FRIENDS OF THE PLEISTOCENE, ROCKY MOUNTAIN CELL, 45TH FIELD CONFERENCE

PLIO-PLEISTOCENE STRATIGRAPHY AND GEOMORPHOLOGY OF THE CENTRAL PART OF THE ALBUQUERQUE BASIN

SECOND-DAY ROAD LOG, OCTOBER 13, 2001

Geology of Southern Albuquerque and Tijeras Arroyo

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The following trip examines the geomorphic and stratigraphic setting of the inset (post-Santa Fe Group) fluvial succession of the ancestral Rio Grande, the stratigraphic and geomorphic relationships between the Llano de Albuquerque and Sunport surfaces, and the lithologic makeup and size distribution of the gravel of the western-margin facies and axial Rio Grande facies. During the trip we will also discuss potential problems inherent with extending lithostratigraphic and allostratigraphic concepts through the basin-fill system. Field-trip stops illustrated on Plate I.

Mi **Description**

0.0 **STOP 2-0**. Begin trip at south side of store at the Isleta Lakes Campground, *Isleta 7.5' quadrangle (1991), GPS: NAD 83, UTM Zone 013 S, N: 3,867,855 m; E: 346,955 m. (Note that the UTM ticks on this quad are incorrect)*. This trip begins on the floodplain of the Rio Grande. The stratigraphy of this uppermost Pleistocene and Holocene deposit has been recently studied in detail for a liquefaction susceptibility evaluation (Kelson et al., *this volume*). Drive east and leave Isleta Lakes Campground. The inner valley of the Rio Grande is a floodplain surface bordered by dissected bluffs that are partially buried by coalescent valley border alluvial fan deposits (Fig. 2-1). This lowest and youngest cut-and-fill deposit of the Rio Grande Valley formed very late in the sequence of episodic incision and partial aggradation after the Rio Grande began to incise into Plio-Pleistocene basin fill of the upper Santa Fe Group between 1.2-0.7 Ma. Deposits of the inner valley, informally referred to herein as the Los Padillas formation (Connell and Love, 2000, 2001), represent the latest aggradational phase of the axial Rio Grande. The inner valley is underlain by about 22 m of sand, gravel, and minor silt-clay deposits that form the floodplain of the Rio Grande (MW-1 Isleta and MW-2 Isleta, Hawley, 1996, appendix A). These floodplain deposits do not exhibit soil development and have very little depositional relief and significant portions of the inner valley have historically been flooded (see Kelley, 1982) prior to the construction of Cochiti and Jemez dams upstream. Thus, the inner valley is hydrologically connected to the modern Rio Grande, whereas the late Pleistocene deposits of the Arenal Fm are well above flood stage. The age of the Los Padillas Fm is poorly constrained, but was likely laid down during latest Pleistocene time after the Rio Grande incised about 85 m into ancestral Rio Grande deposits of the late Pleistocene Arenal Fm (a.k.a. Primero Alto terrace surface of Lambert, 1968), which contains soils having Stage I and II+ pedogenic carbonate morphology (Connell et al., 1998a; Machette, 1997). Inner valley aggradation is demonstrated by an archaic site located 4 m below the valley floor in the north valley of Albuquerque (Sargent, 1987). Tributary aggradation may have slowed by middle Holocene time as indicated by a 4550±160 yr BP (Beta 109129; dendrochronologically calibrated to BC 3640-2895 yrs ±2σ) date on charcoal within 2 m of the top of a broad valley border fan near the mouth of Tijeras Arroyo (Connell et al., 1998a). 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 kept pace with the development of the floodplain.

Upper Pleistocene and Holocene alluvial deposits are aggraded alluvial aprons and channels cut into, or burying, older deposits bordering the valley. The progradation of Holocene valley border alluvial deposits across the floodplain indicates that present discharge of the river along this reach is inadequate to transport accumulated sediment out of the valley. The presence of progressively inset fluvial deposits of the ancestral Rio Grande along the valley margins indicates that episodes of prolonged higher discharge were necessary to flush sediment and erode the valley. Such erosional episodes must have occurred prior to aggradation of fluvial terrace deposits, perhaps during times of increased discharge, such as during full glacial events. Progradation of middle Holocene valley border alluvium across the modern Rio Grande floodplain suggests that deposition of tributary and piedmont facies occurred during drier (interglacial) conditions, possibly coupled with increased monsoonal precipitation. Deposition of fluvial terraces in semi-arid regions has been interpreted to occur during the transition from wetter to drier climates (Schumm, 1965; Bull, 1991). The stratigraphic relationships of the Los Padillas Fm and tributary and valley border alluvial deposits support this concept. Stratigraphic constraints on the deposition of the Los Duranes Fm, a middle Pleistocene deposit of the ancestral Rio Grande, indicate that much of the deposition of this widespread terrace deposit had finished prior to interglacial period of marine oxygen isotope stage 5 (*ca*. 128 ka), although deposition may have continued into the early part of the late Pleistocene. Studies of a lacustrine and eolian succession in the Estanica basin (Allen and Anderson, 2000) indicate a wetter climate in the region existing between about 15-20 ka, which might have driven incision of the inner valley; however, age control is lacking at the base of the Los Padillas Fm.

Drillhole data near Isleta Lakes and just north of Black Mesa, a basalt-capped mesa bordering the western margin of the inner valley, just west of Isleta Lakes, indicates that much of the floodplain succession is mostly pebbly sand and sand. Drillhole data in the inner valley suggests that much of the Los Padillas Fm rests upon Pliocene sediments of the Arroyo Ojito Fm, which were laid down by areally extensive rivers derived from the western margin of the basin. Clay beds, locally recognized within the Los Padillas Fm near Rio Bravo Boulevard (about 8 km to the north; Connell et al., 1998a) are interpreted to represent vertical accretion facies that are probably related to cut-off meander loops of the Holocene Rio Grande (*cf.* Kelson et al., 1999). These clay beds strongly influence the flow of groundwater and the transport of groundwater contamination from the rather heavily industrialized portions of the inner valley. **0.3**

0.3 Railroad Crossing. Ascend valley border alluvium derived from recycled sand and gravel of the upper Santa Fe Group. Valley border alluvium is poorly consolidated, weakly to non-cemented, typically low density, and exhibit weak to no soil-profile development with disseminated calcium carbonate or Stage I pedogenic carbonate morphology at depth. These deposits form a series of coalescent fans along the margins of the valley. These deposits are commonly prone to collapse upon wetting and have resulted in damage to buildings and homes in the Albuquerque area. **0.2**

0.5 Isleta Eagle Golf Course to south, a 27-hole course operated by the tribe and is part of their growing resort complex. **0.4**

0.9 Turn left (north) at stoplight onto highway NM-47. **0.1**

1.4 Cross under I-25 overpass, keep in left lane. **0.2**

1.6 Turn left and head south on NM-47 (South Broadway). **0.1**

1.7 Get into right lane. **0.1**

1.8 Turn right onto southbound I-25 entrance ramp. **0.3**

2.1 Merge with I-25 south (headed west). **0.5**

2.6 East abutment of I-25 bridge over Rio Grande. Rio Grande channel ahead. **0.4**

3.0 Milepost 214. West bridge abutment. **0.5**

3.5 Cross over Isleta Blvd. **0.3**

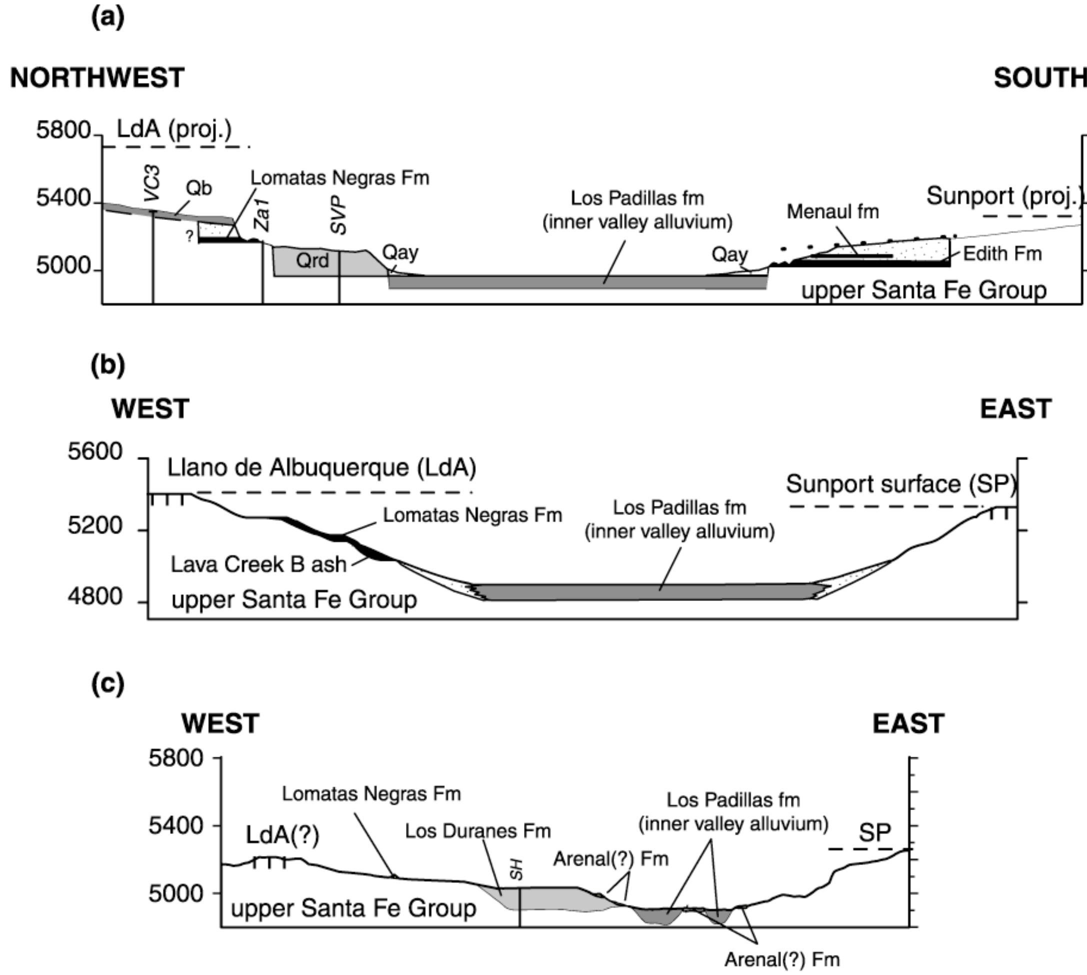

Figure 2-1. Schematic east-trending cross sections (VE=10) across Rio Grande Valley, illustrating inset relationships among middle and late Pleistocene fluvial deposits of the ancestral Rio Grande and upper Santa Fe Group constructional surfaces of the Llano de Albuquerque (LdA) and Sunport (SP). Profile north of I-40 illustrating burial of the Lomatas Negras Fm by the middle Pleistocene basalt of the Albuquerque volcanoes (a). Profile near Isleta Lakes (b). Profile at Isleta Pueblo (c). Approximate elevations of major constructional surfaces of the late Pliocene Llano de Albuquerque, and early Pleistocene Sunport surfaces are illustrated as are inset deposits of the middle Pleistocene Lomatas Negras Fm (containing the ~0.66 Ma Lava Creek B ash), the late-middle Pleistocene Los Duranes Fm (constrained by middle and late Pleistocene lava flows of the 156 ka Albuquerque volcanoes and 98-110 ka Cat Hills volcanic field; Peate et al., 1996; Maldonado et al., 1999), the late Pleistocene Arenal Fm, and the latest Pleistocene-Holocene inner valley deposits of the Los Padillas Fm. The stippled pattern indicates local deposition of valley border fans.

3.8 Entering Isleta Reservation. Overpass of drain and location of Isleta-Black Mesa piezometer, which encountered 22 m of sandy fluvial deposits underlying the Rio Grande floodplain (Los Padillas Fm). Deposits are associated with the last incision/aggradation episode of the Rio Grande. Incision probably occurred during latest-Pleistocene time, and entrenched 40 m below the late Pleistocene Arenal Fm. **0.6**

4.4 Cross bridge over Old Coors Road, which follows a former course of the Rio Grande cut through the lava flow of Black Mesa. Roadcut to right shows the edge of the 2.68±0.04 Ma ($^{40}Ar/^{39}Ar$ date, Maldonado et al., 1999) Black Mesa flow overlying cross-bedded pebbly sands of the Arroyo Ojito Fm and base-surge deposits from Isleta volcano. The tholeiitic Black Mesa flow has no outcrop connection with, and is slightly younger than, Isleta volcano, which forms the dark, rounded hill ahead and to the right of the highway. A buried vent for the Black Mesa flow is suspected in the floodplain area to left (Kelley and Kudo, 1978). **0.3**

4.7 Base-surge deposits of tuff cone associated with emplacement of Isleta volcano in outcrops on both sides of route. **0.5**

5.2 Change in primary dip direction of base-surge deposits at crest of tuff ring on right. Overlying alkali-olivine basalt flows fill tuff ring and extend southeast beyond Isleta volcano. $^{40}Ar/^{39}Ar$ dates indicate that oldest flow is 2.75±0.03 Ma and the second is 2.78±0.06 Ma (Maldonado et al., 1999). Basaltic cinders correlated to the Isleta volcano flows are recognized in the Arroyo Ojito Fm exposed along the eastern margin of the Rio Grande valley. These cinder-bearing deposits are about 70 m (estimated) stratigraphically below exposures of lower Pleistocene, Lower-Bandelier-Tuff bearing sand and gravel of the ancestral Rio Grande facies of the Sierra Ladrones Fm. This stratigraphic relationship indicates that deposition of the Arroyo Ojito Fm continued after 2.72-2.78 Ma, thereby constraining the age of the mesa capping Llano de Albuquerque to between 2.7 to 1.6 Ma. Based on local stratigraphy on both sides of the present valley, it is likely that the Llano de Albuquerque was abandoned as an active fluvial fan prior to deposition of Lower Bandelier ash and pumice gravel at *ca*. 1.6 Ma. Locally, the cinders of Isleta Volcano on the east side of the valley have experienced over 100 m of uplift with consequent erosion of the overlying units before final deposition by the Rio Grande to form the Sunport Surface. Because early Pleistocene terraces of the Rio Grande pass west of Isleta volcano at high levels, the volcanic edifice probably was exhumed during middle and late Pleistocene time (Love et al., 2001). **0.1**

5.3 Entering cut exposing basalt flow of Isleta volcano over base-surge unit (Fig. 2-2). Shell Isleta #2 well is about 1 mi. to the west, where it reached a depth of 6482 m and ended in Eocene rocks. Lozinsky (1994) reports that the Santa Fe Group is 4407 m thick at the Isleta #2 well and is underlain by 1787 m of the Eocene-Oligocene unit of Isleta #2, which overlies more than 288 m of sediments correlated with the Eocene Baca or Galisteo fms. **1.8**

7.1 Leave I-25 at exit 209 overpass to Isleta Pueblo. **0.1**

7.2 Turn left at NM-317 and head east towards Isleta Pueblo. **0.7**

7.9 Descend riser of Segundo Alto surface and middle Pleistocene Los Duranes Fm. A soil described by S. Connell and D. Love, nearby indicates that the Segundo Alto surface exhibits Stage II carbonate morphology. **0.2**

8.1 Water tanks to left. **0.2**

8.3 Turn left at stop sign onto Old Coors Rd (NM-45). **0.2**

8.5 Low rounded quartzite-bearing gravel of an ancestral Rio Grande terrace deposit inset against red cinders of Isleta volcano (2.72-2.79 Ma; Maldonado et al., 1999). **0.3**

8.8 Low inset terrace deposit of the ancestral Rio Grande north of red cinder bluff. **0.1**

8.9 Exposed south end of lava flow beneath terrace gravel. **0.4**

9.3 Descend onto floodplain of the Rio Grande. Basalt flow and underlying base-surge deposits to west. These are part of the tuff ring of Isleta volcano. The 2.68 Ma (Maldonado et al., 1999) Black Mesa flow is straight ahead and overlies deposits of the Arroyo Ojito Fm. **1.4**

11.0 Cross under I-25 overpass and through water gap cut by the Rio Grande. **0.5**

11.5 Leave Isleta Reservation. **0.6**

12.1 Pass intersection with Malpais Rd. Travel along western margin of inner valley floodplain. The low slopes to the west (left) are the toes of coalescent valley border alluvial fans. **1.4**

13.5 Pass intersection with Powers Way (west). **1.2**

14.7 Turn left (west) onto Pajarito Rd. Ascend valley border alluvium. The skyline mesa to the west is the Llano de Albuquerque, the interfluve between the Rio Puerco and Rio Grande drainages. Within next 0.5 miles, note the thin, discontinuously exposed white band at top of Llano de Albuquerque (Cejita Blanca of Lambert, 1968; Kelley, 1977). It is a strongly developed petrocalcic soil of the Llano de Albuquerque surface. Note low east-descending spur ridges, which are inset fluvial deposits of the ancestral Rio Grande. **1.0**

15.7 Pass intersection with Douglas Rd and prepare to stop on left (south) side of road. **0.2**

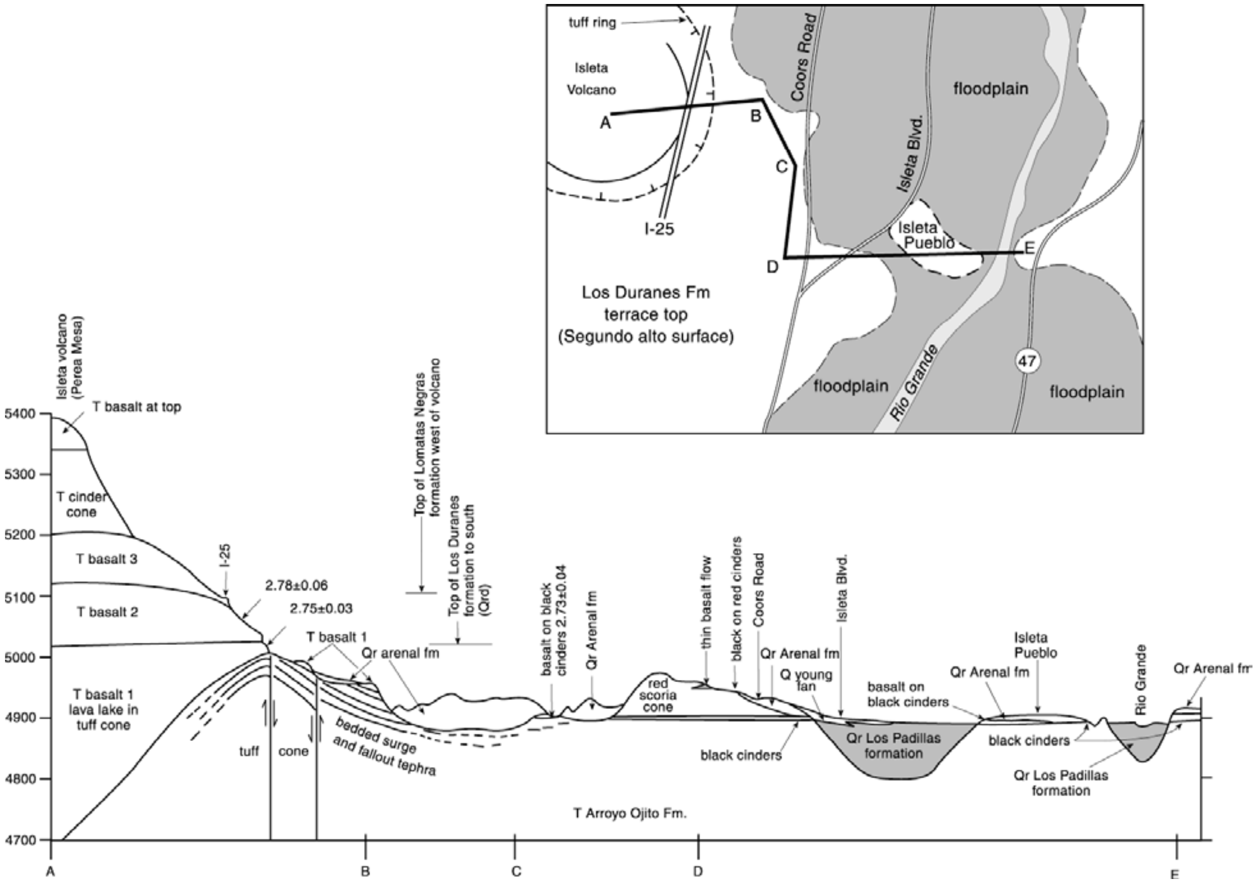

Figure 2-1. Cross Section across eastern flank of Isleta volcano and the Rio Grande Valley, illustrating late Pleistocene and Holocene inset fluvial deposits and the “island” of Isleta.

15.9 **STOP 2-1.** Turn left and park at wide shoulder on south edge of road. Middle Pleistocene inset fluvial terrace deposit of the ancestral Rio Grande (Lomatas Negras Fm). *Isleta 7.5’ quadrangle, GPS, NAD 83, Zone 013 S, N: 3,873,725 m; E: 341,260 m.* Walk to the top of the low hill on south side of road.

The purpose of this stop is to examine a remnant of a middle Pleistocene terrace deposit of the Rio Grande and to discuss recent work on the terrace stratigraphy.

Inset stratigraphic relationships require the development of bounding discontinuities along deposit margins. These buttress unconformities are analogous to buried valley margin bluffs that mark the edge of the paleovalley. At this stop, we are less than 300 m east of such a remnant paleobluff line, which is defined by the terminations of low spur ridges that are underlain by the Arroyo Ojito Fm. Rounded, stratified cobbles and pebbles of metaquartzite and various volcanic rocks dominate the gravel underlying this hill. Sparse Pedernal chert and sandstone clasts are also recognized. Sandstone gravel is not typical of the ancestral Rio Grande facies and are probably remnants of an older alluvial deposit that once overlain this deposit, or the sandstone gravel was incorporated from the nearby buttress unconformity. This deposit is about 60 m below the Sunport surface, the broad mesa about 120 m above the Rio Grande on the eastern side of the valley. This deposit is correlated to the Lomatas Negras Fm, one of the oldest definitively inset fluvial terrace deposits.

Terrace deposits were originally given geomorphic names, such as Primero Alto, Segundo Alto, and Tercero Alto (Lambert, 1968; Machette, 1985). Such terms were originally defined by Bryan and McCann (1936) for terraces of the upper Rio Puerco Valley, which has a distinctly different drainage morphology, and transported (sedimentary dominated) lithology compared to the crystalline- and volcanic-dominated deposits of the Rio Grande Valley. Lambert (1968) defined the Edith, Menaul, and Los Duranes formations as lithostratigraphic units. Connell and Love (2001) proposed additional terms to round out Lambert's stratigraphy and to avoid confusion between geomorphic and lithologic terms.

The oldest fluvial deposit is the Lomatas Negras Fm, an early-middle Pleistocene fluvial deposit exposed at this stop. Love (1997) delineated this unit as a terrace complex because the base(s) are poorly exposed and there is a large range in the heights of the gravel beds (from ~30 to ~73 m above the floodplain), and the tops are buried by several meters of alluvium and eolian sand sheets that prograded across these terraces before erosion dissected arroyo valley fills through the terraces.

Inset against the Lomatas Negras (Tercero Alto of Machette, 1985) is the Edith Fm, which is also middle Pleistocene in age. The late-middle Pleistocene Los Duranes Fm is the best-dated terrace in the area. The 156 ka Albuquerque volcanoes (U/Th date of Peate et al., 1996) is interbedded near the top of this deposit. The broad terrace tread, called the Segundo Alto by Lambert (1968) is buried by 98-110 ka flows of the Cat Hills volcanic field. The Menaul Fm is a gravel deposit found east of the Rio Grande. This deposit may be part of the Los Duranes Fm. Inset against the Los Duranes Fm is the Arenal Fm (Primero Alto surface of Lambert, 1968; also Machette, 1985), which contains a fairly weak soil with Stage I and II+ carbonate morphology (Connell et al., 1998b; Machette et al., 1997). The modern valley alluvium of the Los Padillas Fm insets this lowest terrace deposit.

Entrenchment of the upper Santa Fe Group is constrained by the Lomatas Negras Fm. This deposit contains a fallout ash of the ~0.66 Ma Lava Creek B (Yellowstone National Park, Wyoming and Montana) exposed in an active gravel quarry along the western margin of the Valley (Isleta quadrangle), a couple of kilometers south of this stop (Figs. 2-3 and 2-4). This ash, found about 35 m above the Rio Grande, was geochemically correlated to the middle Pleistocene Lava Creek B (~0.66 Ma; Izett et al., 1992) separately by A. Sarna-Wojcicki (U.S. Geological Survey) and N. Dunbar (N.M. Bureau of Geology and Mineral Resources). Unfortunately, continued quarry operations have buried or possibly obliterated this stratigraphically important ash. This terrace deposit is about 44 m below the Sunport surface, which is underlain by a fallout ash of the upper Bandelier Tuff in Tijeras Arroyo. Boulders of upper Bandelier Tuff are found near the top of the ancestral Rio Grande facies of the upper Santa Fe Group. These were probably deposited from a post-eruption breaching of a lake within the caldera. Thus, the development of the Sunport surface is constrained between 0.7-1.2 Ma.

The slightly higher hills to the west are exposures of the Arroyo Ojito Fm. The discontinuous low spur ridges represent the paleobluff, or buttress unconformity, between this fluvial deposit and the upper Santa Fe Group.

Turn left and continue on Pajarito Rd going west. **0.3**

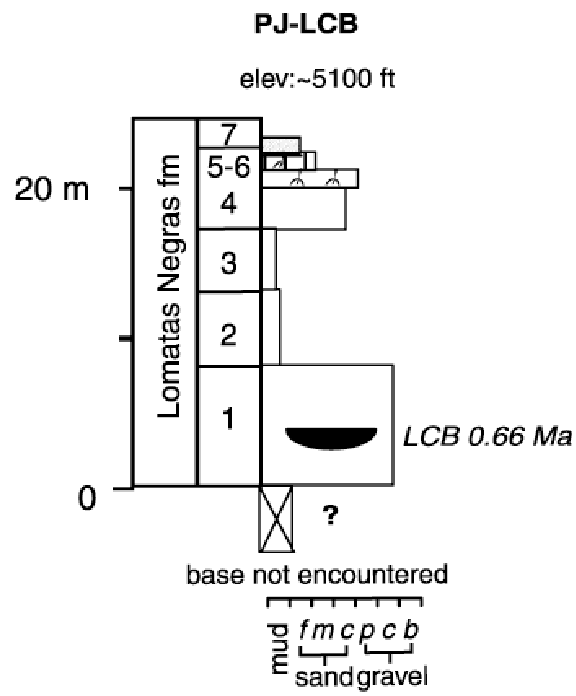

Figure 2-3. Stratigraphic section of the Lomatas Negras Fm at an active gravel quarry in the Pajarito grant. The Lava Creek B ash is within a thick succession of gravel and sand that is overlain by a fining-upward sequence of sand and mud. These fluvial deposits are overlain by a thin tongue of alluvial sediments derived from the western margins of the valley.

16.2 Note slightly higher hill to the northwest (right), which exposes the Arroyo Ojito Fm in a degraded east-facing riser between the Santa Fe Group (ancestral Rio Puerco) and inset fluvial deposits of the ancestral Rio Grande to the east. **0.2**

16.4 Pass under powerlines. The Cejita Blanca is at 1:00. **1.2**

17.6 Top of hill on eastern edge of the Llano de Albuquerque. Turn left (south). Travel south on footwall of west-facing normal fault cutting the Llano de Albuquerque. **0.6**

Figure 2-4. Photograph of fallout ash correlated to the middle Pleistocene Lava Creek B. This ash is within a thick succession of fluvial deposits of the ancestral Rio Grande. Correlative fluvial deposits are 75-85 m above the Rio Grande at the northern end of the basin (Smith et al., 2001).

18.2 Turn right (west) and descend west-facing fault scarp. Light colored hills on horizon between 1:00 and 2:00 are sand dunes that formed along the western edge of the Llano de Albuquerque. Other features on the Llano de Albuquerque include Los Lunas volcano at 10:00, and Wind Mesa, which is cut by a south-trending graben. Between 10:00-11:00 is Gallo Mesa, which is capped by 8 Ma basalt on Colorado Plateau, and lies just west of the rift border Santa Fe fault (Kelley, 1977). **0.4**

18.6 Note brown Quaternary eolian sand with scattered pebbles of Arroyo Ojito Fm. Eolian sand forms a relatively continuous mantle on the Llano de Albuquerque surface, and covers the strongly developed soil, except along its margins or near fault scarps, where gravels are locally exposed. **0.9**

19.5 Ascend one of a number of east-facing fault scarps cut into the Llano de Albuquerque. **0.4**

19.9 Descend west-sloping footwall of fault and descend into another east-facing fault block. **0.4**

20.2 Cross under powerline. We will take this powerline road north to get to Stop 3. **3.2**

23.8 Cinder cones and flows of the middle-to late-Pleistocene Cat Hills volcanic field to the south. Twenty-three cones and seven extensive lava flows, ranging in age from 250 ka to less than 100 ka, mapped by Kelley and Kudo (1978) and Maldonado and Atencio (1998a, b). The Ladron Mts form the skyline to the left. The large facility to the right (north) is the new Bernalillo County Metropolitan Detention center. Water levels from wells drilled in the area indicates about 244 m (800 ft) to water. The water quality on much of the Llano de Albuquerque is poor. At the Detention Center, it is unpotable. Water will likely have to be piped in from the city to accommodate the residents of this institution. **0.6**

24.4 Bear left. **0.1**

24.5 **STOP 2-2.** Ceja del Rio Puerco. Hike south along edge of to Stop. *Dailies NW 7.5' quadrangle. GPS: NAD 83, Z013 S, N: 3,872,220 m; E: 329,510 m.*

The purpose of this stop is to examine the stratigraphy of the uppermost gravels of the Arroyo Ojito Fm (Ceja Mbr) and the overlying soil of the Llano de Albuquerque. We will also discuss the geomorphic development of the Rio Puerco Valley. This stop is at the Ceja del Rio Puerco of Bryan and McCann (1937, 1938), a linear escarpment that defines the eastern margin of the Rio Puerco Valley (Fig. 2-5). Volcanic features of the Llano de Albuquerque are visible to the east (Fig. 2-6).

The broad faulted interfluve between the Rio Puerco and Rio Grande valleys is the Llano de Albuquerque of Bryan and McCann (1938). This surfaces marks a widespread and important local top to the Santa Fe Group and represents the top of the Arroyo Ojito Fm. Kelley (1977) correlated this to the Ortiz surface, which was recognized at the foot of the Ortiz Mts (*cf.* Stearns, 1953). Kelley (1977) extended the Ortiz surface across much of the basin. Other studies (Bachman and Mehnert, 1978; Machette, 1985; Connell et al., 2000, 2001c); however, indicate that a number of surfaces in the basin are of different ages and are not correlative to the Ortiz surface. Lambert (1968) recognized two distinct constructional surfaces in his study of the Albuquerque area. Lambert recognized that the Llano de Albuquerque surface of Bryan and McCann (1938) was probably older than his topographically lower Sunport surface. Machette (1985) also recognized this difference in landscape position and age. On the basis of comparisons of pedogenic carbonate accumulation to other better-dated areas, such as the Mesilla basin of southern New Mexico (Gile et al., 1981), Machette (1985) estimated the age of the Llano de Albuquerque to be around 500 ka, and the Llano de Manzano (Sunport) surface was estimated to be about 300 ka. Geologic mapping, stratigraphic work, and $^{40}Ar/^{39}Ar$ dating indicates that the Llano de Albuquerque surface was formed between 2.58 Ma and 1.6 Ma and the Sunport surface was formed between 1.2 and 0.7 Ma. These revised ages agree somewhat with revised age estimates of similar aged surfaces in the Mesilla basin (i.e., upper and lower La Mesa surfaces, see Gile et al., 1995).

Soils developed on the Llano de Albuquerque are better developed that the Sunport surface and exhibit an ~3-m thick Stage III+ and IV pedogenic carbonate morphology, such as from a trench dug near the center of this surface (Fig. 2-7). This soil forms a discontinuously exposed band along the margins of the Llano de Albuquerque (Fig. 2-6). Soils developed on the Sunport surface commonly exhibit Stage III and III+ pedogenic carbonate morphology. The greater antiquity of the Llano de Albuquerque surface is expressed by the presence of larger fault scarps that cut the surface and the preservation of thick eolian/colluvial wedges adjacent to these intrabasinal faults. In contrast, fault scarps and associated eolian-colluvial wedges are typically shorter and thinner, respectively, on the Sunport surface.

Deposits underlying the Llano de Albuquerque contain cross bedded fluvial sand and gravel and muddy sandstone (Fig. 2-8). Rounded chert, sandstone, and granite, with subordinate amounts of Pedernal chert, porphyritic intermediate to slightly silicic pebbles and cobbles, and scattered basalt, dominate gravel. A bed of pumice-bearing pebble conglomerate with scattered subangular cinders is less than 2 m beneath the base of deposits that contain the Llano de Albuquerque soil (Fig. 2-9). The age of these pumice and cinder gravels are not known, but some of the pumice pebbles correlate may correlate to Pliocene age pumice gravels found beneath the top of the Arroyo Ojito Fm in Rio Rancho, New Mexico and on the Isleta Reservation (N. Dunbar, 2001, personal commun.). $^{40}Ar/^{39}Ar$ dates from these pumice pebbles are pending, but they are similar to other dates pumice pebbles near the top of the Arroyo Ojito Fm section in Rio Rancho and Isleta, New Mexico. Fluvially recycled 2.58 Ma pumice is present the Arroyo Ojito Fm in the Rio Grande Valley to the east. About 4 km south, along the Ceja del Rio Puerco, the 3.00 Ma (Fig. 2-10; date from Maldonado et al., 1999) Cat Mesa basalt is overlain by about 15 m of gravel and sand of the uppermost Arroyo Ojito Fm. These age constraints suggest that the Llano de Albuquerque formed closer to 2.5 Ma, rather than 1.6 Ma. The presence of at least 38-68 m of Arroyo Fm above this 2.58 Ma pumice could also indicate eastward thickening and depositional offlap as deposits of the western margin flowed towards the basin depocenters near the eastern margin of the basin (see Day 1 road log).

Figure 2-5. View to east of the Llano de Albuquerque and late Pliocene and Pleistocene volcanic fields. The Manzano Mountains, in the background, mark the eastern structural margin of the rift.

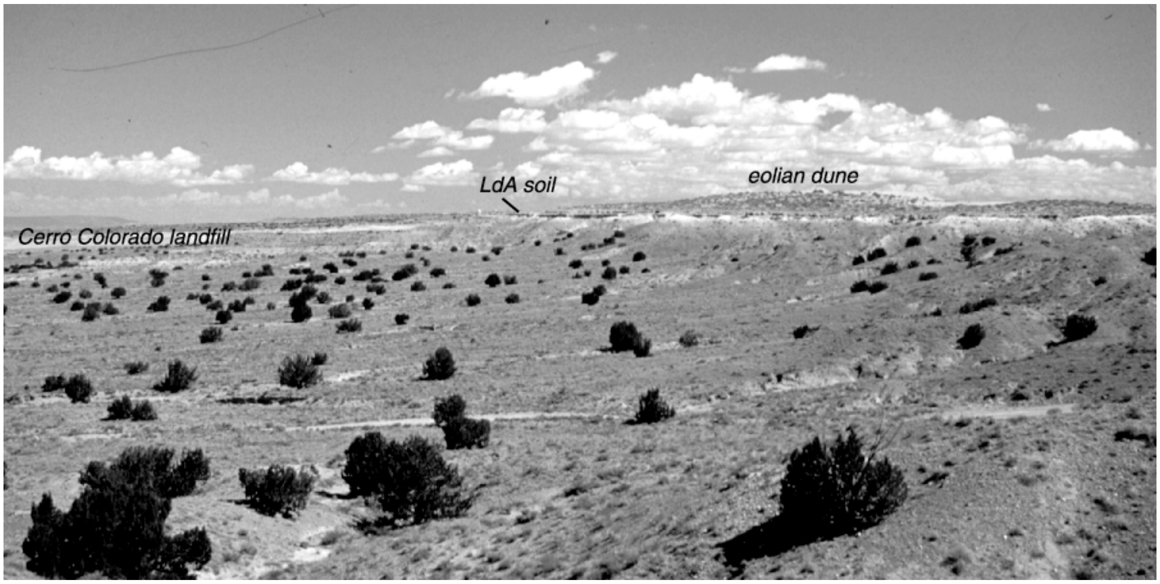

Figure 2-6. View to north along Ceja del Rio Puerco. The white band near the top of the hill is the petrocalcic soil of the Llano de Albuquerque, which is locally overlain by thick dune deposits along the edge.

The Rio Puerco Valley cut about 190 m into the Arroyo Ojito Fm along the western margin of the basin. The presence of ~0.66 Ma Lava Creek B ash (Izett and Wilcox, 1982) about 80 m above the valley floor indicates that this valley was cut prior to 0.7 Ma. A suite of inset, basalt-mantled surfaces are preserved by the Rio Puerco Necks (Hallett, 1990) indicate that these drainages were entrenched on the southeastern Colorado Plateau by late Pliocene time. A longitudinal profile constructed for the lower Rio San Jose (Love, 1986; modified in Love et al., 2001) also indicates Pliocene entrenchment of the Colorado Plateau since about 4 Ma (Fig. 2-11). Aggradation of the upper Santa Fe Group continued after emplacement of the 3.00 Ma (Maldonado et al., 1999) flow and deposition of 2.58 Ma pumice.

Soils of the Llano de Albuquerque contain sparse, scattered pebbles that were probably moved into the soil-profile by bioturbation. Much of the sediment in the soil is fine- to medium-grained sand and is of likely eolian origin. Soils of the Llano de Albuquerque studied to the northeast indicate that horizons contain as much as 53% (weight percent calculation) of micritic carbonate throughout the soil profile (Machette et al., 1997, site 13). This thick petrocalcic soil is overlain at this stop by a 10-m thick succession of eolian sand that contains at least three buried soils.

Differences in height between the Llano de Albuquerque and topographically lower and younger Sunport and Llano de Manzano surfaces are strongly controlled by intrabasinal fault that down-drop the Llano de Albuquerque to the east and to the south (Fig. 2-12; see also Fig. 1-34).

Figure 2-7. Exposure of a petrocalcic soil developed on the Llano de Albuquerque at the Soil Amendment Facility (City of Albuquerque. This exposure is at the east end of a trench cut across an antithetic fault to the San Ysidro (or Calabacillas) fault zone, which was excavated by Jim McCalpin of GEOHAZ, Inc.

The apparent lack of a thick early Pleistocene, Sunport correlative, deposits in the Rio Puerco Valley is puzzling. The lack of preservation of such a thick deposit suggests that erosion within this drainage is quite effective in removing older inset fluvial remnants, or that such older deposits were never deposited along this reach of the Rio Puerco Valley to begin with.

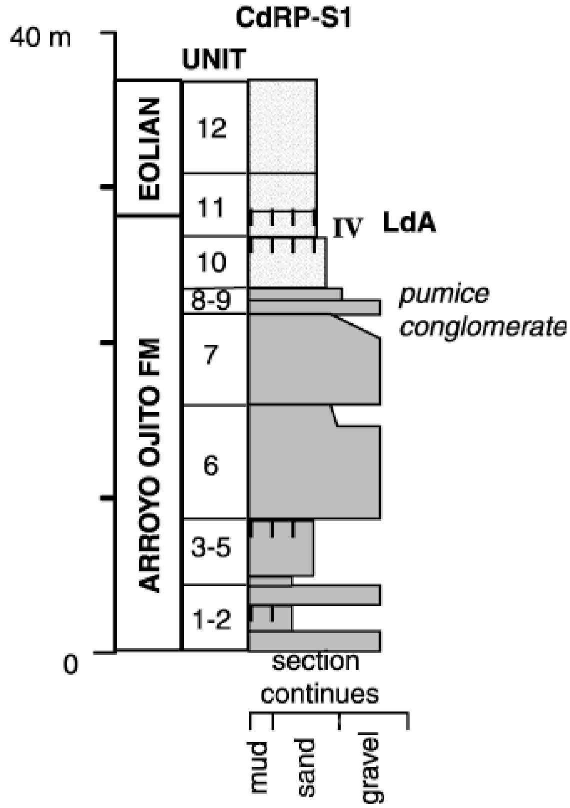

Figure 2-8. Stratigraphic section along Ceja del Rio Puerco at Stop 2-2. A bed of pumice-bearing conglomerate with scattered subangular reddish-brown cinders is less than 2 m below the base of the sandstone that contains the Llano de Albuquerque (LdA) soil.

This lack of preservation of early Pleistocene deposits could be the result of sediment bypass through the valley as a result of a lack of space to accommodate the deposition of such sediment. Activity of the western basin margin faults is not well known, however, projections of Pliocene-aged deposits and volcanic units across the basin boundary (Fig. 2-11) suggest that little significant faulting has occurred since late Pliocene time. Thus, it is possible that faulting did not provide space for significant long-term sediment storage, but rather, sediment was transported out of the Rio Puerco Valley during late Pliocene and early Pleistocene time. This problem warrants further study.

Throughout the literature of the evolution of the Rio Grande one constantly sees references to surfaces, the Llano de Albuquerque, the Llano de Manzano, the Sunport surface etc. What do these surfaces represent and how do you recognize them? Every now and again you also see references to geomorphic surfaces, are they the same as the above surfaces or are they completely different?

Ruhe (1969) defined a geomorphic surface as “ a portion of the land surface comprising both depositional and erosional elements having continuity in space and a common time of origin. It may occupy an appreciable part of the landscape and may include many landforms. A geomorphic surface is established when a stable surface is first exposed to subaerial weathering and soil development”.

Figure 2-9. Uppermost cross bedded gravelly sandstone of the Ceja Mbr. (Arroyo Ojito Fm). A bed of pumice-bearing conglomerate is less than 2 m below the prominent white cliff of the Llano de Albuquerque petrocalcic soil (Stage IV here).

Figure 2-10. The 3.00 Ma Cat Mesa basalt overlies silty sand containing buried paleosols. This basalt is about 15 m below the Llano de Albuquerque. Florian Maldado and Dave Love are kneeling at the foot of this flow.

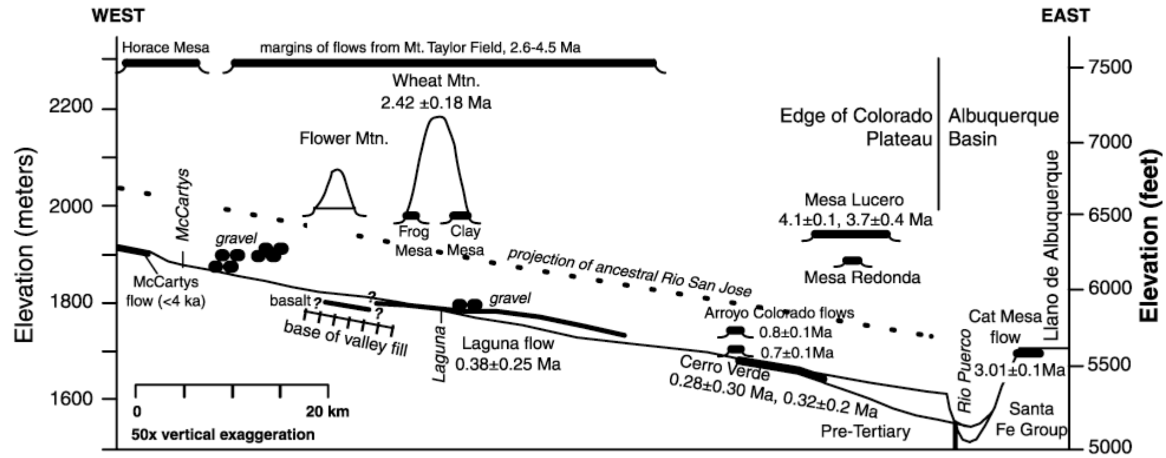

Figure 2-11. Longitudinal profile of the Rio San Jose from the distal end of McCartys flow to the confluence with the Rio Puerco and western edge of the Llano de Albuquerque surface (modified from Love, 1989 with date of Cat Mesa flow from Maldonado et al., 1999). Stratigraphic data indicate that the Llano de Albuquerque is younger than 3.0-2.6 Ma and older than 1.2 Ma. Major incision of the Rio San Jose after about 2.4 Ma suggests that the Llano de Albuquerque surface may have formed somewhat later, perhaps by 2.5-2.0 Ma.

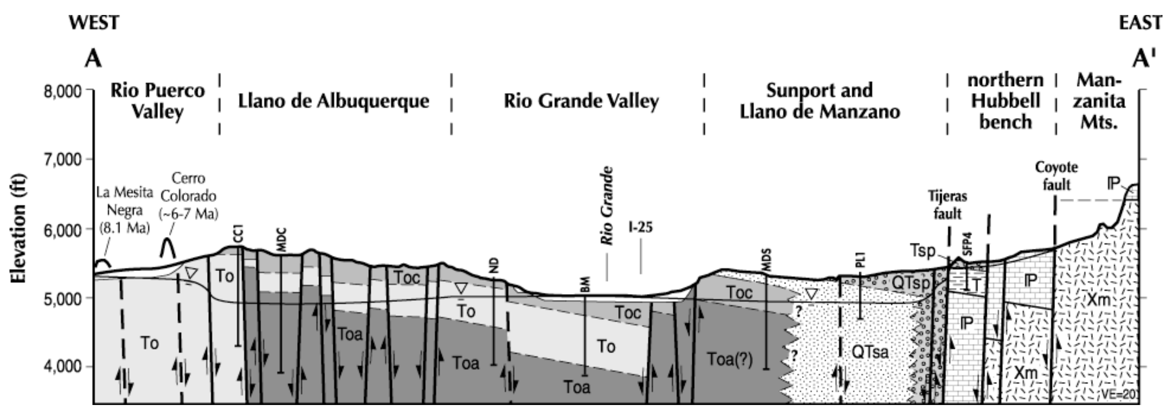

Figure 2-12. Cross section across basin, illustrating structural and geomorphic relationships among the three major lithofacies assemblages. Western fluvial facies of the Arroyo Ojito Fm (undivided, To) are locally subdivided on this diagram into the Ceja Mbr (Toc) and Atrisco unit (Toa, of Connell et al., 1998a). Deposits of the axial Rio Grande (QTsa) and younger (QTsp) and older (Tsp) piedmont facies are east of the Rio Grande deposits. Pre-rift deposits include Paleocene mudstone (T, Thomas et al., 1995), Pennsylvanian limestone and Proterozoic crystalline rocks.

By this definition a geomorphic surface is recognized by the development of a soil profile and it is a time stratigraphic unit. The duration of stability is represented by the degree of soil development. Because of the need to recognize the spatial continuity of erosional and depositional elements the following terms are used: Buried Geomorphic surfaces are parts of former geomorphic surfaces now buried and underlying the present geomorphic surface. Exhumed geomorphic surfaces are former geomorphic surfaces now re-exposed by erosion. Transformation of geomorphic surfaces by erosion or deposition results in the formation of new geomorphic surfaces. The intergrade elements of this continuum are described as degradation and aggradational phases of the present geomorphic surface. These phases are recognized where the soil profile has been modified by degradation exposing B-horizons or aggradation thickening the surface horizons (Tonkin et al., 1981).

The Llano de Albuquerque and Llano de Manzano surfaces as commonly applied in the literature refer to top of the Santa Fe Group gravels, marking the last basin-wide aggradational fill prior to the incision of the Rio Grande Valley in early Pleistocene time. Since this time the surface of these fluvial deposits has been exposed to a wide range of surficial processes, including significant faulting (Machette 1985; McCalpin, 1997) fan progradation from adjacent hillslopes and sand sheet deposition. There are probably very few parts of the original surface existing today and it is unlikely that there are soil profiles that date from that time period and are unaltered by surficial processes. The wide variety of soil profiles described on these surfaces reflects different-aged geomorphic surfaces. This is also true of the incised terrace treads such as the Sunport surface. Thus the bottom line is that soil development cannot be used to identify the Llano de Albuquerque, Llano de Manzano or the Sunport Surfaces.

Turn around and retrace route to intersection of road and powerline at mile marker 20.2. **3.9**

28.4 Turn left (north) at road just east of powerlines. Note prominent west-facing fault scarp to your right (east). **2.8**

31.2 Turn right (east) onto Senator Dennis Chavez Rd. **1.0**

32.2 Descend into valley of the Rio Grande. Deposits of the Arroyo Ojito Fm locally exposed in spur ridges. Valley border fans are incised into the Los Duranes Fm and overlie the Arenal Fm. **2.2**

34.4 Flat surfaces underneath housing development is the Primero Alto surface and underlying Arenal Fm, a late Pleistocene fluvial deposit of the ancestral Rio Grande that is inset against the middle Pleistocene Los Duranes Fm. **0.4**

34.8 Crossing onto floodplain of the Rio Grande. Road is built on fill over this deposit. **0.6**

35.4 Cross Coors Blvd. Continue straight (east) where road becomes Rio Bravo Blvd. (NM-500). **1.9**

37.3 Cross Isleta Blvd (NM-314). Continue east and descend into yazoo along eastern margin of valley. **1.8**

39.1 Ascend valley border alluvium, which prograded over the Rio Grande floodplain. Prepare to turn right. **0.2**

39.3 Turn right (south) onto South Broadway (NM-47). Mesa to left (east) is the Sunport surface and the Albuquerque International Airport (a.k.a. Sunport). **1.4**

40.7 Driving on the sandy alluvium of Tijeras Arroyo. This arroyo contains a mixture of granite, greenstone, gneiss, and sandstone near its mouth at the front of the Sandia Mountains. Deposits derived from the Tijeras Arroyo drainage basin are more heterolithic than alluvium derived from the western front of the Sandia Mts, which contains mostly granite, schist, and minor limestone. **0.4**

41.1 Turn left (east) onto Bobby Foster (Los Picaros) Rd. **0.5**

41.6 Turn right (south) at junction with Los Picaros Rd. Drive uphill towards the Journal Pavilion. Ascend deposits of the Arroyo Ojito Fm. White bed at 2:00 on west side of I-25 is within the Arroyo Ojito Fm. This bed contains a recently discovered microvertebrate site of probable medial Blancan age (Pliocene; G. Morgan, 2001, personal commun.). **0.8**

42.4 Top of hill. Pale beds on top of the mesa contain Stage III+ soils of the Sunport surface, which is developed on a west-thinning wedge of pumice-bearing deposits of the ancestral Rio Grande. The early Pleistocene ancestral Rio Grande fluvial system extended at least 7 km east of here **0.6**

43.0 Disturbed area around road is reclaimed South Broadway landfill, which intermittently operated as an unlined municipal landfill between 1963-1990. **0.4**

43.4 View of range-bounding eastern margin of the Albuquerque Basin. The Sandia Mts at 10:00-12:00, Four Hills salient of the Sandia Mts at 12:00, the flat-topped Manzanita Mts at 12:00-2:00, and the higher Manzano Mts to the south. Tijeras Canyon, one of the largest rift-border drainages in the area and the namesake drainage of Tijeras Arroyo, enters the basin at about 12:00. Scarps of the Hubbell Spring fault zone extend south from the Four Hills. **0.8**

44.2 Large excavations to your right (east), locally known as the "Suez canal," expose the Sunport soil and overlying eolian deposits. **0.3**

44.5 **STOP 2-3.** Pull off road onto shoulder at north end of 3.3 m deep pit. Sunport surface. *Albuquerque East 7.5' quadrangle: GPS, NAD83, Z 013 S, N: 3,874,245 m; E: 352,010 m.*

At this stop we will examine soils of the early Pleistocene Sunport surface, which is commonly overlain by a thick accumulation of eolian sand (Fig. 2-13). The Sunport soil is about 1.6 m thick and commonly exhibits a strongly developed Stage III+ carbonate morphology. Strongly developed platy structure is also present in the strongest developed parts of the soil profile. The top is irregular, eroded, and is overlain by about 1.6 m of eolian sand with weakly to moderately developed soils and is Holocene to latest Pleistocene (?) in age. This soil is developed on loose sand and pebbly sand of the ancestral Rio Grande, which is less than 1 m below the base of this detention pit.

Figure 2-13. Recently constructed flood detention pit on east side of Journal Pavilion parking lot. The Sunport soil is about 1.5 m thick and exhibits Stage III+ carbonate morphology. The top of the soil is irregular and has been modified by relatively deep pipes developed into the profile.

Turn around and leave Journal Pavilion parking area and head towards intersection of Los Picaros and Bobby Foster Rds. **0.5**

45.0 Northern Hubbell bench, and site of stop 2 of the day 1 field trip at 10:00-11:00. The numerous buildings at the foot of the Manzanita Mts and Four Hills salient are part of Sandia National Laboratories. **2.0**

47.0 Cross intersection with Bobby Foster Rd. Continue straight. **0.8**

47.8 Steep-walled arroyo of Tijeras Creek. About 2 m below the surface is a zone containing abundant charcoal. A sample was radiocarbon dated at about 4550 yr. BP. **0.4**

48.2 The exposures to your right (south) contain gray gravel and sand of the ancestral Rio Grande deposits, which overlie brown sand of the Arroyo Ojito Fm. The underlying Arroyo Ojito deposits commonly contain carbonate-cemented sandstone and rhizoconcretionary intervals. **1.3**

49.5 Off-road vehicle recreation area to the south. **0.1**

49.6 Pass intersection with Ira Specter Road. Keep straight. **0.1**

49.7 Pass through gate onto Albuquerque Open-Space Division Headquarters at Montessa Park. Check in with Open-Space division before proceeding east. Drive east towards metal warehouse buildings near end of complex. **0.1**

49.8 **STOP 2-4.** Southeast corner of Kaibab Warehouse #1. Hydrocompactive soils. *Albuquerque East 7.5' quadrangle: GPS, NAD 83, Z 013 S, N: 3,876,195 m; E: 354,435 m.*

Hydrocompactive or collapsible soils lose a significant amount of volume through reduction of porosity when wetted. Hydrocompactive sediments are typically composed of poorly sorted fine-grained sand with minor amounts of silt or clay that were deposited by debris- or hyperconcentrated flows. These deposits typically occur on geologically young, gently sloping alluvial-fan, alluvial-slope, or valley-fill environments that have not been saturated since deposition. Hydrocompactive soils have damaged roads, utility lines, and buildings, such as the Kaibab Warehouse #1 (Fig. 2-14) in several parts of New Mexico (see Haneberg, 1992).

Before collapse, the soil structure of these deposits is porous and has relative low unit weights (typically less than 16 kN/m^3) and high void ratios (typically higher than 1.0). Upon wetting, these deposits typically disaggregate and compact. Because of the geologic age and setting, geologic mapping can be used to predict where such soils may be present. Geologic mapping of the eastern part of the Albuquerque metropolitan area north to Bernalillo, New Mexico (Connell, 1997, 1998; Connell et al., 1995; 1998b) and evaluation of available geotechnical data suggests that the Holocene-latest Pleistocene arroyo and valley border alluvial deposits are particularly susceptible to hydrocompaction. Future studies will attempt to produce predictive hydrocompaction susceptibility maps.

At this stop, we see damage caused by hydrocompactive soils. This building was constructed on about 24 m (80 ft) of poorly sorted sand and mud of Tijeras Arroyo. Note the circular cracks in the asphalt road around a patch of bare ground that was presumably used to drain surface runoff from roads, buildings, and water from a fire hydrant. The concentration of runoff into this patch of bare ground caused collapse of the surrounding soil and foundation, resulting in distress to the warehouse building. Seargent, Hauskins and Beckwith, and Woodward-Clyde studied the Montessa Park facility in 1983 and 1973, respectively (Seargent, Hauskins, Beckwith, 1983). They drilled cores and measured the amount of consolidation, before and after wetting of the sample, under differing static loads (Fig. 2-15). The combined results of this study indicate the presence of hydrocompactive deposits down to the level of groundwater saturation under high loads. Under *in situ* loads, hydrocompaction of up to 5% was reported to a depth of about 18 m. Should the entire column of sediment at this site become saturated, the total consolidation would be about 5.5% and would represent a subsidence of about 1.3 m at *in situ* loads. The addition of greater loads, such as a multi-story building, would increase this subsidence at the more hydrocompactive shallow end of the sediment column. Estimates of ground subsidence, based on elevation differences between the north and south edges of the building, indicate that this structure has undergone approximately 0.6-0.8 m of deformation, mostly on the southern four garage bays. These would be maximum estimates because they assume total saturation of the sediment column, which would create other geotechnical problems, and they also ignore effects of grain bridging of the soil column at depth.

Figure 2-14. Photograph of the south end of the Kaibab Warehouse #1 facility at Montessa Park. Note the arcuate cracks in the asphalt, which have been repaired. These cracks encircle the exposed soil to the left of the building. The doors of this warehouse are out of plumb and rest on the foundation along the right side, but are not supported to the left. Dave Love is at right side of photograph.

Turn around and leave Montessa Park facilities. **0.1**

50.4 Pass through gate. **0.6**

60.0 Turn hard left towards Albuquerque National Speedway. **0.4**

60.4 Exposures of pumice-bearing fluvial deposits of the ancestral Rio Grande to the south are lower in elevation relative to deposits of the Arroyo Ojito Fm at the mouth of Tijeras Arroyo. **0.5**

60.9 Crossing contact between fluvial deposits and overlying piedmont- and eolian-dominated deposits of the Sierra Ladrones Fm. Section contains at least 3 calcic soils. Top of hill is capped by a Stage III+ soil. **0.5**

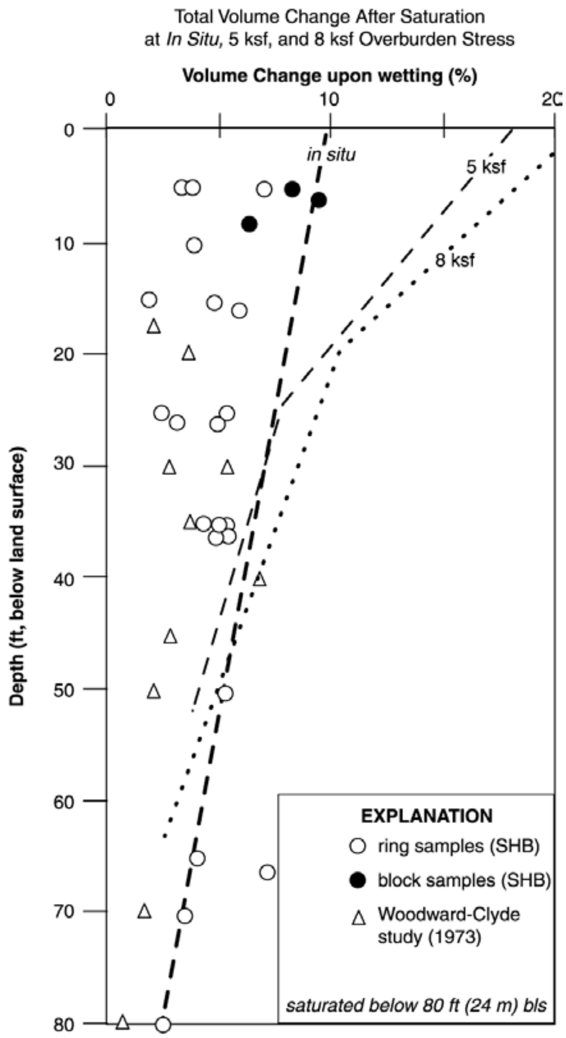

Figure 2-15. Plot of percent consolidation of cored sediment upon saturation with water. From technical report by Seargent, Hauskins & Beckwith (1983)

61.4 **STOP 2-5.** Crest of hill. Turn around and park on right (east) side of road. Walk toward borrow pit to at northeast part of road. Near eastern pinchout of eastern-margin piedmont deposits over ancestral Rio Grande. *Albuquerque East 7.5' quadrangle: GPS, NAD 83, Z 013S, N: 3,875,250 m; E: 354,345 m.*

Recent unpublished geologic mapping of Tijeras Arroyo (Fig. 2-16) delineates the presence of western-fluvial, axial-fluvial, and eastern-piedmont deposits. Gravel from these three major lithofacies assemblages have been studied and indicate that comparing the proportions of metaquartzite can quite easily differentiate among these facies, as can comparisons to chert to sandstone, volcanic, or crystalline rocks (Fig. 2-17).

Gravel was compared among the three lithofacies assemblages. Strong clustering is recognized in comparisons of chert and metaquartzite to sandstone, volcanic, and plutonic/metamorphic constituents (Fig. 2-17). The western fluvial lithofacies assemblage (Arroyo Ojito Fm) contains abundant volcanic tuff, fine-grained red granite, sandstone, and Pedernal chert, whereas the ancestral Rio Grande lithofacies contains abundant volcanic tuffs and well-rounded metaquartzite clasts. These metaquartzite clasts are white, gray, pink, or bluish-purple and are often bedded. Although granites, sedimentary rocks, and Pedernal chert can be found in ancestral Rio Grande deposits, they are not common. Piedmont deposits contain abundant crystalline (plutonic/metamorphic) and sedimentary clasts, and generally lack volcanic detritus in the study area. Chert comprises between 30-60% of the western fluvial lithofacies, and about 2-8% of the axial-fluvial deposits. Metaquartzite is almost entirely composed of the well-rounded metaquartzite variety, comprises between 30-85% of the axial-fluvial lithofacies. In contrast, metaquartzite is a minor constituent of western-fluvial deposits. Volcanic gravel is nearly absent in the eastern-piedmont lithofacies, but is abundant in the western-fluvial and axial-fluvial assemblages. Sedimentary clasts (mostly sandstone) comprise about 35-40% of the western-fluvial lithofacies gravel, but are nearly absent in the axial-fluvial assemblage. Sandstone is locally recognized along the margins of the axial-fluvial assemblage, but only comprises a minor component of those deposits. The absence of the sedimentary component within the piedmont lithofacies in the study area is related to the composition of drainage basins that originate on the footwall uplifts of the Sandia and Manzanita Mts. Plutonic/metamorphic gravel is present in the axial-fluvial and western-margin deposits in similar proportions and comprises the bulk of the piedmont composition in the study area; however, sedimentary gravel is a dominant constituent elsewhere along the piedmont, indicating that the lithologic composition of eastern-margin drainages depends upon on composition of upland drainages.

Discrimination among lithofacies assemblages is best expressed in the ternary relationship among chert-metaquartzite-plutonic/metamorphic and chert-metaquartzite-sedimentary rocks (Figs. 2-17). The field of variation for two standard deviations, around the mean composition, indicates no overlap of the three lithofacies assemblages if chert and metaquartzite are compared to sandstone and volcanic constituents. Strong clustering is also observed in comparisons of chert-metaquartzite-volcanic and to a lesser extent when chert and metaquartzite are combined. The weakest clustering occurs where chert+metaquartzite as compared to other constituents in the absence of the sedimentary component. This is because sedimentary detritus makes up a large component of the western-fluvial lithofacies assemblage.

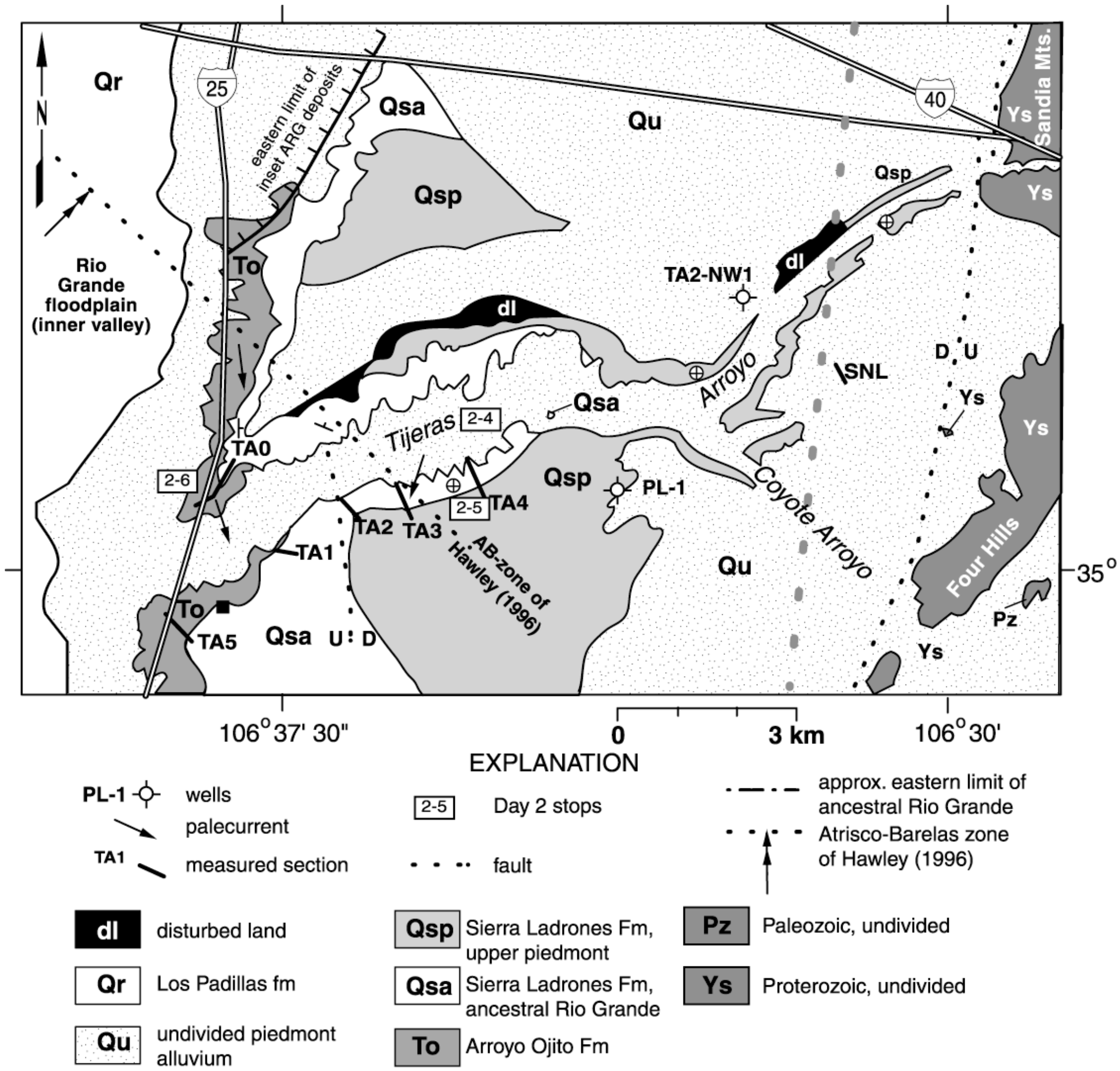

Figure 2-16. Simplified geologic map of Tijeras Arroyo and vicinity (modified from Connell et al., 1998b; Connell, unpubl.; Maldonado et al., *in prep*.).

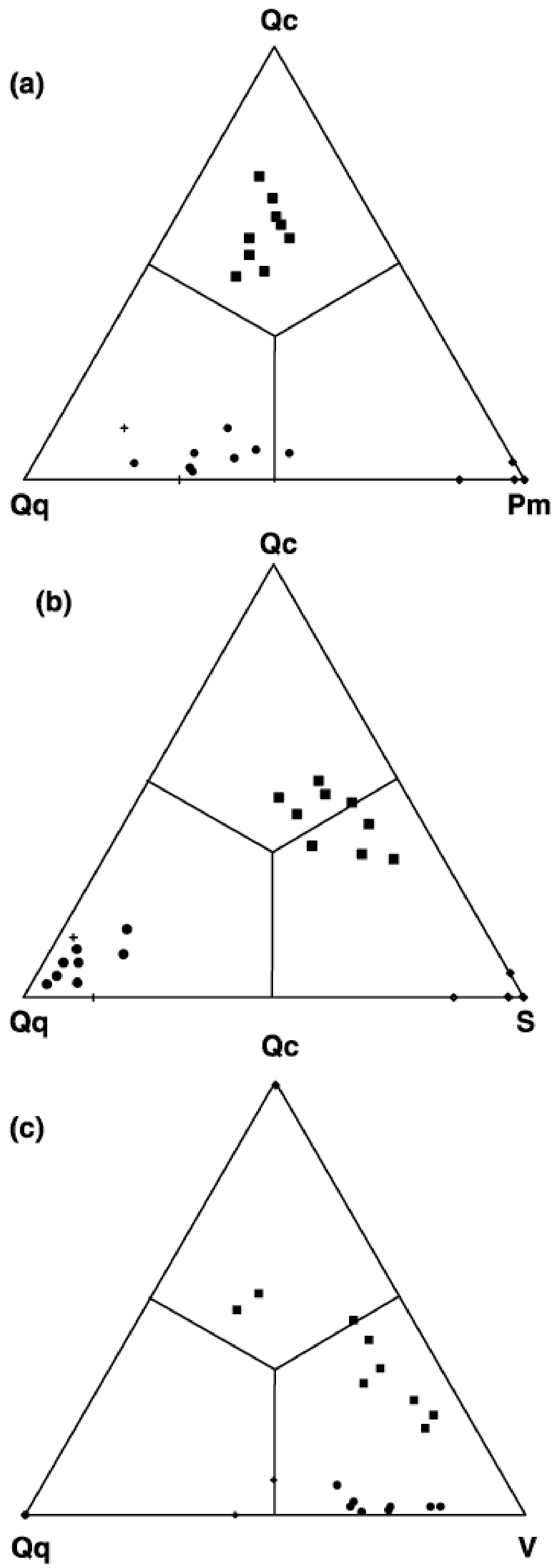

Figure 2-17. Ternary discrimination diagrams of detrital modes of gravel from stratigraphic localities in the southern Albuquerque and Isleta areas. Solid squares, circles, and diamonds indicate western fluvial, axial-fluvial, and eastern piedmont lithofacies assemblages, respectively. The open square, open circle, and "x" denote the mean of the western fluvial, axial-fluvial, and eastern piedmont lithofacies assemblages, respectively. The "+" and open diamond indicate compositions of younger inset (post-Santa Fe Group) fluvial deposits of the ancestral Rio Grande, and Tijeras Arroyo alluvium, respectively. Comparisons of chert (Qc) and quartzite (Qq) to plutonic/metamorphic (Pm) (a) and sandstone (S) (b) constituents indicate the strongest clustering. Comparisons of chert and quartzite to volcanic (V) constituents (c) indicates some overlap of fields of variation.

The spatial variations of lithofacies assemblages in Tijeras Arroyo indicate progradation of the eastern-margin piedmont over the ancestral Rio Grande deposits. Eastern piedmont deposits, which are quite sandy at this stop, pinch out into sandstone about 1.5 km to the west, between TA1 and TA2 (Fig. 2-18). Multiple soils exposed at this site merge into a single soil less than 1.5 km to the west.

Stratigraphic relationships at this stop support the presence of a progradational wedge of early Pleistocene sediment that onlaps onto older sediments of the Arroyo Ojito Fm. Drillhole data also do not support the presence of a buttress unconformity bounding the eastern side of a 6-10 km wide early Pleistocene fluvial terrace as proposed by Cole et al. (2001a, b) and Stone et al. (2001a, b).

Drive towards mouth of Tijeras Arroyo at Bobby Foster-Los Picaros intersection. **3.6**

65.0 Turn right (west) onto Bobby Foster Rd. **0.2**

65.2 Note abundant anthropogenic auto-recyclic deposits at mouth of Tijeras Arroyo. **0.4**

65.6 Turn right (north) onto South Broadway (NM-47). **0.7**

66.3 Turn right (east) onto long dirt driveway at 4500 Broadway SE. The gate may be locked. **0.1**

66.4 Pass through gate. **0.2**

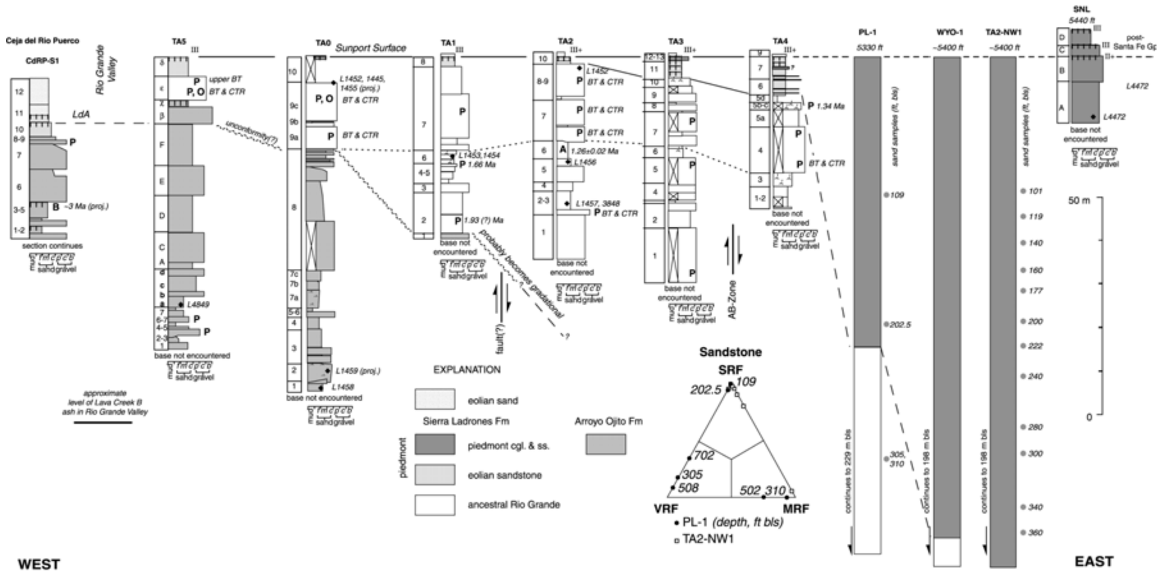

Figure 2-18. Fence diagram of stratigraphic sites for Day 2. Horizontal distances are not to scale. Note westward progradation of eastern-margin piedmont and ancestral Rio Grande deposits. The eastern thickening wedge of piedmont deposits are interpreted from drillhole data from wells on the Sandia National Laboratories. Some of the lithologic interpretations are constrained by sandstone petrography, which shows the proportions of sandstone (SRF), volcanic (VRF), and metamorphic (MRF) rock fragments in these wells (Thomas et al., 1995). The piedmont facies here contain no volcanic detritus, therefore the presence of such material indicates ancestral Rio Grande or Arroyo Ojito sediments. Because of the location of these wells near the eastern side of the basin, the deposits are likely ancestral Rio Grande.

66.6 **STOP 2-6.** Gravel quarry near mouth of Tijeras Arroyo. Walk to northern margin of Tijeras Arroyo along Railroad tracks. Park on north side of gravel quarry. *Albuquerque West 7.5' quadrangle, GPS, NAD 83, UTM Zone 013 S; N: 3,875,400 m; E: 345,000 m.* Walk east to abandoned railroad tracks and under the I-25 overpass to examine the nature and stratigraphic context of the contact between the axial-fluvial Rio Grande and underlying Arroyo Ojito Fm.

Lucas et al. (1993) measured a section at the mouth of Tijeras Arroyo to document the stratigraphic positions of a Pliocene (*medial* Blancan) and numerous early Pleistocene (early Irvingtonian) fossil localities exposed in the arroyo. They suggested the possibility of an unconformity in this section, based mainly on absence of late Blancan fossils and because of an inferred unconformity between Pliocene and lower Pleistocene fluvial sediments near San Antonio, New Mexico (Cather and McIntosh, 1990), in the Socorro Basin, about 140 km to the south. At San Antonio, exposures of pumice-bearing ancestral Rio Grande deposits at the Bosquecito pumice site contain pumice of the lower Bandelier Tuff. This deposit was originally interpreted to be inset against older non-pumiceous deposits of the ancestral Rio Grande (Cather and McIntosh, 1990). Later work, however, demonstrated that this relationship was the result of faulting, and not due to Plio-Pleistocene entrenchment (Dunbar et al., 1996, p. 70). Lucas et al. (1993) note the presence of pumice low in the section that may have represented this unconformity at Tijeras Arroyo. The lowest exposure of pumice in the section would presumably mark the onset of early Pleistocene sedimentation (i.e., contains clasts of Bandelier Tuff). However, the presence of Pliocene-age pumice pebbles in the Arroyo Ojito Fm (see Stop 2-2) indicates that caution must be used in determining age and provenance on the basis of pumice clasts as the sole criterion.

Geologic mapping and preliminary results of gravel and sand petrography indicate that the lower part of the succession at this stop is correlative to the Arroyo Ojito Fm (Fig. 2-16, 2-17; Connell et al., 1998b; Connell and Derrick, unpubl. data). Deposits of the Arroyo Ojito Fm contain sparse scattered pumice pebbles and are overlain by pumice-bearing sand and gravelly sand deposits of the ancestral Rio Grande that are about 20 m below the Sunport surface. Tephra in this upper succession are correlated to the early Pleistocene Bandelier Tuff and Cerro Toledo Rhyolite (Jemez volcanic field) and were laid down by the ancestral Rio Grande during early Pleistocene time. These stratigraphically higher deposits contain early Irvingtonian (early Pleistocene) mammals (Lucas et al., 1993). The ancestral Rio Grande deposits contain more abundant rounded quartzite than the underlying deposits, which contain abundant chert and sandstone clasts. An ash dated at 1.26 Ma is several meters below the top of the ancestral Rio Grande section in an exposure along the southern margin of Tijeras Arroyo.

During repeated reconnaissance of Tijeras Arroyo between 1998-2001, we mapped the geology of the arroyo and re-measured the stratigraphic section of Lucas et al. (1993; Fig. 2-19). Five additional stratigraphic sections supplemented this section in order to document lateral variations in facies (Fig. 2-18). Lucas et al. (1993) recognized, but did not differentiate, two distinct facies in this section. We concur with their observation and have differentiated these facies on our stratigraphic column. At the mouth of Tijeras Arroyo, early Pleistocene-aged, pumice-bearing sand and gravel of the ancestral Rio Grande (Sierra Ladrones Fm) overlie deposits of the Arroyo Ojito Fm.

Comparisons of these two sections indicate significant discrepancies (Fig. 2-19). With the help of Spencer Lucas, we correlated units of the Lucas et al. (1993) section into our recent profile. Comparisons of these marker beds indicate that the overlying Sierra Ladrones Fm is much thinner than portrayed by Lucas et al. (1993). This discrepancy is likely due to mis-correlations of fine-grained marker beds and associated fossil localities into this section and facies variations.

A rich mammalian fossil locality was recently discovered by S. Connell along the southern margin of Tijeras Arroyo at a road cut along I-25. Preliminary studies of this locality indicate a likely *medial* Blancan age (G. Morgan, 2001, personal commun.). This fossil-bearing unit projects to unit 4 of Lucas et al. (1993), which is stratigraphically higher than the unit 2-3 contact of Lucas et al. (1993) (Fig. 2-18).

Aside from the distinctive lithologic changes in the section, there is little evidence for a major unconformity or scour in these exposures. Deposits of the underlying Arroyo Ojito Fm do not contain strongly developed paleosols, however, pauses in sedimentation may be inferred by the presence of locally extensive cemented sandstone intervals and rhizoconcretionary mats. The lack of a buried pedogenic counterpart to the Llano de Albuquerque suggests that some erosion of the top of the Arroyo Ojito Fm has occurred in the Tijeras Arroyo area.

An examination of exposures in Tijeras Arroyo (Fig. 2-18) indicates that the Arroyo Ojito/Sierra Ladrones contact dips to the east and ancestral Rio Grande deposits thicken appreciably to the east. Age constraints in the upper part of the Arroyo Ojito Fm are poor, but the presence of a fluvially recycled pumice at 2.58 Ma indicates that the upper part of the Arroyo Ojito section is younger than 2.58 Ma. Early Pleistocene deposits of the ancestral Rio Grande overlie these deposits. Stratigraphic relationships strongly suggest the presence of an unconformity between these two deposits, which is consistent with angular relationships between these units observed near faults to the south (Fig. 2-20).

Studies of gravel composition (Fig. 2-17) and the discovery of this *medial* Blancan fossil locality support the presence of an unconformity as speculated by Lucas et al. (1993); however, this probable unconformity is stratigraphically higher (at the unit 9/8 contact in TA0, Fig. 2-19) than their reported lowest occurrence of pumice in the section (unit 3 of Lucas et al., 1993). The stratigraphically lower pumice pebbles are likely correlated to the suites of Pliocene-aged pumice pebbles found in the Arroyo Ojito Fm to the south and west, rather than being associated with the early Pleistocene Bandelier Tuff.

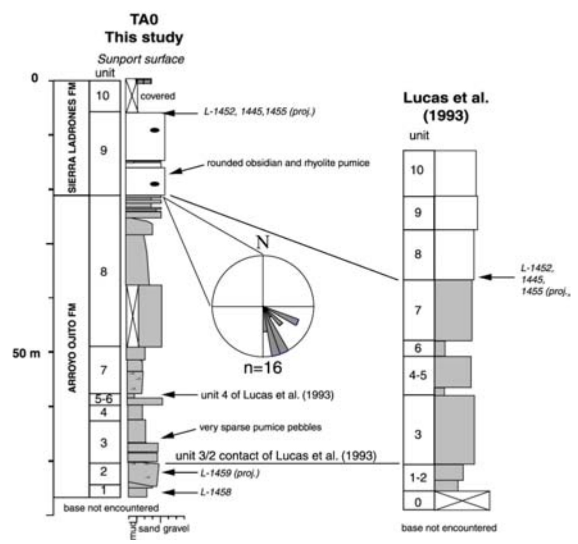

Figure 2-19. Comparison of stratigraphic sections measured at the same location at the northern mouth of Tijeras Arroyo. Left: stratigraphic section TA0. Right: Stratigraphic section of Lucas et al. (1993). Paleocurrent data from the top of the exposed Arroyo Ojito Fm indicates flow to the south-southeast.

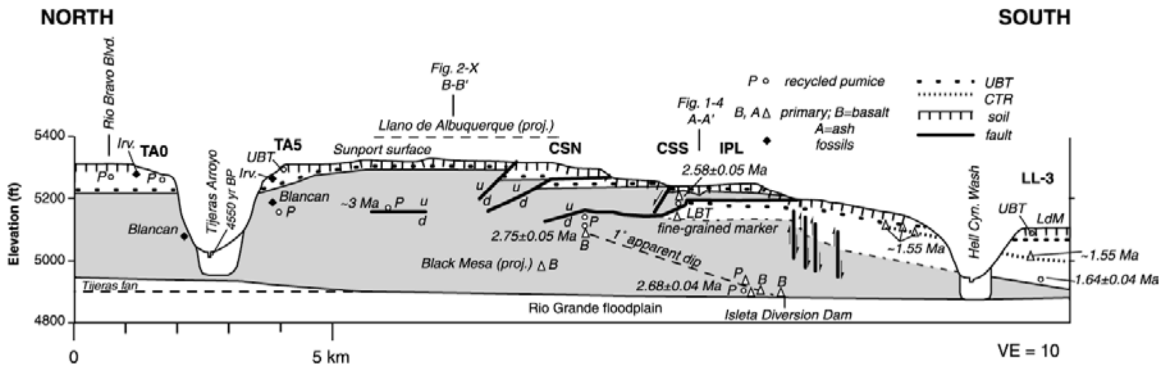

Figure 2-20. Cross section between Rio Bravo Blvd and Hell Canyon Wash showing southward apparent dip of Arroyo Ojito Fm and the preservation and southward thickening of ancestral Rio Grande deposits. Angular unconformity beneath thin ancestral Rio Grande deposits between Tijeras and Hell Canyon arroyos is due to erosion of an intrabasinal horst block. About 100 m of sediment is preserved between 2.7 Ma and 1.6 Ma tephras. About 12-45 m of ancestral Rio Grande deposits that post-date emplacement of a Cerro Toledo Rhyolite ash (~1.55 Ma) are exposed at the mouth of Hell Canyon Wash. This cross section is sub-parallel to faults (shown as bold lines), which have shallow apparent dips.

This unconformity, however, is probably not associated with a Plio-Pleistocene entrenchment event, but rather may represent progressive westward onlap of axial-river facies. Drillhole data to the east of the Tijeras Arroyo measured sections do not support the presence of any significant buttress unconformity between the pumice-bearing ancestral Rio Grande deposits and older basin fill (see Fig. 2-18). This interpretation is supported by studies of the Sandia National Labs by GRAM Inc. and William Lettis and Associates (Thomas et al., 1995) that document interfingering of axial-river and piedmont deposits in the subsurface. The age and stratigraphic significance of such intraformational unconformities is still ambiguous, but ongoing work on the biostratigraphy and pumice pebble correlation should constrain this.

Deposits of the Sierra Ladrones Fm prograde westward and overlie this unconformity with the underlying Arroyo Ojito Fm. Although the stratigraphically significant relationships are buried to the east by Pleistocene fluvial deposits of the ancestral Rio Grande, the geometry of these sediments suggests westward onlap of the Rio Grande over eroded remnants of the Llano de Albuquerque. With few exceptions, deposits of the ancestral Rio Grande are not present west of the Rio Grande Valley, but are quite thick to the east. The location of the Rio Grande Valley could be explained by westward progradation of eastern-margin piedmont deposits and onlap of the Rio Grande during early Pleistocene. During this westward onlap, the Rio Grande entrenched into older basin fill and developed the present valley. This hypothesis is currently being tested by additional field work and dating.

Westward progradation of axial-fluvial and eastern-margin piedmont deposits is recognized along most of the eastern margin of the basin from Isleta Reservation to north of San Felipe Pueblo, about 45 km to the north. Exposures of western, axial, and eastern facies are well exposed in the southern Santo Domingo sub-basin, near San Felipe Pueblo (Fig. 2-21). Pliocene basaltic flows of Santa Ana Mesa and various fluvially recycled and primary tephra constrain the ages of deposits. Stratigraphic sections measured on San Felipe Pueblo document the presence of lithologically indistinguishable pre-2.58 Ma and pre-1.55 Ma vintage ancestral Rio Grande deposits. No unconformities are recognized in the section; however, deposits of the ancestral Rio Grande appear to pinchout to the west and probably buried only part of the eastern edge of the ~1.77-2.58 Ma flows of Santa Ana Mesa (Fig. 2-22).

A significant problem with defining the end of basin aggradation is presented in attempting to correlate unconformities formed along the basin margin, on the up-dip portions of half-graben or asymmetric basins into basin depocenters (see Connell et al., 2001c). Differentiation of stratal discontinuities within deposits of the ancestral Rio Grande would be ambiguous at best, and arbitrary at worst.

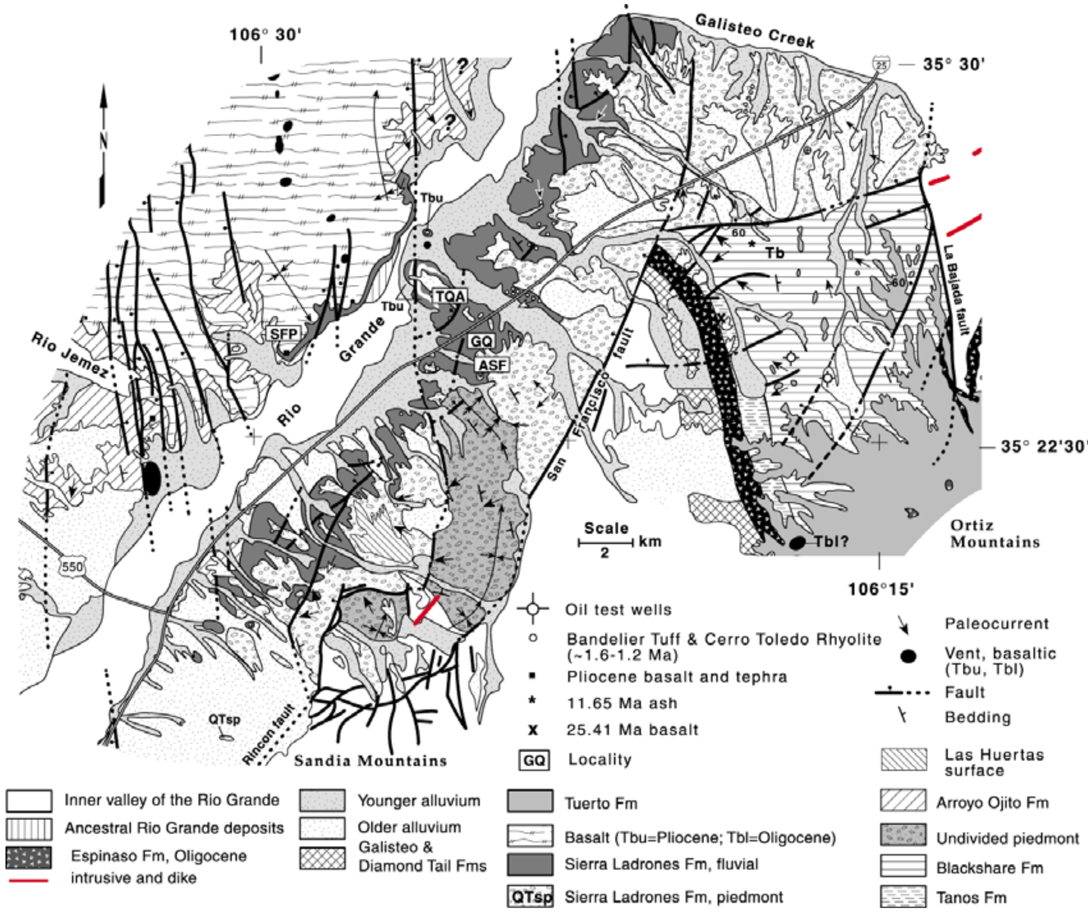

Figure 2-21. Simplified geologic map of the southeastern Santo Domingo sub-basin, illustrating locations stratigraphic sections in San Felipe Pueblo. Compiled from Cather and Connell (1998), Cather et al. (2000), Connell, (1998), Connell et al. (1995), and unpublished mapping.

Pre-Pleistocene deposition of the ancestral Rio Grande is well documented in southern New Mexico, where the earliest appearance is between 4.5 to ~5 Ma (Mack et al., 1996; Mack, 2001). In the San Felipe area, gravel-bearing ancestral Rio Grande deposits are recognized beneath the 1.77-2.58 Ma basalts on the southeastern flank of Santa Ana Mesa.

The earliest documented appearance of a probable ancestral Rio Grande deposits in the Albuquerque Basin is near the northern end at Tent Rocks, where metaquartzite-bearing pebbly sandstone is associated with 6.9 Ma tephra of the Peralta Tuff of the Bearhead Rhyolite (Smith et al., 2001).

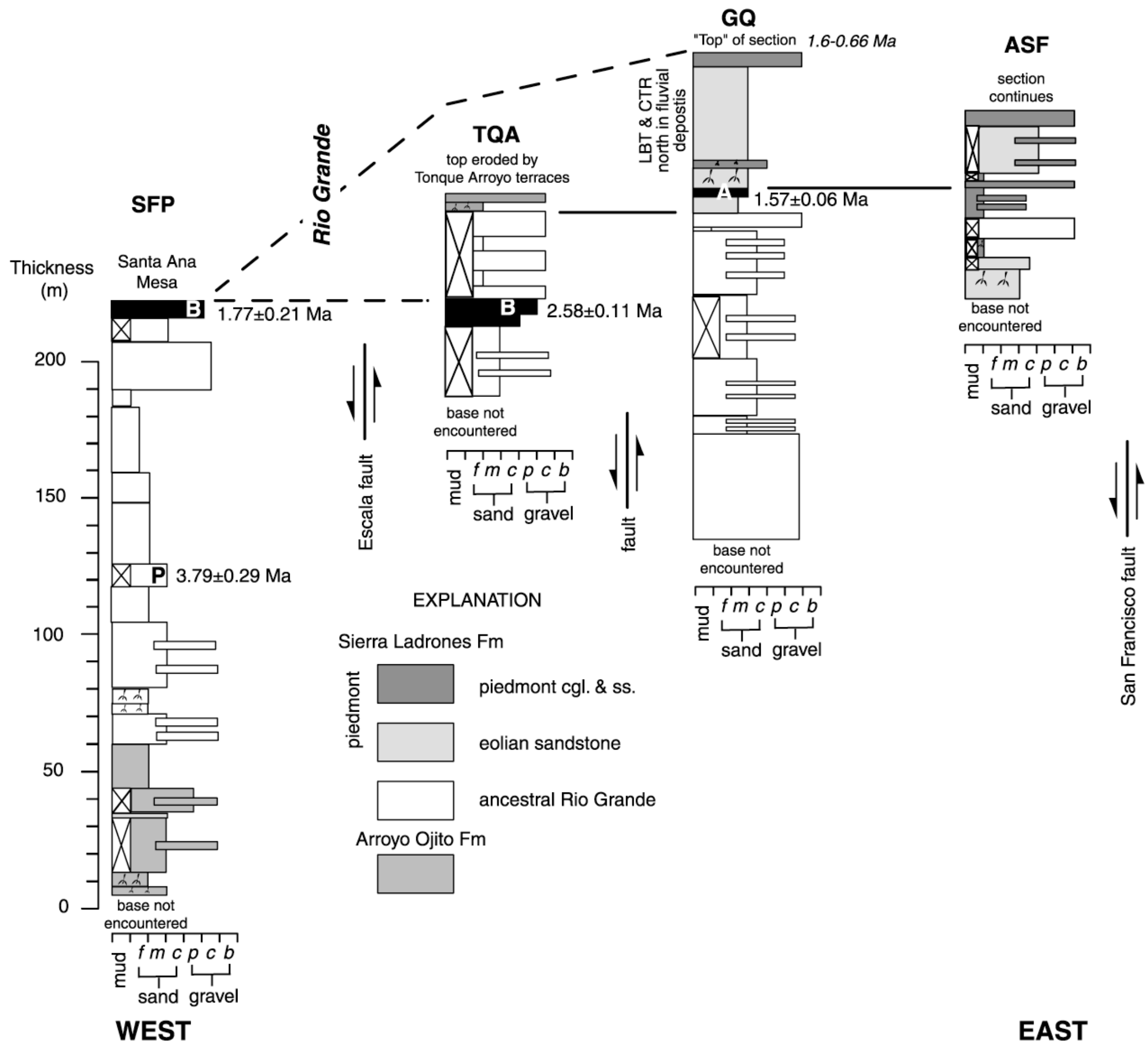

Figure 2-22. Fence diagram on San Felipe Pueblo illustrating stratigraphic relationships among western-fluvial, axial-fluvial, and eastern-margin piedmont deposits (Derrick and Connell, 2001; Derrick, unpubl. data). Santa Fe Group deposits pinchout onto the eastern edge of Santa Ana Mesa. See Figure 2-22 for locations of sections.

If incision of basin fill is climatically driven, then the proposed late Pliocene entrenchment proposed by Stone (2001a, b) and Cole (2001a, b) should be regional in nature. Comparisons of the stratigraphy of the Albuquerque Basin with radioisotopically and paleomagnetically well dated comparable successions of the southern Rio Grande rift (Fig. 2-23; Mack et al., 1993, 1996; Mack, 2001) indicate the presence of nearly continuous aggradation until about 800 ka, when the Rio Grande Valley cut. In the tectonically quiescent part of a southern Basin and Range in southeast Arizona, Smith (1994) documents basin aggradation of the St. David Fm during Pliocene and early Pleistocene times (Fig. 2-23). Thus, it seems reasonable to speculate that this early Pleistocene entrenchment might be climatically driven. However, there is little evidence for the presence of a regional climatically induced unconformity in these basins. These basins tend to coarsen upsection, suggesting that the increased caliber of sediment might be attributed to climate, which presumably became more competent during the late Pliocene. The nature of these stratigraphic changes will no doubt be of continued interest and study.

Return to NM-47. End of Day-two road log.

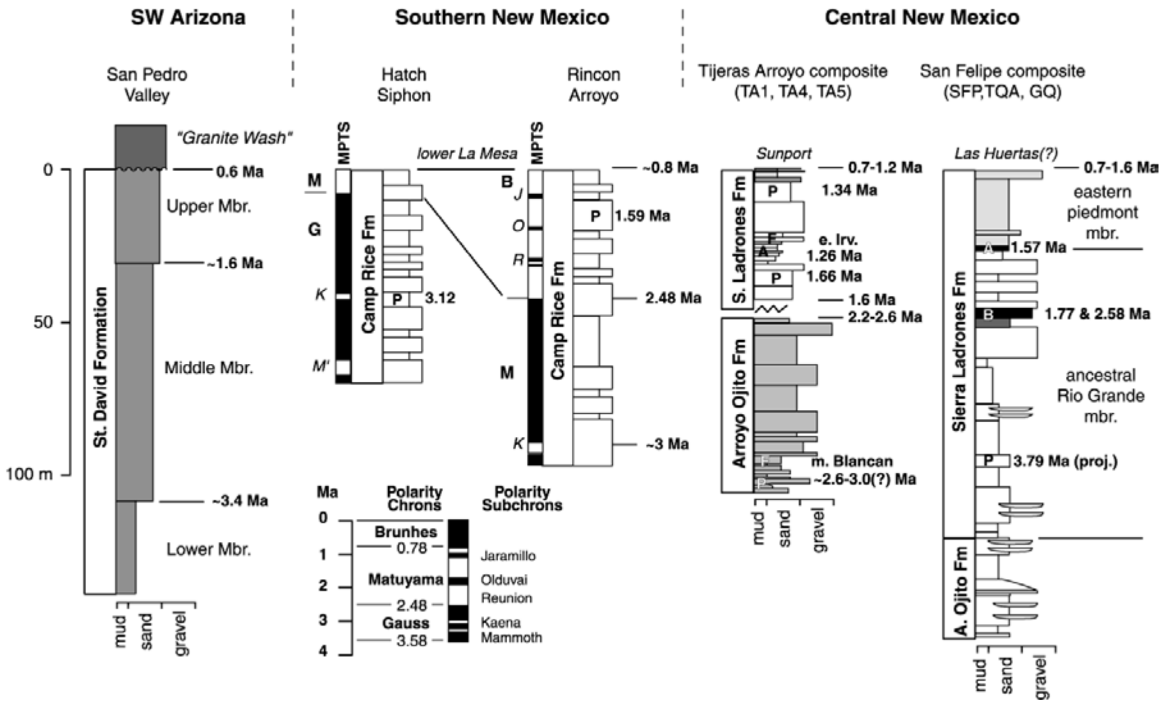

Figure 2-23. Comparison of upper Pliocene and lower Pleistocene alluvial successions in the southern Rio Grande rift, New Mexico, and southeastern Arizona (Smith, 1994; Mack et al., 1993, 1996; Connell, Love, Derrick, unpubl. data). The earliest documented occurrence of the ancestral Rio Grande may be as early as 4.5 or ~5 Ma in southern New Mexico (Mack et al., 1996; Mack, 2001). Entrenchment of the Santa Fe Group is recorded by development of the Rio Grande Valley and the development of constructional surfaces, such as the lower La Mesa surface in southern New Mexico. Aggradation of the St. David Fm is recorded in a tectonically quiescent basin in southeastern Arizona to ~0.6 Ma.