New Mexico Geological Society

Downloaded from: https://nmgs.nmt.edu/publications/guidebooks/37



Upper Cenozoic Palomas Formation of south-central New Mexico

Richard P. Lozinsky and John W. Hawley
1986, pp. 239-247. https://doi.org/10.56577/FFC-37.239

in:

Truth or Consequences Region, Clemons, R. E.; King, W. E.; Mack, G. H.; Zidek, J.; [eds.], New Mexico Geological Society 37th Annual Fall Field Conference Guidebook, 317 p. https://doi.org/10.56577/FFC-37

This is one of many related papers that were included in the 1986 NMGS Fall Field Conference Guidebook.

Annual NMGS Fall Field Conference Guidebooks

Every fall since 1950, the New Mexico Geological Society (NMGS) has held an annual Fall Field Conference that explores some region of New Mexico (or surrounding states). Always well attended, these conferences provide a guidebook to participants. Besides detailed road logs, the guidebooks contain many well written, edited, and peer-reviewed geoscience papers. These books have set the national standard for geologic guidebooks and are an essential geologic reference for anyone working in or around New Mexico.

Free Downloads

NMGS has decided to make peer-reviewed papers from our Fall Field Conference guidebooks available for free download. This is in keeping with our mission of promoting interest, research, and cooperation regarding geology in New Mexico. However, guidebook sales represent a significant proportion of our operating budget. Therefore, only *research papers* are available for download. *Road logs*, *mini-papers*, and other selected content are available only in print for recent guidebooks.

Copyright Information

Publications of the New Mexico Geological Society, printed and electronic, are protected by the copyright laws of the United States. No material from the NMGS website, or printed and electronic publications, may be reprinted or redistributed without NMGS permission. Contact us for permission to reprint portions of any of our publications.

One printed copy of any materials from the NMGS website or our print and electronic publications may be made for individual use without our permission. Teachers and students may make unlimited copies for educational use. Any other use of these materials requires explicit permission.

This page is intentionally left blank to maintain order of facing pages.

UPPER CENOZOIC PALOMAS FORMATION OF SOUTH-CENTRAL NEW MEXICO

RICHARD P. LOZINSKY and JOHN W. HAWLEY
New Mexico Bureau of Mines & Mineral Resources, Socorro, NM 87801

Abstract—Upper Santa Fe Group deposits occurring in the Palomas, Engle, and San Marcial Basins of the southern Rio Grande rift are here named the Palomas Formation. The term "Palomas gravel" was first applied to Plio-Pleistocene basin fill in the region in 1907; however, the formation has never been formally defined. It consists mainly of alluvial-fan and coalescent-fan deposits (piedmont facies) and ancestral Rio Grande fluvial deposits (axial-river facies). Maximum thicknesses range from 100 to locally more than 130 m. Formation deposition probably began prior to 5 my and continued until 400,000–500,000 years ago. The formation can be distinguished from other upper Santa Fe Group deposits by its extensive piedmont facies and relatively narrow belt of axial-river deposits. Older Santa Fe units (Miocene–latest Oligocene), which do not contain axial-river facies, occupy remnants of early rift basins that predate development of the present system of basins and uplifts.

INTRODUCTION

Upper Cenozoic basin fill in the Rio Grande rift is generally referred to as the Santa Fe Formation or Group, a term first proposed by Hayden (1873) for deposits in the Santa Fe area. Cope (1883, quoted by Kelley & Silver 1952) suggested that equivalent deposits occur in the Caballo area. The first definitive statement about the southern extension of the Santa Fe formation was by Bryan (1938: 205): "The main body of sedimentary deposits of the Rio Grande depression, from the north end of San Luis Valley to and beyond El Paso, is considered to be the same general age and to belong to the Santa Fe formation." Kottlowski (1953, 1958, 1960) informally proposed that the Santa Fe be raised to group status and subdivided it into two units: the lower Santa Fe Group of general late Tertiary age and the upper Santa Fe Group mainly of early to mid-Quaternary age. Baldwin (*in* Spiegel & Baldwin 1963: 38–39) formally proposed that the formation be raised to group status and considered the group "to be a broad term including sedimentary and volcanic rocks related to the Rio Grande trough, with a range in age from middle(?) Miocene to Pleistocene(?)." Hawley et al. (1969) reviewed the status of research on the Santa Fe Group and first described reference sections in Doña Ana County.

Once raised to group status and with more detailed mapping, it became necessary to subdivide the Santa Fe into formations (Hawley 1978: charts 1, 2). Thus, the upper Santa Fe Group has been subdivided into the Camp Rice and Fort Hancock Formations in the Mesilla and Hueco Bolson areas of New Mexico and Texas by Strain (1966, 1969), the Camp Rice Formation in the Rincon Valley–Jornada Basin area by Seager et al. (1971), and the Sierra Ladrones Formation in the Socorro and Albuquerque Basins by Machette (1978a, b). Recently, the gap in detailed mapping of the upper Santa Fe Group deposits in the Palomas, Engle, and San Marcial Basins has been partially filled by Lozinsky (1982, 1986). In a study of the Elephant Butte area, Lozinsky proposed the name Palomas be formally used to designate upper Santa Fe Group deposits in his mapped area. The objectives of this paper are to expand upon the description of the type Palomas Formation and to recommend that the formation comprise all upper Santa Fe Group deposits in the Palomas, Engle, and San Marcial Basins.

The concept of calling the upper Santa Fe Group the "Palomas" in this region is not new (Keroher 1966: 2906). Gordon & Graton (1907) and Gordon (1910: 237, pl. XII) initially referred to the basin-fill deposits cropping out along Palomas Creek as the "Palomas gravel." Harley (1934: 29) also referred to these deposits as the Palomas gravels and believed that they were younger than much of the Santa Fe formation occurring elsewhere along the Rio Grande. Kottlowski (1953, 1955) and Jahns (1955a, b) described the "Palomas gravels" as a unit that intertongued with upper Santa Fe strata. They also discussed the geomorphic surfaces in the area (Cuchillo and Palomas) that capped or truncated the Palomas gravels. However, Kelley & Silver (1952) followed Bryan's (1938) terminology in designating the basin-fill (exclusive of "valley fill and pediment-capping gravel") as Santa Fe formation. In addition, they named the extensive high-level "erosion surface" capping the Santa Fe formation the "Palomas surface" and correlated it with the Cuchillo surface to the north and the Jornada and La Mesa surfaces to the east and south of the Palomas Basin.

In ground-water studies of the Palomas and Animas Creek Basins, Murray (1959: 7–8) and Davie & Spiegel (1967: 9) recognized that exposed basin-fill deposits are the "Palomas gravels." The latter authors include these deposits in the "upper part of the Santa Fe group" and show that the unit comprises alluvial-fan (piedmont), axial-river, and transitional facies. The U.S. Geological Survey (Heyl et al. 1983) recently used the term "Palomas Gravel" to designate "purplish-gray gravel and sand about 300 m thick" exposed along and between Alamosa and Cuchillo Negro Creeks in the northwestern part of the Palomas Basin. However, their map unit may include basin fill that is part of the lower Santa Fe Group.

Despite long usage, the name Palomas has never become fully adopted, no type section has ever been described, nor has the rock-stratigraphic unit been formally defined. Due to its varied lithologic character, the Palomas is here designated as a formation rather than a gravel.

LOCATION AND GEOLOGIC SETTING

The Palomas, Engle, and San Marcial Basins are located in the southern part of the Rio Grande rift and cover an area of about 1,400, 1,200, and 1,200 km^2, respectively (Fig. 1). These basins are filled with up to 2,000 m of upper Tertiary–Quaternary Santa Fe Group sediments. The northeast-tilted Mud Springs uplift separates the eastward-tilted Engle and Palomas Basins. The eastern margin of the basins is defined by the Fra Cristobal–Cutter sag–Caballo uplifts. These uplifts (including the Mud Springs) contain Precambrian igneous and metamorphic rocks overlain by Paleozoic and Mesozoic sedimentary rocks. The western margin of the basins is defined by the Black Range, Sierra Cuchillo, and San Mateo Mountains, which are composed mainly of Tertiary volcanic rocks with lesser amounts of Precambrian and Paleozoic rocks.

DESCRIPTION OF THE PALOMAS FORMATION

The Palomas Formation is exposed throughout the Palomas, Engle, and San Marcial Basins (Fig. 2) and can be divided into two major facies, piedmont and axial river. Measured type and reference sections are in Appendix 1. Reference sections 4 and 5 are measured sections 2 and 1 (respectively) in Lozinsky (1986).

Piedmont facies

The piedmont facies comprises the major portion of the Palomas Formation. It rests with an angular unconformity on bedrock of varying lithologies along the major uplifts bordering the basins. However, in many central basin areas the piedmont facies appears to grade downward

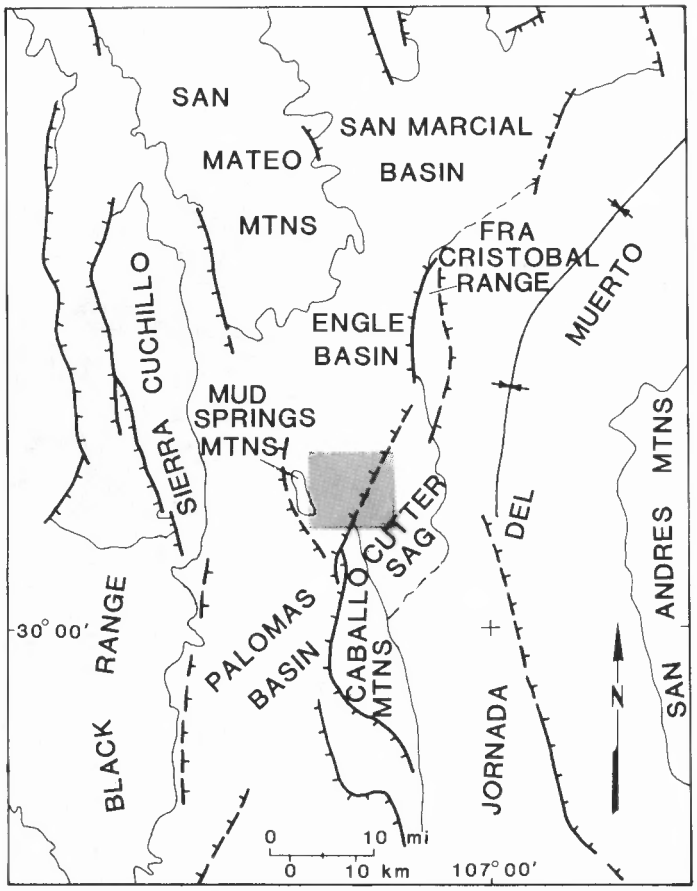


FIGURE 1—Generalized tectonic map showing basin localities. Shaded region is area covered by Lozinsky (1982, 1985). Hatched lines are normal faults (hachures on downthrown side; dashed where inferred). Solid lines delineate major uplifts. Modified from Woodward et al. (1978).

into similar coarse-grained deposits of the lower Santa Fe Group (refer to fig. 6 of Seager et al. 1984). The contact with possible lower Santa Fe beds can be observed just south of T or C in the lower part of the composite type section exposed along the Rio Grande (measured section 3). The contact is poorly exposed and shows a fanglomerate of the Palomas Formation overlying a reddish-brown silty claystone that may correlate with the Miocene Rincon Valley Formation mapped by Seager et al. (1982) south of Caballo Reservoir. However, due to the limited exposure area, the designation of the silty clay unit as Rincon Valley is not absolutely certain.

Based on lithologic character, the piedmont facies can be grouped into proximal, medial, and distal subfacies. The proximal subfacies is described in the upper part of the composite type section southeast of Las Palomas (measured section 1), in the lower part of measured section 3, and in a reference section along Cuchillo Negro Creek northeast of the Mud Springs Mountains (measured section 5). Outcrops of the proximal subfacies seldom extend more than 3 km from mountain fronts. The term proximal refers to local provenance and short transport of sediments. The proximal subfacies consists primarily of light-brown to reddish-brown, poorly sorted, lenticular to weakly stratified fanglomerates and fan gravels (Fig. 3). These deposits were laid down by debris-flow-dominated alluvial fans that derived detritus from adjacent uplifts. Thus, clast composition reflects lithologies of nearby uplifts and beds tend to coarsen and become more massive nearer to uplifts. Scattered reddish-brown clay interbeds represent argillic paleosols that locally include basal, light-colored, calcic-soil horizons. The proximal subfacies ranges from nonindurated to strongly indurated. Cliff-forming fanglomerate beds that are moderately to well cemented with calcium carbonate are commonly present in this unit.

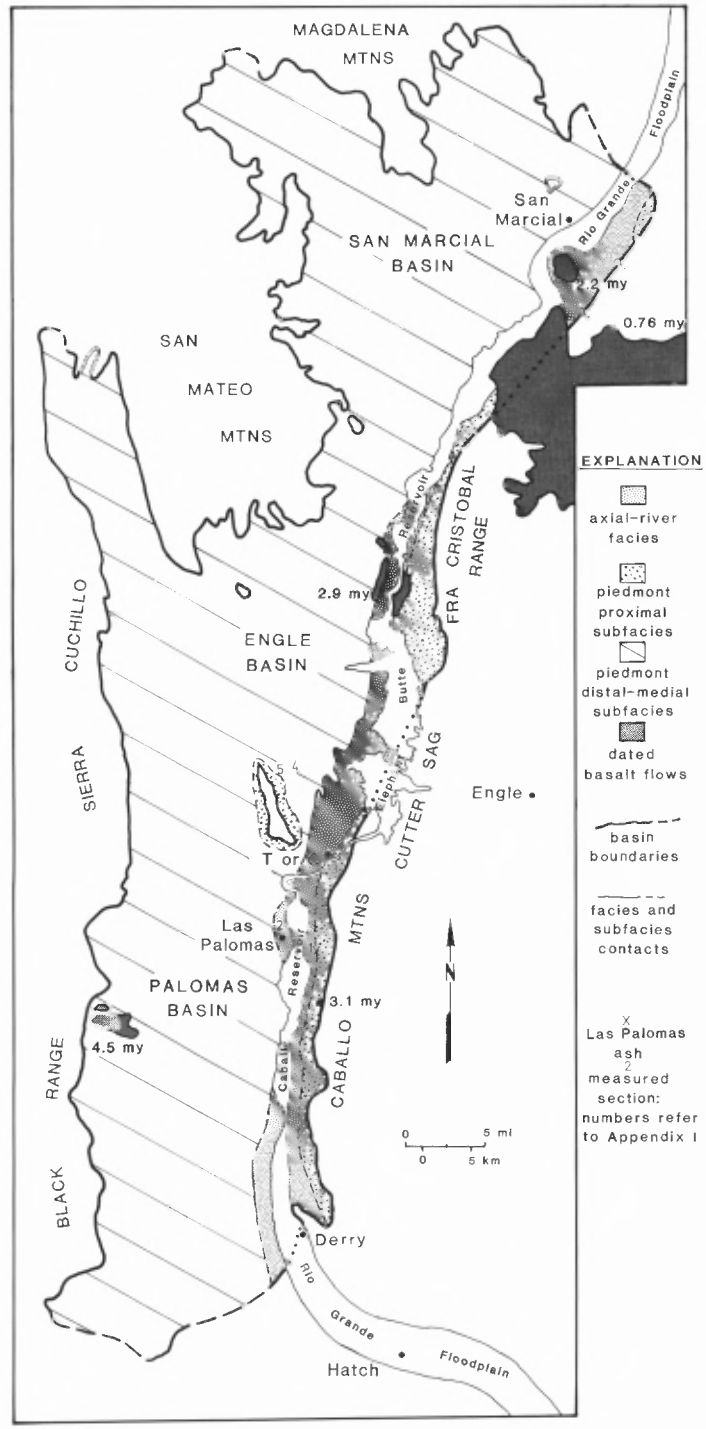


FIGURE 2—Geologic map of Palomas Formation showing locations of dated basalt flows, volcanic ash, and measured sections.

The medial and distal subfacies crops out extensively in the region between the western-margin uplifts and the Rio Grande and intertongue with proximal-subfacies deposits. The medial subfacies is transitional between the proximal and distal piedmont units. It forms a broad belt of deposits in parts of Palomas, Engle, and San Marcial Basins west of the Rio Grande valley. Excellent exposures of the medial subfacies, which mainly consists of gravelly deposits of coalescent alluvial fans, occurs in deep arroyo valleys west of I-25 between Caballo dam and San Marcial (e.g. valleys of Percha, Animas, Seco, Cuchillo Negro, Alamosa, Nogal, and Mulligan Gulch arroyos). Piedmont gravels of



FIGURE 3—Fanglomerate of proximal subfacies. Note poorly sorted and massive nature of the deposits. Clasts derived from Caballo Mountains to the east. Outcrop occurs on south side of Cuchillo Negro Creek north of T or C.

this subfacies are illustrated in Hawley (1978: 91–92) and Seager et al. (1984: fig. 6).

Distal refers to a distant source area and long transport. The distal subfacies forms most of the type section along Palomas Creek (measured section 2), and this subfacies is also described in reference section 4 and upper part of section 5. Alternating beds of light-pink to dark reddish-brown sandy silt, conglomerate, and clay comprise the distal subfacies (Fig. 4). Beds are generally better sorted, finer-grained, and better stratified than proximal-subfacies deposits. Conglomerate beds in particular show better clast rounding, are less massive, and contain a variety of mostly volcanic clasts including rhyolites, tuffs, basalts, and andesites. Interbedded argillic and calcic paleosols also occur in the distal subfacies. These deposits are interpreted to have been deposited in channels and channel margins of a large piedmont fan system that extended from the western uplifts into the basins. This is supported by clast composition and imbrication direction that indicate the source area was mainly the volcanic terranes to the west. Deposits of the distal subfacies range from nonindurated to moderately indurated and weather to form either badland topography or cliffs with resistant ledges.

Axial-river facies

This facies crops out within a 3 km wide strip that extends through the length of the three basins and roughly follows each basin axis. This fluvial facies is composed of a thick accumulation of internally cross-stratified sandstones and sands with pebble conglomerate, gravel, and clay lenses (Fig. 5), and calcite is the dominant cementing agent. The unit intertongues with the piedmont facies (parts of the composite type section are described in measured sections 1 and 2). The thickest axial-river deposit described herein (8.1 m) occurs in measured section 3;



FIGURE 4—Alternating and conglomerate and silty clay beds of distal subfacies. Clasts derived from Sierra Cuchillo and Black Range to the west. Outcrop occurs along NM-52 just east of I-25.



FIGURE 5—Crossbedded and well sorted sand of axial river facies. Outcrop located on US-85 just north of T or C.

however, fluvial sequences exposed along the Rio Grande valley are commonly much thicker (see below). The moderately to well-sorted, fine- to medium-grained sand is typically light gray and arkosic. Gravel lenses commonly occur along the bottom of trough crossbeds. Clay lenses and mudballs are scattered throughout the unit, but not in great abundance. Due to the prolific crossbeds, lack of clay, and good sorting, the unit is believed to have been deposited by an aggrading, through-flowing braided river, the ancestral Rio Grande. The nonindurated to moderately indurated character of the axial-river facies results in a low-rolling, erosional topography.

Cuchillo surface

The terms "Cuchillo" and "Palomas" have long been used to designate correlative, high-level geomorphic surfaces in the Engle and Palomas Basins (Kelley & Silver 1952: 177–178, Kottlowski 1953, 1955, Jahns 1955a, b, Hawley, 1965, 1978). Moreover, earlier workers (Gordon 1910: 221–222, Harley 1934: 22–23) specifically discussed "bolson plain" remnants in the Cuchillo area of the Engle Basin as representative of the "clinoplain" landform previously described in the Socorro area by Herrick (1904). Their maps show that these surfaces are coextensive with basin fill mapped as Palomas gravel. To avoid confusion between the rock-stratigraphic unit and informal geomorphic-surface names, the term Cuchillo is used here to designate Plio-Pleistocene surfaces that predate cutting of the present Rio Grande valley in the Palomas, Engle, and San Marcial Basins.

The Cuchillo surface is mainly a constructional surface marking the end of deposition of the Palomas Formation and ranges from late Pliocene to middle Pleistocene in age. In pediment areas along the mountain fronts, the Cuchillo surface is erosional and is capped by a thin veneer of coarse-grained deposits that are mapped as the uppermost part of the proximal-piedmont subfacies. The surface can be found along the eastern margin uplifts, but it is most extensively preserved on the west side of the Rio Grande. The surface occurs as a slightly undulating piedmont alluvial plain or bajada (formed by coalescence of fans and pediment veneers) which gently slopes between 1 and 2° to the east and southeast. Valleys of major arroyos are now deeply incised below Cuchillo surface remnants. The surface formed when aggradation of the Palomas Formation ceased due the initial incision of the Rio Grande valley. Long-term stability of the Cuchillo surface is indicated by the presence of strong calcic soils (stage III and IV carbonate accumulations, Gile et al. 1981) in uppermost deposits of the Palomas Formation.

Thickness

Limited data exist on the thickness of the Palomas Formation because no complete section through the unit has been observed in outcrop. The maximum measured thickness in the type area is about 66 m along the north side of Palomas Creek (measured section 2), but this is an incomplete section. As much as 90 m of Palomas piedmont gravels are exposed in cuts along both sides of Monticello Canyon (Hawley 1978: 91–92). An approximate thickness can be calculated by extrapolating the top of the formation to where its base may be exposed along the east side of the Rio Grande near T or C. By using this method, a minimum thickness of about 100 m is obtained.

Foster (1978: hole q) reported that the upper Santa Fe Group is 177 m thick in the Gartland 1 Brister wildcat well. However, re-evaluation of cuttings from this hole shows that determination of the base of the Palomas Formation is very difficult due to the lithologic similarity between the upper and lower Santa Fe Group piedmont facies. Therefore, it is unlikely that the formation is as thick as 177 m in this well. The best record of the Palomas Formation thickness can be obtained from the West Elephant Butte Federal 3 no. 2 wildcat well completed in 1983 by Getty Oil. This well was spudded in the axial-river facies, and preliminary examination of well cuttings shows a thickness of 131 m for this facies. Thus, the Palomas Formation ranges in thickness from 100 to at least 131 m. This is consistent with thickness estimates of the upper Santa Fe deposits (Camp Rice Formation) occurring to the south in the Jornada and Mesilla Basin area (Seager et al. 1971, Gile et al. 1981: 33).

Age of the Palomas Formation

The age of the Palomas Formation is not precisely known; however, using faunal remains, volcanic material, and correlations with other units, upper and lower age limits can be approximated.

Mastodon, *Equus simiplicidens* (horse), *Gigantocamelus* (camel), and *Tapirus* (tapir) bones of median Blancan age have been recovered from the axial-river facies along the western shore of Elephant Butte Reservoir (Tedford 1981). A 90–120 cm thick, white, diatomaceous interbed occurs in the piedmont (distal) facies just east of the Mud Springs Mountains. Diatoms identified include *Denticula elegans* var. and are perhaps of early Blancan age (J.P. Bradbury, U.S. Geological Survey, written comm. 1981). Lucas & Oakes (1986) report a Cuchillo Negro Creek fauna of medial Blancan age or about 3 my at the intertonguing contact between the piedmont and axial-river facies. The oldest faunal dates from the Palomas Formation are from Repenning & May (1986) for vertebrate fossils occurring in the lower part of the axial-river facies near T or C. These fossils include aff. *Oryzomys* (rice rat), *Prosigmodon intermedium* (cotton rat), and *Paraneotoma quadriplicatus* (pack rat), and indicate an early Blancan age between 4.05 and 4.2 my.

Dated volcanic features include scattered basalt flows in all three basins and tephra in the Palomas Basin. Their locations are shown in Fig. 2. K–Ar ages of basalt flows, unless otherwise noted, are from Bachman & Mehnert (1978).

Three dated basalt flows are located along the eastern margins of the San Marcial and Engle Basins. The oldest flow is located in the Engle Basin at the northern end of Elephant Butte Reservoir (Mitchell Point). This flow is interbedded in axial-river sand and has been dated at 2.9 ± 0.1 my. The Black Mesa flow at San Marcial overlies about 90 m of axial-river sands and has a date of 2.2 ± 0.1 my. Located just south of Black Mesa is the extensive Jornada flow which has the youngest radiometric date for the Palomas Formation at 0.76 ± 0.1 my. This flow was possibly once interbedded in the youngest member of the axial-river facies and has since become exhumed.

The Palomas Basin contains three dated volcanic units (Seager et al. 1982, 1984). The oldest, located along the western margin of the basin northeast of Animas Peak (Copper Flat), is a basalt flow dated at 4.5 ± 0.1 my. This partly exhumed flow was buried within the basin by upper Santa Fe piedmont gravels. Along the western slope of the Caballo Mountains, a basalt flow dated at 3.1 ± 0.1 my is interbedded with piedmont fanglomerates. About 6 km north of this flow is a lenticular bed of volcanic ash capping axial-river sand that intertongues with the piedmont facies (measured section 1). This ash-fall deposit is informally called the "Las Palomas ash" and has been correlated with an unspecified member of the Cerro Toledo rhyolite in the Jemez Mountains (M. Machette written comm. 1982). The Cerro Toledo eruptions occurred 1.2–1.45 my ago between emplacement of the upper and lower Bandelier Tuff (Izett 1981, Izett et al. 1981, Heiken et al. 1986). Younger ages than the 0.76 my date have not been established for the Palomas Formation, but when correlated with the Camp Rice Formation to the south, the uppermost Palomas beds may be 400,000–500,000 years old (Gile et al. 1981).

These dated sections, although restricted to a few areas, do establish a general age range for the Palomas Formation. The lower part of the axial-river facies is older than 4.2 my and parts of the piedmont facies may be significantly older than 4.5 my. The upper part is at least 1.4 my and is probably closer to 400,000–500,000 years. This indicates that the Palomas Formation was deposited over at least a 5 my time span.

DISTINGUISHING FEATURES OF THE PALOMAS FORMATION

The Palomas Formation is lithologically similar and can be correlated with two other upper Santa Fe formations, the Sierra Ladrones to the north and the Camp Rice to the south (Tab. 1). However, there are some important differences, specifically in the physiographic framework of the basins and in the mode of deposition of the fluvial facies.

The Sierra Ladrones Formation occurs in the Socorro and Albuquerque Basins. These basins have irregular boundaries and are only

TABLE 1—Comparison of Camp Rice, Sierra Ladrones, and Palomas Formation. General references: Hawley (1978), Hawley et al. (1976).

Unit (Key references)	Lithology of major facies	Geographic distribution of major facies	Age
Camp Rice Formation (Seager and Hawley, 1973) (Seager et al., 1971, 1984) (Strain, 1969) (Gile et al., 1981)	Fluvial facies—light-gray to brown sand, gravel, sandstone, and conglomerate that are internally cross-stratified. Sand is fine- to coarse-grained and is moderately well sorted. Laterally intertongues with and overlain by piedmont facies.	Very broad fan-delta complex of "fluvial" distributaries of ancestral Rio Grande on basin floor.	Ranges from late(?) Pliocene to middle Pleistocene. Contains Blancan and Irvingtonian vertebrate faunas and volcanic ashes dated at 0.6 my, 0.7 my, and 2 my.
	Piedmont facies—gravelly fan and coalescent-fan deposits containing clasts derived from adjacent uplifts.	Piedmont deposits of varying width along basin margins.	
Sierra Ladrones Formation (Machette, 1978a, b)	Axial stream deposits—light-gray to light-yellow-brown, fine- to medium-grained, crossbedded sand and sandstone. Contains green clay beds, reworked clay balls, and sparse pebbly to gravelly channels. Laterally intertongues with and overlain by piedmont deposits.	Very broad belt of "axial stream" deposits, including ancestral Rio Grande and major tributary streams, on basin floor.	Ranges from early Pliocene to middle Pleistocene. Contains Blancan invertebrate fauna and volcanic ashes dated at 1.45 my and a basalt flow occurring near base dated at 4.5 ± 0.1 my.
	Piedmont deposits—light brown to light red brown sandstone and fanglomerate; medium to massively bedded; containing clasts derived from adjacent uplifts.	Piedmont deposits of varying width along basin margins.	
Palomas Formation (this study)	Axial river facies—light-gray to buff, moderately well sorted, fine- to coarse-grained sand that is crossbedded and contains gravel lenses. Green and red clay lenses and mudballs also occur. Overlies, laterally intertongues with, and is overlain by piedmont facies.	Narrow belt of axial river deposits, ancestral Rio Grande, near eastern basin margins	Ranges from early Pliocene to middle Pleistocene. Contains Blancan faunas, basalt flows ranging in age 4.5 ± 0.1 to 0.76 ± 0.1 my, and a volcanic ash dated at 1.45 my.
	Piedmont facies—light-brown in reddish-brown sandy silt, conglomerate, and fanglomerate derived from nearby and distant uplifts.	Piedmont deposits occupy a very broad belt west of present Rio Grande valley and form a narrow strip along eastern basin margin.	

locally flanked by major uplifts. The Albuquerque Basin is also much larger than the basins containing the Palomas Formation. In addition, the axial-stream facies covers a wider area than the piedmont facies and is the dominant lithology of the Sierra Ladrones Formation. This facies-distribution pattern is mainly attributed to deposition by several major fluvial systems (including the ancestral upper Rio Grande, Rio Puerco, and Rio San Jose) on a very broad basin floor rather than deposition by a single large stream following the axis of a narrow basin. The resulting distribution pattern of the fluvial facies is very complex and several belts of axial-stream deposits may be present that converge southward to a single trunk stream near Socorro.

Contrasting depositional environments also characterize the Camp Rice Formation. The Mesilla Basin, like the Albuquerque Basin, lacks a major bounding uplift to the west and is very broad. The Camp Rice Formation is also dominated by basin-floor fluvial facies; but unlike the tributary drainage system associated with the Sierra Ladrones Formation, the Camp Rice was mainly deposited by fan-delta distributaries extending southward into bolsons of Trans-Pecos Texas and Chihuahua. The fan-delta deposits begin in the southern Palomas Basin just north of Hatch and widen to the south (Hawley et al. 1969, 1976, Seager 1981, Gile et al. 1981). At its widest point near El Paso, the fan-delta width exceeds 65 km.

In examining the Palomas Formation, some interesting differences exist. Basins containing the Palomas Formation are much narrower than other basins to the north and south (i.e. Albuquerque and Mesilla Basins) and have major uplifts bounding the basins to the east and west. No fan-delta or extensive tributary deposits occur in the axial-river facies. Rather this facies comprises braided-river deposits that seldom exceed 3 km in width. The Palomas Formation is a piedmont-facies-dominated deposit associated with the present series of north-trending rift basins between Derry and Socorro that formed in late Miocene and early Pliocene (3–9 my, Seager et al. 1984). Older Santa Fe units of latest Oligocene and Miocene age partly fill remnants of early rift basins and are only exposed in a few areas near modern basin margins. Detailed mapping to the south (Seager et al. 1982) shows that lower Santa Fe deposits are dominated by intertonguing coarse piedmont-alluvial and fine-grained basin-floor facies, which include fanglomerates and playa sediments.

SUMMARY AND CONCLUSIONS

The Palomas Formation forms the bulk of the exposed fill of the present Palomas, Engle, and San Marcial Basins. The formation consists of alluvial-fan and coalescent-fan deposits (piedmont facies) and ancestral Rio Grande fluvial deposits (axial-river facies). The Cuchillo constructional surface occurs, where preserved, at the top of the formation. Based on vertebrate fossils and radiometric dates, the age ranges from slightly more than 5 my to about 400,000 years. Distinguishing characteristics of the Palomas Formation are: (1) deposition occurred in relatively narrow basins bordered by major uplifts; (2) an axial-river facies was deposited by an ancestral Rio Grande that was not affected by major contributions from other tributaries or by fan-delta formation; and (3) deposition was mainly in a piedmont environment (coalescent fans). Thus, the Palomas Formation can be described as a piedmont-facies-dominated deposit possessing a relatively narrow (3 km wide) axial-river facies deposit that roughly follows the basin axis.

ACKNOWLEDGMENTS

Original work in the Elephant Butte area was done by Lozinsky in 1981–82 as a M.S. thesis at the University of New Mexico under the direction of Stephen Wells, Albert Kudo, Vincent Kelley, and John Hawley. Funding was provided by New Mexico Bureau of Mines & Mineral Resources. Teresa Mueller aided in measuring sections 1, 2, and 3. Lynne McNeil typed Table 1 and Appendix I. Special thanks to Earle and Jean George and Ival and Helen Kennedy for their hospitality during field work. This paper benefited from reviews by Bill Seager and Frank Kottlowski.

REFERENCES

Bachman G.O. & Mehnert H.H. 1978. New K–Ar dates and late Pliocene to Holocene geomorphic history of the Rio Grande region, New Mexico.—Geological Society of America, Bulletin, 89(2): 283–292.

Bryan K. 1938. Geology and groundwater conditions of the Rio Grande depression in Colorado and New Mexico. *In* Natural Resources Planning Board (U.S.), The Rio Grande joint investigation in the upper Rio Grande Basin.—U.S. Government Printing Office, Washington, DC, 1(2): 197–225.

Cope E.D. 1883. On distribution of the Loup Fork formation in New Mexico.—American Philosophical Society, Proceedings, 21: 308–309.

Davie W. & Spiegel Z. 1967. Geology and water resources of Las Animas Creek and vicinity, Sierra County, New Mexico.—New Mexico State Engineer, Hydrographic Survey Report, 44 pp.

Foster R.W. 1978. Selected data for deep drill holes along Rio Grande rift in New Mexico. *In* Hawley J.W. (compiler), Guidebook to the Rio Grande rift in New Mexico and Colorado.—New Mexico Bureau of Mines & Mineral Resources, Circular 163: 236–237.

Gile L.H., Hawley J.W. & Grossman R.B. 1981. Soils and geomorphology in the Basin and Range are of southern New Mexico—Guidebook to the desert project.—New Mexico Bureau of Mines & Mineral Resources, Memoir 39: 222 pp.

Gordon C.H. 1910. Sierra and central Socorro Counties. *In* Lindgren W., Graton L.C. & Gordon C.H. (eds.), The ore deposits of New Mexico.—U.S. Geological Survey, Professional Paper 68: 213–285.

Gordon C.H. & Graton L.C. 1907. Lower Paleozoic formations in New Mexico.—Journal of Geology, 15: 91–92.

Harley G.T. 1934. The geology and ore deposits of Sierra County, New Mexico.—New Mexico Bureau of Mines & Mineral Resources, Bulletin 10: 220 pp.

Hawley J.W. 1965. Geomorphic surfaces along the Rio Grande from El Paso, Texas to Caballo reservoir, New Mexico.—New Mexico Geological Society, Guidebook 16: 188–198.

Hawley J.W. (compiler) 1978. Guidebook to the Rio Grande rift in New Mexico and Colorado.—New Mexico Bureau of Mines & Mineral Resources, Circular 163: 241.

Hawley J.W., Bachman G.O. & Manley K. 1976. Quaternary stratigraphy in the Basin and Range and Great Plains provinces, New Mexico and western Texas. *In* Mahaney W.C. (ed.), Quaternary stratigraphy of North America.—Dowden, Hutchison & Ross Inc., Stroudsburg, Pennsylvania, pp. 235–274.

Hawley J.W., Kottlowski F.E., Seager W.R., King W.E., Strain W.S. & LeMone D.V. 1969. The Santa Fe Group in the south-central New Mexico border region. *In* Kottlowski F.E. & LeMone D.V. (eds.), Border stratigraphy symposium.—New Mexico Bureau of Mines & Mineral Resources, Circular 104: 52–76.

Hayden F.V. 1873. First, second, and third annual reports of the U.S. Geological Survey of the territories for years 1867, 1868, 1869 (reprint).—U.S. Government Printing Office, Washington, DC, 261 pp.

Heiken G., Fraser G., Stix J., Tamanyu S., Shafiqullah M., Garcia S. & Hagan R. 1986. Intracaldera volcanic activity, Toledo caldera and embayment, Jemez Mountains, New Mexico.—Journal of Geophysical Research, 91(B2): 1799–1815.

Herrick C.L. 1904. The clinoplains of the Rio Grande.—American Geologist, 33: 376–381.

Heyl A.V., Maxwell C.H. & Davis L.L. 1983. Geology and mineral deposits of the Priest Tank quadrangle, Sierra County, New Mexico.—U.S. Geological Survey, Miscellaneous Field Studies Map MF-1665, scale 1:24,000.

Izett G.A. 1981. Volcanic ash beds: recorders of upper Cenozoic silicic pyroclastic volcanism in the western United States.—Journal of Geophysical Research, 86(B11): 10200–10222.

Izett G.A., Obradovich J.D., Naeser C.W. & Cebula G.T. 1981. Potassium–argon and fission-track zircon of Cerro Toledo rhyolite tephra in the Jemez Mountains, New Mexico.—U.S. Geological Survey, Professional Paper 1199-D: 37–43.

Jahns R.H. 1955a. Second-day road log in Sierra Cuchillo and neighboring areas.—New Mexico Geological Society, Guidebook 6: 25–32.

Jahns R.H. 1955b. Geology of Sierra Cuchillo, New Mexico.—New Mexico Geological Society, Guidebook 6: 163–166.

Kelley V.C. & Silver C. 1952. Geology of the Caballo Mountains, with special reference to regional stratigraphy and structure and to mineral resources, including oil and gas.—University of New Mexico Publications in Geology, no. 4: 286 pp.

Keroher G.C. et al. 1966. Lexicon of the geologic names of the United States for 1936–1960, Pt. 3, P–Z.—U.S. Geological Survey, Bulletin 1200: 2887–4341.

Kottlowski F.E. 1953. Tertiary–Quaternary sediments of the Rio Grande valley in southern New Mexico.—New Mexico Geological Society, Guidebook 4: 144–148.

Kottlowski F.E. 1955. Cenozoic sedimentary rocks of south-central New Mexico.—New Mexico Geological Society, Guidebook 6: 88–91.

Kottlowski F.E. 1958. Geologic history of the Rio Grande near El Paso.—West Texas Geological Society, Guidebook 1958 field trip, pp. 46–54.

Kottlowski F.E. 1960. Reconnaissance geologic map of Las Cruces 30-minute quadrangle.—New Mexico Bureau of Mines & Mineral Resources, Geologic Map 14, scale 1:126,720.

Lozinsky R.P. 1986. Geology and late Cenozoic history of the Elephant Butte area, Sierra County, New Mexico.—New Mexico Bureau of Mines & Mineral Resources, Circular 187: 40 pp.

Lucas S.G. & Oakes W. 1986. Pliocene (Blancan) vertebrates from the Palomas Formation, south-central New Mexico.—This guidebook.

Machette M.N. 1978a. Geologic map of the San Acacia quadrangle, Socorro County, New Mexico.—U.S. Geological Survey, Geologic Quadrangle Map GQ-1415, scale 1:24,000.

Machette M.N. 1978b. Preliminary geologic map of the Socorro $1^\circ \times 2^\circ$ quadrangle, central New Mexico.—U.S. Geological Survey, Open-File Report 78-607, scale 1:250,000.

Murray C.R. 1959. Ground-water conditions in the non-thermal astesian-water basin south of Hot Springs, Sierra County, New Mexico.—New Mexico State Engineer, Technical Report no. 10: 33 pp.

Repenning C.A. & May S.R. 1986. New evidence for the age of the Palomas Formation, Truth or Consequences, New Mexico.—This guidebook.

Seager W.R. 1981. Geology of Organ Mountains and southern San Andres Mountains, New Mexico.—New Mexico Bureau of Mines & Mineral Resources, Memoir 36: 97 pp.

Seager W.R. & Hawley J.W. 1973. Geology of the Rincon quadrangle, New Mexico.—New Mexico Bureau of Mines & Mineral Resources, Bulletin 101: 42 pp.

Seager W.R., Clemons R.E. & Hawley J.W. 1975. Geology of the Sierra Alta quadrangle, Doña Ana County, New Mexico.—New Mexico Bureau of Mines & Mineral Resources, Bulletin 102: 56 pp.

Seager W.R., Hawley J.W. & Clemons R.E. 1971. Geology of the San Diego Mountain area, Doña Ana County, New Mexico.—New Mexico Bureau of Mines & Mineral Resources, Bulletin 97: 38 pp.

Seager W.R., Clemons R.E., Hawley J.W. & Kelley R.E. 1982. Geology of the northwest part of Las Cruces $1^\circ \times 2^\circ$ sheet, New Mexico.—New Mexico Bureau of Mines & Mineral Resources, Geologic Map 53, scale 1:125,000.

Seager W.R., Shafiqullah M., Hawley J.W. & Marvin R.F. 1984. New K–Ar dates from basalts and the evolution of the southern Rio Grande rift.—Geological Society of America, Bulletin, 95: 87–99.

Spiegel Z. & Baldwin B. 1963. Geology and water resources of the Santa Fe area, New Mexico.—U.S. Geological Survey, Water Supply Paper 1525: 21–89.

Strain W.S. 1966. Blancan mammalian fauna and Pleistocene formations, Hudspeth County, Texas.—Texas Memorial Museum, Bulletin 10: 55 pp.

Strain W.S. 1969. Late Cenozoic strata of the El Paso–Juarez area. *In* Kottlowski F.E. & LeMone D.V. (eds.), Border stratigraphy symposium.—New Mexico Bureau of Mines & Mineral Resources, Circular 104: 122–123.

Tedford R.H. 1981. Mammalian biochronology of late Cenozoic basins of New Mexico.—Geological Society of America, Bulletin, Part I, 92: 1008–1022.

Woodward L.A., Callender J.F., Seager W.R., Gries J.C., Shaffer W.L. & Zilinski R.E. 1978. Tectonic map of the Rio Grande rift region in New Mexico and Colorado. *In* Hawley J.W. (compiler), Guidebook to the Rio Grande rift in New Mexico and Colorado.—New Mexico Bureau of Mines & Mineral Resources, Circular 163, sheet 2, scale 1:1,000,000.

APPENDIX I—Measured sections

Sections 1, 2, and 3 comprise the composite type section. Sections 4 and 5 are reference sections.

Section 1
Upper Palomas Formation

This part of the composite type section includes proximal subfacies, two fluvial sand intertongues (units 1 and 5) and a dated volcanic ashbed (unit 6). It is located about 3 km southeast of Las Palomas on south side of Red Wash (Palomas Gap arroyo) in the NE1/4 SW1/4 sec. 33, T14S R4W. Begin on hilltop overlying ashbed.

Unit	Lithology	Thickness ft	Thickness m
10	Fanglomerate, light reddish brown (5YR 6/3) weathers reddish yellow (5YR 6/6). Poorly sorted, matrix-supported, moderately indurated, massive fanglomerate with sandy silt matrix. Pedogenic calcium carbonte horizon (Stage III-IV) for top 1 m. Clasts are angular to subrounded and include limestone, red siltstone (Abo), chert, minor granite and vesiculated olivine basalt. Clasts up to 10 cm in size. Scoured contact at base.	12.2	3.7
9	Sandy silt, red (2.5YR 4/6) weathers to light reddish brown (2.5 YR 6/4). Contains thin (<30 cm) pebbly lenses and rare scattered pebbles with lithologies same as above. Unit weakly to moderately indurated and bedding is weakly developed. Red (10R 4/6), 30 cm thick clay zones are scattered throughout unit and may be paleosols. Grades into lower unit.	10.4	3.2
8	Fanglomerate, light reddish brown (5YR 6/3) weathers reddish yellow (5YR 6/6). Similar to unit 10, but without pedogenic zone and with a few very coarse-grained sandstone lenses about 30 cm thick. Scoured basal contact.	13.2	4.0
7	Sandy silt, red (2.5YR 5/6) weathers to light reddish brown (2.5YR 6/4). Same as unit 9. Sharp basal contact.	21.3	6.5
6	Volcanic ash, white (7.5YR N8/) to pinkish white (5YR 8/2). Bed thickness up to 30 cm near base and becomes almost laminated near top. Weakly indurated, friable, powdery and clean. Sharp basal contact. Has been correlated with Cerro Toledo ash of the Jemez volcanic center, which has a fission-track of about 1.45 ma (Izett and others, 1981; Machette, written comm., 1982).	4.2	1.3
5	Medium- to fine-grained sand, light gray (10YR 7/2). Well sorted, loosely consolidated exhibiting weak trough crossbedding. Fines upward and contains silt with thin (<20 cm thick), pale olive (5Y 6/3), red (2.5YR 5/6) and pale yellow (2.5Y 7/4) clay lenses for top 0.5 m. Sharp basal contact.	6.7	2.0
4	Fanglomerate with sandy silt interbeds, red (2.5 YR 4/6), weathers light reddish brown (2.5YR 6/4). Poorly sorted, moderately indurated, lenticular to thick bedded fanglomerate with a sandy silt matrix. Fanglomerate beds are better cemented near base and show weak planar crossbeds. Beds up to 3 m thick. Clasts are angular to subrounded and mainly consist of limestone, chert and red siltstone (Abo) with minor granite, sandstone and scoriaceous basalt. Clasts average 6-8 cm in size but can be up to 50 cm and are slightly imbricated westward. Most beds are clast-supported near base and become matrix-supported near top. Sandy silt beds contain pebbly lenses and scattered pebbles throughout unit with lithologies similar to fanglomerate beds. Fanglomerates usually have scoured basal contact with sandy silt beds, but grade upward into sandy silt beds. Unit as a whole is very resistant and a traceable cliff-former.	28.9	8.8
3	Sandy silt, reddish brown (5YR 5/4) to brown (7.5YR 5/4). Similar to units 9 and 7, except unit is less indurated and no red clay zones were observed. Unit grades into unit 2. Slope-former.	10.1	3.1
2	Alternating beds of medium- to coarse-grained sand, sandy-silt and pebbly conglomerate. Sand is moderately sorted and pale brown (10YR 6/3). Sandy silt beds are similar to unit 3. Pebbly conglomerate is poorly sorted; has clast lithologies similar to unit 7. Bed thickness ranges from 30-60 cm, averaging about 30 cm. Unit appears to represent transition between fluvial and fanglomerate material. Slope-former. Sandy silt unit grades into unit 1.	14.1	4.3
1	Medium- to fine-grained sand, light gray (10YR 7/2). Loosely consolidated, well sorted, trough crossbedded, massive sand with scattered rounded pebbles (quartz, rhyolites, tuff) and pebble lenses. Clasts average 3-4 cm in size. Red (2.5YR 5/6) and pale yellow (5Y 7/3) clay balls and lenses are scattered throughout unit. Laterally (eastward) grades into sandy silt unit. Fines upward near top. Section ends where covered by tributary arroyo.	16.7	5.1
	Total Thickness:	137.8	42.0

Offset section to main tributary. Units 1, 2, and 3 repeated. Begins on bottom of traceable unit 4.

Unit	Lithology	Thickness ft	Thickness m
d	Sandy silt, light reddish brown (5YR 6/3). Similar to unit 3. Sharp basal contact. Weakly to moderately indurated.	12.2	3.7
c	Fanglomerate, light reddish brown (5YR 6/4). Poorly sorted, matrix-supported, pebble-size fanglomerate with silty matrix. Similar to pebbly conglomerate in unit 2, except thicker. Scoured basal contact. Moderately indurated and cliff-former.	5.5	1.7
b	Sandy silt, reddish-brown (5YR 5/4). Similar to sandy silt in unit 2. Both this unit and unit c are similar to unit 2 when combined except no sand beds are found. Grades down into unit a. Weakly- to moderately-indurated.	5.2	1.6
a	Medium- to fine-grained sand, light gray (10YR 7/2). Loosely consolidated, well sorted with trough crossbedding. Scattered rounded pebbles (mostly quartz and volcanics) occur throughout exposure. Section ends where colluvium buries unit. Only small exposure occurs.	3.1	0.9
	Total Thickness	26.0	7.9

Section 2
Upper Palomas Formation

This part of the composite type section includes the Cuchillo surface (?), distal subfacies and fluvial sand intertongues (units 1 and 3). It is located just north of Palomas Creek and west of Las Palomas in the NW1/4 NW1/4 sec. 30, T14S R4W. Section begins on top of Cuchillo surface (?).

Unit	Lithology	Thickness ft	Thickness m
7	Conglomerate, reddish brown (5YR 5/4) to light brown (7.5YR 6/4). Plugged pedogenic calcium carbonate horizon for top 80 cm (Stage IV). Conglomerate is clast-supported (60-70% clasts) poorly to moderately sorted and massive with a medium-grained sand matrix. Subrounded to rounded clasts include tuffs, basalt, porphyritic and non-porphyritic rhyolites and andesites, and siliceous fragments (chalcedony and chert). Clasts up to 40 cm in size average 5-6 cm and are imbricated eastward. Unit is a moderately cemented cliff-former with a scoured basal contact.	42.6	13.0
6	Alternating beds of sandy silt and clay, reddish brown (5YR 6/4; mostly clay) to pink (5YR 7/3). Beds vary in thickness (4 cm-1 m) and in cementation. Sandy silt beds are moderately to well cemented and can contain scattered 1-3 cm size pebbles with lithologies similar to unit 7. Clay beds are darker colored, sometimes laminated and may represent paleosols where calcareous zones occur. Scattered 25-50 cm thick, well cemented, crossbedded, coarse-grained sand lenses are also present. Unit is a cliff-former with prominant ledges. Grades down into unit 5.	16.4	5.0
5	Conglomerate, pinkish gray (7.5YR 6/2). Mainly moderately sorted, clast-supported (50-60% clasts), massive conglomerate, but top 2 m grades into predominantly medium-grained sand with 30% clasts. Clast size and lithologies same as unit 1. Matrix andn some 10-30 cm thick lenses are comprised of medium-grained sand. Unit is a moderately cemented cliff-former with a scoured basal contact.	34.1	10.4
4	Alternating beds of sandy silt and clay. Same as unit 2. Grades down into unit 3.	29.2	8.9
3	Medium-grained sand with silty sand interbed, reddish yellow (7.5YR 6/6) on top to very pale brown (10YR 7/3) on bottom. Sand is poorly indurated, well sorted, and faintly crossbedded. Silty sand bed is 40 cm thick and occurs between sand beds. Slope-former. Contains a basal pebble lag deposit on scoured contact with unit 2.	5.2	1.6

Unit	Lithology	Thickness ft	Thickness m
2	Alternating beds of sandy-silt and clay. Same as unit 6. Sharp basal contact with unit 1.	74.5	22.7
1	Medium-grained sand, light yellowish brown (10YR 6/4). Loosely consolidated, well sorted, trough crossbedded sand with scattered pebbly and coarse-grained sand lenses. Subrounded to rounded pebbles (1-2 cm in size) include basalt, schist, siliceous fragments (quartz, chert, petrified wood) and granite. Pebbly and coarse-grained sand lenses are moderately to well indurated. Generally a slope-former. Section ends in arroyo about 5 m above Rio Grande floodplain.	13.4	4.1
	Total Thickness	215.4	65.7

Section 3

Upper Rincon Valley (?) and Lower Palomas Formation

This part of the composite type section includes the fluvial facies (units 8-10), the proximal subfacies (unit 7), and possibly the top of the Rincon Valley Formation of the lower Santa Fe Group (units 1-6). Units 9 and 10 are younger pediment and terrace deposits. It is located south of T or C and the Rio Grande in secs. 3 and 4, T14S R4W. Section begins on hilltop along the east side access road.

Unit	Lithology	Thickness ft	Thickness m
10	Conglomerate, white (5YR 8/1) to light brown (7.5YR 6/4). Poorly sorted, massive, well cemented, clast-supported (60-70% clasts) pediment veneer. Top 40 cm, intensely calcium carbonate impregnated (pedogenic--Stage III-IV) and forms resistant cap. Clasts similar to unit 7. Section ends on top of pediment surface. Sharp upper contact.	2.6	0.8
9	Medium- to fine-grained sand, reddish yellow (7.5YR 7/6) to light yellowish brown (2.5Y 6/4). Loosely consolidated, and primarily massive, but locally shows faint trough crossbedding. Slope-former. Contains scattered pebble lenses with clasts similar to unit 8. Grades down into unit 8.	14.4	4.4
8	Conglomerate, light gray (10YR 7/1) to light yellowish brown (2.5Y 6/4). Moderately sorted, matrix-supported, massive conglomerate with a medium to fine sand matrix. Contains a well cemented, 30-cm-thick basal layer with coarse sand; otherwise, the unit is weakly consolidated and is a slope-former. Subrounded to rounded clasts comprise about 25-35% of the unit and include porphyritic volcanics, tuffs, chert, basalt and quartz. Clasts become less numerous and smaller towards the top. Clast size averages 5-10 cm, but can be up to 20 cm. Sharp basal contact.	9.5	2.9
7	Fanglomerate, light reddish brown (5YR 6/4) to light brown (7.5YR 6/4). Poorly sorted, lenticular to weakly stratified, moderately to well indurated fanglomerate with 40-50% clasts. Clasts are angular to subrounded and include limestone, chert, siliceous rocks, granite and schist. Clasts up to 20 cm in size are slightly imbricated to the west. Mainly matrix-supported with sandy silt. Prominant ridge-former. Has scoured contact with underlying unit.	53.1	16.2
6	Silty-clay, brown (7.5YR 5/4) to reddish yellow (7.5YR 6/6). Thin-bedded (5 cm thick). Top 60 cm consists of light red (2.5YR 6/6), massive clay bed with scattered calcium carbonate concretions similar to unit 1. Generally a slope-former except for top 60 cm which is a cliff-former. Grades down into unit 5.	12.8	3.9
5	Very fine sandstone, light brown (7.5YR 6/4). Thin-bedded (<5 cm thick) at base and bedding becomes poorly developed near top. Contains a 6-cm-thick calcium carbonte layer in middle. Generally a slope-former. Sharp basal contact.	7.5	2.3
4	Massive clay with 2-3 cm thick fine sand interbeds, reddish brown (5YR 4/4). Poorly developed bedding with scattered calcium carbonate concretions similar to unit 1. Slope-former. Sharp basal contact.	15.7	4.8
3	Massive clay with minor silt, brownish yellow (10YR 6/6). Contains thin (5 cm thick) reddish brown (5YR 4/4) clay interbeds. Slope-former. Sharp basal contact.	7.2	2.2
2	Alternating beds of silty clay and very coarse sand with scattered pebbles up to 3 cm in size. Sand grains and clasts are angular to subangular and are poorly sorted. Beds range in thickness from 20-30 cm. Color similar to unit 1. Coarse units form resistant ledges. Scoured basal contact.	3.6	1.1
1	Silty clay, yellowish red (wet; 5YR 4/6), reddish yellow (dry; 5YR 6/6). Massive with scattered very fine sand and silt interbeds. Contains calcium carbonate concretions up to 6 cm long which are elongated vertically. Weakly consolidated and slope-former. Section ends where buried by recent Rio Grande floodplain deposits.	9.2	2.8
	Total Thickness	135.6	41.4

Section 4

Upper Palomas Formation

This reference section includes the Cuchillo surface and the upper part of the distal subfacies. It is located just north of Cuchillo Negro Creek in the SE1/4 NW1/4 sec. 5, T13S, R4W. Section begins on the Cuchillo surface.

Unit	Lithology	Thickness ft	Thickness m
4	Conglomerate, matrix white (5YR 8/1 to 7.5YR N8/). Plugged pedogenic calcium carbonate horizon (Stage IV) for top 1 m. Conglomerate is poorly sorted, clast-supported and exhibits faint crossbedding. Clasts are subangular to rounded and include mostly volcanic clasts with minor quartz clasts and Abo sandstone. Clast size average 8 cm, but can be up to 30 cm. Sandy silt matrix. Unit is a cliff-former and has sharp conformable basal contact.	6.9	2.1
3	Sandy silt, reddish brown (5YR 5/4) to brown (7.5YR 5/4). Bedding poorly expressed. Unit poorly indurated and has calcium carbonate coatings on top 30 cm. Slope-former. Conformable contact at base.	4.9	1.5
2	Alternating beds of conglomerate and sandy silt. Conglomerate matrix, reddish brown (2.5YR 5/4) to light reddish brown (5YR 6/4). Conglomerate beds are poorly sorted, moderately indurated, clast-supported and massive. Clasts are subangular to subrounded and include mostly volcanic clasts with minor quartz clasts and Abo sandstone. Clast size average 6-10 cm but can be up to 30 cm and are slightly imbricated to the southeast. Bed thickness ranges from 30 cm to 2 m. Thinner beds tend to be lenticular, matrix-supported and contain smaller clasts. Sandy silt beds are reddish brown (5YR 5/4) to light brown (7.5YR 6/4), poorly indurated with poorly expressed bedding. Bed thickness ranges from 1-3 m. Contacts between the conglomerate and the sandy silt beds are conformable. About halfway down in the section scattered, 30-cm-thick, red (10R 4/6) clay beds occur. Conglomerate beds tend to be cliff-formers while the sandy silt beds are slope-formers. Grades down into sandy silt.	61.7	18.8
1	Sandy silt, reddish brown (5YR 5/4) to brown (7.5YR 5/4) with alternating 30-cm-thick, weak red (10R 4/4) to brown (2.5YR 4/4) clay beds. Sandy silt beds are poorly indurated with poorly expressed beds up to 1 m thick. Lenticular, pinkish white (5YR 8/2) to light brown (5YR 6/4), calcareous zones are possible paleosols. Unit very erodable and forms badland topography. Section ends where buried by arroyo.	25.9	7.9
	Total Thickness	99.4	30.3

Section 5

Lower Palomas Formation

This reference section includes the lower part of the distal subfacies (units 1-5), the proximal subfacies (units 4-9), and the unconformable contact with the underlying Abo Formation. It is located along the north side of Cuchillo Negro Creek in the NW1/4 SW1/4 sec. 8, T13S R4W. Section begins hilltop.

Unit	Lithology	Thickness ft	Thickness m
9	Conglomerate, matrix white (5YR 8/1 to 7.5YR N8/), intensely calcium carbonate impregnated, especially top 45 cm. Very poorly sorted, rounded to subangular clasts of mostly volcanic clasts and Abo sandstone. Clasts average about 10 cm in size but can be up to 30 cm. Grades down into noncalcium carbonate impregnated unit. Prominent ridge-former. Has a scoured basal contact.	4.3	

Unit	Lithology	Thickness ft	Thickness m
8	Conglomerate, light gray (5YR 7/1) to light reddish brown (5YR 6/4), poorly indurated, poorly sorted and thin- to medium-bedded with subangular to subrounded clasts in a silty sand matrix. Clasts are primarily volcanic with minor Abo sandstone and average about 15 to 20 cm in size. Clasts are slightly imbricated to the southeast. Cliff-former. Grades down into sandy silt unit.	27.2	8.3
7	Sandy silt, pink (7.5YR 7/4) to light brown (7.5YR 6/4), poorly indurated. Beds poorly expressed. Slope-former. Conformable basal contact.	23.9	7.3
6	Conglomerate with sandy silt lenses, reddish brown (2.5YR 5/4) to light reddish brown (5YR 6/4). Sandy silt lenses, pinkish white (5YR 8/2). Grades down from a matrix-supported pebbly conglomerate into a clast-supported cobble and boulder conglomerate. Conglomerate is poorly sorted, poorly indurated and weakly bedded. Clasts are subrounded to subangular and include volcanic clasts and minor Abo sandstone. Clast size averages 20-30 cm. Clasts are slightly imbricated to the southeast. Sandy-silt matrix. Sandy silt lenses range from 15-30 cm thick and extend laterally up to 2 m. A 15-cm-thick, medium- to coarse-grained, slightly crossbedded, well cemented (calcium carbonate) sandstone with scattered subrounded to subangular pebbles forms a prominent ledge at the base. Unit generally a cliff-former. Sharp basal contact.	41.6	12.7
5	Sandy silt with clay interbeds, light red (2.5YR 6/8) to light reddish brown (5YR 6/4). Clay interbeds, red (2.5YR 5/8) to light brown (7YR 6/4). Sandy silt beds are poorly expressed and form badland topography. Clay interbeds range from 15-30 cm thick and form color bands in exposures. Unit generally poorly indurated and friable. Sharp conformable contact at base.	30.5	9.3
4	Conglomerate, reddish brown (2.5YR 5/4) to light reddish brown (5YR 6/3). Poorly sorted, lenticular, weakly bedded, clast-supported conglomerate with a sandy silt matrix. Clasts are subangular to subrounded and consist of mostly volcanic clasts and minor Abo sandstone. Unit is moderately indurated and pinches out about 2 m on either side. Cliff-former. Sharp basal contact.	9.2	2.8
3	Fanglomerate (proximal subfacies intertongue), pinkish gray (5YR 6/2) to light pink (5YR 8/3). Massive, matrix-supported, poorly sorted fanglomerate with a sandy silt matrix. Clasts are angular to subrounded and include mostly limestone and Abo sandstone with minor chert. Clasts average 15-30 cm in size. Unit moderately well indurated with calcium carbonate cement and is a cliff-former. Unit grades down into sandy silt.	8.5	2.6
2	Sandy silt, light red (2.5YR 6/6) to pinkish white (7.5YR 8/2). Poorly indurated and weakly bedded with well indurated silt concretions. A 30-cm-thick, pebbly lense occurs about 150 cm from base. Pebbles include angular to subrounded limestone and Abo sandstone. Unit generally a slope-former. Sharp basal contact.	15.1	4.6
1	Fanglomerate (proximal subfacies), reddish brown (2.5YR 4/4) to light reddish brown (2.5YR 6/4). Well indurated, poorly sorted, massive, matrix-supported fanglomerate with a sandy silt matrix. Clasts are angular to subrounded and include mostly limestone and Abo sandstone with minor chert. Clasts average 20-30 cm in size but can be up to 60 cm and are slightly imbricated to the north. Top 60 cm very well indurated. Prominent ledge-former. Rests with angular unconformity on Abo Formation.	12.1	3.7
	Total Thickness:	172.4	52.6


1985 · Day 3 · Stop 1
Lou Jordan 1985