STRATIGRAPHY OF MIDDLE AND UPPER PLEISTOCENE FLUVIAL DEPOSITS OF THE RIO GRANDE (POST-SANTA FE GROUP) AND THE GEOMORPHIC DEVELOPMENT OF THE RIO GRANDE VALLEY, NORTHERN ALBUQUERQUE BASIN, CENTRAL NEW MEXICO

SEAN D. CONNELL
New Mexico Bureau of Mines and Mineral Resources-Albuquerque Office, New Mexico Institute of Mining and Technology, 2808 Central Ave. SE, Albuquerque, NM 87106

DAVID W. LOVE
New Mexico Bureau of Mines and Mineral Resources, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, NM 87801

INTRODUCTION

Alluvial and fluvial deposits inset against Plio-Pleistocene deposits of the upper Santa Fe Group (Sierra Ladrones and Arroyo Ojito formations) record the development of the Rio Grande valley (Fig. 1) in the northern part of the Albuquerque basin since early Pleistocene time. These fluvial terrace deposits contain pebbly to cobbly sand and gravel with abundant rounded quartzite, subordinate volcanic, and sparse plutonic clasts derived from northern New Mexico. Although the composition of the gravel in these deposits is similar, they can be differentiated into distinct and mappable formation- and member-rank units on the basis of landscape-topographic position, inset relationships, soil morphology, and height of the basal contact above the Rio Grande as determined from outcrop and drillhole data (Table 1; Connell and Love, 2000). These fluvial deposits overlie, and locally interfinger with, alluvial deposits derived from paleo-valley margins and basin margin uplands (Fig. 2). Constructional terrace treads are not commonly preserved in older deposits, but are locally well preserved in younger deposits.

Kirk Bryan (1909) recognized two distinct types of ancestral Rio Grande deposits, his older Rio Grande beds (now called upper Santa Fe Group), and his younger, inset Rio Grande gravels (post Santa-Fe Group). Lambert (1968) completed the first detailed geologic mapping of the Albuquerque area and proposed the terms Los Duranes, Edith, and Menaul formations for prominent fluvial terrace deposits associated with the ancestral Rio Grande, however, these terms were not formally defined. Lambert (1968) correctly suggested that a higher and older unit (his Qu(?)g) may be an inset fluvial deposit of the ancestral Rio Grande (Tercero alto terrace of Machette, 1985).

We informally adopt three additional lithostratigraphic terms to clarify and extend Lambert's inset Rio Grande stratigraphy. We propose lithostratigraphic terms to these fluvial deposits principally to avoid confusion in the use of geomorphic terms, such as the primero, segundo, and tercero alto surfaces (Lambert, 1968), for lithologic units. Furthermore, these geomorphic (i.e., "-alto") terms were imported by Lambert (1968) for geomorphic surfaces described by Bryan and McCann (1936, 1938) in the upper Rio Puerco valley without careful comparison of soil-morphologic and geomorphic character of deposits within each drainage basin. Thus, these geomorphic terms may not be applicable in the Rio Grande valley without additional work to establish surface correlations across the Llano de Albuquerque, the interfluve between the Rio Grande and Rio Puerco valleys. Fluvial deposits discussed in this paper are, in increasing order of age, the Los Padillas, Arenal, Los Duranes, Menaul, Edith, and Lomatas Negras formations.

Although these inset ancestral Rio Grande units may be classified and differentiated allostratigraphically, we consider them as lithologic units of formation- and member rank that can be differentiated on the basis of bounding unconformities, stratigraphic position, and lithologic character.

Recent geologic mapping of the Albuquerque area (Cather and Connell, 1998; Connell, 1997, 1998; Connell et al., 1998; Love, 1997; Love et al., 1998; Smith and Kuhle, 1998; Personius et al., 2000) delineate a suite of inset fluvial deposits associated with the axial-fluvial ancestral Rio Grande. Inset terrace deposits record episodic incision and partial aggradation of the ancestral Rio Grande during Pleistocene and Holocene time. Lack of exposure and preservation of terrace deposits between Galisteo Creek and Las Huertas Creek hampers correlation to partially dated terrace successions at the northern margin of the basin and in White Rock Canyon (Dethier, 1999; Smith and Kuhle, 1998), southward into Albuquerque; however, correlation of these units using soil-morphology, landscape position, and stratigraphic relationships provide at least limited local constraints on the Rio Grande terrace stratigraphy.

Soil-morphologic information derived from profiles for fluvial and piedmont deposits are described on well preserved parts of constructional geomorphic surfaces (Connell, 1996). Carbonate morphology follows the morphogenetic classification system of Gile et al. (1966).

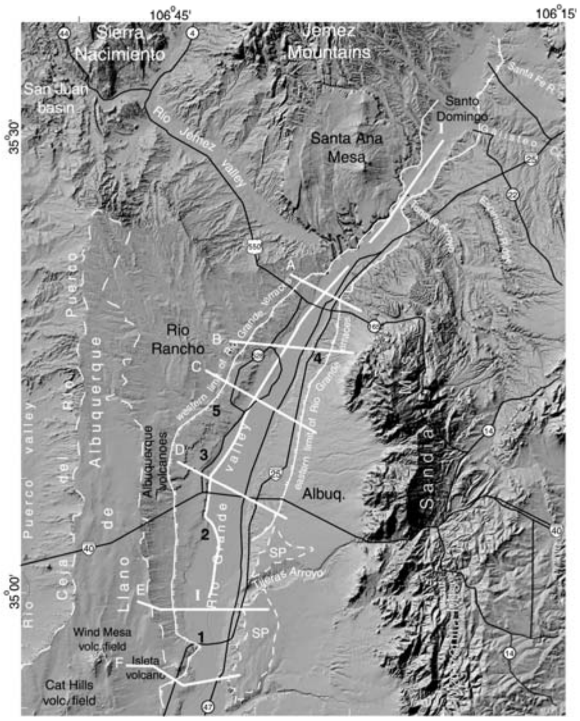

Figure 1. Shaded relief image of the northern part of the Albuquerque Basin (derived from U.S. Geological Survey 10-m DEM data) illustrating the approximate locations of terrace risers (hachured lines), the Sunport surface (SP), stratigraphic sections (1-5), and cross section lines (A-F).

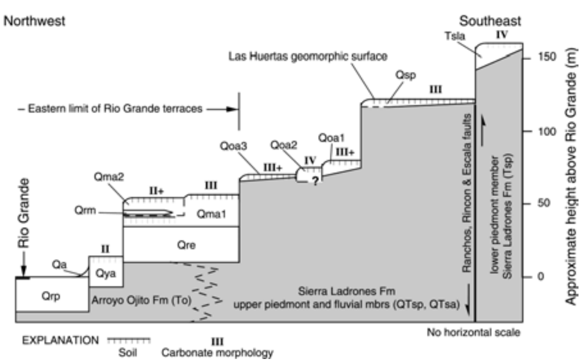

Figure 2. Block diagram of geomorphic relationships among entrenched post-Santa Fe Group deposits along the western piedmont of the Sandia Mountains and east of the Rio Grande valley (from Connell and Wells, 1999).

Lomatas Negras Formation

The highest and presumably oldest preserved Rio Grande terrace deposit in the Albuquerque-Rio Rancho area is informally called the Lomatas Negras Formation for Arroyo Lomatas Negras, where a buttress unconformity between this deposit and the underlying Arroyo Ojito Formation is exposed in the Loma Machete quadrangle (unit Qtag, Personius et al., 2000). The Lomatas Negras Formation is typically less than 16 ft (5 m) thick and consists of moderately consolidated and weakly cemented sandy pebble to cobble gravel primarily composed of subrounded to rounded quartzite, volcanic rocks, granite and sparse basalt (Fig. 3). This unit is discontinuously exposed along the western margin of the Rio Grande valley, where it is recognized as a lag of rounded quartzite-bearing gravel typically between about 215-245 ft (65-75 m) above the Rio Grande floodplain, which is underlain by the Los Padillas Formation (Fig. 4). The basal contact forms a low-relief strath cut onto slightly tilted deposits of the Arroyo Ojito Formation. The top is commonly eroded and is commonly overlain by middle Pleistocene alluvium derived from drainages heading in the Llano de Albuquerque. Projections of the base suggest that it is inset against early Pleistocene aggradational surfaces that define local tops of the Santa Fe Group, such as the Las Huertas and Sunport geomorphic surfaces (Connell et al., 1995, 1998; Connell and Wells, 1999; Lambert, 1968).

Correlative deposits to the south (Qg(?) of Lambert, 1968) underlie the late-middle Pleistocene (156±20 ka, Peate et al., 1996) Albuquerque Volcanoes basalt (Figs. 3-4). Projections of the Lomatas Negras Formation north of Bernalillo are limited by the lack of preserved terraces, so, we provisionally correlate these highest gravel deposits with the Lomatas Negras Formation, recognizing the possibility that additional unrecognized terrace levels and deposits may be present along the valley margins. Similar deposits are recognized near Santo Domingo (Qta1 of Smith and Kuhle, 1998), which contain the *ca*. 0.66 Ma Lava Creek B ash from the Yellowstone area of Wyoming. A gravel quarry in the Pajarito Grant (Isleta quadrangle) along the western margin of the Rio Grande valley exposes an ash within an aggradation succession of fluvial sand and gravel. This ash has been geochemically correlated to the Lava Creek B (N. Dunbar, 2000, personal commun.) It lies within pebbly to cobbly sand and gravels that grade upward into a succession of sand with lenses of pebbly sand. This unit is slightly lower, at ~46 m above the Rio Grande, than Lomatas Negras deposits to the north, suggesting the presence of additional unrecognized middle Pleistocene fluvial units, or intrabasinal faulting has down-dropped the Pajarito Grant exposures. The Lomatas Negras Formation is interpreted to be inset against the Sunport surface, which contains a 1.26 Ma ash near the top of this Santa Fe Group section in Tijeras Arroyo. These stratigraphic and geomorphic relationships indicate that the Lomatas Negras Formation was deposited between about 1.3 and 0.7 Ma.

Table 1. Summary of geomorphic, soil-morphologic, and lithologic data for ancestral Rio Grande fluvial, piedmont and valley border deposits, listed in increasing order of age.

Unit	Height above Rio Grande (m)	Thickness (m)	Carbonate Morphology	Geomorphic/stratigraphic position
Qrp	0	15-24	0	Lowest inset deposit; inner valley floodplain.
Qay	0-3	<21	0, I	Inset against Qpm; grades to Qrp.
Qra	15	3-6	II+	Primero alto surface, inset against Qrd.
Qam, Qpm	~65, eroded top	45	III	Alluvial deposits west of Rio Grande valley; Overlies Qrd.
Qrd	44-48	6-52	II+	Segundo alto surface, inset against Qre
Qpm	8-30	15-51	II+, III+	Piedmont deposits of Sandia Mts; east of Rio Grande valley; interfingers with Qrm.
Qrm	26-36	3	II+	Overlies Qpm and Qre; may be correlative to part of Qrd.
Qre	12-24, eroded top	3-12	not determined	Inset against Qrl, inset by Qrd; underlies Qpm with stage III + carbonate morphology.
Qao, Qpo	~100, eroded top	<30	III to IV	Overlies Qrl; inset by Qpm and Qre.
Qrl	~46-75, eroded top	5-20	III, eroded	Inset against Sunport surface. Contains ash correlated to the Lava Creek B.
Las Huertas	~120	---	III+	Local top of Sierra Ladrones Formation
SP	~95	---	III+	Sunport surface of Lambert (1968): youngest Santa Fe Group constructional basin-floor surface.

Edith Formation

The Edith Formation is a 10-40 ft (3-12 m) thick deposit that typically comprises a single upward fining sequence of basal gravel and overlying sandy to muddy floodplain deposits. The Edith Formation serves as a useful and longitudinally extensive marker along the eastern margin of the Rio Grande valley, between Albuquerque and San Felipe Pueblo, New Mexico. This fluvial deposit can be physically correlated across 33 km, from its type area in Albuquerque (Lambert, 1968, p. 264-266 and p. 277-280), to near Algodones, New Mexico (Lambert, 1968; Connell et al., 1995; Connell, 1998, 1997; and Cather and Connell, 1998). The Edith Formation is a poorly to moderately consolidated, locally cemented deposits of pale-brown to yellowish-brown gravel, sand and sandy clay that forms laterally extensive outcrops along the inner valley escarpment of the Rio Grande. Commonly recognized as an upward-fining succession of a 7-26 ft (2-8 m) thick, basal quartzite-rich, cobble gravel that grades up-section into a 13-32 ft (4-10 m) thick succession of yellowish-brown sand and reddish-brown mud. The upper contact is locally marked by a thin, white diatomite between Sandia Wash and Bernalillo. Gravel contains ~30% rounded quartzite and ~40% volcanic rocks with subordinate granite, metamorphic, and sandstone clasts, and sparse, rounded and densely welded Bandelier Tuff (Connell, 1996). The Edith Formation unconformably overlies tilted sandstone of the Arroyo Ojito and Sierra Ladrones formations and is overlain by piedmont alluvium derived from the Sandia Mountains (Fig. 5). Where the top of the Edith Formation is preserved, it typically contains weakly developed soils with Stage I carbonate morphology. This weak degree of soil development suggests that deposition of piedmont and valley border fan sediments occurred shortly after deposition of the Edith Formation.

The Edith Formation contains Rancholabrean fossils, most notably *Bison*, *Mastodon*, *Camelops*, and *Equus* (Lucas et al., 1988). Lambert (1968) considered the Edith Formation to represent a late Pleistocene terrace deposited during the latest Pleistocene glacial events. Soils developed in these piedmont deposits exhibit moderately developed Bt and Btk horizons with moderately thick clay films and Stage III+ carbonate morphology, suggesting a middle Pleistocene age for these deposits (Connell, 1996; Connell and Wells, 1999).

The base of the Edith Formation forms a prominent strath that lies about 40-80 ft (12-24 m) above the Rio Grande floodplain and is about 30 m higher than the base of the Los Duranes Formation (Connell, 1998). The elevation of this basal strath is lower than the base of the Lomatas Negras Formation suggesting that the Edith Formation is inset against

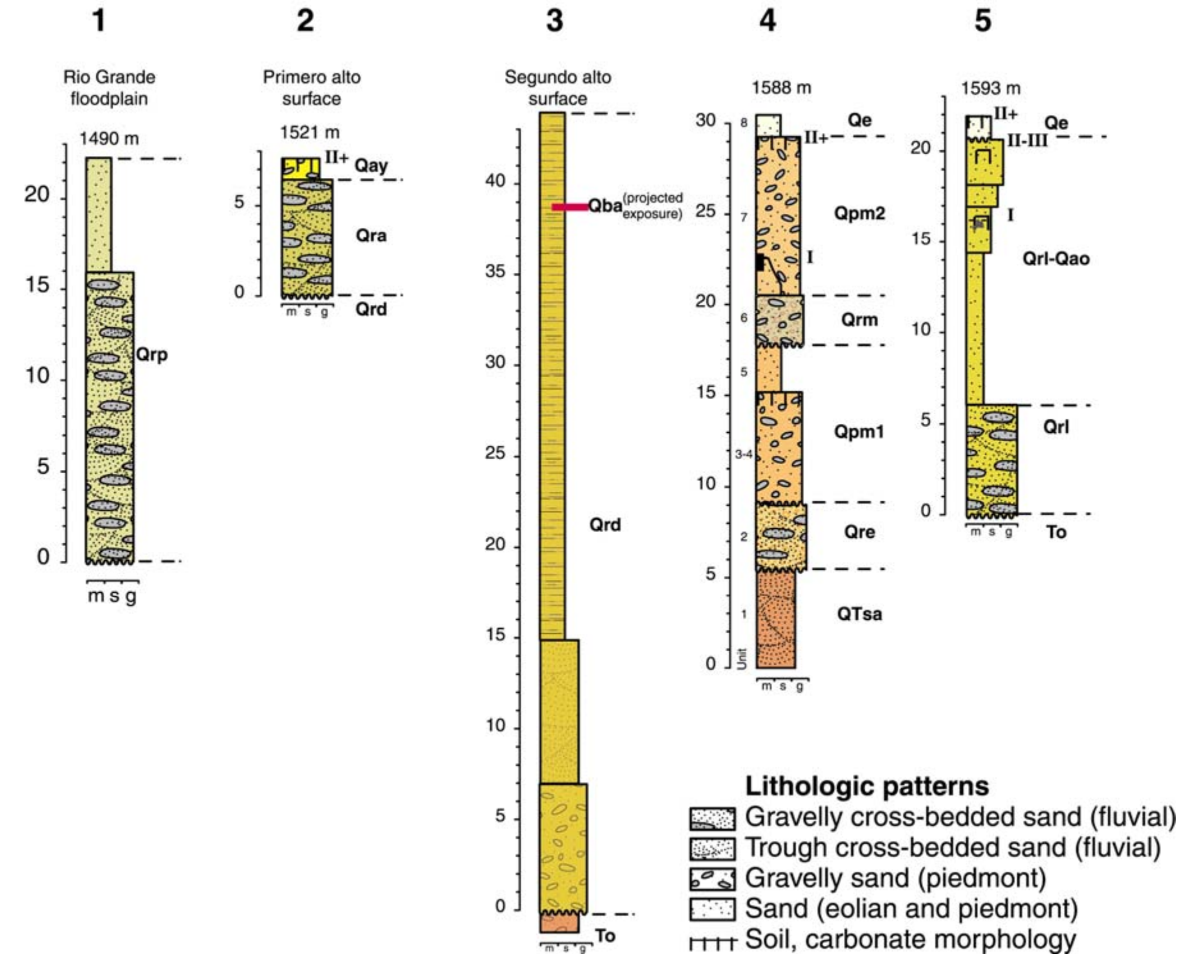

Figure 3. Stratigraphic and drillhole sections of Pleistocene fluvial deposits of the ancestral and modern Rio Grande along the Rio Grande valley: 1) Los Padillas Formation at the Black Mesa-Isleta Drain piezometer nest; 2) Arenal Formation at Efren quarry (modified from Lambert, 1968; Machette et al., 1997); 3) Los Duranes Formation at the Sierra Vista West piezometer nest (data from Chamberlin et al., 1998); 4) Edith and Menaul formations at Sandia Wash (Connell, 1996); and 5) Lomatas Negras Formation at Arroyo de las Calabacillas and Arroyo de las Lomatas Negras.

the Lomatas Negras Formation. A partially exposed buttress unconformity between eastern-margin piedmont alluvium and upper Santa Fe Group deposits marks the eastern extent of this unit. This unconformity is locally exposed in arroyos between Algodones and Bernalillo, New Mexico.

Lambert (1968) recognized the unpaired nature of terraces in Albuquerque, but assigned the Edith Formation to the topographically lower primero alto terrace, which is underlain by the Los Duranes Formation in SW Albuquerque. Lambert (1968) correlated the Edith Formation with the primero alto terrace, and therefore interpreted it to be younger than the Los Duranes Formation. The primero alto terrace is the lowest fluvial-terrace tread in SW Albuquerque and is underlain by rounded pebbly sandstone that is inset against the Los Duranes Formation. Soils on the primero alto terrace are weakly developed (stage I to II+ carbonate morphology, Machette et al., 1997) compared to piedmont deposits overlying the Edith Formation. Therefore, it is likely that the gravels underlying the primero alto terrace are probably much younger than the Edith Formation. Therefore, if the Edith Formation is older than the Los Duranes Formation (see below), it was deposited prior to about 100-160 ka.

The Edith Formation may correlate to fluvial terrace deposits near Santo Domingo Pueblo (Smith and Kuhle, 1998). Deposits at Santo Domingo Pueblo are approximately 30-m thick and about 30-35 m above the Rio Grande (Qta3 of Smith and Kuhle, 1998). The lack of strongly developed soils between the Edith Formation and interfingering middle Pleistocene piedmont alluvium suggests that the Edith Formation was deposited closer in time to the Los Duranes Formation. Thus, the Edith Formation was deposited between 0.66 and 0.16 Ma, and was probably laid down during the later part of the middle Pleistocene.

Los Duranes Formation

The Los Duranes Formation of Lambert (1968) is a 40-52 m fill terrace consisting of poorly to moderately consolidated deposits of light reddish-brown, pale-brown to yellowish-brown gravel, sand, and minor sandy clay derived from the ancestral Rio Grande and tributary streams. The base typically buried by deposits of the Rio Grande floodplain (Los Padillas Formation) in the Albuquerque. The basal contact forms a low-relief strath approximately 20 ft (6 m) above the Rio Grande floodplain near Bernalillo, New Mexico (Figs. 3-4), where the Los Duranes Formation is eroded by numerous arroyos and is about 20-23 ft (6-7 m) thick. The basal contact is approximately 100 ft (30 m) lower than the base of the Edith Formation. The terrace tread on top of the Los Duranes Formation (~42-48 m above the Rio Grande) is about 12-32 m higher than the top of the Edith Formation. Geologic mapping and comparison of subsurface data indicate that the base of the Edith Formation is about 20-25 m higher than the base of Los Duranes Formation, suggesting that the Los Duranes is inset against the Edith. Just north of Bernalillo, New Mexico, deposits correlated to the Los Duranes Formation (Connell, 1998) contain the Rancholabrean mammal *Bison latifrons* (Smartt et al., 1991, SW1/4, NE1/4, Section 19, T13N, R4E), which supports a middle Pleistocene age. The Los Duranes Formation is also overlain by the 98-110 ka Cat Hills basalt (Maldonado et al., 1999), and locally buries flows of the 156±20 ka (Peate et al., 1996) Albuquerque volcanoes basalt. Thus deposition of the Los Duranes Formation ended between 160-100 ka, near the end of the marine oxygen isotope stage 6 at about 128 ka (Morrison, 1991).

Near Bernalillo, the basal contact of the Los Duranes(?) Formation, exposed along the western margin of the of the Rio Grande valley, is approximately 30 m lower than the basal contact of the Edith Formation, which is well exposed along the eastern margin of the valley. This western valley-margin fluvial deposit was originally assigned to the Edith Formation by Smartt et al. (1991), however, these are interpreted to be younger inset deposits that are likely correlative to the Los Duranes Formation (Connell, 1998; Connell and Wells, 1999).

The terrace tread (top) of the Los Duranes Formation is locally called the segundo alto surface in the Albuquerque area (Lambert, 1968; Hawley, 1996), where it forms a broad constructional surface west of the Rio Grande. Kelley and Kudo (1978) called this terrace the Los Lunas terrace, near Isleta Pueblo, however, we support the term Los Duranes Formation as defined earlier by Lambert (1968). The Los Duranes Formation represents a major aggradational episode that may have locally buried the Edith Formation; however, the Edith Formation could also possibly mark the base of the aggrading Los Duranes fluvial succession.

Menaul Formation(?)

The Menaul Formation of Lambert (1968) is generally less than 10 ft (3 m) thick and overlies interfingering piedmont deposits that overlie the Edith Formation. The Menaul Formation consists of poorly consolidated deposits of yellowish-brown pebble gravel and pebbly sand derived from the ancestral Rio Grande. Rounded quartzite pebbles that are generally smaller in size than pebbles and cobbles in the Edith Formation. The Menaul gravel forms discontinuous, lensoidal exposures along the eastern margin o the Rio Grande valley. The basal contact is approximately 85-118 ft (26-36 m) above the Rio Grande floodplain. The Menaul Formation is conformably overlain by younger, eastern-margin piedmont alluvium exhibiting Stage II+ carbonate morphology, and is inset by younger stream alluvium that exhibits weakly developed soils, suggesting a late Pleistocene age of deposition.

Soils on piedmont deposits overlying the Menaul are generally similar to the Los Duranes Formation; however, differences in parent material texture make soil-based correlations somewhat ambiguous. Similarities in height above the Rio Grande and soil development on the Los Duranes Formation and the Menaul Formation suggest that these two units may be correlative. Thus, the Menaul Formation may be temporally correlative to the Los Duranes Formation, and is likely a member of this unit. These units may be associated with an aggradational episode, possibly associated with aggradation of the Los Duranes, middle Pleistocene piedmont alluvium. The Edith Formation may represent the base of a Los Duranes-Menaul aggradational episode during the late-middle Pleistocene. The base Edith Formation is consistently higher than the base of the Los Duranes Formation, suggesting that the Edith is older; however, definitive crosscutting relationships have not been demonstrated.

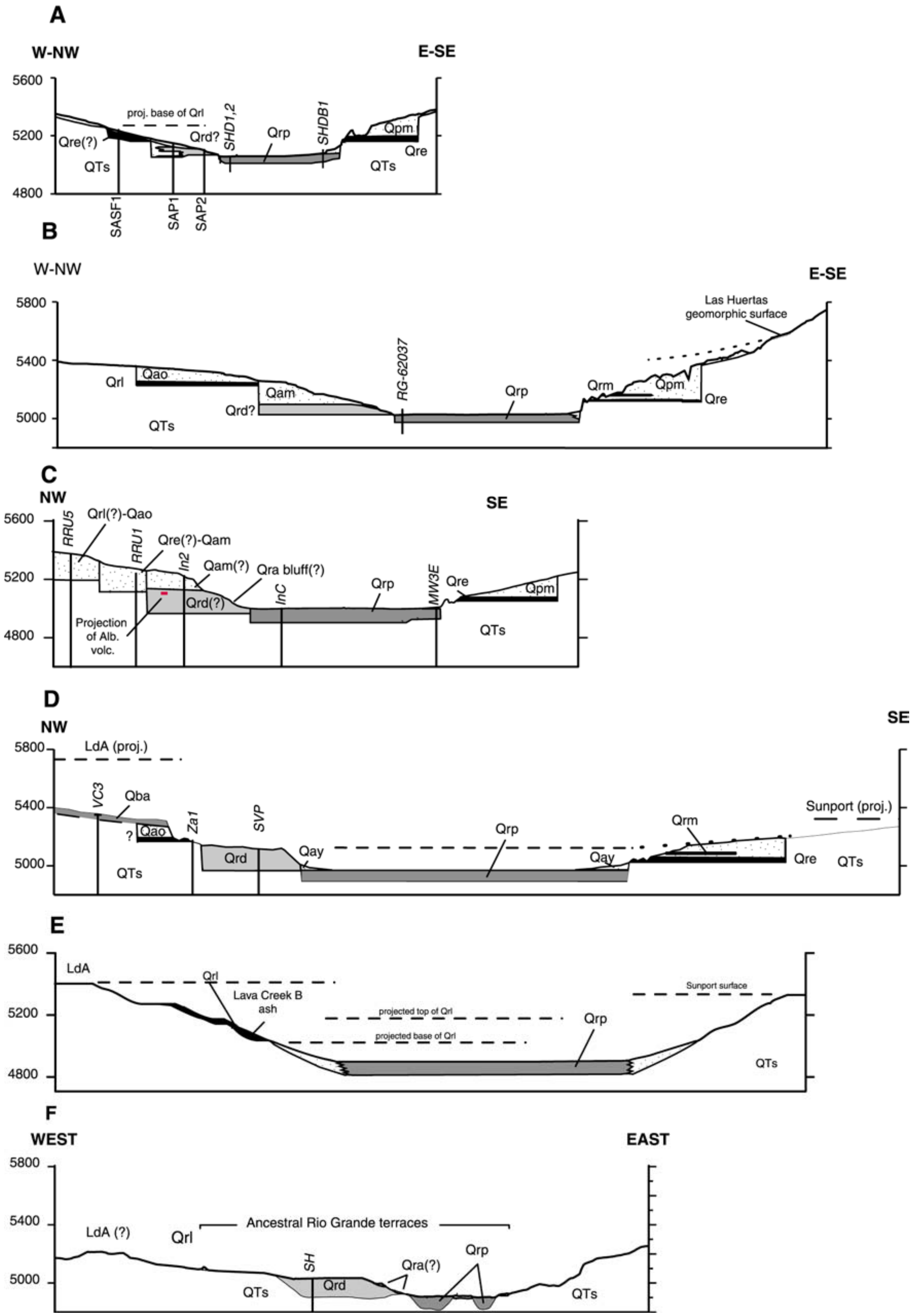

Figure 4. Simplified geologic cross sections across the Rio Grande valley, illustrating inset relationships among progressively lower fluvial deposits. Letters indicate location of profiles on Figure 1 and elevations of cross sections are in feet above mean sea level. See Table 1 for description of symbols. Unit QTs denotes upper Santa Fe Group deposits.

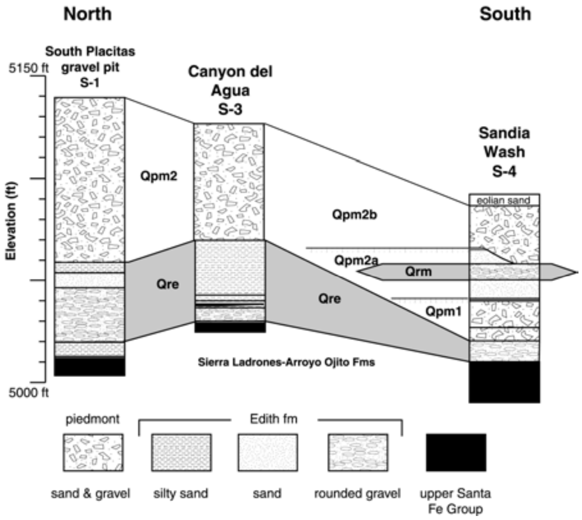

Figure 5. Stratigraphic fence of Edith Formation and piedmont deposits exposed along eastern margin of the Rio Grande valley, between Sandia Wash and highway NM-165, illustrating stratigraphic relationships among fluvial-terrace and piedmont deposits.

Arenal Formation

The lowest preserved terrace deposit is the Arenal Formation, which was named for exposures just west of the Arenal Main Canal in SW Albuquerque (Connell et al., 1998). The Arenal Formation is 3-6 m thick and is inset against the Los Duranes Formation. The Arenal Formation consists of poorly consolidated deposits of very pale-brown to yellow sandy pebble to cobble gravel recognized along the northwestern margin of the Rio Grande inner valley. Gravel clasts are primarily rounded quartzite and subrounded volcanic rocks (welded tuff and rare pumice) with minor granite. Soil development is very weak, with Stage I to II+ carbonate morphology (Machette et al., 1997; Machette, 1985). The top of the Arenal Formation is the primero alto surface of Lambert (1968), which is 15-21 m above the Rio Grande. This deposit is not correlative to the Edith Formation as originally interpreted by Lambert. This unit is interpreted to have been deposited during late Pleistocene time, probably between about 71-28 ka.

Los Padillas Formation

The Las Padillas Formation underlies the modern Rio Grande valley and floodplain and is interpreted to represent the latest incision/aggradation phase of the Rio Grande, which was probably deposited during latest Pleistocene-Holocene time. The Rio Grande floodplain (inner valley) ranges 3-8 km in width in most places and occupies only a portion of the 10-12 km maximum width of the entire ancestral Rio Grande systems tract of the Sierra Ladrones Formation (Connell, 1997, 1998; Connell et al., 1995; Maldonado et al., 1999; Smith and Kuhle, 1998). The top comprises the modern floodplain and channel of the Rio Grande. The Los Padillas Formation is 15-29 m thick and consists of unconsolidated to poorly consolidated, pale-brown, fine- to coarse-grained sand and rounded gravel with subordinate, discontinuous, lensoidal interbeds of fine-grained sand, silt, and clay derived from the Rio Grande. This unit is recognized in drillholes and named for deposits underlying the broad inner valley floodplain near the community of Los Padillas in SW Albuquerque (Connell et al., 1998; Connell and Love, 2000). Drillhole data indicate that the Los Padillas Formation commonly has a gravelly base and unconformably overlies the Arroyo Ojito Formation. This basal contact is locally cemented with calcium carbonate. The Los Padillas Formation is overlain, and interfingers with, late Pleistocene to Holocene valley border alluvial deposits derived from major tributary drainages.

Because this unit has not been entrenched by the Rio Grande, no age direct constraints are available for the base of the alluvium of the inner valley in the study area. This deposit underlies a continuous and relatively broad valley floor that extends south from the Albuquerque basin through southern New Mexico, where radiocarbon dates indicate aggradation of the inner valley by early Holocene time (Hawley and Kottlowski, 1969; Hawley et al., 1976). The base of the Los Padillas Formation was probably cut during the last glacial maximum, which is constrained at ~15-22 ka in the neighboring Estancia basin, just east of the Manzano Mountains. (Allen and Anderson, 2000). Thus, the inner valley alluvium was probably incised during the latest Pleistocene and aggraded during much of Holocene time. Near the mouth of Tijeras Arroyo, charcoal was recovered from about 2-3 m below the top of a valley border fan that prograded across the Los Padillas Formation and forms a broad valley border fan than has pushed the modern Rio Grande to the western edge of its modern (inner) valley. This sample yielded a radiocarbon date of about 4550 yrs. BP (Connell et al., 1998), which constrains the bulk of deposition of the Los Padillas Formation to middle Holocene and earlier.

EVOLUTION OF THE RIO GRANDE VALLEY

Santa Fe Group basin-fill deposits of the ancestral Rio Grande generally differ in the scale and thickness relative to younger inset deposits, which were deposited in well defined valley. During widespread aggradation of the basin (Santa Fe Group time), the ancestral Rio Grande intimately interfingered with piedmont deposits derived from rift-margin uplifts, such as the Sandia Mountains

(Connell and Wells, 1999; Maldonado et al., 1999). Field and age relationships in the near Santa Ana Mesa also indicate that the ancestral Rio Grande also interfingered with fluvial deposits correlated with the Arroyo Ojito Formation (Cather and Connell, 1998). During development of the Rio Grande valley (post-Santa Fe Group time), the Rio Grande cut deeply into older basin-fill, typically leaving large buttress unconformities between inset deposits and older basin fill of the upper Santa Fe Group (Fig. 8).

Younger late Pleistocene-Holocene alluvial deposits are commonly confined in arroyo channels cut into older piedmont deposits east of the Rio Grande valley. These deposits commonly form valley border alluvial fans along bluffs cut by a meandering Rio Grande. These fans commonly prograde across floodplain and channel deposits in the inner valley. The present discharge is inadequate to transport sediment out of the valley. The presence of progressively inset fluvial deposits along the margins of the modern valley indicates that episodes of prolonged higher discharge were necessary to flush sediment and erode the valley. Such episodes must have occurred prior to aggradation of valley fills, such as these fluvial terrace deposits.

Progradation of middle Holocene tributary valley border fans across the modern Rio Grande floodplain suggests that deposition of tributary and piedmont facies occurred during drier (interglacial) conditions. Deposition of fluvial terraces in semi-arid regions probably occurred during the transition from wetter to drier climates (Schumm, 1965; Bull, 1991). The lack of strong soils between the terrace deposits of the ancestral Rio Grande and piedmont and valley border deposits suggests that piedmont and valley border deposition occurred soon after the development of major fluvial terrace deposits.

Age constraints for the Los Duranes Formation indicate that aggradation of fluvial deposits occurred near the end of glacial periods. If we extrapolate ages based on this model of terrace development, then we can provide at least a first order approximation for ages of other poorly dated terrace deposits throughout the study area (Fig. 6). The age of the Edith Formation is still rather poorly constrained. The Edith Formation is Rancholabrean in age and older than the Los Duranes Formation, suggesting that the Edith may have been deposited sometime during MOIS 8, 10, or 12. The lack of strongly developed soils on the top of the Edith Formation suggests that deposition of this unit occurred closer in time to the Los Duranes Formation.

Correlation of these deposits and provisional age constraints indicate that the ancestral positions of the Rio Grande have been modified by tectonic activity (Fig. 7). Most notably, the Edith Formation, which forms a nearly continuous outcrop band from Albuquerque just south of San Felipe, New Mexico, is faulted. The Bernalillo fault displaced this deposit by about 7 m down to the west near Bernalillo (Connell, 1996). Between cross sections B-B’ and C-C’ of Figure 4, the basal contact of the Edith Formation is down-dropped to the south by about 15 m by the northwest-trending Alameda structural zone. This decrease in height above local base level is also recognized by a change in stratigraphic positions relative to piedmont deposits to the east. Younger piedmont alluvium (Qay, Fig. 2) is typically found overlying the Edith Formation south of the Alameda structural zone (East Heights fault zone), a zone of flexure or normal faults that displace the Edith Formation in a down-to-the-southwest sense. North of the Alameda zone, tributary stream deposits are inset against the Edith Formation and are found in well defined valleys (*see map by* Connell, 1997).

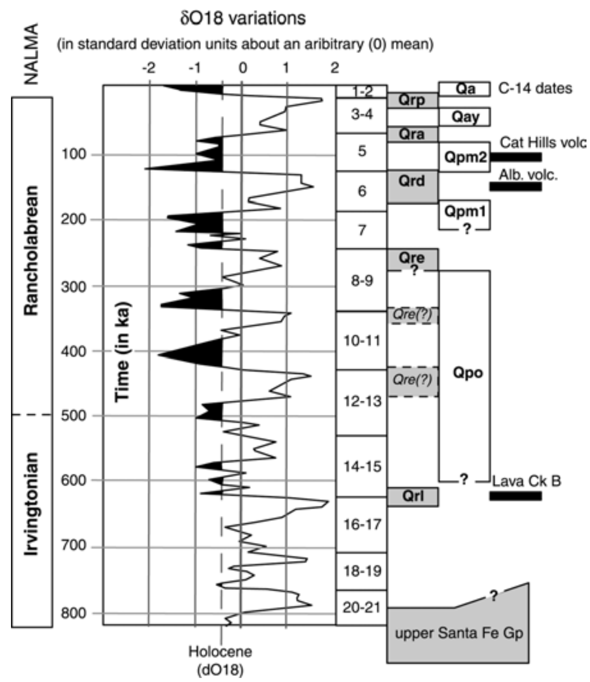

Figure 6. Correlation of fluvial deposits inferred ages. The age of the top of the Los Duranes Formation is constrained by middle and late Pleistocene basalt flows. The Lomatas Negras Formation contains the middle Pleistocene Lava Creek B ash. The Edith Formation contains middle-late Pleistocene Rancholabrean fossils and is older than the Los Duranes Formation, however, its precise age is not well constrained. Younger deposits are constrained by a radiocarbon date of 4550 yr. BP. The Edith Formation is interpreted to be older than the Los Duranes Formation and precise than the Lomatas Negras Formation. More precise age control has not been established and the Edith Formation could have been deposited during different climatic episodes.

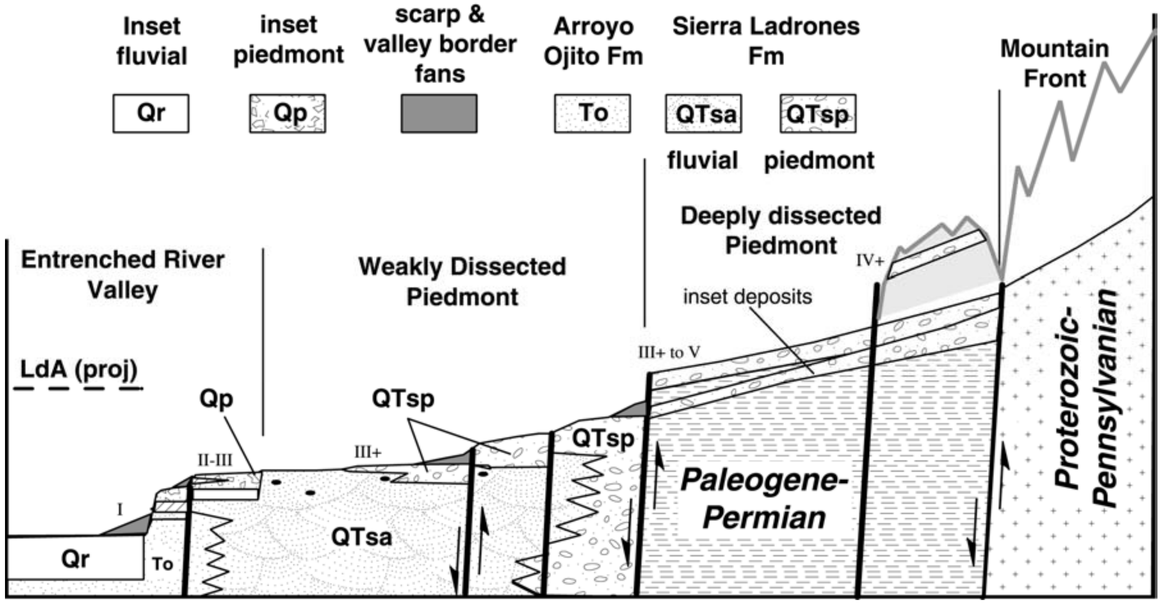

Figure 7. Generalized cross section across part of the piedmont of the Sandia Mountains, illustrating interfingering relationships among aggrading sediments of the upper Santa Fe Group, and inset post-Santa Fe Group deposits. Pedogenic carbonate morphology of constructional deposit surfaces is indicated by roman numerals that indicate the morphogenetic stage of soil development.

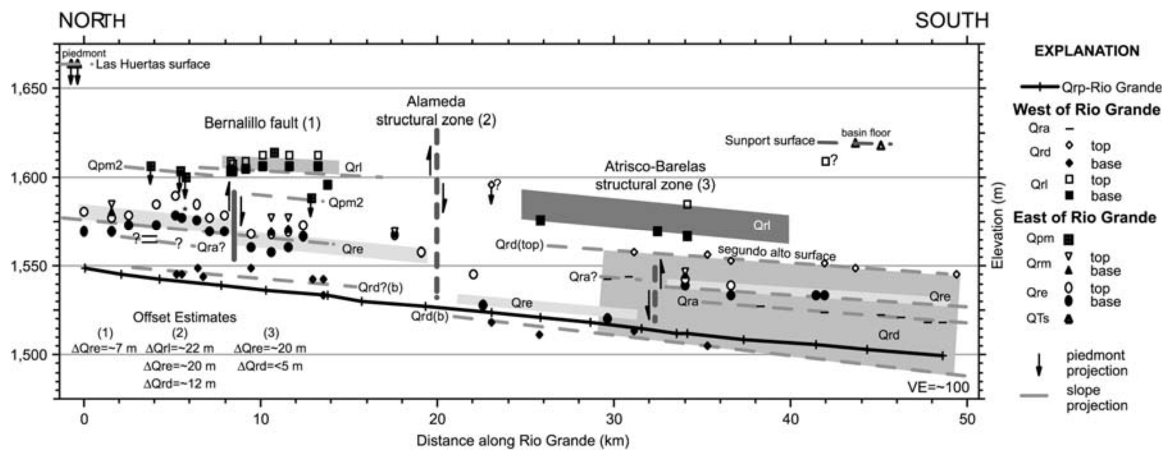

Figure 8. Longitudinal profile along Rio Grande, illustrating inset relationships among ancestral Rio Grande terraces and early Pleistocene aged constructional surfaces that locally mark the end of Santa Fe Group deposition (Las Huertas and Sunport geomorphic surfaces). The Edith and Los Duranes formations are deformed by northwest-trending faults that alter the elevation of the basal contact of these two units.

During late Pliocene time, the ancestral Rio Grande formed an axial-river that flowed within a few kilometers of the western front of the Sandia Mountains (Fig. 9a). During early Pleistocene time, between about 1.3-0.7 Ma, the Rio Grande began to entrench into the basin fill, just west of the modern valley. Piedmont deposits prograded across much of the piedmont-slope of the Sandia Mountains and buried these basin-fill fluvial deposits (Fig. 9b). During middle Pleistocene time, the Rio Grande episodically entrenched into older terrace deposits and basin-fill of the Santa Fe Group. These episodes of entrenchment were followed by periods of partial backfilling of the valley and progradation of piedmont and valley border deposits (Figs. 9c and 9d). The latest episode of entrenchment and partial backfilling occurred during the latest Pleistocene, when middle Pleistocene tributary deposits were abandoned during entrenchment, and valleys partially aggraded later during latest Pleistocene and Holocene time (Fig. 9e).

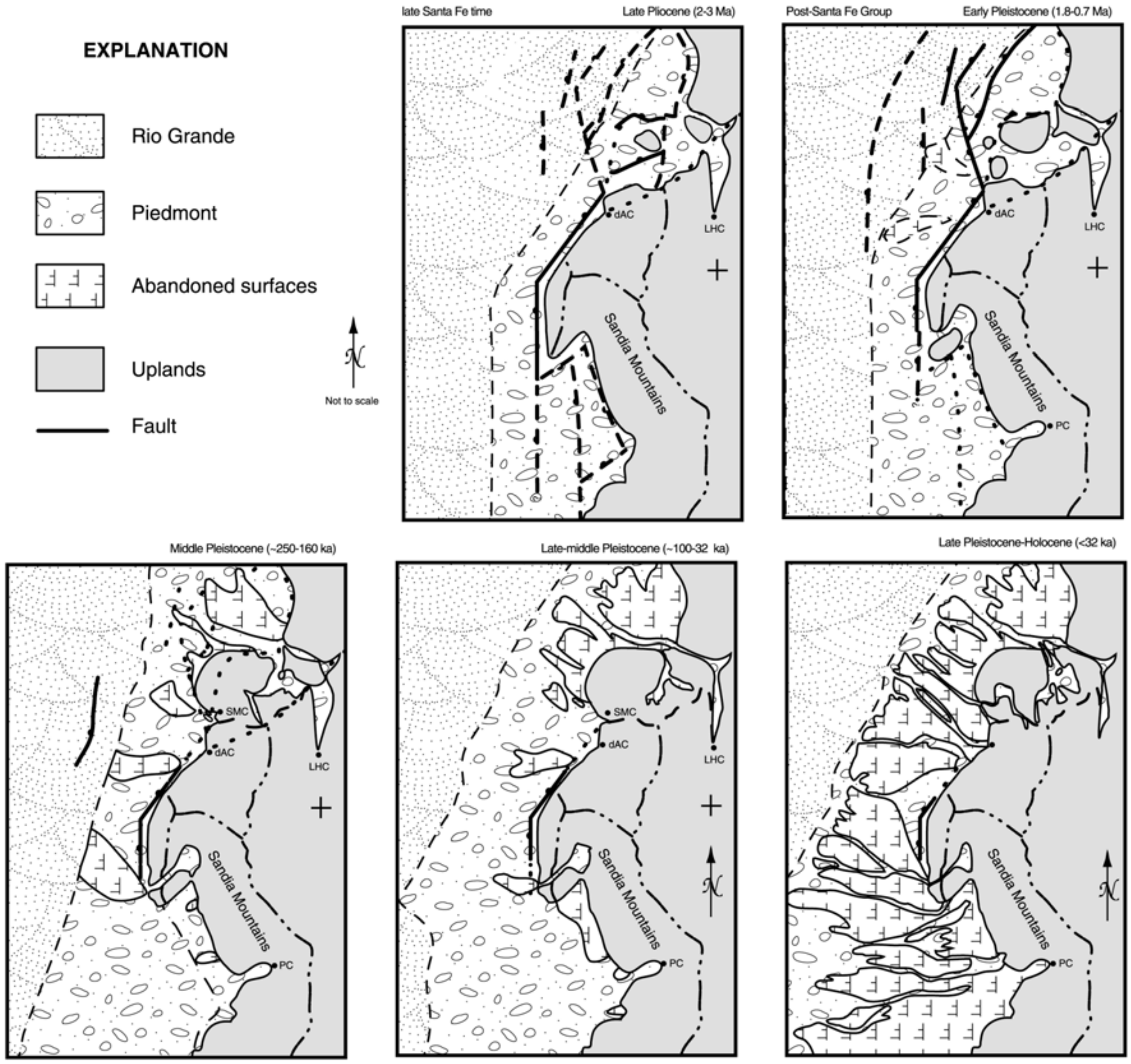

Figure 9. Paleogeographic maps of the latest phase of basin filling of the Santa Fe Group, and Pleistocene development of the Rio Grande valley (modified from Connell, 1996). Las Huertas Creek (LHC), Pino Canyon (PC), and del Agua Canyon (dAC) are shown for reference.

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