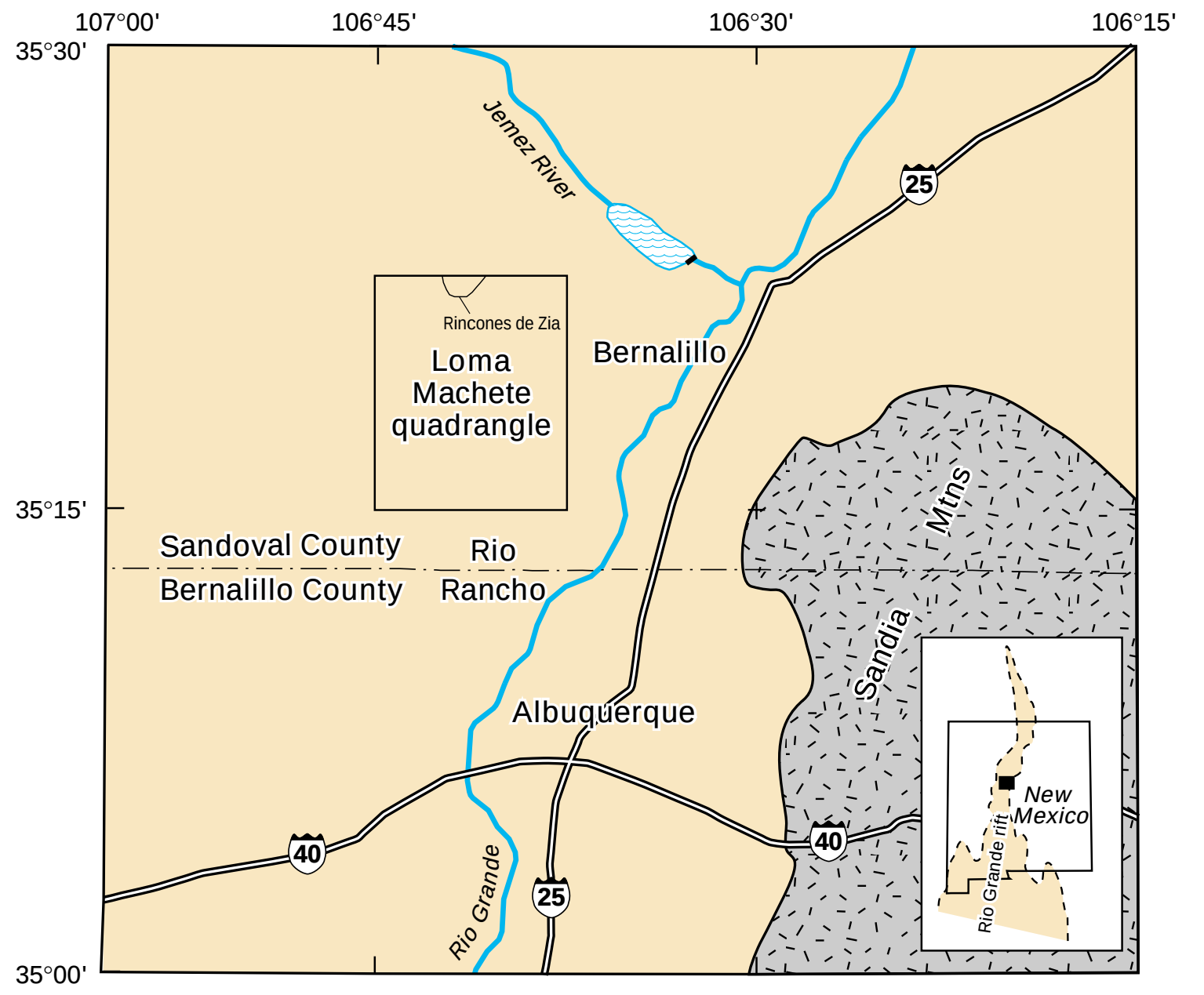
Numerous normal faults in the Loma Machete quadrangle offset upper Santa Fe Group rocks (QTsug and Tsus). Given the uncertainty in the age of these deposits, these faults may have undergone Quaternary movement (Machette and others, 1998; Personius and others, 1999). However, with a few exceptions, most of these faults do not offset younger deposits or geomorphic surfaces, and thus probably have not been active since the early Pleistocene. Examples of such possible Quaternary structures are the numerous faults near Picuda Peak and Loma Barbon in the northern part of the quadrangle. Quaternary faulting is more clearly demonstrated on several faults in the southern part of the quadrangle, with perhaps the youngest movements occurring on the East Paradise fault zone. About 5 km south in the Los Griegos quadrangle, thermoluminescence (TL) dating of sediments exposed in a fortuitous housing excavation cut into the East Paradise fault showed evidence of three surface-faulting events in the last roughly 200,000 years (Machette and others, 1998; Personius and others, 1999; Personius and Mahan, 2000). On 1967 vintage airphotos, the East Paradise fault zone is manifested in the Loma Machete quadrangle as aligned drainages and a single west-facing, approximately 5-m-high scarp in valley-floor alluvium [Qvd(s)] just north of the Rio Rancho Golf Course. Unfortunately this scarp has been destroyed by subsequent development.

Several other faults show evidence of Quaternary movement in the southern part of the quadrangle. At least three normal faults in the neighborhood of Star Heights offset upper Santa Fe Group rocks and younger Quaternary sediments. These north- and northeast-trending faults include parts of the Star Heights fault of Kelley (1977), but our mapping indicates that the Star Heights fault as originally mapped includes parts of at least two separate faults, so we have abandoned this name. The faults in the vicinity of Star Heights have offsets of a few tens of meters in upper Santa Fe Group (QTsug and Tsus) rocks, and offset the Llano de Albuquerque (QTla) 15–20 m and valley-floor deposits [Qvd(s)] 5–10 m. Two faults that offset upper Santa Fe Group sedimentary rocks on Loma Colorado de Abajo may have been active in the Quaternary. These faults have offsets of 5–15 m in strongly developed calcic soils that may be correlative with the Llano de Albuquerque. All of these Quaternary faults are important because they have the potential for producing rare, large-magnitude earthquakes that could cause severe damage in the cities of Albuquerque and Rio Rancho. With the exception of the East Paradise fault zone, none of these structures have been the subject of earthquake hazards studies.

REFERENCES CITED

Bachman, G.O., and Machette, M.N., 1977, Calcic soils and calcretes in the southwestern United States: U.S. Geological Survey Open-File Report 77–794, 163 p.
Bachman, G.O., and Mehnert, H.H., 1978, New K-Ar dates and the late Pliocene to Holocene geomorphic history of the central Rio Grande region, New Mexico: Geological Society of America Bulletin, v. 89, p. 283–292.
Birkeland, P.W., 1984, Soils and geomorphology: New York, Oxford University Press, 372 p.
Black, B.A., and Hiss, W.L., 1974, Structure and stratigraphy in the vicinity of the Shell Oil Co. Santa Fe Pacific No. 1 test well, southern Sandoval County, New Mexico, *in* Siemers, C.T., Woodward, L.A., and Callender, J.F., eds., Ghost Ranch: New Mexico Geological Society 25th Field Conference Guidebook, p. 365–370.
Bryan, Kirk, and McCann, F.T., 1937, The Ceja del Rio Puerco—A border feature of the Basin and Range Province in New Mexico, Part I, Stratigraphy and structure: Journal of Geology, v. 45, p. 801–828.
———1938, The Ceja del Rio Puerco—A border feature of the Basin and Range Province in New Mexico, Part II, Geomorphology: Journal of Geology, v. 46, p. 1–16.
Cather, S.M., 1997, Toward a hydrogeologic classification of map units in the Santa Fe Group, Rio Grande rift, New Mexico: New Mexico Geology, v. 19, p. 15–21.
Connell, S.D., Koning, D.J., and Cather, S.M., 1999, Revisions to the stratigraphic nomenclature of the Santa Fe Group, northwestern Albuquerque Basin, New Mexico, *in* Pazzaglia, F.J., and Lucas, S.G., eds., Albuquerque geology: New Mexico Geological Society 50th Annual Field Conference Guidebook, p. 337–353.
Galusha, T., 1966, The Zia Sand Formation, new early to medial Miocene beds in New Mexico: American Museum Novitates, no. 2271, 12 p.
Gawne, C.E., 1981, Sedimentology and stratigraphy of the Miocene Zia Sand of New Mexico: Geological Society of America Bulletin, Part I, v. 92, p. 999–1007.
Grauch, V.J.S., and Millegan, P.S., 1998, Mapping intrabasinal faults from high-resolution aeromagnetic data: The Leading Edge, v. 17, p. 53–55.
Hawley, J.W., 1996, Hydrogeologic framework of potential recharge areas in the Albuquerque basin, central New Mexico, *in* Hawley, J.W., and Whitworth, T.M., compilers, Hydrogeology of potential recharge areas and hydrogeochemical modeling of proposed aquifer recharge methods in basin- and valley-fill aquifer systems, Albuquerque basin, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Open-File Report 402–D, p. 1–71.
Hawley, J.W., and Love, D.W., 1991, Quaternary and Neogene landscape evolution—A transect across the Colorado Plateau and Basin and Range provinces in west-central and central New Mexico, *in* Julian, B., and Zidek, J., eds., Field guide to geologic excursions in New Mexico and adjacent areas of Texas and Colorado: New Mexico Bureau of Mines and Mineral Resources Bulletin 137, p. 105–148.
Izett, G.A., and Obradovich, J.D., 1994, ^{40}Ar/^{39}Ar age constraints for the Jaramillo Normal Subchron and Matuyama-Brunhes geomagnetic boundary: Journal of Geophysical Research, v. 99, p. 2925–2934.
Joesting, H.R., Case, J.E., and Cordell, L.E., 1961, The Rio Grande trough near Albuquerque, New Mexico: U.S. Geological Survey Professional Paper 424–D, p. 282–286.
Kelley, V.C., 1977, Geology of Albuquerque Basin, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Memoir 33, 60 p., 2 plates, scales 1:190,000 and approximately 1:281,600.
Lambert, P.W., 1968, Quaternary stratigraphy of the Albuquerque area, New Mexico: Albuquerque, N. Mex., University of New Mexico Ph.D. thesis, 329 p.
———1978, Upper Santa Fe stratigraphy and geomorphic features of the Llano de Albuquerque, *in* Hawley, J.W., compiler, 1978, Guidebook to Rio Grande rift in New Mexico and Colorado: New Mexico Bureau of Mines and Mineral Resources Circular 163, p. 151–152.
Lozinsky, R.P., 1988, Stratigraphy, sedimentology, and sand petrology of the Santa Fe Group and pre-Santa Fe Tertiary deposits in the Albuquerque basin, central New Mexico: Socorro, N. Mex., New Mexico Institute of Mining and Technology Ph.D. dissertation, 298 p.
Machette, M.N., 1978, Geologic map of the San Acacia quadrangle, Socorro County, New Mexico: U.S. Geological Survey Geologic Quadrangle Map GQ–1415, scale 1:24,000.
———Calcic soils of the southwestern United States, *in* Weide, D.L., ed., Soils and Quaternary geology of the southwestern United States: Geological Society of America Special Paper 203, p. 1–21.
Machette, M.N., Long, T., Bachman, G.O., and Timbel, N.R., 1997, Laboratory data for calcic soils in central New Mexico—Background information for mapping Quaternary deposits in the Albuquerque basin: New Mexico Bureau of Mines and Mineral Resources Circular 205, 63 p.
Machette, M.N., Personius, S.F., Kelson, K.I., Haller, K.M., and Dart, R.L., 1998, Map and data for Quaternary faults in New Mexico: U.S. Geological Survey Open-File Report 98–521, 443 p., 1 plate, scale 1:750,000.
Manley, K., 1978, Geologic map of the Bernalillo NW quadrangle, Sandoval County, New Mexico: U.S. Geological Survey Geologic Quadrangle Map GQ–1446, scale 1:24,000.
Morgan, G.S., and Lucas, S.G., 1999, Pliocene (Blancan) vertebrates from the Albuquerque basin, north-central New Mexico, *in* Pazzaglia, F.J., and Lucas, S.G., eds., Albuquerque geology: New Mexico Geological Society 50th Annual Field Conference Guidebook, p. 363–370.
Morley, C.K., Nelson, R.A., Patton, T.L., and Munn, S.G., 1990, Transfer zones in the East African rift system and their relevance to hydrocarbon exploration in rifts: American Association of Petroleum Geologists Bulletin, v. 74, p. 1234–1253.
Peacock, D.C.P., and Sanderson, D.J., 1991, Displacements, segment linkage and relay ramps in normal fault zones: Journal of Structural Geology, v. 13, p. 721–733.
———1994, Geometry and development of relay ramps in normal fault systems: American Association of Petroleum Geologists Bulletin, v. 78, p. 147–165.
Personius, S.F., Machette, M.N., and Kelson, K.I., 1999, Quaternary faults in the Albuquerque area—An update, *in* Pazzaglia, F.J., and Lucas, S.G., eds., Albuquerque geology: New Mexico Geological Society 50th Annual Field Conference Guidebook, p. 189–200.
Personius, S.F., and Mahan, S.A., 2000, Paleoearthquake recurrence on the East Paradise fault zone, metropolitan Albuquerque, New Mexico: Bulletin of Seismological Society of America, v. 90, no. 2, unpaginated.
Rosendahl, B.R., 1987, Architecture of continental rifts with special reference to East Africa: Annual Review of Earth and Planetary Sciences, v. 15, p. 445–503.
Spiegel, Z., 1961, Late Cenozoic sediments of the lower Jemez River region, *in* Northrop, S.A., ed., Guidebook of the Albuquerque Country: New Mexico Geological Society 12th Field Conference Guidebook, p. 132–138.
Tedford, R.H., 1982, Neogene stratigraphy of the northwestern Albuquerque basin, *in* Grambling, J.A., and Wells, S.G., Albuquerque Country II: New Mexico Geological Society 33rd Field Conference Guidebook, p. 273–278.
Tedford, R.H., and Barghoorn, S., 1997, Miocene mammals of the Española and Albuquerque basins, north-central New Mexico, *in* Lucas, S.G., Estep, J.W., Williamson, T.E., and Morgan, G.S., eds., New Mexico’s Fossil Record 1: New Mexico Museum of Natural History and Science Bulletin 11, p. 77–95.
U.S. Geological Survey, and SIAL Geosciences, Inc., 1997, Description of digital aeromagnetic data collected north and west of Albuquerque, New Mexico: U.S. Geological Survey Open-File Report 97–286, 40 p.

Contact—Dashed where approximately located
Fault—Bar and ball on downthrown side. Arrow indicates amount and direction of dip. Dashed where approximately located; dotted where concealed
Aeromagnetic anomaly—Analysis by authors of high-resolution aeromagnetic data from U.S. Geological Survey and SIAL Geosciences, Inc. (1997)
Strike and dip of beds
  Inclined
⊕ **Horizontal**
Rio Rancho #10 ● **Selected well locations**—Showing well name
9/16/96-1 x **Tephra outcrop**—Numbered where sample location discussed in text
→ **Paleowind direction**—Geomorphic wind indicators in units Qesy and Qeso
Qeso/Qalo **Thin surficial deposit (upper symbol) covering older unit**



INDEX MAP

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