Open-File Report 96-4
Field Trip No. 21

Field Trip Guide to the Quaternary Valles Caldera and Pliocene Cerros del Rio Volcanic Field

By
David Sawyer and Ren A. Thompson
USGS, Denver,
Colorado 80215

Colorado Geological Survey
Department of Natural Resources
Denver, Colorado
1996

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David Sawyer
Ren A. Thompson
USGS, Denver, CO 80215

with contributions by:
Fraser Goff, Jamie Gardner, Dave Broxton, Steve Reneau, Scott Baldridge, and Giday Woldegabriel
Los Alamos National Laboratory

INTRODUCTION

This guide is intended as a supplement to the 1996 Annual Field Guide of the New Mexico Geological Society for purposes of field discussion and reference during our 1996 Geological Society of America field trip to the Jemez region. The intent of this trip is to provide an overview of volcanism of the Quaternary Valles caldera and the adjacent Pliocene Cerros del Rio volcanic field and to focus on new geologic, geochemical and geochronologic data related to the evolution of both. Readers are referred to New Mexico State highway maps and USGS topographic maps for highway and road information.

ROAD LOG

Day 1

Mileage 0.0 Intersection of I-40 and I-25 in Albuquerque

15.7 (15.7)
Take second Bernalillo exit on I-25 North (Exit 242), New Mexico Highway 44. Turn left (west) on NM Highway 44 West toward Bernalillo, Rio Rancho, and Farmington; route to right is NM Highway 165 East to Placitas.

16.1 (0.4)
Midpoint of overpass on Highway 44 over I-25.

16.3 (0.2)
Midpoint of Atchison, Topeka, and Santa Fe (now Santa Fe, part of Burlington Northern railway system) railroad bridge overpass. Starting point of Bailey and Smith (1978) field trip log to the Jemez Mountains.

17.5 (1.2)
Midpoint of Rio Grande bridge at Bernalillo.

18.5 (1.0)
Intersection with NM Highway 528 heading south to Rio Rancho and Corrales. Continue west on Highway 44.

39.4 (21.1)
Intersection of NM Highway 44 with New Mexico Highway 4 in San Ysidro. Turn right (north) on Highway 4 toward Jemez Springs. Mileage marker 0 on Highway 4.

43.9 (4.5)
Jemez Pueblo Tribal Administration building to left. Observe 30 mph speed limit in Pueblo.

49.8 (5.9)
Stop 1 Jemez River terrace deposits, containing clasts of Banco Bonito lava (John Rogers, guest stop leader?). Pullout to right at Bus Stop shelter. Terrace deposit Qt5 of Rogers, 1996 interpreted as late Wisconsin (10-25 ka) in age. Banco Bonito clasts are not found in the next oldest terrace (Qt4?) interpreted as Illinoisan (about 150 ka in age). Cliff exposures of Bandelier Tuff above Permian Abo and Yeso Formations at south end of Mesa de Guadalupe. The bright white material locally exposed at the Bandelier-Yeso contact is fluvially reworked, poorly consolidated fall that preceded deposition of the Bandelier ignimbrites. Locally, stratified gravels and associated floodplain sediments are also preserved at the base of the Bandelier Tuff

52.3 (2.5)
Jemez Springs, Los Ojos restaurant to right, Hot Springs bath house ahead to left.

53.8 (1.5)
Stop 2 Soda Dam and Jemez fault zone
Park in turnout on right; a second larger turnout occurs 100 m further to left. The travertine dam across the Jemez River is about 100 m long and 15 m high and was built by carbonated thermal waters that discharge from a strand of the Jemez fault. There are presently about 15 springs and seeps in this area having a maximum temperature of 48°C. About 25 years ago water flowed along the central fissure at the crest of the dam, but the New Mexico State Highway Department eliminated the hump in the paved road by dynamiting a notch in the west end of the dam. This forever changed the plumbing of hot-spring water and

today Soda Dam is slowly disintegrating (Goff and Shevenell, 1987).

The hot springs at Soda Dam and at Jemez Springs have been know since pre-historic times, and were among the most-studied geologic features of north-central New Mexico after the American occupation, beginning with Simpson's (1850) observations. Summers (1976) summarized previous studies of the Soda Dam and other nearby hot springs. Trainer (1984) conducted investigations on the geohydrology of the springs and calculated total thermal discharge at about 1200 l/min.

Thermal/mineral waters at Soda Dam contain about 1500 ppm Cl, 1500 ppm bicarbonate, and substantial quantities of As, B, Br, Li, and other trace elements typical of high-temperature geothermal fluids. They are composed of about 50% geothermal reservoir fluid from Valles Caldera and about 50% cold meteoric waters. 36Cl and 3H isotopes indicate that the water is relatively old, at least a few thousand years (Rao et al., NMGS 1996 Jemez Guidebook; Shevenell and Goff, 1995; NMGS 1996 Jemez Guidebook). Several people have claimed that the hot waters follow a trace of the Jemez fault zone out of the caldera and mix with dilute groundwater (Dondanville, 1971; Trainer, 1975; Goff et al., 1981). By combining geochemical data on hot spring waters and hot aquifers throughout the southwestern perimeter of the caldera with other geologic, geophysical, and drill hole data, Goff et al. (1988) showed that a major subsurface tongue of reservoir water flowed out of the caldera along the Jemez fault zone.

The travertine deposits of Soda Dam proper have been dated by the U-Th disequillibrium technique and have a maximum age of about 7 ka (Goff and Shevenell, 1987; Goff and Gardner, 1994). Two older deposits at slightly higher elevation occur across the Jemez River (age 60-110 ka). On the west side of the road roughly 30 m above the road, occurs an extremely large deposit of travertine that has an age range of about 0.48-1.0 Ma byevaluation with the U-U dating method (Goff and Shevenell, 1987). These older deposits do not overlie Bandelier Tuff; instead they lie directly on Paleozoic and Precambrian rocks. A discontinuous deposit of ancestral Jemez River gravels can be seen beneath the travertine and a large cave is found along the contact. The travertine deposits show that hydrothermal fluids have discharged at the Soda Dam area for the last 1 Ma.

The Jemez fault zone is very complex in this area. The main trace trends northeast across the highway and creates a 15 m scarp along the north side of the older travertine. Generally, displacement along the fault in Paleozoic rocks is about 200-250 m, down to the east. At Soda Dam, a local horst of sheared Precambrian granite-gneiss is uplifted and overlain by distorted Paleozoic rocks. The granite-gneiss is hydrothermally altered and contains secondary chlorite, barite, galena, and sphalerite in veins and fracture fillings. The Jemez fault zone continues to the southwest and displaces the Tshirege Member of the Bandelier Tuff by about 50 m in the canyon wall.

If you gaze carefully at the upper east wall of San Diego Canyon you can see a white band of Abiquiu Formation (late Oligocene) overlying orange Permian Yeso Formation sandstone and shale. The Abiquiu is overlain by basalt flows and an andesite flow and flow breccia sequence (8-10 Ma?) of the Paliza Canyon Formation, and the mesa is capped by a thin layer of the Tshirege Member of the Bandelier Tuff. Looking northwest, the canyon wall is composed of Pennsylvanian Madera Formation, Permian Abo Formation, Abiquiu Formation, Paliza Canyon Formation, and both members of the Bandelier Tuff. The canyon is partly controlled by erosion along the Jemez fault zone and the stratigraphy is different on either canyon wall.

57.6 (3.8)
Turn right and head into picnic area parking lot. Stop and park (about 0.15 mi)

Stop 3 Battleship Rock pyroclastic flow deposit
Entrance to Battleship Rock picnic ground and Camp Shaver on right. The East Fork of the Jemez River runs between them. The Madera roadcut across and a little south of the entrance is abundantly fossiliferous.

Battleship Rock is a spectacular outcrop of columnar-jointed ignimbrite of post-Valles caldera age formed by small eruptions of rhyolitic ash that flowed down an ancestral Jemez River. Subsequent erosion by later streams has formed canyons on either side of this beautiful example of reversed topography. San Antonio Creek drains the western caldera while the East Fork Jemez River drains the eastern caldera; the streams combine at Battleship Rock.

The ignimbrite is about 80 m thick and is composed of two main flow units that comprise a single cooling unit (Bailey and Smith, 1978). Although the base is poorly consolidated, the center is densely welded and very striking in appearance, having black fiami as long as 20 cm. Abundant lithic and crystal fragments are found in the matrix of the ignimbrite with glass shards and pumice. Chemical analyses of the pumice show it contains about 73 wt-% SiO_2. $Sr^{87/86}$ values are about 0.704, more primitive than most rhyolites in the caldera (Vuataz et al, 1988). The age of the Battleship Rock ignimbrite has been difficult to determine, but recent electron spin resonance dates indicate an age of about 55-60 ka (Toyoda et al., 1995; Toyoda and Goff, NMGS 1996 Jemez Guidebook).

59.7 (2.1)
Stop 4 Spence Hot Spring
Large parking area for Spence Hot Spring on right. Banco Bonito rhyolite lava fills incised paleovalley cut into Battleship Rock ignimbrite; significant pre-Banco Bonito relief may correspond to eroded top of VC-1 rhyolite in drillhole. Several springs (T 42°C) flow from the contact of Abo Formation and overlying Battleship Rock ignimbrite and Banco Bonito flow along a small bench about 30 m above the east side of the Jemez River. The largest pool is a favorite destination for bathers. In contrast to the mineralized thermal waters down-canyon, Spence Hot Spring is one of a group of dilute thermal waters that issue in the southern and western moat of Valles caldera (Goff and Grigsby, 1982). Silica and trace element contents of these springs are relatively low. ^{36}Cl isotope work indicates that Spence Hot Spring may contain a few percent of geothermal reservoir water from the caldera (Rao et al., NMGS 1996 Jemez Guidebook). Heat flow in this sector of the caldera is high due to proximity of the youngest post-caldera eruptions and the underlying reservoir (Sass and Morgan, 1988).

60.1 (1.4)
La Cueva. Junction of NM Highway 4 and NM Highway 126; turn left (northwest) on Highway 126.

62.0 (1.9)
Bridge over San Antonio Creek. Redbeds on right across bridge are Permian Abo and Yeso Formations.

62.9 (0.9)
Perennial landslide in smectite-rich beds in the Permian Yeso Formation.

63.9 (1.0)
Base of Bandelier Tuff, lower Otowi Member above Tschicoma volcaniclastic sediments.

64.6 (0.7)
Fenton Hill Overlook; turn left from the middle of right bend in Highway 126 and park.

Stop 5 West Caldera overlook, just before Fenton Hill Geothermal site. LUNCH
From right (south) to left (north) are the: A) South topographic wall of Valles caldera in front of Cerro Pelado, Los Griegos, Las Conchas (composed Paliza Canyon dacite above altered andesite); B) the Late Quaternary Banco Bonito rhyolite flow, having a distinctive surface flowage morphology (Manley and Fink, 1987), it slopes down to west, and is about 9 km in length; C) Redondo Peak (11,250 feet/3460 m), summit of the resurgent structural dome consisting of intracaldera Tsherige (Upper) Member of the Bandelier Tuff, and Redondito (Bailey and Smith, 1978); D) the Sulfur Creek-Sulfur Springs active acid-sulfate geothermal system in the Redondo Creek graben is the hottest surface manifestation of geothermal system; dates on alteration at VC-2A indicate was in the liquid zone of the geothermal system, but is now in the vapor zone; E) Redondo Border, consisting of the nearer and lower irregular-crested ridge that forms the western half of the resurgent dome; F) San Antonio rhyolite/South Moutain rhyolite (just beyond Redondo Peak) are the youngest Valles rhyolite at about 549 ka; there is nearly a 400 ka eruption gap before the El Cajete plinian eruptions. The Otowi Member of the Bandelier Tuff is exposed in the cliffs below our feet, and the Canon San Diego ignimbrite (now dated 1.75-1.78 Ma) is poorly exposed beneath it in the valley to the south.

69.0 (4.4)
Double back to La Cueva on Highway 126; turn left (east) on Highway 4.

71.3 (2.7)
Santa Fe National Forest sign "San Diego Canyon Overlook" to right.

71.8 (2.8)
Turn off to right on road to VC-1 site.

72.1 (0.3)
Gate (sometimes closed).

72.6 (0.5)
Stop 6 VC-1 site and short hike to look at contact relations Banco Bonito-Battleship Rock (Gardner-Goff). Site of Continental Scientific Drilling Program (CSDP) corehole VC-1 The hole was drilled in August 1984 on the southern side of the Banco Bonito rhyo-obsidian flow on strike with the southwestern projection of the Redondo Creek graben. Objectives were: (1) to intersect the hydrothermal outflow plume of the Valles geothermal reservoir relatively near source, (2) to study the structure and stratigraphy near the intersection of the ring-fracture zone and the pre-caldera Jemez fault zone, and (3) to study the petrology of the youngest moat volcanics in the caldera (Goff et al., 1986). Total depth is 856 m and the BHT is about 185 °C. Fluid geochemistry of aquifers at 400-600 m depth in VC-1 resembles, but is more dilute than, reservoir waters in the caldera. A model of the hydrothermal outflow plume is shown in Goff et al. (1988). VC-1 core is altered and structurally disrupted below 335 m, particularly the lowermost interval of brecciated Precambrian rocks and Sandia Formation (Hulen and Nielson, 1988). Molybdenite was found in this breccia zone along with chalcopyrite, sphalerite, galena, pyrite, and barite. Fluid inclusion work indicates that the molybdenite was deposited from dilute liquid water at temperatures as high as 280°C (Sasada,

1988). Geissman (1988) found that the paleomagnetic character of Paleozoic rocks in the corehole was overprinted by a reversed magnetic signature and concluded that major hydrothermal activity occurred between 1.4 and 0.97 Ma at about 300°C. K-Ar dates on hydrothermal illites have dates as young as Ma (WoldeGabriel, 1991). Sturchio and Binz (1988) obtained ages of 95 to >400 ka on calcite veins using the U-Th disequilibrium technique.

The moat volcanic sequence contained several surprises, including an obsidian flow (VC-1 rhyolite) with no surface expression (Goff et al., 1986). Compositionally, the youngest moat rhyolites are amazingly similar in major/trace element chemistry and phenocryst assemblages and composition (Gardner et al., 1986). Several interpretations of the moat sequence based on VC-1 core have been presented but no interpretation is universally accepted (Goff and Gardner, 1987; Self et al., 1991; Wolff and Gardner, 1995; Wolff et al, NMGS 1996 Jemez Guidebook; Toyoda et al., 1995; Toyoda and Goff, NMGS 1996 Jemez Guidebook).

73.4 (0.8)
Double back to Highway 4; turn right and head east.

76.3 (2.9)
Stop 7 Three Rhyolites (Gardner-Goff) Banco Bonito rhyolite flow (colluvium) overlying El Cajete overlying El Cajete rhyolite fall, flow, and surge deposits, overlying 520 ka South Mountain rhyolite. This is the famous "Three Rhyolites Stop" of many previous field trip guides. The El Cajete deposits fill in old channels of the ancestral Jemez River which cut into the South Mountain Rhyolite. The outcrop displays vitrophyric blocks of colluvium and stream reworked fragments of Banco Bonito, but in-place material is found higher in the slope. The deposits at this site show so much variation that this stop is a favorite of student field trips. The Banco Bonito flow is the youngest eruption in the Valles caldera and forms a 7-km-long sequence of several flow units that fills a paleovalley in the southern moat of the caldera (Manley and Fink, 1987; Goff et al., 1986; Self et al, 1991). Recent age determinations on the El Cajete deposits using ESR, TL, and carbon-14 methods show that they are about 55-60 ka (Toyoda et al., 1995; Reneau et al., 1996). $^{40}Ar/^{39}Ar$ dates on the South Mountain Rhyolite are about 520 ka (Spell and Harrison, 1993).

80.0 (3.7)
Stop 8 El Cajete deposits at turnout to abandoned, reclaimed Copar Pumice's East Fork mining pit. Hike 0.1 mile east on road to roadcut showing several fall and surge beds in El Cajete Pumice. The youngest sequence of eruptions from the Valles caldera, consisting of the El Cajete, Battleship Rock, and Banco Bonito members of the Valles Rhyolite, happened about 50-60 ka (Toyoda et al, 1995; Reneau et al., 1996). Given the new age constraints on these eruptions, taken in the context of post-caldera volcanic history, there are previously unrecognized implications for future volcanism in the caldera area and volcanic hazards in northern New Mexico (Wolff and Gardner, 1995). The main center of vents for these young units lies about 4 km northwest of this stop, and exposed in the roadcuts are the basal fall and pyroclastic surge deposits of the earliest phases of the sequence of eruptive events. The lowest fall units are massive to crudely bedded pumice lapilli and bombs, and are draped over a paleomound of South Mountain Rhyolite (521 ka; Spell and Harrison, 1993). The fall deposits blanketed topography, burying a conifer forest with five to six meters of pumice. In these lower fall units, vertical casts of standing trees can be found, some of which have been evident in this roadcut in the past. Overthese lower fall deposits lies a thin light brown surge deposit of mostly sand to very fine sand pyroclasts and lithic fragments. This surge had surmounted the paleohill, blanketed with the pumice fall, and was flowing downhill, pretty much right out of the roadcut towards us. The surge deposits exhibit interesting thickness and textural variations that correlate with the topography that the flow encountered. Within the surge deposit, many holes are evident. These holes, although animals have pirated some in this roadcut, are not animal burrows, but are rather casts of the snapped off tree tops that still were exposed above the early pumice fall deposits. The surge was energetic enough to snap tree tops up to 30 cm in diameter, and was hot enough to carbonize the wood. Consequently, these casts contain abundant charcoal. In contrast, the earlier pumice fall was not hot enough to carbonize the standing trees and the vertical parts of the trees rotted, resulting in preferential preservation of the trees as the carbonized snapped off tree tops within the surge. The paper by Wolff et al. (NMGS 1996 Jemez Guidebook) presents a great deal of new information on these youngest volcanic products of the Valles caldera.

Hike back 0.2 mi to examine surge E, Fall F (with vitrophyre clasts). On left, surge E between Fall D (lower) and Fall F (upper); surge E is brownish band and has this appearance due to inclusion of vitrophyre debris (Wolff et al, NMGS 1996 Jemez Guidebook).

83.0 (3.0)
Rabbit Mountain, a Cerro Toledo rhyolite dome at 12 o'clock ahead; South Mountain rhyolite to left (north)

86.0 (3.0)
(Pass Valle Grande)

87.4 (15.6)
Rim of caldera; pass into Frijoles Canyon.

93.2 (6.2)
Stop 9 Pajarito fault zone overlook on Highway 4-tight parking (Gardner-Reneau); very tight parking but possible for 4 12-passenger vans in two pullouts. We are standing on a monster scarp (125 m) in post-Tsherige Upper Bandelier Tuff deposits (1.22 Ma). The 16-24 km wide, 48 km long Pajarito Plateau is bounded by the Pajarito fault zone on the west, the Rio Grandeon the east, the Puye Escarpment on the northeast, and the Cañada de Cochiti fault on the southwest. The Pajarito fault zone is one of a system of faults that form the local, active western boundary of deformation in the Espa§ola Basin of the Rio Grande rift. The gross geometry of the Española Basin is asymmetrical, with rift-fill sediments pinching out altogether against the Sangre de Cristo Mountains on the east and as much as 1.5 km of Tertiary and younger rift-fill sediments and volcanics immediately east of the Pajarito fault (Kelley, 1978; Goff and Grigsby, 1982). Combining geophysical and drill hole data, Dransfield and Gardner (1985) developed a structure contour map of the pre-Bandelier surface beneath the Pajarito Plateau. The map reveals that, at least for the western part of the basin, the asymmetrical geometry is caused by a series of north-trending down-to-the-west normal faults that effectively stair-step the basin down to its deepest part here on the west. Thus, the area between the westernmost of these smaller faults and the Pajarito fault is a large, deep graben which has been recognized in numerous geophysical studies (Budding, 1978; Cordell, 1978; Goff and Grigsby, 1982; Ferguson et al. 1995). Furthermore, there is some evidence from microseismicty that most of the faults of the area are high angle to seismogenic depths (15 km); thus, if any of the faults develop into listric faults with depth, it happens at mid-crustal levels. There is no conclusive information on the displacement history of Pajarito fault zone despite several trenching attempts In middle distance is intra-rift Cerros del Rio volcanic field, location of late Second and Third Day field trip stops.

93.8 (0.6)
Intersection with NM-501 (Jemez Road); turn left (north) toward Los Alamos.

98.2 (4.4)
Los Alamos National Laboratory to right before intersection of Jemez Road and Diamond Drive; turn left (north) and cross over bridge across Los Alamos Canyon.

98.6 (0.0)
Intersection with Trinity (NM Highway 502); turn right (east).

99.6 (1.0)
Pull into Los Alamos Inn to spend the night.

Day 2

Mileage 0.0
Leave from Los Alamos Inn on Trinity Drive, Los Alamos Head west on Trinity, retrace route to Diamond Drive to Jemez Road to NM Highway 4 at Back (west) gate; turn right (west) and follow Highway 4 to Valle Grande pullout.

13.9 (13.9)
Stop 1 Valle Grande (Lee Steck, LANL)
Read the New Mexico Highway Department sign and then forget it: the Valle Grande is not a crater, nor is it the entire caldera. Redondo Peak is the flat-topped mountain to the west, and is the resurgent dome of the Valles caldera. The Valles caldera is the type resurgent caldera, formed by the two cycles of eruption of the Bandelier Tuff (Smith and Bailey, 1968). The Valles caldera formed at 1.22 Ma during catastrophic eruption of ca. 300 km^3 of the Tshirege Member of the Bandelier Tuff (Smith and Bailey, 1968; Izett and Obradovich, 1994). While Redondo Peak is clearly formed by doming of the Tsherige (Upper) Member, the source of the Otowi (Lower) Member of the Bandelier has remained controversial; recent work indicates that Toledo embayment is not part of an Otowi age caldera. Postcaldera ring domes are distributed within and above sedimentary deposits in the moat of the Valles caldera; to the west is the youngest of the Valles Rhyolite domes, the South Mountain rhyolite (about 520 ka) and the coeval dome of the Cerro La Jara (515 ka). Directly to the north of the pullout is the oldest of the Valles Rhyolite domes, Cerro del Medio, which has two distinct flow units dated at 1.21 Ma and 1.16 Ma (Izett and Obradovich, 1994) and exhibits a distinctive flow-margin morphology. Valles Rhyolite ring domes young counter-clockwise to the northwest from Cerro del Medio within the moat of the Valles caldera: Cerro del Abrigo (1.00 Ma), Cerro Santa Rosa (0.92 Ma and 0.79 Ma), Cerro San Luis (0.81 Ma), and Cerro Seco (0.79 Ma). It was in this locality that Doell and Dalrymple documented evidence for the Jaramillo subchron, a critical proof for the Vine-Matthews spreading sea-floor hypothesis and plate tectonics (Dalrymple and others, 1967; Doell and others, 1968; the significance of these discoveries recounted in Glen, 1982). The north rim of the Valles caldera is visible in the distance (about 18 km) beyond the Valles rhyolite domes, and is made of precaldera Paliza Canyon and Tschicoma Formation andesites and dacites. The east flank of the Valles caldera is made up of a string of mainly Pliocene Tschicoma Formation dacite volcanoes known locally as the Sierra del los Valles.

The amount and distribution of magmatic rock emplaced into the crust beneath the Jemez volcanic field and other large volcanic systems is poorly known. The Jemez Tomography EXperiment (JTEX) was designed, in part, to address this question. JTEX was primarily a seismic experiment, consisting of both active and passive (teleseismic) components. The first phase of the two-year teleseismic experiment began in June of 1993 with deployment of 22 PASSCAL short-period and broad-band sensors in profiles at azimuths of N460W and N600E with an average spacing of 3 km. Recording continued through September (Lutter et al., 1995). In the summer of 1994 a larger array of 49 instruments was deployed in and adjacent to the caldera and left in place for about two months. The active experiment, comprised of three 170 km-long lines, was conducted in two phases in 1993 and 1995. Both Vibroseis and explosives were used as sources. Recording instruments consisted of IRIS/PASSCAL Refteks (3-component, digital seismographs) and SGRs (vertical-component seismographs). Sensor spacing was a nominal 300 m in the middle of the line and 1600 m near the ends.

Preliminary results indicate a distinct, shallow low-velocity zone beneath the Toledo embayment, a strong mid-crustal low velocity (up to -30% from background) zone at a depth of about 12 km, and a deeper low-velocity zone (approximately -10 to -15%) extending from the lower crust into the upper mantle. Depth to basement in the caldera increases from about two km in the NW to three km in the SE. Compressional velocity of caldera fill is 3.4-5.0 km/s and of upper crust is 5.7-5.9 km/s (Davidson and Braile, 1995). Comparing to realistic rock types, the strong mid-crustal anomaly, which confirms earlier results of Roberts et al. (1991, 1995), can only be explained by the present of melt, probably indicating continued intrusion of magma into the crust. The lower crustal/upper mantle anomaly, which is broadest and strongest near the assumed Moho depth of 35-37 km, could result either from gabbroic rock in the upper mantle or from mafic melt in the lower crust, depending on the exact location of the anomaly with respect to the Moho. In either case, the anomaly is interpreted to show ponding of basaltic melts at or near the base of the crust (underplating).

26.4 (12.5)
Double back to Diamond Drive and Trinity Drive in Los Alamos; continue straight ahead on Diamond Drive past LA High School

29.2 (2.8) Pass Golf Course and Fire Station; turn left on road to Guaje Pines Cemetery

29.5 (0.3) Turn left at first turn (Aspen Lane-unmarked); take first right and proceed on clockwise 0.8 mile loop with 3 outcrop stops

30.3 (0.8)
Stop 2 Ponderosa Estates
"Ponderosa Estates" (also known locally as the "Cemetery Tracts") is a new subdivision of Los Alamos within Rendija Canyon whose roadcuts provide exceptional and unique exposures. Tectonically, Ponderosa Estates is on the hanging wall of the Rendija Canyon fault zone, <0.5 km west of the main trace of this west-facing normal fault (the prominent escarpment east of the subdivision). Post-Bandelier displacement in this area is estimated at ~36 ± 10 m, with the youngest faulting event occurring about 9 or 23 ka, as estimated from radiocarbon and thermoluminescence dating methods, respectively (Kelson et al., 1996; Olig et al., 1996). The preservation of the early Pleistocene deposits examined at this stop is probably aided by their relative protection from erosion on this down-faulted block. The rugged mountains to the north are underlain by Miocene-to-Pliocene dacitic lavas of the Tschicoma Formation, and a plug of the Tshirege Member can be seen partly filling a paleovalley in the dacite to the northeast.

Stop 2A - At this stop we will examine post-emplacement crystallization and gas escape structures in the upper part of the Tshirege Member. The Tshirege Member is partly welded and devitrified in this road cut exposure. Deposition of sugary crystals in lapilli indicate that these tuffs have also undergone vapor-phase crystallization. Vapor phase alteration is also indicated by the presence of numerous gas escape structures within the tuffs in this area. These structures acted as conduits for escaping volcanic gases that were trapped in the thick sequence of ignimbrites following their emplacement. Fine volcanic ash was selectively winnowed from the tuff by the streaming gasses, resulting in narrow, near vertical anastomosing structures containing high concentrations of phenocrysts and lithic fragments compared to adjacent wall rocks. The well-defined boundaries and dominantly vertical form of these structures at this site appears to be characteristic of deeper levels of out gassing ignimbrites. At stop 2B, we will examine the greater variety of gas escape structures found at the top of the Tshirege Member.

Stop 2B - This stop includes an unusually well-preserved top of a major ignimbrite sequence. This portion of the ignimbrite sheet is poorly consolidated and was removed by erosion soon after deposition elsewhere on the Pajarito Plateau. The unusual preservation of this deposit is probably partly due to its proximity to the mountain front which resulted in rapid burial by dacite-rich alluvial deposits soon after deposition.

The Tshirege Member at this location grades upwards from a partly welded, devitrified ignimbrite to a nonwelded vitric ignimbrite. Gas escape structures thoroughly pervade the top of the member, and the ignimbrite, which was probably massive orginally, has been extensively disrupted by escaping gasses. The gas escape structures have a variety forms including vertical pipes and upwards-widening funnels. Like at stop 2A, the structures contain high concentrations of phenocrysts and lithics. The funnel-like structures contain zones of cryptic stratification of uncertain origin. In places, these stratified zones appear to sag possibly due to settling following the elutriation of ash.

Stop 2C - This stop on Maple Drive includes excellent new exposures of post-Bandelier tephras that were uncovered when the roads to this new subdivision were built. Deposits exposed in the roadcuts include, in ascending order, 1) the top of the Tshirege Member, 2) fine-grained, cross-bedded tuffaceous sediments, 3) stratified, topography-mantling pumice- and ash-fall deposits, and 4) modern soils. The post-Bandelier tephras are 3- to 5-m thick in this area. Though not present at this stop, post-Bandelier tephras are commonly overlain by coarse-grained dacite-rich alluvial deposits in other locations.

The post-Bandelier tuffaceous deposits rest on devitrified ignimbrite in the upper part of the Tshirege Member at this location. Nearby, the same deposits overlie nonwelded glassy ignimbrite, suggesting erosion partially stripped the soft top of Tshirege Member before the post-Bandelier tephras were deposited.

The tuffaceous sediments at the base of the post-Bandelier tephras are about 1 m-thick and consist of reworked coarse tuffaceous sands. These deposits are cross-bedded and contain lenticular beds rich in pumices. A discontinuous white ash bed occurs in the upper part of the tuffaceous sediments. This ash bed, which is up to 10 cm thick here and 20 cm thick in nearby exposures, is an ash-fall deposit that was partly eroded before deposition of the overlying pumice fall.

A crudely-stratified pumice- and ash-fall sequence makes up the upper part of the post-Bandelier tephras at this stop. Pumices in the fall deposits coarsely porphyritic, containing large phenocrysts of sanidine and quartz. Small normal faults displace ash beds within these deposits 5 to 10 cm. Three additional pumice-fall deposits separated by ash beds occur above the stratigraphic level of this roadcut in the foundation of 15 Maple Court.

Early post-Bandelier tephras (pre-El Cajete in age) have been documented in at least five other locations on the Pajarito Plateau. These tephras are rhyolites (74% to 76% SiO_2, volatile-free) , and their age, mineralogy, and chemistry indicate they are equivalent to the Deer Creek and Valle Grande Members of the Valles Rhyolite. Mineralogically, the pumice and ash falls at this stop are similar to the Deer Creek Member, which erupted from the Redondo Peak area prior to resurgence. Nearby post-Bandelier tephras are mineralogically and chemically similar to lavas of Cerro Medio dome, the earliest and closest of the Valles Rhyolite ring fracture dome complexes in the Valles caldera. Izett and Obradovich (1994) report $^{40}Ar/^{39}Ar$ ages of 1.16 ± 0.01 Ma and 1.21 ± 0.02 Ma for Cerro Medio lava flows I and II, respectively. Our attempts to date tephras at this location by $^{40}Ar/^{39}Ar$ methods are unsatisfactory thus far. Single crystal laser fusion ages on three samples of pumices collected from this section yielded an age range of 1.2 Ma to 2.2 Ma, suggesting that xenocrystic contamination is present in the samples. Additional studies are underway to correlate these tephras with post-collapse dome complexes in the Valles caldera.

Faults in Ponderosa Estate outcrops have small displacement, and reflect an association with the major Rendija Canyon fault to the east. The faults in Ponderosa Estates exist in the hanging wall of the Rendija Canyon fault and generally trend NNW and dip steeply east and west. The Rendija Canyon fault zone is populated with faults that trend generally N to NW and dip steeply east. Thus, the secondary faults in the hanging wall of Rendija Canyon tend to be synthetic to the main west-dipping fault, but dip opposite to many of the east-dipping faults that are associated with the fault zone along it's entire length.

Average displacements on individual Ponderosa Estates faults is very small, on the order of 15.5 cm and cumulative displacement on faults in this area (again, at the time of early development of this subdivision) is on the order of 2 m. Displacement on the Rendija Canyon fault is a maximum of 35m, so the contribution to displacement on the entire Rendija Canyon fault zone from Ponderosa Estates faults is quite small (<5%).

Ponderosa Estate faults probably formed in response to the same N or NNE directed extension that caused the major fault zones in the area. Additionally, however, Ponderosa Estate faults represent accommodation of extension within the hanging wall of the Rendija Canyon fault zone. The density of normal faults in the hanging wall is greater than in the footwall of the fault zone, which I believe is also a reflection of the concentration of local stresses within the hanging wall.

30.6 (0.3)
Return to Diamond Drive (0.3), turn right (south)

31.7 (1.1)

Stop 3 Pyroclastic Surges in Welded Tshirege Member of the Bandelier Tuff
Across from First Baptist Church on Diamond Drive (K.Wohletz, LANL)

Park in the Church of Christ parking lot and walk along sidewalk exposures.

In the roadcut at this stop, welded Bandelier Tuff (Qbt-4) contains an unusually well developed and thick sequence of pyroclastic surge deposits. Common as thin horizons generally much less than one meter thick within the Tshirege Member, pyroclastic surge beds are thought to be the products of either (1) initial unsteady flow preceding emplacement of a pyroclastic flow or (2) ash clouds drifting across the top of a pyroclastic flow after it is emplaced. While the latter products have been termed "ash-cloud surges", the pyroclastic surges present at this exposure appear to be the former type, called "ground surges."

At this stop, surges form an interval ~0.5 to 2.0 m thick that marks the boundary between two pyroclastic flow units (ignimbrites). The surge interval apparently drapes over gentle topography that rises towards the middle of the roadcut, but nonetheless shows finer-scale features indicating that it in fact eroded several tenths of a meter into the underlying pyroclastic flow. In addition to the clearly exposed, centimeter-scale bedding, the surges can be distinguished from the massive pyroclastic flows by their higher degree of sorting and by their higher crystal concentrations.

The general stratigraphy of the surge unit includes: (1) planar to gently undulating beds at its base; (2) one to several massive, poorly sorted beds that pinch and swell in thickness to ~0.5 m near the middle of the unit; and (3) festooned dune beds (indicative of eastward flow directions) in the upper half of the interval. Although the massive beds of this unit resemble pyroclastic flows, their texture along with planar and dune bedded deposits are a characteristic of pyroclastic surges.

The pyroclastic flow overlying the surge unit shows an inverse gradation of pumice sizes at its base and faint laminations, which combined with the underlying ground surges, forms a typical basal section of large pyroclastic flows. Finally, in addition to these textural features, note that the tuff is poorly to nonwelded within the surge interval and increases in welding both downward and upward from it. While the paucity of glass in the surge beds explains the lack of welding, the poor welding in the pyroclastic flows adjacent to this interval are in stark contrast to the dense welding displayed throughout most of cooling unit 4 in nearby exposures.

33.0 (1.3)
Continue south on Diamond Drive; pass LA High School again, turn left on Trinity in front of Los Alamos Hospital; drive east through town of Los Alamos; pass airport east of town

37.2 (4.2) Pass East Gate and Rest area to North; pull off to right just past Santa Fe County sign

Stop 4 Camp Hamilton trail, LUNCH
At this stop we will examine typical exposures of the outflow facies of the Otowi and Tshirege Members of the Bandelier Tuff on the Pajarito Plateau. We will also discuss the landscape on which the Otowi Member was deposited as well as landscape development prior to deposition of the Tshirege Member. This stop includes a short hike into Pueblo Canyon to see subunits of the Tshirege Member and tephras of the Cerro Toledo Rhyolite which are intercalated between the two members of the Bandelier Tuff.

The Otowi Member of the Bandelier Tuff (1.61 Ma; Izett and Obradovich, 1994) is exposed in the lower slopes of Pueblo Canyon. It is a relatively homogenous unit made up of a succession of nonwelded to partially welded ignimbrites, and the entire sequence apparently forms a simple cooling unit. The base of the Otowi Member includes the Guaje Pumice Bed, a thick (10- to 20-m), crudely stratified pumice fall deposit. The thickness of the Otowi Member is variable across the Laboratory because it was deposited over a deeply dissected paleotopography and was subject to about 400,000 years of erosion before deposition of the Tshirege Member (Broxton and Reneau, in press). The Otowi Member was emplaced onto an early Pleistocene landscape dominated by a broad SSW-trending drainage. This stop is near the northern headwaters of this buried Pleistocene valley. Otowi thicknesses were greatest where ignimbrites ponded in the axis of valley.

The Tshirege Member of the Bandelier Tuff (1.22 Ma; Izett and Obradovich, 1994) is a compound cooling unit divided into four distinct cooling units on the Pajarito Plateau (Broxton and Reneau, 1995). Three of these units are well exposed on the canyon walls at this stop. Each cooling unit represent episodes of rapid ash-flow emplacement. Cooling unit boundaries represent periods of inactivity or nondeposition that were long enough for partial cooling to occur before overlying ash flows were emplaced.

The pre-Tshirege landscape that developed on top of the Otowi ignimbrites had relatively little relief, with drainage channels incised about 15-30 m below drainage divides in this area (Broxton and Reneau, in press). We will examine one of these paleo-canyons in cross section at this stop. Notably, because the Otowi Member is entirely nonwelded in this area, the pre-Tshirege landscape lacked the sharp mesa-canyon topography that is so prominent today. The pre-Tshirege drainages drained primarily to the SE and have little relation to the modern drainage systems.

During the ~400,000 y that separated the emplacement of the two members of the Bandelier Tuff, the Pajarito Plateau was periodically blanketed by pumice and ash-falls of Cerro Toledo Rhyolite. These tephras were erupted from the Cerro Toledo and Rabbit Mountain rhyolite domes located in the Sierra de los Valles on the rim of the earlier Bandelier caldera (Heiken et al., 1986). The Cerro Toledo Rhyolite lies between the Tshirege and Otowi Members, but it is not considered part of the Bandelier Tuff because of its unique petrologic features and its different eruptive style and source.

The Cerro Toledo deposits at this stop consist of pumice falls and interbedded reworked tuffaceous sediments. At least 4 buried soils, some with evidence for bioturbation (animal burrows), occur within the Cerro Toledo section. Prominent unconformities occur at the bottom and top of the Cerro Toledo deposits.

The hike at this stop ends in a side drainage to Pueblo Canyon where a paleovalley incised into Cerro Toledo deposits are filled by the Tshirege Member. The Tsankawi Pumice Bed of the Tshirege Member is preserved in the axis of the paleovalley, but it was eroded by emplacement of the overlying ignimbrite on the paleovalley margin. Surge deposits occur at the base of the ignimbrite in the axis of the paleovalley.

The pre-eruptive phenocryst assemblage of both the Tshirege and Otowi Members is dominated by alkali feldspar and quartz (generally from 10-25 vol %), with lesser amounts (<2 vol %) of Fe-rich pyroxene, Fe-Ti oxides, and fayalite, but they also contain other minerals at trace abundances (Warshaw and Smith, 1988; Stimac et al., in press). Broxton et al. (1995) provide more detailed information on the general modal petrography of the Bandelier Tuff and associated units.

The bulk-tuff mineralogy of the Bandelier Tuff is relatively simple, consisting primarily of alkali feldspar + quartz ± cristobalite ± volcanic glass ± tridymite. These four minerals and the volcanic glass make up over 95% in nearly all samples of the tuffs, although their relative proportions vary as a function of stratigraphic position. Minor contituents of the tuffs include smectite and hematite. Trace amounts of mica, hornblende, clinoptilolite, and kaolinite occur in some samples.

Volcanic glass is the dominant mineralogic component of tuffs in Qbt 1g. The glass occurs as pumices, shardy tuff matrix, and fine ash. The presence of abundant glass and paucity of low temperature alteration minerals such as smectites and zeolites indicates that the tuffs of Qbt 1g have had limited contact with groundwater since their deposition.

Alkali feldspar, cristobalite, quartz, and tridymite are the main mineralogic components of tuffs above the Qbt 1g/Qbt 1v contact. Alkali feldspar and cristobalite occur mainly in the tuff matrix as fine-grained (micron-size), high temperature devitrification products that replaced the original volcanic glass during cooling of the tuff. The tridymite and some alkali feldspar were deposited in open pore spaces by vapors released during outgassing of the tuff after emplacement. Tridymite is most abundant in Qbt 2 and Qbt 3 whereas cristobalite is most abundant in Qbt 1v and Qbt 4.

Cristobalite and tridymite abundances vary inversely, suggesting the occurrence of these minerals is controlled by coupled processes. Tridymite is an indicator mineral for vapor-phase alteration and its abundance in Qbt 2 and Qbt 3 suggests that post-emplacement vapor phase crystallization was greater in these tuffs relative to Qbt 1v and Qbt 4. The repetition of this alteration pattern over regional distances suggests that the eruptive hiatuses between units of the Tshirege Member were relatively brief, allowing the entire assemblage of units to devitrify together in a single stage. However, significant differences in degree of welding for adjacent units (e.g. Qbt 2 and Qbt 3) indicate that eruptive hiatuses were of sufficient duration to allow development of distinct cooling breaks.

39.0 (1.8) Turn off right on New Mexico Highway 4 toward White Rock

40.1 (1.1) Intersection of East Jemez Road with New Mexico Highway 4, turn right on East Jemez Road (truck route to Los Alamos National Laboratory).

Tsankawi Ruin and Tsankawi unit of Bandelier National Monument to east (left) before turn. Continue west driving up Sandia Canyon, past TA-72 Protective Force Live Firing Range to right (north) at about 1.6 miles west of East Jemez Road-NM Highway 4 intersection. Colonnade in Tsherige Member (Upper Bandelier Tuff) is in the lowest part of unit 1v above the vapor-phase notch

42.6 (2.5) Park just past guard rail on right side of the road, cross road to south, and head 200 m east on south side of East Jemez Road.
DOE PROPERTY - PERMISSION REQUIRED

Stop 5 Sandia Canyon, El Cajete pumice on Pajarito Plateau

A 7.5 m high north-facing stream bank provides an excellent exposure of the El Cajete pumice deposit at a site 27 km from its source in the Valles caldera. The typical phenocryst assemblage of the El Cajete (plagioclase-hornblende-biotite) is readily apparent in hand specimens of the pumice. The pumice here was deposited on the lower part of a steep canyon wall, and buries a colluvial soil that in turn overlies older Sandia Canyon stream deposits. Thermoluminescence (TL) analyses by Steve Forman of buried soils on the Pajarito Plateau similar to this one, in both hillslope and mesa-top settings, have yielded key geochronologic data on the age of the pumice bed, supporting an age estimate of ca. 50-60 ka (Reneau et al., 1996). In particular, the TL analyses indicate that an age of >60 ka is improbable, and support the reasonableness of the ca. 45-72 ka electron spin resonance (ESR) analyses of Toyoda et al. (1995).

The pumice and the buried soil dip beneath the present stream channel, showing that the channel at ca. 50-60 ka was somewhere below the level of the late Holocene canyon floor. At this site, up to 0.75 m of generally unstratified, presumably fallout pumice is overlain by stratified pumice displaying lenticular beds that are suggestive of hillslope scree deposits. The stratified pumice beds are interpreted as being derived from stripping of the steeper canyon wall upslope relatively soon after the eruption. The overlying colluvial deposits contain progressively higher percentages of Bandelier Tuff clasts, post-dating much of this erosion of pumice from higher slopes. Notably, modern streams on the Plateau often deposit relatively pure lens of El Cajete pumice in suitable depositional settings downstream of eroding pumice deposits, such as this one, suggesting that such beds of reworked pumice can in many cases provide only very general, maximum-limiting age constraints.

Turn around and head 2.5 miles back to the Highway 4-East Jemez Road intersection.

45.1 (2.5)
Turn right on New Mexico Highway 4 toward White Rock

47.8 (2.7)
Community of White Rock to left (Shell gas station to right, Conoco gas station to left at corner of Rover Road and New Mexico Highway 4). Continue straight ahead on NM Highway 4

48.8 (1.0)
Intersection of New Mexico Highway 4 and Pajarito Road. Bear left, continuing on NM Highway 4.

49.7 (0.9)
Intersection of Monterey South and NM Highway 4; turn left on Monterey South into Pajarito Acres subdivision.

50.5 (0.8)
Turn right on Portrillo

51.3 (0.8)
Turn right on Estante Way

51.5 (0.2)
Park by fire hydrant on right, past 422 Estante Way, and across from 428 Estante Way

Stop 6 Lower Water Canyon Hike south to Water Canyon/White Rock Canyon rim.

The north rim of Water Canyon at this location, 1.3 km east of the Rio Grande, is the exhumed rim of the meandering, pre-Tshirege Rio Grande paleocanyon which was incised into the western Cerros del Rio volcanic field. About 180 m of tuff plug the paleocanyon west of here, contrasting with a thickness of only about 20 m immediately to the east on the flank of a pre-Tshirege basaltic high (Broxton and Reneau, 1996). Well-rounded quartzite gravels and other exotic clasts, derived from the north and characteristic of gravels transported by the modern Rio Grande, are exposed beneath remnants of the basal Tshirege Member 160 m below the rim at this site, and also at several other locations both to the northeast (across the Rio Grande) and to the southwest (Reneau and Dethier, 1996b). This paleocanyon can be traced for 12 km beneath the eastern Pajarito Plateau, and indicate that the Rio Grande at ca. 1.22 Ma was up to 2 km west of its present location. Deposition of the Tshirege Member completely filled the paleocanyon and undoubtedly dammed the river. The low spot on the dam was east of the river, farther into the Cerros del Rio field, forcing the river to cut through about 200 m of basaltic rocks to reach its former grade and resulting in abandonment of its former course (Reneau and Dethier, 1996b).

Immediately west of this stop, near the confluence of Potrillo and Water Canyons, the late Pliocene Cerros del Rio basalts reach their highest elevation above the paleocanyon. This presumably marks the location of the highest of a series of late Pliocene basalt dams. Evidence of lakes impounded behind these dams are widespread to the north, including pillow basalts and lacustrine deposits (Dethier, 1996, and earlier workers; Stop 1 of Day 3). The late Pliocene to early Pleistocene Rio Grande at this location meandered between a basaltic andesite to the southeast (Tcba of Dethier, 1996; hill across Water Canyon, beneath powerlines) and an extensive tholeiitic basalt that underlies White Rock and this stop (Tcb3); we infer that the tholeiitic basalt flows produced the highest of the dams (Reneau and Dethier, 1996b).

Multiple mafic flows with compositions ranging from tholeiite to benmorite are exposed on both sides of the White Rock Canyon. Two major episodes of mugearite flows erupted during the late Miocene and late Pliocene periods. These rocks contain variable major and trace elements contents and their source centers are mostly buried under younger volcanic units. The late Miocene (9.30 Ma) mugearite (DN85-137 and SLR93-1) and a nearby flow (DN85-4) at the mouths of Ancho and Water Canyons, respectively, are characterized by higher Al_2O_3 (18.2-19.9 wt %) and alkalis (6.66-7.35 wt %) and lower MgO (1.8-2.3 wt %) unlike the younger Pliocene flows of similar compositions exposed along the canyon walls. However, the high-alumna mugearites differ from each other in their trace element compositions whereby the late Miocene flow from Ancho Canyon contains higher Cr and Ni and lower Ba and Sr while DN85-4 shows the opposite trend. Despite their close proximity, their exposure at the base of the White Rock Canyon section close to Miocene Santa Fe Group sediments, and having similar major element compositions, it is not clear if they erupted contemporaneously. Two other samples (DN85-14 and 104) from the mouth of Water Canyon are also of mugearite composition and are chronologically (2.50 Ma) correlative to a basal flow (DN85-147b) at the Overlook section. However, a nearby volcanic center (DN93-8) located between the Ancho and Water Canyons is older (2.59 Ma) and contains slightly different major and trace element contents compared with the adjacent Pliocene mugearite flows.

The youngest lava flow (DN85-141) in Water Canyon is exposed at the crossing of State Road 4. This is tholeiitic in composition and yielded an age of 2.39 Ma consistent with its position above the 2.5 Ma mugearite flows exposed downstream from the tholeiite outcrop. This flow is chemically similar to a number of flows exposed in Pajarito Canyon and the upper flow at the Overlook section except for somewhat lower Cr and Ni contents in DN85-141. A nearby dike (DN93-13, 3.18 Ma) that intruded an eroded cinder cone of unknown age and composition has the same major element and trace element compositions as the tholeiite sample (DN84-141, 2.39 Ma) from Water Canyon. Though poorly radiogenic, the total gas and isochron ages from the dike are much older compared with the flow. Despite chemical correlations, the age of the dike and the degree of erosion suggest that none of the tholeiitic flows erupted from this center. The fissure and/or centers responsible for the tholeiitic lavas of the Pajarito Plateau are probably buried by the Bandelier Tuff.

The late Pliocene tholeiitic basalts ($^{39}Ar/^{40}Ar$ ages of ca. 2.4-2.5 Ma; Woldegabriel et al., 1996) were apparently erupted near the end of a relatively brief period of volcanism that resulted in a rapid rise in the level of the Rio Grande. A similar $^{39}Ar/^{40}Ar$ age of ca. 2.47 Ma was obtained from the lowest exposed flow near the mouth of Water Canyon, a flow whose base is within 15-20 m of the modern river, 260 m lower than this stop. The major, relatively rapid rise in river level that is suggested by these dates may have directly aided deposition of the contemporaneous Puye Formation upriver (Reneau and Dethier, 1996b), a thick and extensive fan complex derived from erosion of the dacitic Tschicoma Formation highlands in the northeastern Jemez Mountains.

From the rim of White Rock Canyon, an extensive complex of Pleistocene slump complexes can be seen that occupies most of the area within the canyon. These landslides mainly involved failure of basaltic rocks capping relatively weak sedimentary rocks, including Miocene rift-filling sediments of the Santa Fe Group (Reneau et al., 1995). The occurrence of deposits of the El Cajete pumice on most of the larger slumps indicates that they were emplaced prior to 50-60 ka. Immediately downstream from the mouth of Water Canyon, the Rio Grande is incised through a latest Pleistocene landslide that dammed the river at ca. 12.4 14C ka, as shown by analyses of charcoal associated with lacustrine deposits upriver of this slide (Dethier and Reneau, 1996; Reneau and Dethier, 1996a). This landslide involved failure of the toe of a larger slump complex to the west, and the resultant lake probably extended ~12 km upriver to near Otowi Bridge. Deposits from at least 5 late Pleistocene landslide-dammed lakes have been recognized in White Rock Canyon, and the available age control indicates that most of these slides were triggered during wetter climatic periods than have existed in the Holocene. The thickest section of lacustrine sediment is exposed near Stop 2 of Day 3, immediately downstream from Cañada Ancha, where 30 m of well-laminated sediments occur in bluffs above the Rio Grande.

Return to Los Alamos Inn via Highway 4-Trinity Drive or by Pajarito Road to Trinity Drive

Day 3

Mileage 0.0
Leave from Los Alamos Inn on Trinity Drive, Los Alamos Drive east through town of Los Alamos; pass airport east of town

3.2 (3.2) Pass East Gate and Rest area to North; Camp Hamilton pullout of Day 2

6.4 (1.8) Go straight on New Mexico Highway 4? toward Pojojaque and Santa Fe

7.3 (0.9) Outcrops of Guaje pumice bed to left, upper end of Stop 1 outcrops

8.0 (0.7) Water tanks on right; pull off and park. Cross 4-lane highway (BE CAREFUL)

Stop 1 Palagonitized Cerros del Rio basalts to Guaje pumice
Outcrops of Cerros del Rio basalt are exposed in roadcuts on the north side of Los Alamos Canyon. Basaltic flows exhibit brittle and soft-sediment deformation where they overrode fluvial sediements containing related basaltic tuff. The basalt flow dammed the ancestral Rio Grande to the south and lava flow front became a palagonite-pillow delta advancing into a lava-dammed lake. Eastward-dipping foreset beds of this delta are spectacularly exposed in Los Alamos Canyon south of the water tank. Ashy sediment, forming a green lacustrine shale unit, filled the lake to a level which locally topped the lava flow. The green shales have acted as a highly deformable layer, and to the northeast of these roadcuts, the overlying Bandelier Tuff section is extensively slumped.

The youngest tholeiitic flow (DN93-21, 2.33 Ma) occurs in the vicinity of the Los Alamos and Pueblo Canyons intersection. The tholeiitic flows are probably underlain by 2.57-2.55 Ma mugearite flows from the Buckman Mesa that flowed westward and are exposed on the south side of Los Alamos Canyon not far from the La Mesita cone. The 2.3-2.5 Ma basalt flows of tholeiitic composition occur along the western side of White Rock Canyon and consistently stratigraphically overlie the mugearite/hawaiite flows. These tholeiitic lavas flowed east or south-southeast into an ancestral lake in White Rock Canyon as indicated by the occurrence of pillow lavas. Other tholeiite lavas from the central and the southern parts of White Rock Canyon yielded similar isotopic ages and appear to have erupted along a fissure east of and parallel to the Pajarito fault zone.

The lava flows on the south side of Los Alamos Canyon and those from the La Mesita cone (Buckman Mesa) on the opposite side are chemically correlative and of mugearite composition. Although none of the flows from the La Mesita cone were dated, similarity in chemical composition and geographic proximity suggest that the flows on the south side of Los Alamos Canyon came from the vicinity of the Buckman Mesa. A sample (2.59 Ma) from a center between Ancho and Water Canyons is similar in age to the mugearite flows at the northern end of the White Rock Canyon. The chemically and temporally correlative La Mesita and Los Alamos Canyon flows crop out on top of the Puye Formation gravels.

Walking west along the north side of the road, the basal contact of the Guaje Pumice bed directly ovelies the Cerros del Rio basalt. The basalt has a prominent soil developed on its upper surface. The Guaje pumice (1.61 Ma, Izett and Obradovich, 1994) is about 7 m thick here, though it is commonly up to 10 m thick in expsoures on the Pajarito Plateau. The Guaje pumice fall is the initial stage of the eruption of the Otowi Member of the Bandelier Tuff and is overlain by thin, bedded pyroclastic surge beds that mark the beginning stages of Otowi ash-flow eruptions. The Otowi is a nonwelded ash-flow deposit where exposed here on the north side of Los Alamos Canyon and is about 50 m thick. At the base of the cliffs is 1 m of fine-grained ash fall deposits of the Tsankawi Pumice Bed of the Tsherige (Upper) Bandelier Tuff, overlain by 50 m of cliff-forming partly welded Tsherige ash-flows. These are the units 1g, 1v, and 2 of the Tsherige Member stratigraphy discussed at stop 4 of Day 2.

Return to vehicles and continue east toward Pojojaque and Santa Fe

10.6 (2.6) Highway 30 to left leads to Espanola; continue straight ahead.

11.6 (1.0) Otowi Bridge over Rio Grande

12.4 (0.8) La Mesita (Buckman Mesa) to right. San Ildefonso Pueblo land, do not enter without permission; violators are subject to prosecution!!

18.7 (6.3) Intersection with U. S. Highway 84/285, turn right (south) toward Santa Fe.

32.5 (13.8) Old Taos Highway to left (East)

32.8 (0.3) Las Campanas/Camino La Tierra turn off; turn right (west)

36.9 (4.1) Las Tierra subdivision, stop sign; continue straight

38.5 (1.6) Camino La Tierra/Camino Las Campanas Junction; bear left on Camino La Tierra.

38.9 (0.4) La Tierra subdivision to right; continue straight ahead.

44.0 (5.1) Dead Dog Well/windmill, Canada Ancha intersection; bear right.

51.1 (7.1) 3-way Junction; bear left on main track

51.5 (0.4) Rio Grande raft put-in directly ahead; pull-off to left and park.

Stop 2 Buckman Wash-La Mesita (2 mi hike, then LUNCH); Hike through typical sedimentary facies in Miocene Tesuque up to the basaltic cap of Cerros del Rio at Buckman Mesa. Primary basalt hydroclastic deposits are well exposed beneath a thick lava flow emplaced subaqueously. The mesa rim provides an excellent view of the eastern edge of the Pajarito Plateau and Valles caldera/Jemez Mountains. The west side of Buckman Mesa is flanked by a series of classic slump blocks, back-tilted to the east, that involved failure of the Pliocene basaltic rocks and underlying relatively weak sedimentary rocks of the Santa Fe Group (Reneau et al., 1995; Dethier, 1996). Failure of other similar landslides downriver repeatedly dammed the Rio Grande during the late Pleistocene (see Day 2, Stop 6). The bluffs immediately downriver from the mouth of Cañada Ancha provide an excellent exposure of 30 m of well-laminated lacustrine sediments that were deposited within one of the landslide-dammed lakes. That lake had an estimated age of ca. 40-70 ka, a maximum depth of ~60 m, and a length of ~25 km, extending upriver to near Española. It apparently had a very stable dam and persisted for >100 yr, allowing the lake to completely fill with sediment (Reneau and Dethier, 1996a).

Return to 84/285 and back to Denver

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