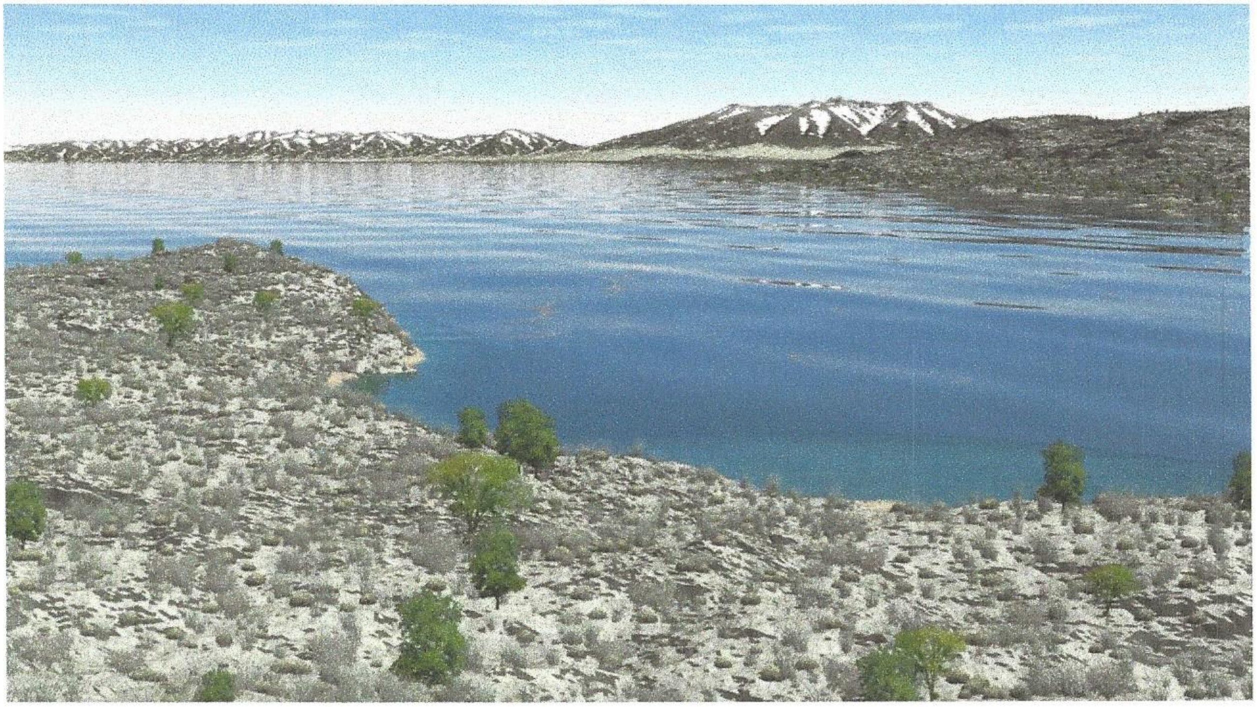
Quaternary Geology of the San Luis Basin near Alamosa, Colorado

with Ancient Lake Alamosa

June 2-3, 2007

Led by Michael Machette, U.S. Geological Survey



GIS recreation of Lake Alamosa at about 500 ka. View is to the NNE from San Luis Hills.

June 2-3, 2007: The CSS spring field trip was led by Mike Machette to ancient Lake Alamosa, the Plio-Pleistocene lake that occupied a large part of the San Luis Valley. On this trip, participants examined various lake features, such as spits, bars and lagoon deposits, discussed the timing and ultimate overflow of the lake, peat and tufa deposits, and visited the Quaternary Mesita Volcano. The trip also visited the Sangre de Cristo fault zone and its scarps near Fort Garland, some of which are as young as early Holocene. There was a brief stop near Kenosha Pass to arm wave at the eastern margin of South Park where mapping by USGS has shown possible late Quaternary faults.

Chris Morrison

2007 Colorado Scientific Society Field Trip: Quaternary Geology of the San Luis Basin near Alamosa, Colorado June 2-3, 2007

Michael Machette
U.S. Geological Survey

Orientation for Field Trip

On the first day of the fieldtrip, we will discuss various aspects of middle Pleistocene to Pliocene Lake Alamosa, including its extent, relict geomorphic features, and age. In addition, we will see the ancient outlet of the lake and discuss its overflow through the Costilla Plain and into New Mexico. We will visit Mesita Cone, a 1.0-Ma basaltic vent on the Costilla Plain, and stop along the base of San Pedro Mesa to discuss landslide and fault hazards along the Southern Sangre De Cristo fault zone.

On the second day of the field trip, we will see extensive peat deposits and associated tufa mounds that formed in a paleo-wetland during latest Pleistocene time. Next are deposits exposed at Hansen Bluff—the type section of the Alamosa Formation, which was deposited in Lake Alamosa. From there, we travel east to see fascinating fluted ventifacts, and barrier bars and lagoons of the ancient lake. At our final stop will see Holocene(?) scarps of the Central Sangre de Cristo fault zone, which extend through the town of Fort Garland.

Stop 1. Deposits of Lake Alamosa at the Bachus Pit

Location: Bachus Pit; Alamosa West 7.5' quadrangle
GPS: NAD27, Zone 13, 418200 m E., 4144720 m N., near center of pit
Elevation: About 7540 ft (2298 m) asl at base of pit

Exposures within the Bachus Pit show evidence of transgression and regression of Lake Alamosa, followed by incision of alluvial channels graded to post-lake base levels. The Bachus Pit is one of the few places in the lake basin where lake deposits are well exposed: elsewhere, post-lake surficial deposits, high water tables, and strong efflorescence of gypsum typically obscure exposures of lacustrine sediment.

The Bachus Pit produces sand and pebble-size gravel for local use (mainly fill material). Although the pit walls change with continued mining, the base of the pit is controlled by fine-grained, water-saturated silt and clay deposited by Lake Alamosa prior to its last transgression and subsequent overflow. The walls of the pit expose well-sorted, sandy small-pebble gravel that represents transgressive and regressive near shore and low-energy beach deposits. Between these deposits is sandy silt (deeper water phase of the lake) that is finely laminated and contorted by pressure loading from the overlying sedimentary package. The entire lacustrine section is capped, unconformably, by several meters of fine-grained alluvium that was deposited in response to falling base levels as the lake emptied though the Fairy Hills. This alluvium is capped by loess and has relict soils, but their discontinuous Bt and Bw horizons (disturbed by animal burrows) are suggestive of middle Pleistocene age.

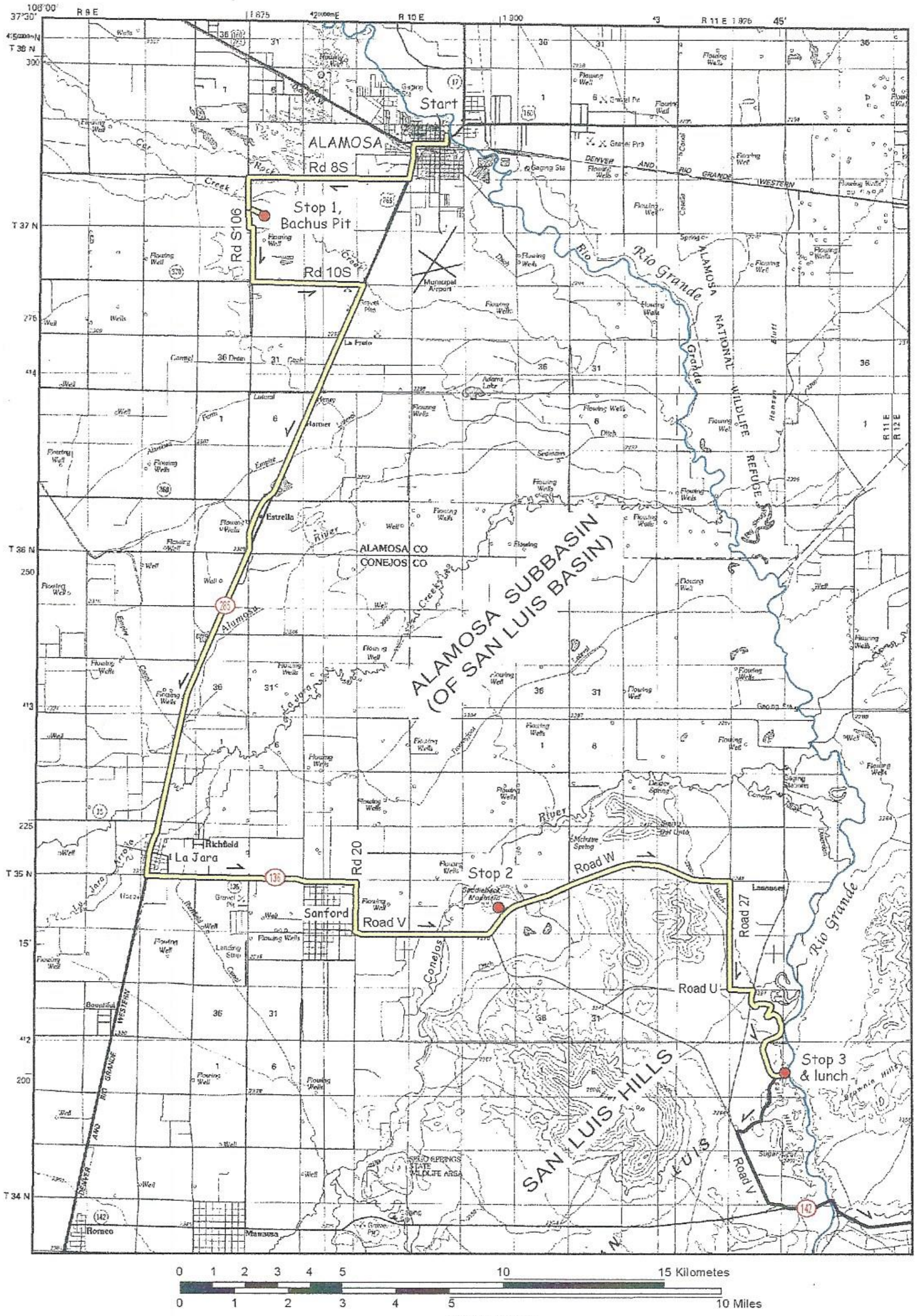


Figure A. Index map showing route and stops for Stops 1-3, Day 1 of CSS 2007 fieldtrip.

Sediment in the Bachus Pit, together with high-energy near-shore gravel seen at the next stop and lagoonal features seen at Stop 9, comprise new and important stratigraphic and geomorphic evidence for the culmination and subsequent overflow of ancient Lake Alamosa.

Stop 2. Soils on and experimental dating of lacustrine gravels of Lake Alamosa at Saddleback Mountain

Location: Gravel spits on south face of Saddleback Mountain, about 1.5 miles NE of bridge over Rio Costilla; Pikes Stockade 7.5' quadrangle
GPS: NAD27, Zone 13, 425340 m E., 4123725 m N.
Elevation: About 7575 ft (2309 m) asl (base of slope at turn off from paved road)

This stop is a key locality for understanding the extent and age of Lake Alamosa. Two spits perched on the southern side of Saddleback Mountain provide unequivocal evidence for the presence of a large ancient lake (Lake Alamosa) that occupied the San Luis Basin, probably during the Pliocene and Pleistocene. Soils on these spits show strong development of calcic (Bk) horizons, which suggest a middle Pleistocene age for the spits.

The lower and upper spits were trenched in order to describe the soils formed on the lacustrine gravels and to sample for a variety of experimental cosmogenic nuclide and U/Th dating techniques. As of May 2007, only the surface-exposure dating using ^{3}He isotopes had been completed. This technique yielded an age of 439±6 ka from a single bedrock boulder; thus, for the purposes of discussions of Lake Alamosa we use a time of 440 ka for its overflow and catastrophic lowering.

Stop 3. Overview of the Rio Grande Outlet

Location: Overlook, east of BLM Road 5003, west side of Rio Grande, about 3.6 miles (5.8 km) S of Lasauses, CO; ca. 1.5 mile SSE of Lasauses Cemetery; Mesito Reservoir 7.5' quadrangle
GPS: NAD27, Zone 13, 433780 m E., 4118190 m N.
Elevation: 7610 ft (2319 m) asl (turn around point overlooking river)

This scenic overview of the Rio Grande is located near the overflow point of Lake Alamosa. The gap between the Fairy Hills and Brownie Hills to the south of here is the lowest point in the San Luis Hills, and thus represented the first opportunity for a rising Lake Alamosa to overtop a hydrologic sill. Overflow of the lake through the Fairy Hills cut a deep, narrow gorge and allowed the lake waters to drain southward across the Costilla Plain and northern Taos Plateau, eventually joining the Red River/Rio Grande, west of Questa, New Mexico. In addition, we are near the point where Jacob Fowler described the first account of Lake Alamosa—in 1811-12.

On the route to this stop, we drove uphill and across a bedrock-cored saddle. This saddle is covered with small rounded pebbles of locally reworked volcanic rock. These gravels represent low-energy, beach (shoreline) deposits of Lake Alamosa at its highest stand (ca. 7660 ft or 2335 m asl). A soil pit excavated about 20 m west of this gravel road exposed sandy pebble to small cobble gravel that was deposited just offshore (west of) the highest shoreline. Further west, gullies expose fine-grained sand, silt and marl that represent deeper water, offshore deposits (Alamosa Formation) of Lake Alamosa.

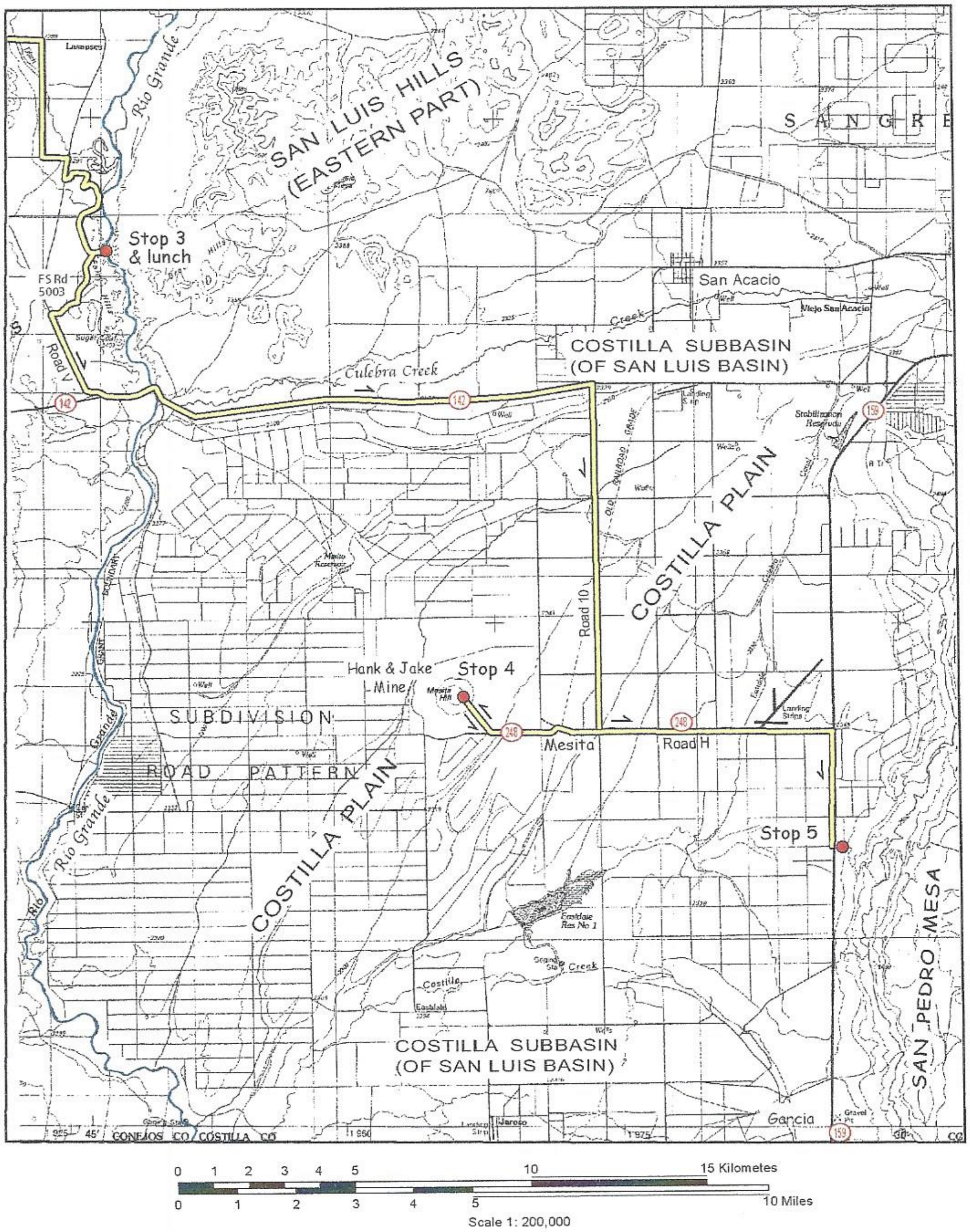


Figure B. Index map showing route and Stops 3-5, Day 1 of CSS 2007 fieldtrip.

Stop 4—Mesita Hill: An early Pleistocene volcano adrift on a sea of dirt

Location: Entrance to Jake and Hank Mine (cinder quarry) at Mesita Hill, ca. 2 miles (3.2 km) WNW of Mesita, CO; Sky Valley Ranch 7.5' quadrangle
GPS: NAD27, Zone 13, 443580 m E., 4106700 m N.
Elevation: 7800 ft (2377 m) asl (at entrance gate)

Mesita Hill is an early Pleistocene basaltic shield volcano in the Costilla Plains between San Pedro Mesa and the Rio Grande. With a $^{40}Ar/^{39}Ar$ age of 1.03 ± 0.01 Ma, the volcano is the youngest eruptive center within the San Luis Basin and in the Rio Grande rift north of Albuquerque, New Mexico. Younger volcanoes, generally considered to be associated with crustal extension, exist further north in west-central Colorado, including Dotsero "crater" (4,150 ± 30 ^{14}C yrs B.P.) and Willow Peak volcano (0.28 ± 0.04 Ma), but are well outside of the present physiographic boundary of the rift. The Mesita volcano is cut by an intra-rift fault, informally known as the Mesita fault, with recurrent post-4 Ma movement including offset of the western flank of Mesita volcano, middle Pleistocene alluvium of the Costilla Plain, and upper and late middle Pleistocene alluvium of the Costilla drainage south of Mesita.

Stop 4 includes a walking traverse from the parking area on the south side of the reclaimed quarry pit, skirting the east side of the remaining pit to the north end of the cinder quarry, followed by a short excursion (about 0.5 km) to the northern flank of the volcano and subsequent return to the starting point via a route along the footwall of the Mesita fault. We will have an opportunity to discuss the volcanic history of this beautifully exposed rift volcano and examine sedimentary deposits and structures preserved on the north rim of the excavation pit. The origin of these sedimentary deposits has been the subject of some debate that centers on the post-eruption geologic history of Mesita Hill, whether it is a relict (primary) feature or exhumed feature, and the associated geologic histories involved with these vastly different interpretations. This debate will be examined in light of the observed deposits and models for basin evolution and the origin of the Costilla Plain. If time allows, we walk west of the pit to get an overview of the Mesita fault, a down-to-west intrabasin fault with recurrent Quaternary movement that cuts the 1.0 Ma basalt flows on the west side of the volcano.

Stop 5. Landslides and the Sangre de Cristo fault zone along San Pedro Mesa

Location: Entrance to Melby Ranch (Wild Horse Mesa) on CO Highway 159, about 3.2 km S of CO Highway 248 to Mesita, CO; Garcia 7.5' quadrangle
GPS: NAD27, Zone 13, 453790 m E., 4102500 m N.
Elevation: 7666 ft (2337 m) asl (at entrance to Melby Ranch)

This stop provides a convenient place to view and discuss landslides and the Southern Sangre de Cristo fault zone, which bounds the western margin of San Pedro Mesa—the high (8500-8900 ft or 2590-2713 m asl) basalt-covered surface to the east. The nearly 1000-ft (300-m) high western escarpment of San Pedro Mesa is riddled with landslides, some quite massive (i.e., many square kilometers in area). Faulting and landsliding have left large blocks of the Pliocene Servilleta Basalt at various altitudes and orientations. Landslides, rockfalls, colluvium, and ramps of eolian sand obscure the underlying problem unit—poorly consolidated sediment of the Santa Fe Group. To the west of us is the Costilla Plain, an extremely large, coalesced alluvial fan-piedmont slope complex that was deposited by Culebra Creek in middle Pleistocene time.

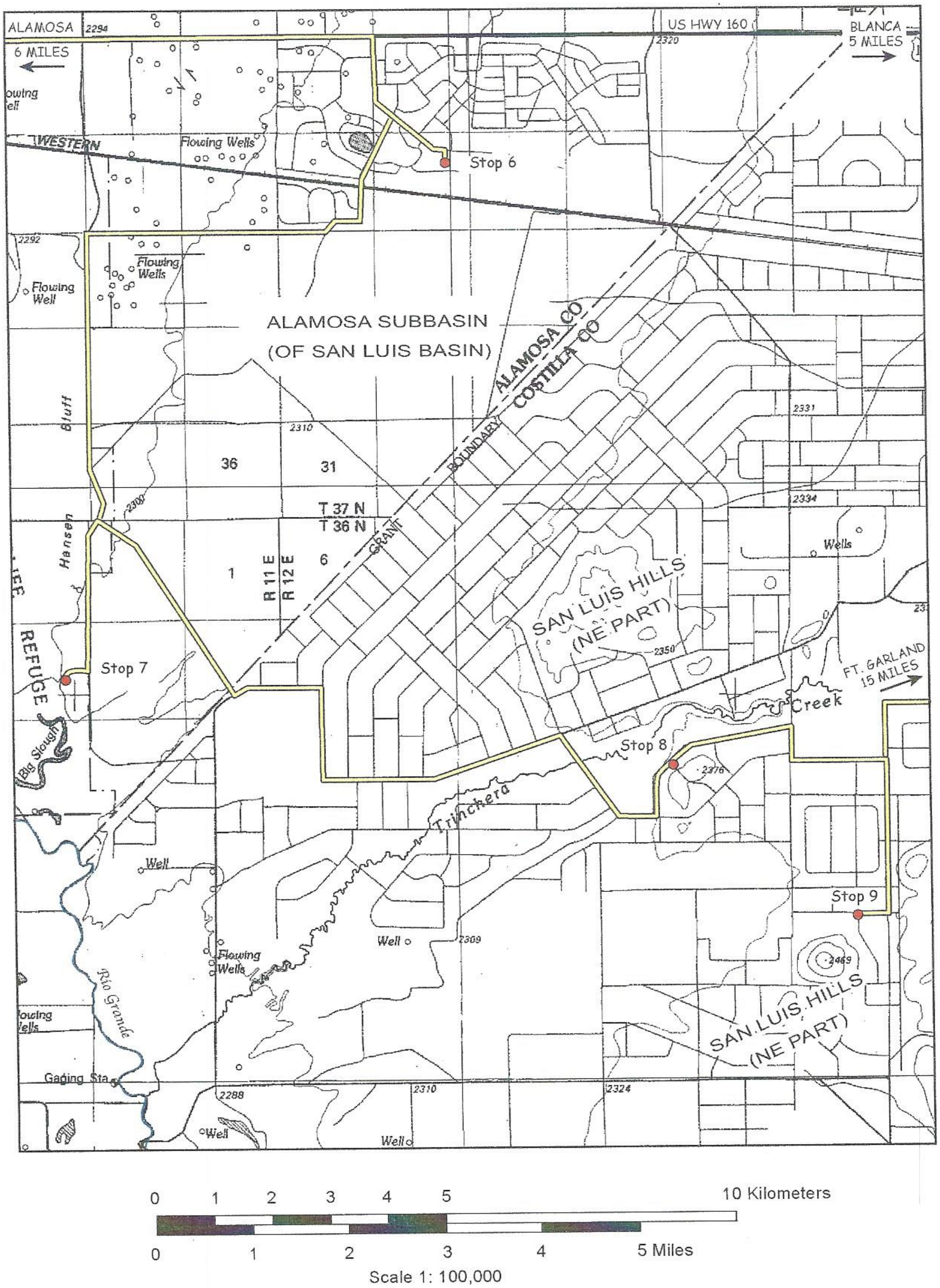


Figure C. Index map showing route and stops for Day 2 of CSS 2007 fieldtrip.

Drill-hole logs show that downdropped flows of Servilleta Basalt (ca. 4.0±0.3 Ma) are 30-50 m beneath the Costilla Plain, having been displaced about 300-400 m by the Sangre de Cristo fault zone and buried by Santa Fe Group sediment in the past 4 m.y.

Stop 6. Late Pleistocene to early Holocene paleo-wetland deposits

Location: North edge of Mr. Peat pit. Location is about 2 miles south of U.S. Highway 160 and about 10 miles east of Alamosa, CO; Baldy 7.5' quadrangle
GPS: NAD27, Zone 13, 440123 m E., 4145465 m N.
Elevation: 7590 ft (at north edge of pit on section-line fence)

This stop provides an opportunity to see peat deposits related to paleospring waters that flowed down a now-abandoned late Pleistocene paleostream channel. The peat deposits have been commercially mined since about 1950, and the workings we'll see at this stop are located at the Mr. Peat Pit. In the summer of 2006, Machette and Schumann excavated four pits in these deposits to better understand the timing and duration of peat accumulation, facies of the peats, the age of underlying fossil-bearing alluvial deposits and the age and origin of overlying tufa deposits. Radiocarbon dating of the peats show that most of the deposits accumulated from 13.5 ka to about 11.6 ka, but continued on until middle Holocene time (4.3-6.7 ka), whereas locally overlying tufaceous spring deposits started to accumulate at about 6.7 ka and continued until about 3.9 ka. The peats lie in a late-glacial age paleovalley that is underlain by well-bedded sand and sandy fluvial gravel. An organic seam in the alluvium about 1.4 m below the peat yielded an age of 14.4 ka (latest Pleistocene), whereas OSL dating of the alluvium yielded two stratigraphically inconsistent ages (9.9 ka and 6.45 ka) and a viable age of about 20.3 ka for late Pleistocene fluvial sands 2.8 m below the peats.

Stop 7. Hansen Bluff—Alamosa Formation

Location: Hansen Bluff
Alamosa East quadrangle
GPS: NAD27, Zone 13, 433322 m E., 4136731 m N.
Elevation: About 7525 ft (2294 m) asl (Wildlife Refuge parking lot)

Although we don't have time to visit this site, Hansen Bluff is one of the most important localities in terms of understanding the Alamosa Formation. Karel Rogers and her colleagues conducted integrated, multidisciplinary studies of these bluffs in the late 1970s and early 1980's and published a number of excellent papers describing the Quaternary geology, environments of deposition, fauna and floral remains, magnetostratigraphy and age control for the section. They followed up by drilling a 127-m-long core to extend the sedimentary record into the Pliocene. The main contributions that we have made at Hansen Bluff are to map the local geology, to recognize a stratigraphic unconformity between the fine-grained Alamosa Formation and the overlying coarser sandy gravel beds (older alluvium, unit Qao), and to suggest how these deposits fit into the broader history of Lake Alamosa.

Stop 8. And the Wind Blows—Fluted ventifacts on the ancient shore of Lake Alamosa

Location: Thatcher Road (unmarked), S side of Trinchera Creek, about 8.2 miles (13.2 km) SW of Blanca, CO; Lasauses 7.5' quadrangle
GPS: NAD27, Zone 13, 4432787 m E., 4135480 m N.
Elevation: 7655 ft (2336 m) (at crest of road)

This ridge of resistant volcanic rocks of the Conejos Formation shows evidence of prolonged erosion from sand blasting (i.e., the formation of ventifacts). Finger-size troughs, cones, and broad mullions on the windward and leeward sides of intact bedrock blocks reflect hundreds of thousands of years of wind erosion at a location where sand is available and the wind is funneled into a valley. The base of this ridge was cut by the highest stand of Lake Alamosa (elevation 7660 ft or 2335 m asl) at this site and there is a persistent gravel bench from here south along bedrock hills for at least 1 km on the southeast side of Trinchera Creek. The ridge may have been initially cut as part of the channel of Trinchera Creek, but this cutting would have predated the highest stand of Lake Alamosa, about 440 ka. Ventifacts are present hundreds of meters south and tens of meters above the ridge, thus eliminating water erosion as a significant factor in their formation.

Stop 9. Lagoons and barrier bars of ancient Lake Alamosa

Location: Appleblossum Lane (N-S) and 24th Street N (E-W), Trinchera Creek Estates; about 8 miles (13 km) SW of Blanca, CO; Blanca SE 7.5' quadrangle
GPS: NAD27, Zone 13, 446639 m E., 4132967 m N.
Elevation: 7650 ft (2332 m) asl (at road intersection)

From this road intersection, you can see two sets of bay-mouth barrier bars that have blocked a north-trending shallow stream valley. The bars impounded the drainage and formed lagoons, which have been playas since Lake Alamosa was drained. The lower bar (to the north of us) has elevations of 7645-7655 ft (2310-2333 m) asl and declines in height from NE to SW, in the direction of its propagation. The upper bar (the Appleblossum Lane bar) spans the stream valley and has a medial E-W elevation of about 7662 ft (2312 m) asl: it is attached to bedrock that borders the valley on both ends. A soil pit excavated on the crest of this bar penetrated sandy, well-rounded pebble to boulder gravel and laminated sands, all of which were deposited in shallow water. The soil on this barrier bar has a discontinuous 65-cm-thick Bk horizon, and is not as well developed as the soils on the upper and lower spits of Saddle Mountain (Stop 2) or in shoreline deposits in the Fairly Hills (Stop 4). A second, exploratory pit on the margin of the playa south of the Appleblossum bar exposed unbedded silt and sand that is extensively bioturbated.

Stop 10. Sangre de Cristo fault zone in Fort Garland, CO

Location: Entrance to Forbes Trinchera Ranch, Fort Garland, CO; Fort Garland 7.5' quadrangle
GPS: NAD27, Zone 13, 460700 m E., 4142300 m N.
Elevation: 7905 ft (2410 m) asl

From this roadside stop, you can see the spectacular Sangre de Cristo Mountains to the north and east, with Blanca Peak (14,345 ft asl) dominating the northern horizon. These Proterozic-cored mountains are uplifted along the Sangre de Cristo fault system, which extends from Poncha Pass on the north to Taos on the south, a distance of nearly 250 km.

The geology of the Fort Garland quadrangle was mapped in 1977 by Alan Wallace (USGS), and revised by Michael Machette mainly adding detail and differentiation to the Quaternary deposits (Wallace and Machette, USGS Map SI-2963, in prep., 2007). This mapping documents recurrent and young movement on the Central Sangre de Cristo fault zone, which is the central of three zones that comprise the larger fault system. Scarps from the fault zone are hundreds of meters high along Garland Mesa (3.67 Ma Servilleta Basalt), tens of meters high on middle Pleistocene alluvium, and 2-3 m high on latest Pleistocene alluvium. The smallest, youngest scarps are the product of a single movement, which near San Luis (35 km south) is dated by Crone and Machette (2006) at about 9.0±2 ka. The average recurrence interval for large magnitude (7) earthquakes on this fault zone has averaged about 12 k.y. over the past 50 k.y. This young, small scarp extends across the meadow of Trinchera Ranch, in front of the Ute Campground and Lodge Motel, and crosses Highway 160 just to the east of this stop. As such, the Sangre de Cristo is the longest and fastest slipping fault system in the entire Rio Grande rift, which extends from northern Mexico (Chihuahua) to Leadville, Colorado.