

COLORADO GEOLOGICAL SURVEY

Research Notes RN-01

The Vallecito flood— a catastrophic flood on Los Pinos River, southern San Juan Mountains, Colorado and New Mexico

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ABOUT THIS REPORT

From the abstract:

“A catastrophic flood ran down the length of Los Pinos River into the San Juan River valley. The flood originated in the southern San Juan Mountains of Colorado, and deposits from the flood are still recognized 72 miles downstream near Farmington, New Mexico. This catastrophic flood is here called the Vallecito flood. The cause of the flood is unknown, but it was likely a glacial outburst flood, like many other known glacial outburst floods in the San Juan Mountains. Glaciers flowed down the headwater valleys of Los Pinos River and its tributary Vallecito Creek, and they merged at Vallecito. The glacier that arrived first may have dammed the other fork creating a glacial lake, or a proglacial lake could have formed behind an end morainal dam during the merged glaciers’ retreat. Failure of the glacial dam led to an outburst flood whose path can be determined from the distribution of flood deposits. The time of the flood is likewise unknown, because no flood deposits have been dated. Flood gravels on high mesas in New Mexico suggest the flood occurred in the early Pleistocene.”

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COLORADO GEOLOGICAL SURVEY
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THE VALLECITO FLOOD

A CATASTROPHIC FLOOD ON LOS PINOS RIVER

SOUTHERN SAN JUAN MOUNTAINS

COLORADO AND NEW MEXICO



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2025

ABSTRACT

A catastrophic flood ran down the length of Los Pinos River into the San Juan River valley. The flood originated in the southern San Juan Mountains of Colorado, and deposits from the flood are still recognized 72 miles downstream near Farmington, New Mexico. This catastrophic flood is here called the Vallecito flood.

The cause of the flood is unknown, but it was likely a glacial outburst flood, like many other known glacial outburst floods in the San Juan Mountains. Glaciers flowed down the headwater valleys of Los Pinos River and its tributary Vallecito Creek, and they merged at Vallecito. The glacier that arrived first may have dammed the other fork creating a glacial lake, or a proglacial lake could have formed behind an end morainal dam during the merged glaciers' retreat. Failure of the glacial dam led to an outburst flood whose path can be determined from the distribution of flood deposits.

The time of the flood is likewise unknown, because no flood deposits have been dated. Flood gravels on high mesas in New Mexico suggest the flood occurred in the early Pleistocene.

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Frontispiece: Glaciers flowed down the valleys of Los Pinos River and Vallecito Creek, merging at the site of modern Vallecito Reservoir. This was the source area of the Vallecito flood.

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INFORMAL TERMS USED IN THIS REPORT

I have used the informal name Vallecito flood for the catastrophic flood described in this report. Place names used for clarity that do not appear on U.S. Geological Survey topographic maps: Los Pinos Canyon, Archuleta Canyon.

INTRODUCTION

FLOOD ROUTE

The Vallecito flood originated on Los Pinos (The Pines) River in the San Juan Mountains of Colorado and flowed into the San Juan River in New Mexico, where it continued at least to Farmington, New Mexico (fig. 1). The source area required deep, constricted valleys to store the necessary water volume, limiting the potential source area to valleys on the south side of the San Juan Mountains. Flood boulders of the distinctive Vallecito Conglomerate further restrict the source to one near Vallecito Reservoir, whose two principal tributaries pass through nearby outcrops of that conglomerate (fig. 1).

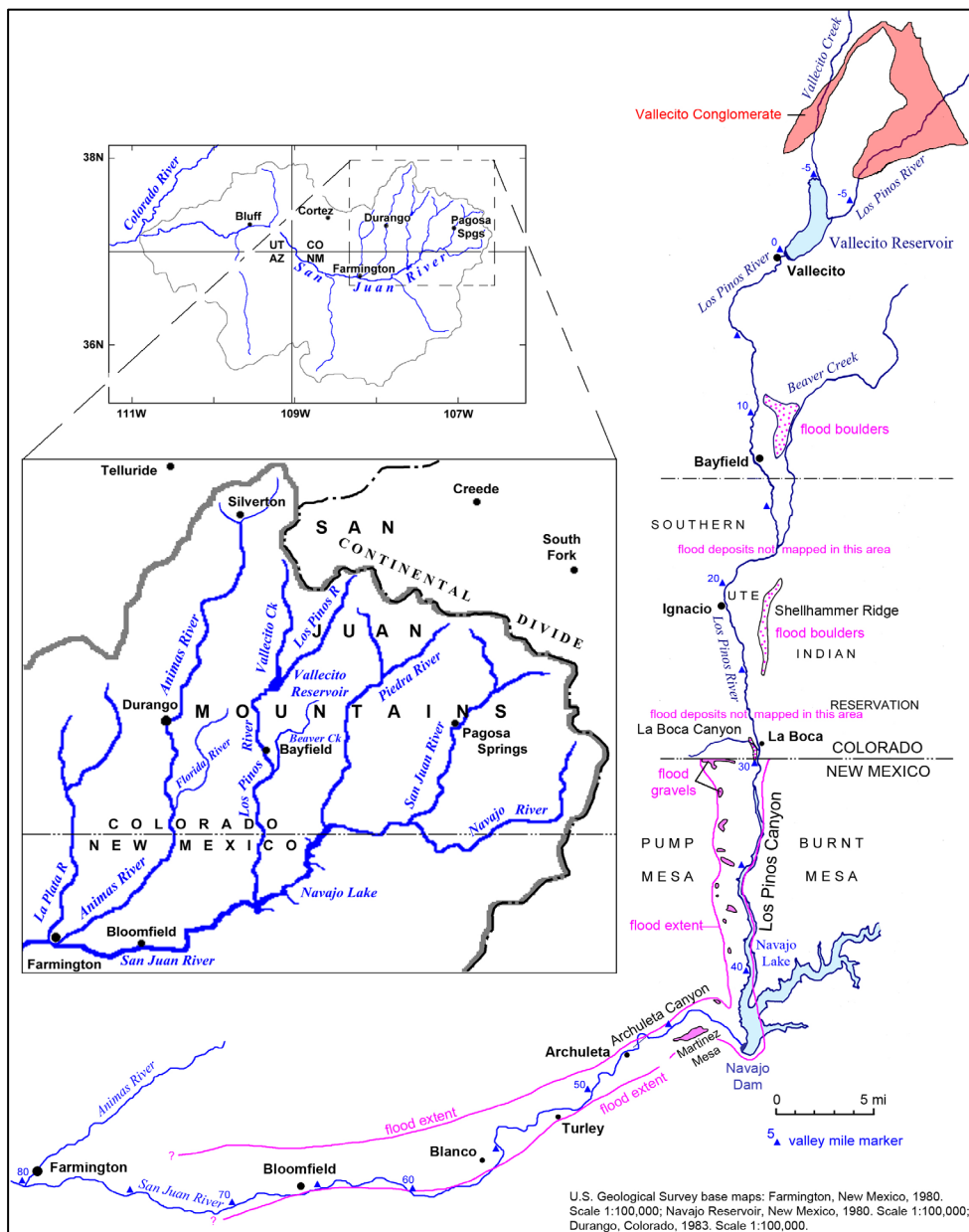


Figure 1—Vallecito flood area with insets of the San Juan River drainage basin. The flood began near Vallecito Reservoir on Los Pinos River, where the distinctive Vallecito Conglomerate crops out, crucial for tracing flood deposits.

Downstream from the San Juan Mountains is broad open country around Bayfield and the Southern Ute Indian Reservation (fig. 2). Flood boulders form lag deposits near Bayfield, and they are recognized discontinuously downstream to New Mexico on nontribal lands. No flood gravels remain north of the reservation, but they are probably present on tribal land in the Mesa Mountains near the southern boundary of the reservation, because they are present farther south on nontribal land along the border in New Mexico.

At the Colorado–New Mexico border, Los Pinos River valley narrows into the head of a canyon, here called Los Pinos Canyon (fig. 3). The canyon is about a thousand feet deep (fig. 4) and continues south to the river’s confluence with the San Juan River (fig. 5). Flood deposits lie along the west rim of the canyon on Pump Mesa.

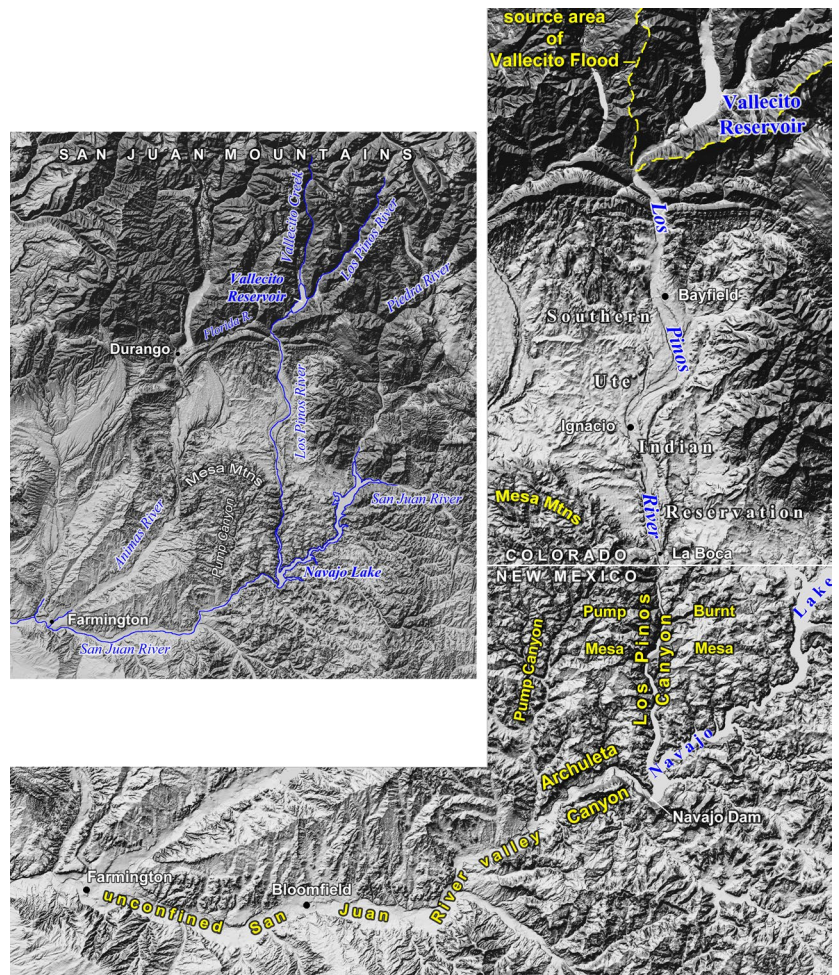


Figure 2—Topography of Los Pinos River–San Juan River drainage.

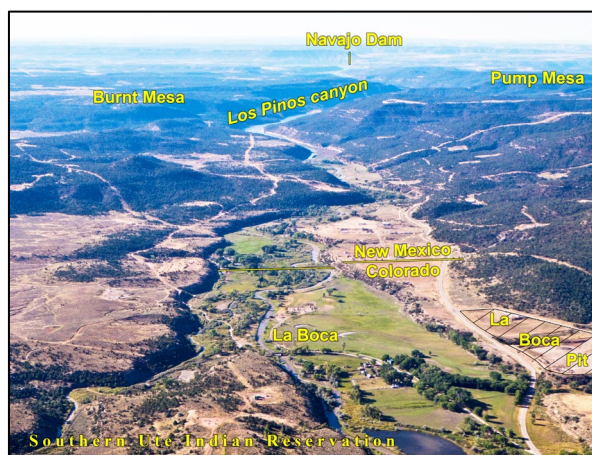


Figure 3—View downstream to the south from La Boca, where Los Pinos River leaves unconfined valley of the Southern Ute Indian Reservation and enters the thousand-foot-deep Los Pinos Canyon. Navajo Dam was built at the confluence of Los Pinos River with the San Juan River.



Figure 4—View upstream to the north of Los Pinos Canyon with San Juan Mountains on horizon (valley mile 37, fig. 1).

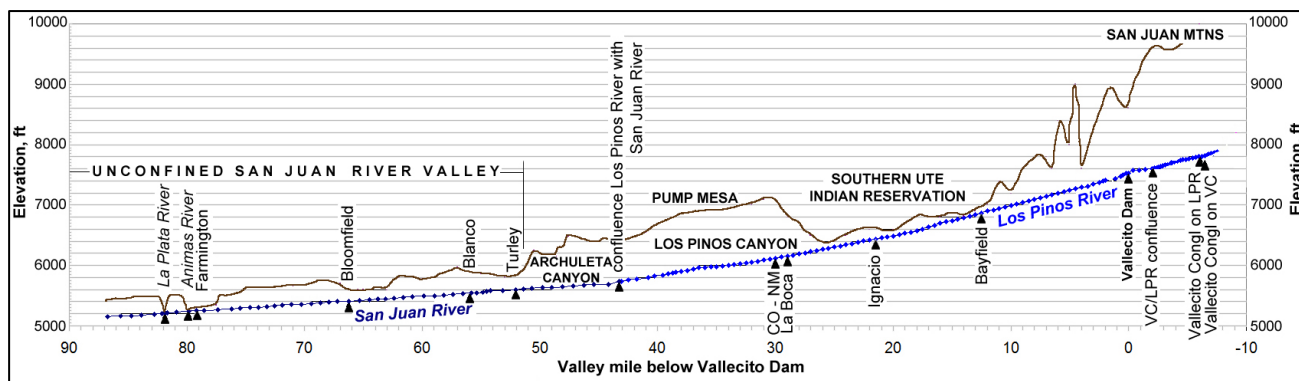


Figure 5— Generalized topography (solid line) along Los Pinos and San Juan Rivers, view to west and north. Presumed glacial dam was at the same location as constructed Vallecito Dam, used as the origin for mileage down valley. CO, Colorado; Congl, Conglomerate; LPR, Los Pinos River; NM, New Mexico; VC, Vallecito Creek.

At the south end of Los Pinos Canyon the river joins the San Juan River. The San Juan River above and below the confluence also flows in a deep canyon (fig. 2). (Navajo Dam was built near the confluence and uses both canyons to store water in Navajo Lake.) The canyon below the confluence, Archuleta Canyon, is about 800 feet deep and continues for about 10 miles (fig. 1, 2). Downstream of Archuleta Canyon the San Juan River valley opens into a broad, unconfined reach that continues beyond Farmington, New Mexico (figs. 2, 5).

HYDROGRAPHY

The San Juan River heads at the Continental Divide and drains the south side of the San Juan Mountains (fig. 1). Los Pinos River is one of three main tributaries to the San Juan River, flanked on the east by the Piedra River and on the west by the Animas River. The divide between the Los Pinos and Animas Rivers bifurcates at the north end of the Mesa Mountains (fig. 2), enclosing a small, separate drainage basin, here called the Pump Canyon basin (fig. 6).

GEOLOGY

The flood source was in the San Juan Mountains, a northwest-trending Laramide structural dome with a core of Precambrian crystalline rock and a cap of Tertiary volcanic rock (Cross and Larsen, 1935; fig. 6). The confluence of Los Pinos and San Juan Rivers is near the center of the asymmetric, northwest-trending San Juan basin, a predominantly Laramide structure. Structural relief between the San Juan dome and the San Juan basin is on the order of 20,000 feet (Kelley, 1957).

Bedrock in the headwaters area of Los Pinos River is predominantly Precambrian plutonic and metamorphic rock, with lesser amounts of younger sedimentary and volcanic rock (fig. 6). Main lithologies are granite and quartzites (these are metaquartzites, referred to in following discussions simply as quartzite), and fluvial clasts derived from the area are dominated by quartzites, most notably the Vallecito Conglomerate, described below.

The rest of the drainage basin, as well as the valley of the San Juan River, consists of sandstones and shales of variable resistance to erosion. The gently rolling topography of the area between Bayfield and La Boca developed on nonresistant sandstones and shales. Farther south on Los Pinos River, the Mesa Mountains, better described as a cuesta rather than mountains, and tops of canyonland mesas are capped by resistant sandstone (fig. 6). Below the junction of the Los Pinos and San Juan Rivers, these resistant sandstones end at the downstream end of Archuleta Canyon (figs. 2, 6); beyond there the valley widens, no longer confined by canyon walls, because the underlying sandstones and shales are less resistant and typically erode to low, rounded hills or to badlands.

SOURCE AREA OF THE VALLECITO FLOOD

The magnitude of the Vallecito flood required massive amounts of water that could have been stored only in deep, constricted valleys such as those in the San Juan Mountains (fig. 1), behind a dam formed by a landslide, a glacier, or an end moraine. A landslide dam cannot be ruled out, but no evidence remains of a candidate landslide.

Outlet valley glaciers from the San Juan icefield flowed down both Vallecito Creek and Los Pinos River, and they merged at the site of the present Vallecito Reservoir. Atwood and Mather (1932) reconstructed this configuration for the latest glaciation (fig. 7). The main drainage has not changed since the time of the flood, as indicated by the path of the Vallecito flood that followed closely the route of the modern Los Pinos and San Juan Rivers, so the scenario shown by figure 7 can reasonably be applied to the time of the flood.

This assumption is further reinforced by the end moraines of two earlier glaciations, Durango and Bull Lake (terminology of Johnson et al., 2017; see table below), that ended at the same place (fig. 8). If, at the time of the

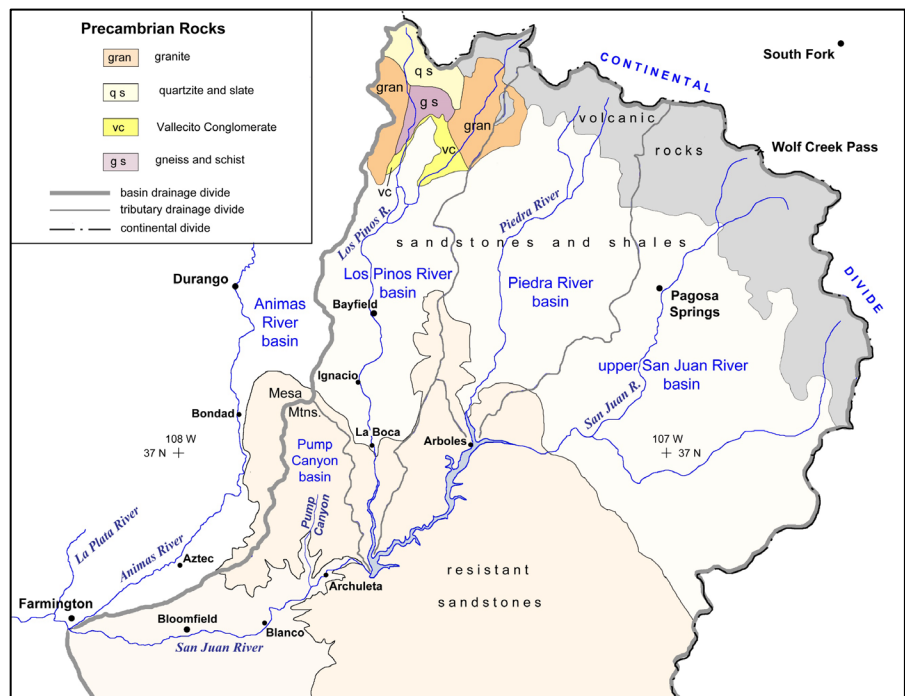


Figure 6—Rock types in San Juan River basin above Farmington, NM, simplified from Steven et al. (1974; Colorado), Manley et al. (1987; New Mexico), and Barker (1969; Precambrian). Volcanic rocks are mainly andesites and ash-flow tuffs.

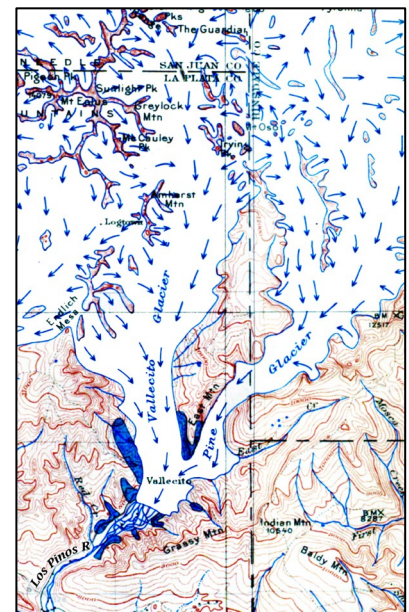


Figure 7—Southern San Juan icefield reconstructed by Atwood and Mather (1932) for most recent glaciation. Vallecito Glacier and Pine Glacier (in Los Pinos River valley) merged at Vallecito.

flood, one of the tributary glaciers preceded the other to their junction, it would have dammed the other river to create a glacial lake behind an ice dam. Alternatively, a proglacial lake could have formed behind an end morainal dam during the merged glaciers' retreat.

San Juan Mountains Glaciations			
Rocky Mountains stratigraphic unit	San Juan Mountains stratigraphic unit	Range of absolute age	Marine Isotope Stage (MIS)
Pinedale	Animas City	~29–14 ka	MIS 2 (Last Glacial Maximum)
Bull Lake	Spring Creek	~191–130 ka	MIS 6
	Durango	~374–243 ka	MIS 8–10

Data from Johnson et al., 2017

The provenance of the flood deposits also requires that the flood began at or above the end moraine. Large boulders in flood deposits far downstream match a unique lithology found only within the Vallecito Conglomerate, which crops out only upstream of the end moraine.

These rocks, called calico rocks by local gravel pit operators, are coarse metaconglomerates containing distinct clasts of red iron formation and red jasper (fig. 9).

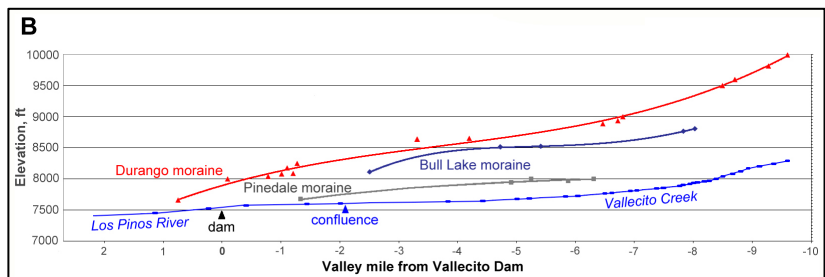


Figure 8— Vallecito area. A. View to northeast of Vallecito Dam and Reservoir. The oldest end moraine (Durango) extends one mile beyond the dam. The youngest (Pinedale) is one mile above the dam, submerged except for a small island near the southeast end at the break in dot pattern. Bull Lake moraine is not visible. B. Longitudinal profiles of the three moraines.

The Vallecito Conglomerate was described in detail by Gonzales et al. (2004):

“Vallecito Conglomerate (Paleoproterozoic, absolute age not constrained)—The Vallecito Conglomerate...is quartz-rich metamorphosed conglomerate ...a thick succession of interstratified fluvial pebble- to cobble-conglomerate and quartz-rich sandstone.... Estimates of the thickness range from 2,000 feet to 6,000 feet.

Conglomerates contain subangular to subrounded fragments of ... quartzite, milky quartz, chert, jasper, banded-iron formation, argillite, and metamorphosed felsic to mafic schist and gneiss.... Quartzite and quartz clasts are generally dominant in any given exposure... Clasts in the conglomerates range from less than 1 inch up to several feet in maximum dimensions, but generally are 2 to 6 inches.”

Vallecito Conglomerate crops out in the steep canyon walls of both Vallecito Creek and Los Pinos River a few miles above their confluence (fig. 6), and it is not found in any of the neighboring watersheds. Large boulders of calico rock are contained in tills of the three recognized moraines—Pinedale, Bull Lake, and Durango. Glaciers of each of these three advances terminated within two miles of the present Vallecito Dam (fig. 8).

If the postulated glaciers responsible for the flood were of similar size, floodwaters originated, therefore, at or above the present-day Vallecito Dam. (All measured distances down valley are given with respect to the dam, as shown in figure 1).

The Uncompahgre Formation, which is mostly quartzite with minor slates and phyllites, also crops out in the headwaters area above the reservoir (“qs” in fig. 6). These quartzites, however, contain only minor conglomerates with small pebbles, occasional jaspers that are black more often than red, and no iron formation. Other bedrock in the putative source area consists of several granite plutons and gneisses and schists.

CATASTROPHIC FLOOD DEPOSITS

The catastrophic flood that raced down Los Pinos River is documented by the flood deposits that remain today. These deposits consist of flood gravels and flood boulders. The term *flood gravels*, as used here, refers to gravels deposited by catastrophic floods that had discharges orders of magnitude greater than normal floods from storms or annual peak runoff. These flood gravels are mostly unsorted, unstratified, or poorly stratified masses of gravel containing flood boulders. The term *flood boulders*, as used here, refers to boulders very much larger than those that can be transported by



Figure 9—Calico rock is a distinctive facies of Vallecito Conglomerate with large clasts of quartz, quartzite, red iron formation, and red jasper. A. Calico flood boulder at confluence of Los Pinos River with San Juan River. B. Calico cobbles are common in flood gravels along Los Pinos River.

normal floods and thus must have been transported by very much larger floods, called catastrophic floods¹.

There is no definitive size above which a boulder is considered a flood boulder, because the size is a function of the local fluvial regime and hydraulic gradient. Along Los Pinos River below Bayfield, flood boulders are as large as 13 feet (ft) in long dimension, whereas the nominal maximum boulder size in river sediments here is less than 2 ft. When one considers boulder sizes, it is helpful to remember that volume and weight of a round boulder increase as the cube of the boulder diameter. For example, one could hold a one-foot-diameter spherical boulder of quartzite, which weighs 87 pounds, whereas a two-foot boulder weighs 693 pounds. The flood boulder in figure 9A, which is about four feet in diameter, weighs about three tons.

All flood gravels and flood boulders described in this report, both along Los Pinos River and the San Juan River, were deposited by the catastrophic Vallecito flood. Actual deposits of flood gravels are observed only on remnants of a high terrace in New Mexico along the lower reach of Los Pinos River and immediately below its confluence with the San Juan River (fig. 1). Isolated flood boulders, however, are much more widespread, and they provide the primary criterion for mapping the extent of the Vallecito flood.

Some of these flood boulders remain at the same elevation as the flood gravels, but many have dropped to lower elevations as float or as lag flood boulders. A lag deposit is generally taken to be a residual accumulation of coarse, usually hard rock fragments remaining after finer or softer material has been removed. I use the term *lag flood boulder* to refer to flood boulders that remain after other deposits have been eroded. These lag flood boulders, usually of Vallecito Conglomerate, are especially resistant, and some have been let down hundreds of feet as the land surface was lowered. Some were incorporated into younger fluvial sediments that were deposited on and around them.

EVIDENCE OF FLOOD DEPOSITS IN COLORADO

No flood deposits are known in Colorado (fig. 1). Only lag flood boulders have been observed, in the areas discussed below.

Bayfield Area

Northeast of the town of Bayfield, flood boulders as much as 11 feet long lie on bedrock throughout a broad area covering the interfluvium between Los Pinos River and Beaver Creek, a small river east of and tributary to Los Pinos River (fig. 10). Nowhere is there a deposit of flood gravel; the deposits are mostly boulders and cobbles of Vallecito Conglomerate, and they are lag deposits. The flood boulders occur mostly as isolated clasts (fig. 11), although they concentrate somewhat in drainages. The largest flood boulder observed in this area is $11 \times 8 \times >5\frac{1}{2}$ ft. These lag flood boulders are observed at heights up to 350 ft above the modern Los Pinos River (fig. 12).

Patches of gravel on a terrace along the northwest bank of Beaver Creek contain flood boulders (fig. 10). This terrace, about 100–150 ft above Los Pinos River, consists of boulder-cobble-pebble fluvial gravel about 15 ft thick, covered by 5–10 ft of loess. The gravel contains occasional clasts of

¹ “The term catastrophic flooding may be applied to flooding of high magnitude and low frequency...Catastrophic floods may result from... failure of natural or man-made dams”, from Preface of “Catastrophic Flooding”, edited by Larry Meyer and David Nash, 1987.

Vallecito Conglomerate, including a few large boulders, with a maximum observed size of $6\frac{1}{2} \times 3\frac{1}{2} \times >3$ ft.

Vallecito Conglomerate does not crop out in the Beaver Creek drainage, so all clasts of Vallecito Conglomerate came down Los Pinos River. The flood distributed boulders across the interfluvium into what is today the Beaver Creek drainage, and with time some of the clasts were incorporated into the terrace gravels of Beaver Creek.

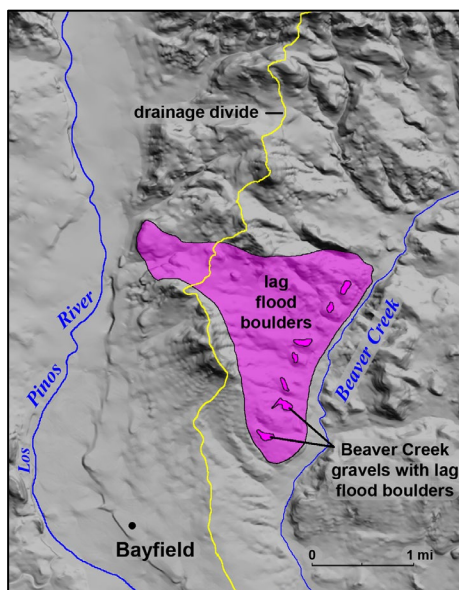


Figure 10—Distribution of lag flood boulders near Bayfield, Colorado.



Figure 11—Lag flood boulder of Vallecito Conglomerate on bedrock in Beaver Creek drainage, $10\frac{1}{2} \times 6\frac{1}{2} \times >5$ ft.

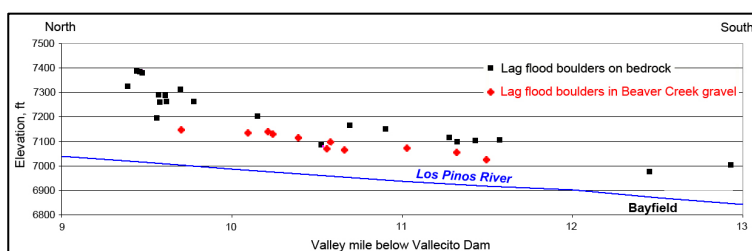


Figure 12—Elevations of lag flood boulders along Los Pinos River near Bayfield, Colorado.

Southern Ute Indian Reservation

Access to the Southern Ute Indian Reservation is restricted. Some observations of gravel deposits can be made on nontribal properties at Shellhammer Ridge, east of Ignacio, and near the state line at La Boca (fig. 1).

Shellhammer Ridge Shellhammer Ridge is capped by a fairly continuous deposit of gravel about 300 ft above Los Pinos River. Atwood and Mather (1932) called this deposit the Florida Gravel and considered it an interglacial alluvium. Richmond (1965) also used the designation Florida Gravel, but he considered it outwash of the Sacagawea Ridge glaciation (middle Pleistocene, MIS 16).

In Hocker Construction LLP gravel pits on this ridge, the gravel is about 15 to 20 ft thick, covered by loess as much as 15 ft thick (fig. 13). The deposit is a sandy cobble-pebble gravel with infrequent boulders. Clasts are mostly quartzose—quartzite, calico rock, quartz, and jasper—with lesser igneous and metamorphic rocks, many of which are highly weathered. Imbrication indicates south transport. At the base of the gravel a pebbly sand lies on weathered shale bedrock, an ordinary fluvial-gravel/bedrock contact (fig. 14). This deposit is a normal fluvial gravel, not a flood gravel.



Figure 13— Normal fluvial gravels in Hocker pit on Shellhammer Ridge, overlain by loess.



Figure 14—Basal contact (red knife) of fluvial gravel on shale bedrock in Hocker pit; lowest bed is pebbly sand overlain by cobble-pebble gravel.

Hundreds of flood boulders were extracted from these pits (fig. 15), mostly quartzite and calico rock, but also some sandstone. The largest of these boulders (left in place at the bottom of the gravel) is a calico rock measuring $13 \times 12 \times 7$ ft (fig. 16). All flood boulders were found at the bottom of the deposit, between fluvial gravel and shale bedrock (Roy Hocker, 2011, oral communication). The fluvial gravels were deposited on and around remnant lag flood boulders from the Vallecito flood.



Figure 15—Lag flood boulders from Hocker pit are mostly Vallecito Conglomerate.

Atwood and Mather observed similar large boulders on Shellhammer Ridge that they considered lag boulders:

“There are scores of large boulders of Vallecito conglomerate, as much as 10 feet in diameter. Typical ones are shown in Plate 22C [fig. 17 of this report]. They rest upon Tertiary shale, are not part of any recognizable glacial or fluvial deposit, and appear to have been let down to their present position during the dissection of the terrane upon which they rested” (Atwood and Mather, 1932, p. 106).

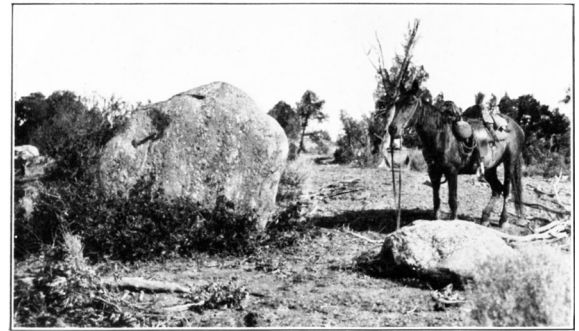


Figure 16—Lag flood boulder in place at base of normal fluvial gravel in Hocker pit is $13 \times 12 \times 7$ ft and weighs about 45 tons.

Atwood and Mather ascribed the origin of these large boulders to glaciation:

“They are at least 25 miles from their source.... Although it would be unwise to assert that boulders 7 to 10 feet in diameter could not be washed over low gradients for distances of 25 or 30 miles, such a contingency is certainly very unlikely” (Atwood and Mather, 1932, p. 106–107).

“They...were probably brought to this position by an ancient glacier” (Atwood and Mather, 1932, Plate 22C, caption).



Atwood and Mather, 1932, Plate 22
C. BOULDERS OF VALLECITO CONGLOMERATE

Figure 17—Large boulders on Shellhammer Ridge described by Atwood and Mather (1932).

Recent geologic quadrangle mapping (Carroll et al., 1998; Gonzales et al., 2004; Gonzales et al., 2008) between these boulders on Shellhammer Ridge and the end moraines in the San Juan mountains some 25 miles to the north does not support their suggestion of glacier transport, because there are no glacial deposits anywhere below the end moraines at Vallecito Reservoir.

Lava Creek B ash was found on top of the Florida Gravel along the Animas River (Gillam, 1998). This ash, from the Yellowstone caldera, was dated at 639 ka (Lanphere et al., 2002), indicating that the Florida Gravel is older than 639 ka, and thus the lag flood boulders are considerably older than 639 ka.

La Boca Canyon Flood boulders are observed at two sites near La Boca Canyon (fig. 1). Just north of the canyon on a low ridge of resistant sandstone are lag flood boulders of Vallecito Conglomerate, 200 to 300 ft above Los Pinos River. On the west side of Los Pinos River, a low terrace about 90 ft above the river extends from just north of La Boca Canyon (fig. 1) south into New Mexico (fig. 18). This terrace was mapped by Richmond (1965) as Pinedale outwash. A gravel pit on the terrace (Crossfire Aggregate Services La Boca Pit, fig. 3) just south of La Boca Canyon shows normal, mainstem fluvial cobble-pebble gravel, crudely stratified with sand lenses, and imbrication showing transport to the south. The lowest part of the gravel is normal fluvial gravel. At the base of this gravel nearly one hundred flood boulders, mainly Vallecito Conglomerate, were uncovered in the pit (Jay Nielson, Crossfire Aggregate Services, La Boca Pit Supervisor, 2013, written communication).

These gravels are analogous to the deposits on Shellhammer Ridge, although of a younger age, in that they indicate deposition of fluvial gravels on and around lag flood boulders.

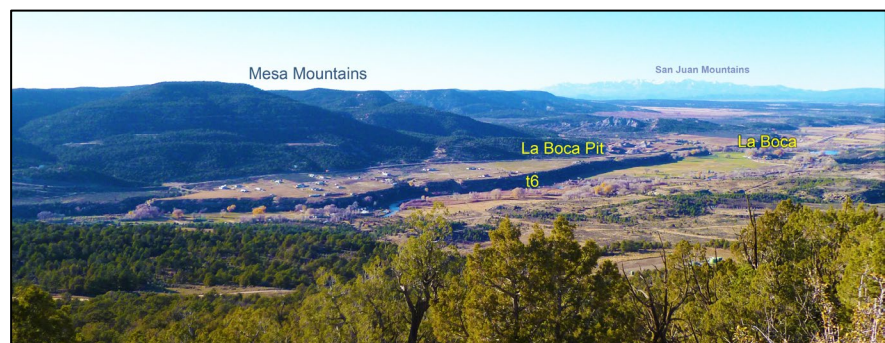


Figure 18—View to northwest across Los Pinos River at La Boca. Low terrace, t6, has lag flood boulders at the base of fluvial gravels in La Boca Pit. Annotation “t6” is at Colorado—New Mexico border. Mesa Mountains are capped by fluvial gravels from the Animas-Florida river system (figs. 1, 2).

A Durango-age river terrace intermediate to the two discussed also contains lag flood boulders, so the three main river terraces in Colorado all contain lag flood boulders incorporated into younger, normal fluvial

gravels. These terraces, t4–t6 of figure 19, may be followed south into New Mexico, but they were not mapped in this study, in part because of extremely limited access to the rugged terrain of Los Pinos Canyon.

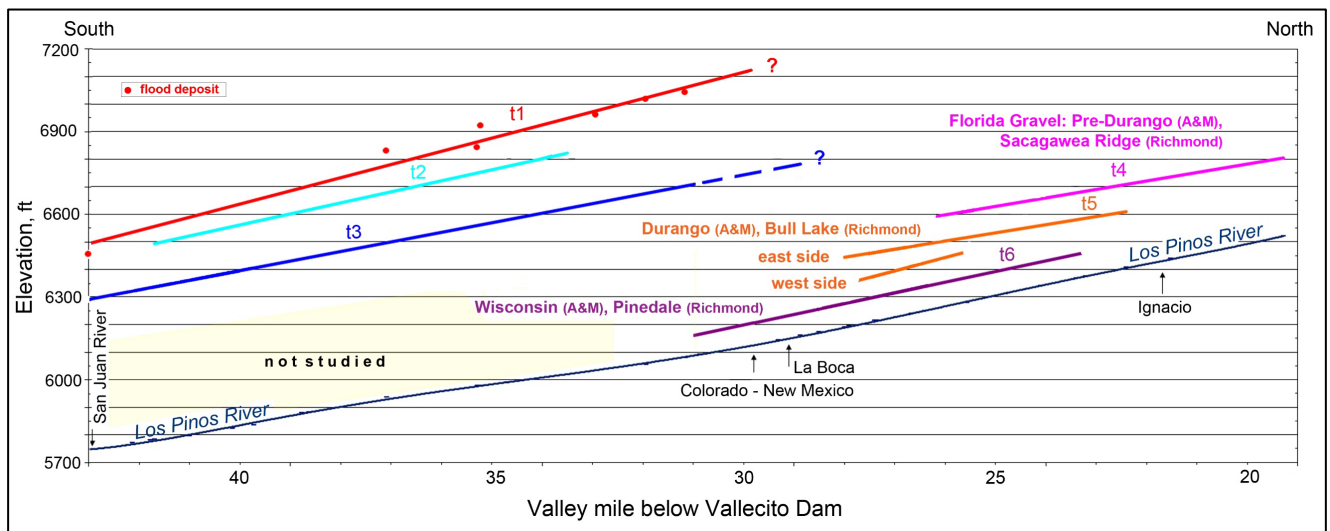


Figure 19— Longitudinal profiles of Los Pinos River terraces (t1 to t6, oldest to youngest) from Ignacio to San Juan River. Ages from Atwood and Mather (1932, A&M) and Richmond (1965). Flood deposits on terrace 1 are significantly higher and older than terrace 4, which is older than 639 ka.

Three high terraces are recognized on Pump Mesa in northernmost New Mexico, and at least two of them appear to continue north into the Southern Ute Indian Reservation in Colorado (fig. 19). The highest (oldest) of these terraces, t1, contains flood deposits.

LOS PINOS CANYON

A clearer picture of the Vallecito flood emerges south of the Colorado–New Mexico border, where fairly continuous flood deposits extend all the way down Los Pinos River to its confluence with the San Juan River—about 13 miles—and for some distance down that river (fig. 20). Flood deposits consist of both isolated flood boulders and flood gravels.

Flood Boulders

Flood boulders are observed in a swath one to two miles wide on Pump Mesa west of Los Pinos Canyon, where they define the path and extent of the Vallecito flood (figs. 1, 20). The only flood boulders on the eastern side of the canyon are on narrow terraces of the canyon wall within a few hundred feet of the river. On the western side of the canyon, flood boulders occur as isolated boulders in place on the highest terrace (t1, fig. 19), now referred to as the flood terrace, they occur as float below the flood terrace, and as lag flood boulders incorporated in younger mainstem alluvium. They also occur in deposits of flood gravels.

Flood Gravels

The north rim of the Mesa Mountains in Colorado (figs. 2, 18), capped by Animas-Florida gravels, curves southeast toward Pump Mesa and Los Pinos Canyon at about the same elevation as the flood terrace, about 1,050 ft above the modern Los Pinos River at the Colorado–New Mexico border.

The flood terrace on Pump Mesa slopes to the southeast. Streams tributary to Los Pinos River have dissected the terrace, producing a series of narrow, flat-topped ridges that slope southeastward (fig. 20).

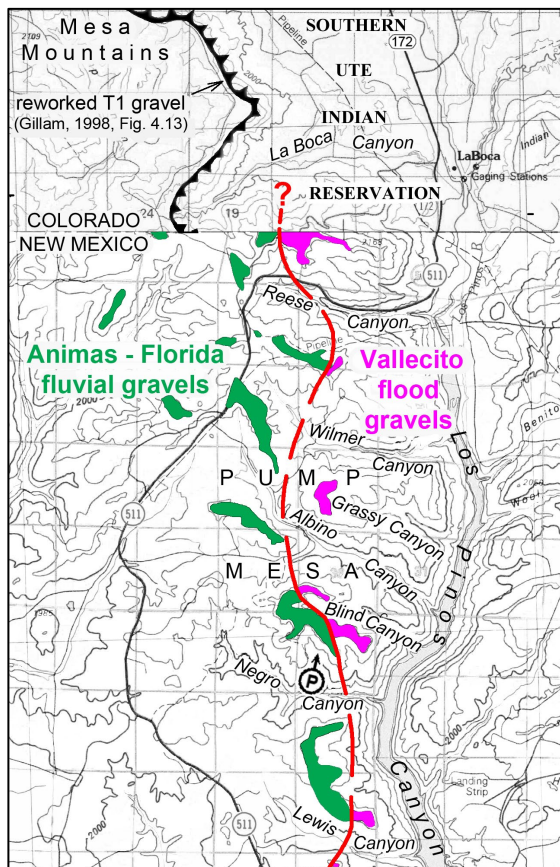


Figure 21—Fluvial gravels from the Animas–Florida River system (green) are a continuation of reworked early Pleistocene gravels of Gillam (1998) capping Mesa Mountains. Vallecito flood gravels (magenta) are about the same elevation and appear to be incised into those gravels. Red line is approximate contact. “P” at Negro Canyon is photo point of fig. 22.

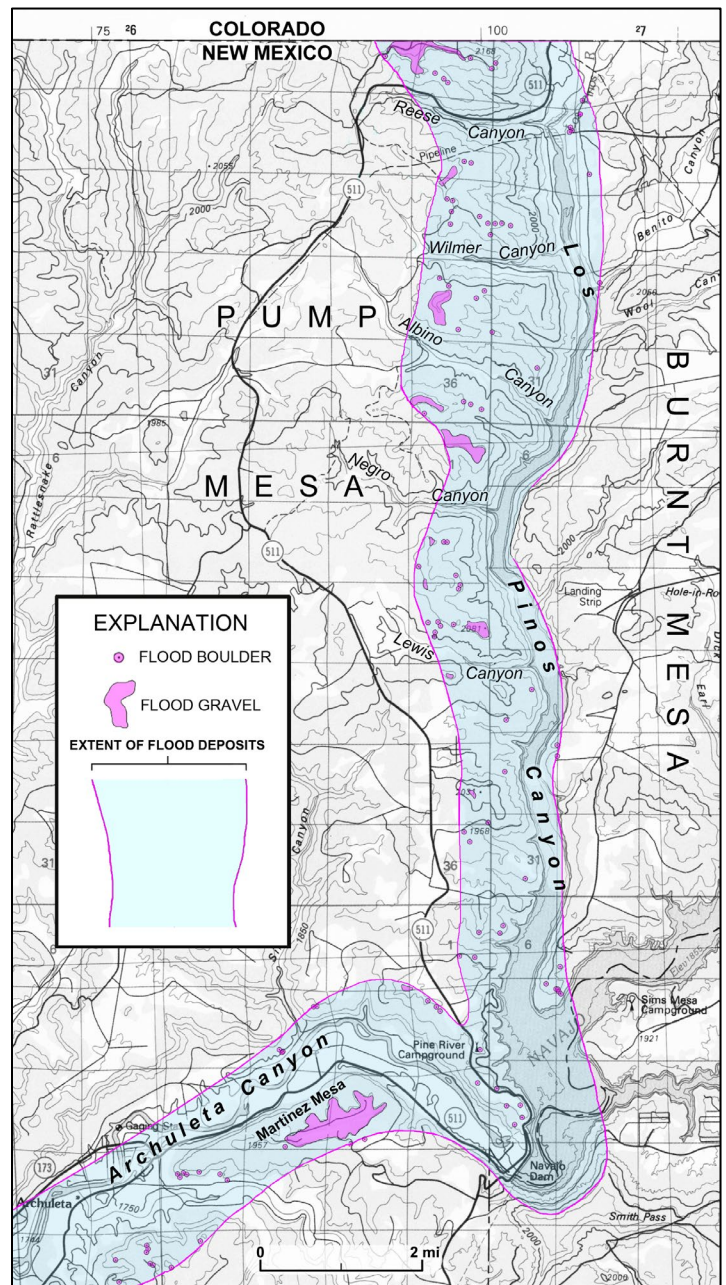


Figure 20—Flood deposits in New Mexico define the course and extent of catastrophic Vallecito flood along Los Pinos Canyon and Archuleta Canyon.

The western parts of these ridges are covered by Animas-Florida fluvial gravels (fig. 21) (appendix provides distinctions between the two gravels). The eastern ends of six of these ridges preserve gravels that are interpreted as Vallecito flood gravels (fig. 21), which are at nearly the same elevation as the Animas-Florida gravel (fig. 22).

No exposure of flood gravels has been located, so no definitive description can be given. Because flood gravels lie on the tops of the flat ridges and are blanketed by loess (not mapped), observations are thus limited to the shoulders of the ridges, where gravels in place cannot be distinguished from float.



Figure 22—View to north from Negro Canyon (fig. 21) shows Animas-Florida gravels on western surface of ridge and Vallecito flood gravels slightly lower to the east, separated by a gentle 20-ft slope.

These gravels are interpreted as flood gravels on the basis of the following observations:

- flood boulders are numerous (fig. 23),
- no stratification has been observed in the gravels (fig. 23),
- some flood boulders lie at the very top of the gravel (fig. 24),
- the caliber of flood gravels is larger than the caliber of normal fluvial gravels (fig. 25),
- in some instances, the flood gravels appear to be incised into the Animas-Florida gravels (fig. 21, both sides of Reese Canyon and both sides of Blind Canyon; fig. 22), and
- flood gravels are at concordant, correlative heights above Los Pinos and San Juan Rivers (fig. 26).



Figure 23—Flood gravel on ridge between Blind and Negro Canyons (fig. 21). Numerous flood boulders, seven in this view, are at different levels - five-ft-long flood boulder at upper right is near the top of flood gravel.



Figure 24—Flood boulder at top of flood gravel on mesa north of Lewis Canyon (fig. 21). Calico flood boulder is nearly buried by capping loess, exposed dimensions $5\frac{1}{2} \times 4\frac{1}{2} \times 1\frac{1}{2}$ ft.

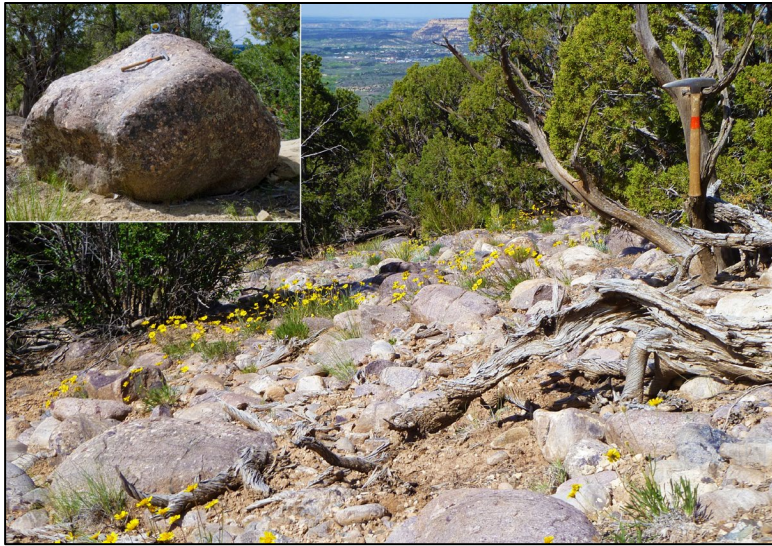


Figure 25—Flood gravel on north side of San Juan River. Abundant 2½ to 3 ft boulders are more than 49 miles from their source and were deposited where river gradient was only 40 ft per mile. Inset: Eight-foot-long flood boulder nearby.

Where flood gravels have been stripped of their loess cover, they show extreme weathering; calico boulders have been riven in place, fragmented, and disaggregated (fig. 27). Two such exposures show these effects: a broad rounded hill at the head of Grassy Canyon (fig. 21) and a low rise north of the San Juan River (fig. 20, northwest of Pine River Campground).

The largest deposit of flood gravel lies on the south side of the San Juan River, just below the confluence of Los Pinos River with the San Juan River, on Martinez Mesa (fig. 20). The mesa, which is used by Navajo Lake Airport, has a 5,000-ft-long paved landing strip on loess that

overlies the flood gravels capping the mesa (fig. 28). Gravels are about 750 ft above the San Juan River, and they have been carried about 45 miles below the Vallecito Dam, or about 51 miles beyond the nearest outcrop of Vallecito Conglomerate. These gravels are also the most distal flood gravels remaining, although flood boulders can be found for at least 27 miles farther downstream.

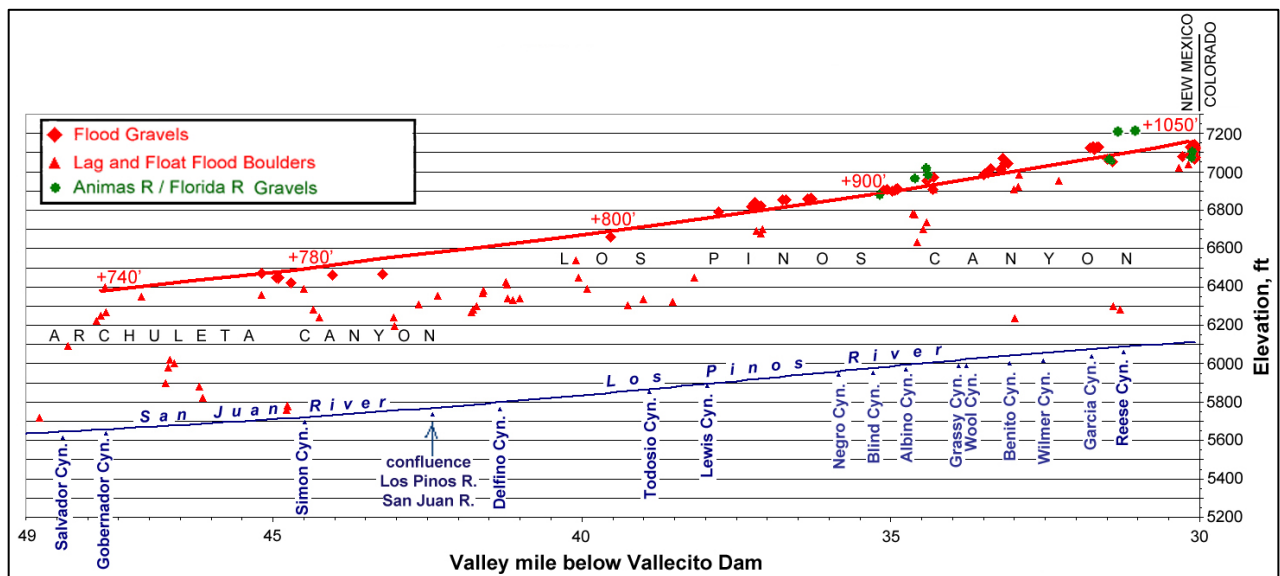


Figure 26— Flood gravels and flood boulders along Los Pinos and Archuleta Canyons (west- and north-looking). Red line is trendline of flood gravels, with heights above river, in ft. Cyn., Canyon.



Figure 27—Flood gravel exposed at top of hill at Grassy Canyon (fig. 21) shows severe weathering: calico flood boulder riven in place; fragmented and disaggregated calico boulder.

percent volcanic rock, 7 percent calico rock, 2 percent plutonic rock, and 1 percent other. As noted, flood gravels in this area are incised into Animas-Florida gravels on the west, so they likely contain clasts from that source.



Figure 28—Aerial view to southwest of Martinez Mesa, capped by flood gravels.

Flood gravels were characterized by pebble counts on four different flood gravel deposits along Los Pinos Canyon. The average sizes of clasts an inch or larger are: 70 percent pebbles, 23 percent cobbles, and 7 percent boulders². Average compositions of clasts are: 65 percent quartzite, 15 percent gneiss and schist, 10

SAN JUAN RIVER VALLEY

Archuleta Canyon

Along the Archuleta Canyon reach of the San Juan River, just below the confluence with Los Pinos River, flood gravels are preserved only on Martinez Mesa, as noted above. These gravels are the farthest downstream flood gravels (fig. 29). For a few miles beyond Martinez Mesa, however, small patches of coarse gravel studded with numerous flood boulders probably are reworked flood gravels, found on the south rim of the canyon at a slightly lower elevation than the flood gravels (fig. 30). Lag flood boulders are found lower in the canyon.

Unconfined San Juan River Valley

San Juan River valley changes markedly below Archuleta Canyon, where the resistant sandstones that make up the canyon walls give way to nonresistant sandstones and shales. The valley broadens into more subdued topography (fig. 2), and the river gradient decreases from 18 to 20 feet per mile (ft/mi) in the canyon to 10 to 15 ft/mi in the unconfined valley.

² Pebbles, 4–64 mm [0.2–2.5 in.]; cobbles, 64–256 mm [2.5–10.1 in.]; boulders, >256 mm [10.1 in.].

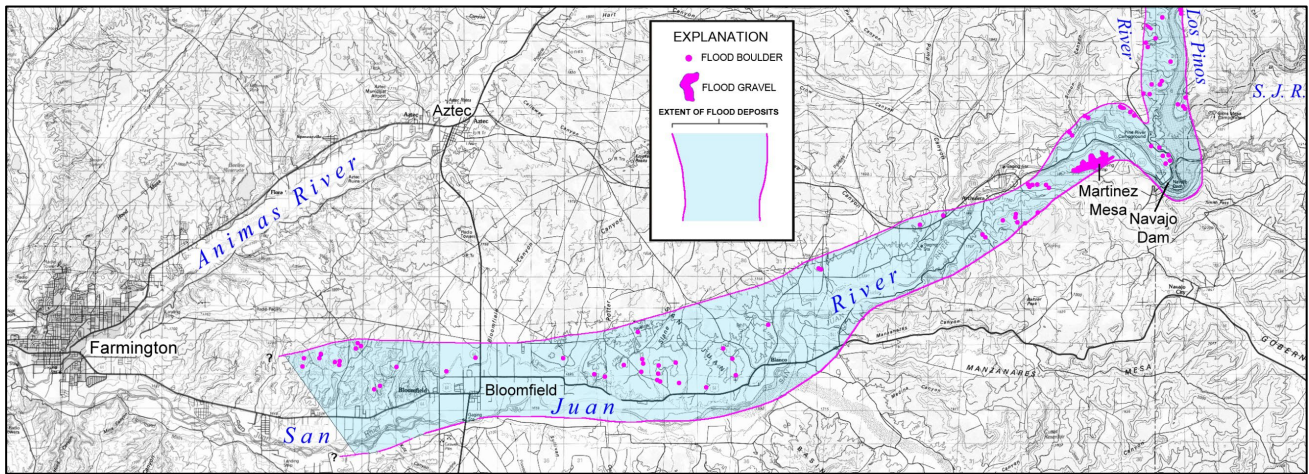


Figure 29—Flood deposits in San Juan River valley. S.J.R., San Juan River.

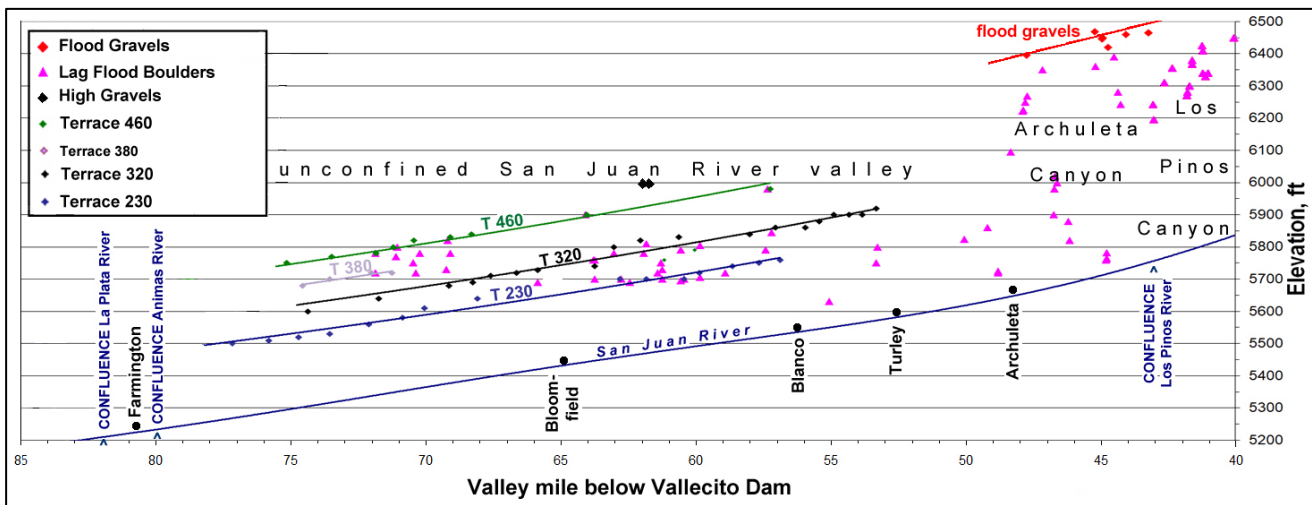


Figure 30—Flood deposits and fluvial terraces along San Juan River from confluence of Los Pinos River to Farmington, New Mexico. Flood gravels remain only a short distance below confluence, but flood boulders recognized nearly to Farmington. Fluvial terraces all contain lag flood boulders.

Below Archuleta Canyon, fluvial terraces are preserved on the north side of the river. Three terraces can be mapped from Blanco to Farmington, and a fourth, intermediate, terrace is recognized just upstream from Farmington (figs. 31, 32). The terraces are designated by their height above the San Juan River (fig. 30), with height measured from the river to the edge of the terrace nearest the river.

The lowest and youngest terrace, T230, is the most continuous, and it extends right to the Animas River valley at Farmington. The next higher terrace, T320, is also fairly continuous. The oldest terrace, T460, is well preserved between Bloomfield and Farmington, but only one small remnant remains upstream of Bloomfield. An intermediate terrace, T380, is recognized only in the lower part of the Bloomfield-Farmington reach.

All terrace gravels are mainstem San Juan River gravels, dominated by volcanic rocks, with a substantial contribution from Los Pinos River, mainly quartzite and calico rock (described in appendix). Flood boulders are found, however, as lag boulders in each of the terrace gravels.

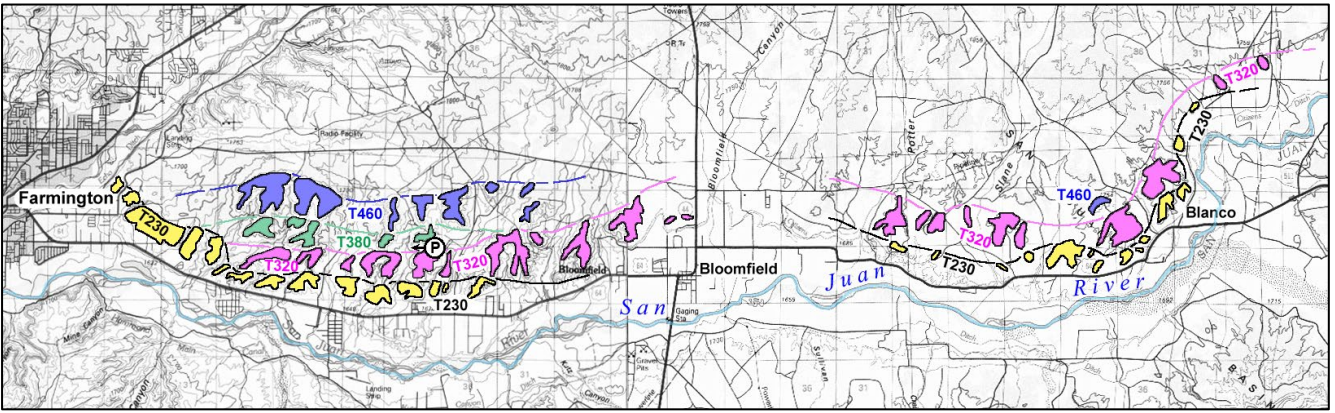


Figure 31— San Juan River terraces. Numbers refer to heights above river, in feet. “P” about midway between Bloomfield and Farmington is photo point of fig. 32.

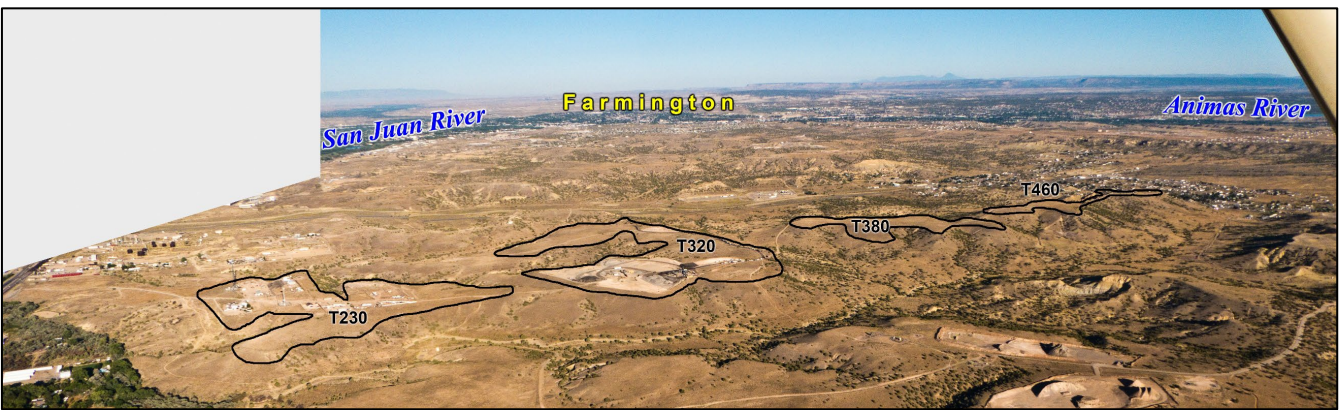


Figure 32—View to west shows San Juan River terraces (fig. 31). Lag flood boulders are found in gravels of all terraces.

Gravels of the oldest terrace, T460, are younger than the flood gravels farther upstream (fig. 30). They are at about the same elevation as adjacent terrace gravels on the Animas River mapped by Mary Gillam (1998; her terrace gravel T3) (fig. 33), which she estimates to be about 700–800 ka (MIS 18–20). This correlation is rather tenuous, however, because the Animas River has a higher gradient than the San Juan River. A further uncertainty comes from a curious topographic reversal between the two rivers — the interfluvium has eroded away completely, leaving the alluvial terraces higher than the former divide (fig. 33).

Although flood boulders are found in T460 gravels, the gravels themselves are not flood gravels. Because the T460 gravel is the highest gravel remaining along this reach of the San Juan River, it indicates that any flood gravels deposited this far downstream have been removed.

Flood boulders become increasingly difficult to recognize downstream of Bloomfield. The size of the

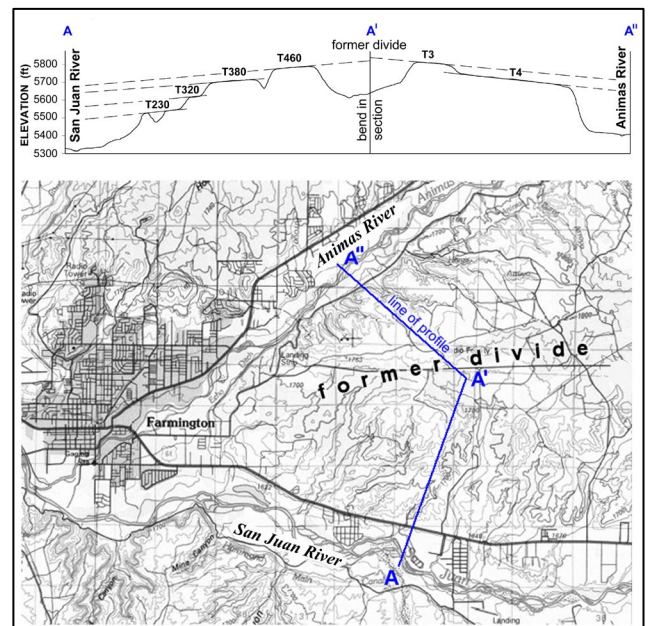


Figure 33—Profile of terraces of San Juan and Animas Rivers. Highest terraces are about the same elevation.

boulders has diminished to about 2 to 2½ ft, and it becomes difficult to differentiate flood boulders from the coarser channel boulders of normal alluvium (fig. 34). The most distal flood boulders recognized are on the T460 terrace a few miles upstream from Farmington, at a valley distance of 72 miles below Vallecito Dam.

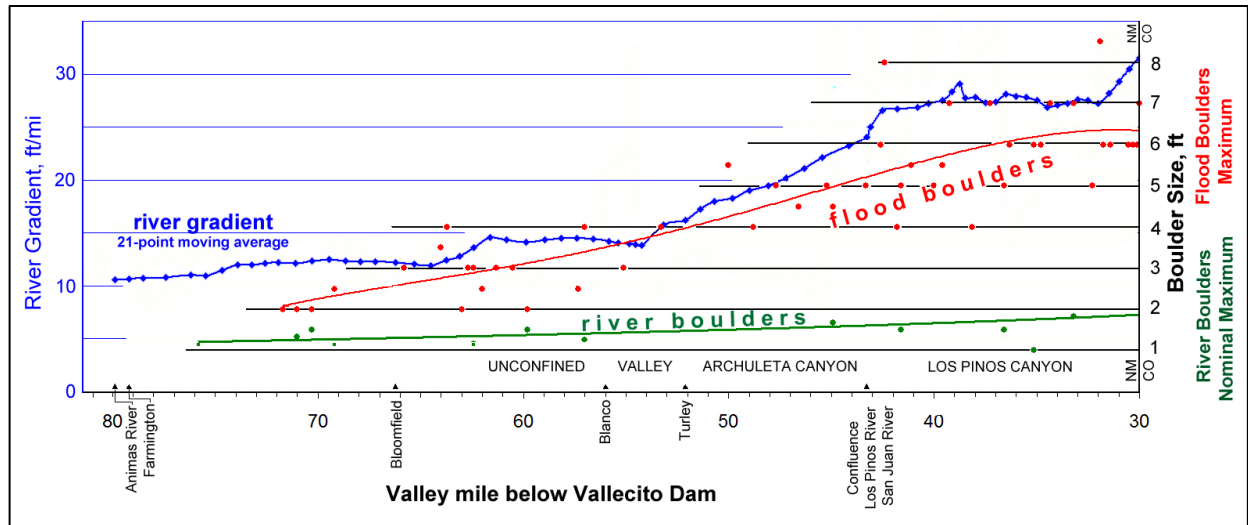


Figure 34—Distribution of boulder sizes in New Mexico. Flood boulders (red dots) are large in canyons with steep river gradients but diminish where flood waters spread out in unconfined valley. Boulders in normal fluvial gravels (green dots) have maxima that vary little in size, usually between 1 and 2 feet.

San Juan River Below Farmington

Although flood boulders are not recognized as far downstream as Farmington, the flood surely continued there with diminished discharge. Gravels downstream from Farmington do not appear to contain flood boulders from the Vallecito flood.

There are flood boulders within the first 10-mile reach, however, but their lithologies indicate they came from the Animas River (fig. 35).



Figure 35—Flood boulders on the San Juan River below the confluence of the Animas River came down the Animas River. Left: Granite flood boulder >57 × >36 × >21 in. on Martin Mesa four miles below confluence. Right: Animas River flood boulders in Harper Hill Pit six miles below confluence; nearest boulder is quartzite, in order behind are sandstone concretion, granite, and sandstone; broken granite boulder is 64 × 34 × 31 in.

AGE OF FLOOD DEPOSITS

The precise age of the flood deposits has not been determined, but one can estimate the bounds of their age range. Flood gravels are at the same elevation as the Animas-Florida fluvial gravels or very slightly lower where they have been incised (figs. 21, 26). The Animas-Florida gravels are the continuation of gravels on the north rim of the Mesa Mountains (fig. 21), which are reworked T1 gravels described by Gillam (1998). Gillam estimated the age of T1 gravels as 2.4 Ma (early Pleistocene³) based on incision-rate calculations, corroborated by reversed remanent magnetism (Gillam, 1998, p. 205). Consequently, the flood deposits are younger than 2.4 Ma.

Lag flood boulders on Shellhammer Ridge are older than the Florida Gravel, which is older than 639 ka (middle Pleistocene). How much older is uncertain, but a qualitative estimate can be inferred from the heights of the gravels above Los Pinos River. As illustrated in figure 19, the river has incised about 300 ft below terrace t4 in the past ~640 ky and about 1000 ft since the flood deposited boulders on the flood terrace, t1, suggesting the flood deposits are considerably older than 640 ka, probably early Pleistocene.

Furthermore, the flood terrace predates the oldest San Juan River terrace (fig. 30), which appears to correlate with Gillam's terrace T3, estimated to be between 800—700 ka (Gillam, 1998). This further indicates that the flood deposits are likely early Pleistocene.

There is evidence for a large early Pleistocene flood on the adjacent Animas River. Flood gravels on the Animas River at the Colorado—New Mexico state line, 14 miles due west of the flood gravels on Los Pinos River, are estimated to be early Pleistocene, about 1.5 Ma (Lee, 2025a).

THE VALLECITO FLOOD

The precise origin of the flood is unknown. The source area was the headwaters of Los Pinos River near its confluence with Vallecito Creek. A large landslide could have dammed one or both rivers, and the terrain is compatible with this possibility, but no vestige of a large landslide has been mapped in the source area. I suggest the most logical source of the floodwaters is a glacial outburst flood.

Large valley glaciers from the San Juan icefield flowed down both Los Pinos River and Vallecito Creek, and they merged at the present Vallecito Reservoir. One of the glaciers may have reached the confluence first and dammed the other drainage creating a glacial lake, or a proglacial lake could have formed behind an end morainal dam during the merged glaciers' retreat. When the glacial dam failed, the lake water drained immediately, creating a catastrophic flood. Such glacial outburst floods have been documented on rivers all around the San Juan Mountains: the Rio Grande (Leonard et al., 1994), the Animas River (Gillam, 1998; Scott and Moore, 2007; Lee, 2025a) the Uncompahgre River (Lee, 2025b), and the Lake Fork of the Gunnison River (Lee, 2025c), as well as on the Upper Arkansas River in Colorado (Lee, 2019).

The poorly constrained route of floodwaters in Colorado was east of the modern Los Pinos River, as shown by numerous lag flood boulders on Beaver Creek and Shellhammer Ridge. The evidence is sparse, however, and allows room for conjecture.

In New Mexico, by contrast, the flood route is well defined: steep canyon walls on the eastern side of Los Pinos canyon constrained the floodwaters. The main channel of Los Pinos River at the time of

³ Early Pleistocene, 2.58 Ma—788 Ka; middle Pleistocene, 788—132 ka, late Pleistocene, 132—11.7 ka (U.S. Geological Survey Geologic Names Committee, 2009)

the flood was a mile or so west of the modern river (fig. 20), where floodwaters incised the Animas-Florida gravels (fig. 21). Floodwaters extended to the west beyond the limits of mapped flood gravels, however, as evidenced by scattered clasts of Vallecito Conglomerate on Animas-Florida gravels as much as a mile west of the flood gravels.

Floodwaters reaching the San Juan River valley carried right across the valley and directly impacted a high sandstone wall on the south side of the valley. Floodwaters may have carved out the alcove present there now (figs. 20, 36), or it may have coincidentally enhanced a former alcove. Floodwaters ricocheted off this wall and turned back to the northwest before continuing down the San Juan River valley (fig. 20). This path created a massive point bar on which the flood gravels of Martinez Mesa were deposited (Fig. 20).



Figure 36—Aerial view to south shows the very steep wall of the alcove cut into resistant sandstones. This wall took the direct force of the Vallecito flood.

Flood boulders of Vallecito Conglomerate can be recognized nearly to Farmington, a distance of 72 miles from the dam. They surely extend farther, but at that point they have become small enough that they cannot be differentiated with confidence from coarser boulders in normal alluvium.

Flood boulders are found on the San Juan River downstream from Farmington, below the confluence of the Animas River, but these were carried down by a flood on the Animas River.

CONCLUSIONS

A catastrophic flood came from the headwaters of Los Pinos River, probably from the failure of a glacial dam that released a glacial lake. Floodwaters transported large boulders more than 70 miles down the ancestral Los Pinos and San Juan Rivers. The flood occurred during early to middle, probably early Pleistocene time.

ACKNOWLEDGMENTS

I was led to investigate this flood while rereading the paper by Atwood and Mather (1932) on the Quaternary geology of the San Juan Mountains. What struck me was their photograph of a 10-foot-long boulder sitting on Shellhammer Ridge (fig. 17) with their suggestion that it was very unlikely such a boulder could be transported by water 30 miles along a low-gradient river. Their work, of course, was done in the context of uniformitarianism, before J Harlan Bretz's assertion of catastrophic floods was generally accepted.

Mary Gillam, Colorado Geological Survey, was extremely helpful in discussing and reviewing this work while it was in progress. In the field, she offered numerous helpful suggestions and dissuaded me from at least one erroneous interpretation. Her dissertation provided a framework for the contiguous Animas River drainage.

I benefitted from discussions with David Gonzales and Ray Kenny of Fort Lewis College (Durango, Colorado), and Joe Hewitt, Bureau of Land Management (Farmington, New Mexico). David Gonzales provided very useful comments on an earlier version of this report.

Roy Hocker and Rodney Hocker provided access to their gravel pits on Shellhammer Ridge and Beaver Creek, Colorado, and their descriptions of the gravels greatly helped me. I especially appreciate their making a special excavation for me to expose the basal contact of the gravel in the pits.

I appreciate access to several other gravel pits provided by Crossfire Aggregate Services (La Boca Pit), Paul and Son Construction, Mesa Sand and Gravel, and Four Corners Materials (Crouch Mesa Pit, Harper Hill Pit). David Acree, Elam Ready Mix, provided important information on Animas River flood boulders.

I thank numerous landowners in the Bayfield area who kindly provided access to their properties, especially Robert Dulin, Harry Goff, and Richard Parry.

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APPENDIX CHARACTERISTICS OF GRAVELS

Pebble counts were used to characterize the different gravels in this study. Because the purpose was to provide criteria that could be used in the field to identify gravel sources, rock types were broadly categorized, such as *plutonic rock* instead of specific types like *monzodiorite* or *granodiorite* that might not be readily identified in a round, dirty pebble. Standard clast sizes—pebble, cobble, and boulder—were noted, along with the maximum size.

Field procedures were typically as follows: I selected a site with good exposures, chose a representative area, turned around, and tossed my pick over my left shoulder. I then centered a ring about 3 ft across (fig. A4, center photo) on the pick point and counted clasts larger than a 25-cent coin (~1 in.), categorizing them by size and rock type, usually tallying one hundred clasts.

LOS PINOS GRAVELS

Gravels along Los Pinos River in New Mexico are characterized by the presence of calico rock and metamorphic rocks (gneisses and schists) in greater abundance than volcanic rocks.

Gravels are dominantly quartzite, with decreasing abundance of metamorphic rocks (excluding metaquartzite), volcanic rocks and calico rocks in about equal amounts, and minor plutonic rocks (tbl. A1, fig. A1). The purest Los Pinos gravel is at site LPx east of Los Pinos Canyon (fig. A2), because the gravels on the west side of the canyon may have received contributions from reworked Animas-Florida gravels. Samples are from terraces below the flood terrace.

Table A1

GRAVEL CHARACTERISTICS, %												ABBREVIATIONS:	
Site	P	C	B	Q	P	M	V	O	C	MTv			
ANIMAS - FLORIDA GRAVELS												P	PEBBLE
AF Sloan Knob	76	24	9	49	8	2	39	2	0	0.05		C	COBBLE
AF X	73	25	2	53	2	1	43	2	0	0.02		B	BOULDER
AF1A				55	14	5	26	0	0	0.19		Q	QUARTZITE
AF IB	69	28	3	82	0	0	14	4	0	0.00		P	PLUTONIC ROCK
AF Composite	73	26	5	60	6	2	31	2	0	0.07		M	METAMORPHIC ROCK [not quartzite]
LOS PINOS GRAVELS												V	VOLCANIC ROCK
LP X	78	21	1	68	2	19	5	0	6	3.80		O	OTHER
LP 1	96	4	0	74	3	12	8	1	2	1.50		C	CALICO
LP 3	89	11	0	76	3	10	4	1	6	2.50		MTv	RATIO of METAMORPHIC/VOLCANIC
LP Composite	88	12	0	73	3	14	6	1	5	2.60			

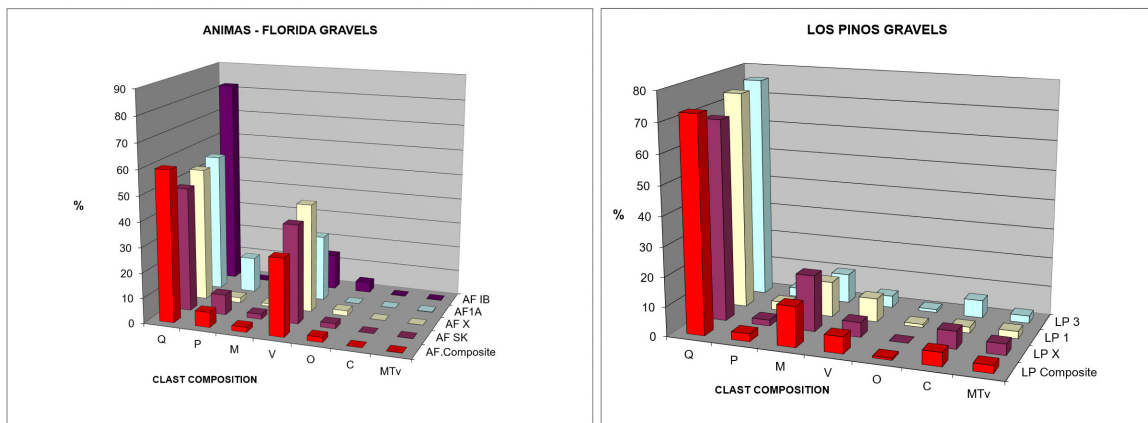


Figure A1—Composition of gravels from Animas-Florida and Los Pinos Rivers; abbreviations as in table A1.

ANIMAS - FLORIDA GRAVELS

Gravels from the Animas-Florida river system are characterized by abundant volcanic rocks and the virtual absence of calico rock.

Gravels are mostly quartzite, with lesser volcanic rocks. Plutonic rocks are common and are more abundant than metamorphic rocks (tbl. A1, fig. A1). Conglomeratic quartzite with jasper is occasionally observed, but the clasts are quite small, usually black jasper is more abundant than red jasper, and iron formation has not been observed.

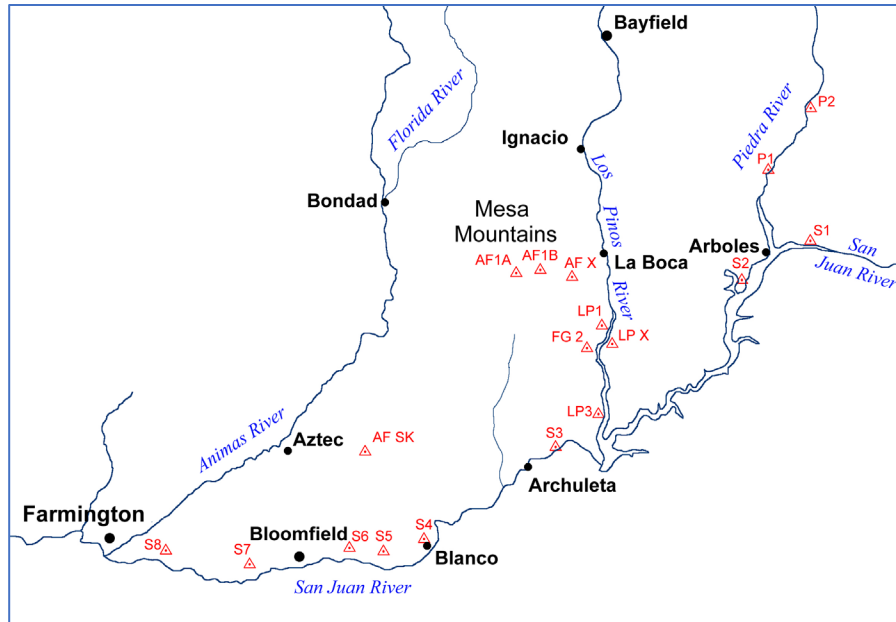


Figure A2—Locations of pebble counts.

DISTINCTION BETWEEN LOS PINOS AND ANIMAS-FLORIDA GRAVELS

Los Pinos gravels always contain calico rocks, and the ratio of metamorphic rocks to volcanic rocks is always greater than 1, whereas Animas-Florida gravels do not contain calico rocks, and the metamorphic/volcanic ratio is always less than 1 (fig. A3).

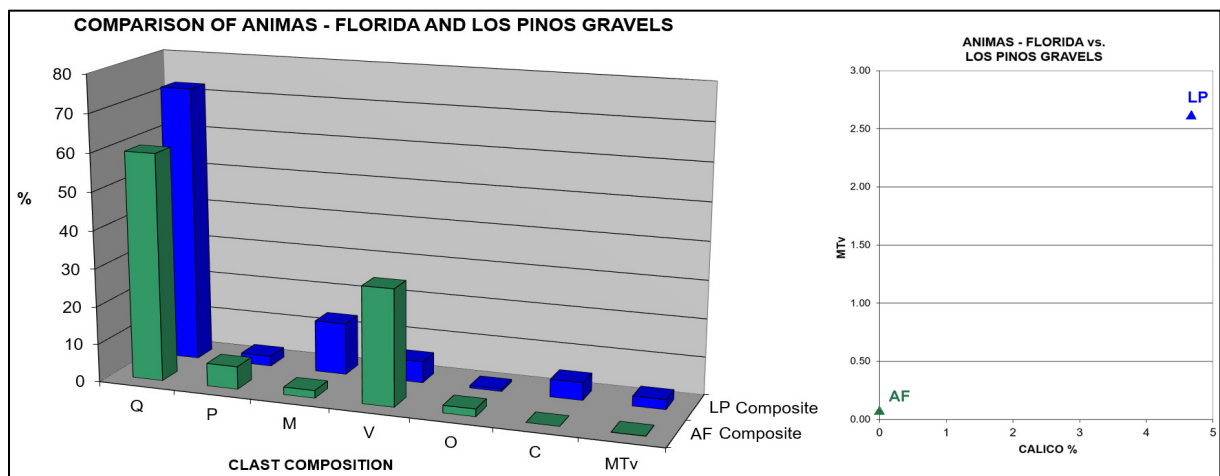


Figure A3—Comparison of Animas-Florida gravels with Los Pinos gravels; abbreviations as in table A1.

FLOOD GRAVELS

Flood gravels are characterized by large caliber of the gravel and almost always by the inclusion of numerous flood boulders.

Figure A4 shows gravels from three sites along the same reach of Los Pinos River (map). Normal fluvial gravels of both Los Pinos (LP 1) and the Animas-Florida (AF X) Rivers are cobble pebble gravels; the few boulders observed at each site are less than two feet in long dimension. Flood gravel (FG 2) contains numerous boulders in the 3 ft to 5 ft range, with the largest (here) 5 x 4 x >3 ft.

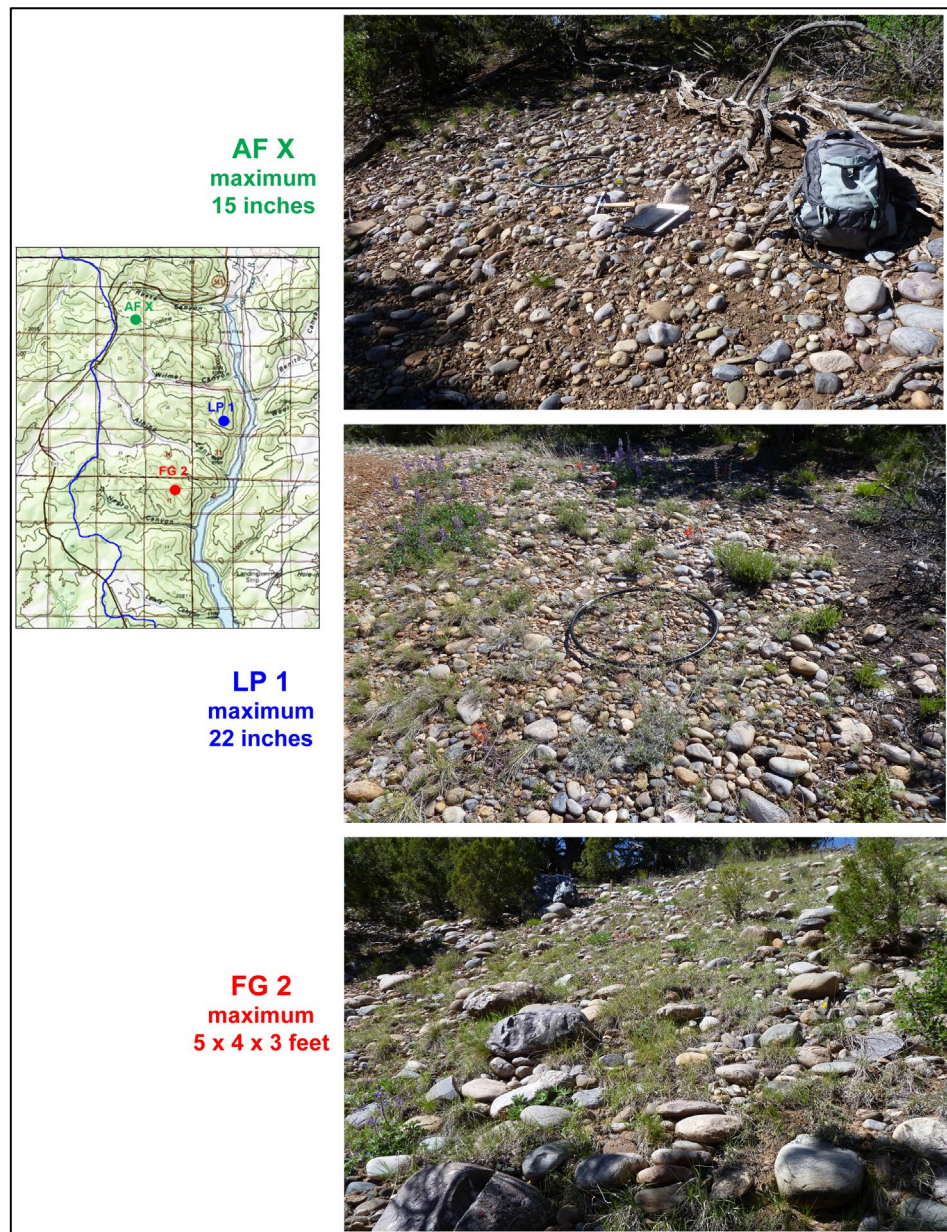


Figure A4—Flood gravels are characterized by large caliber, usually with flood boulders.

SAN JUAN RIVER GRAVELS

Gravels in the eastern headwaters of the San Juan River above the confluence of the Piedra River are predominantly volcanic rocks, with small amounts of sandstone (tbl. A2) (locations in fig. A2). Andesite is the main lithology, with lesser ash-flow tuff clasts.

Table A2

			GRAVEL COMPOSITION - %								
RIVER	Site		QTZT	CAL- ICO	PLUT	META	VOLC	SS	LS	ETC	n
San Juan River above the Piedra River											
San Juan River	1						92	8			53
Piedra River											
Piedra	1						17	82	1		108
Piedra	2		1				46	51		3	101
	ave		tr				32	66	tr	1	209
San Juan River below the Piedra River											
San Juan River	2						71	29			102
Los Pinos River											
Los Pinos	x		68	6	2	19	5			0	100
Los Pinos	1		74	2	3	12	8			1	100
Los Pinos	3		76	6	3	10	4			1	100
	ave		73	5	3	14	6			1	300
San Juan River below Los Pinos River											
San Juan	3		26	3	1	1	64	4	1		132
San Juan	4		18	3		1	74	3		1	159
San Juan	5		23	8	1	5	62	2			132
San Juan	6		23	3	2		68	3			94
San Juan	7		29	2		1	65	2			130
San Juan	8		24	1	1		73	1			159
	ave		24	3	1	1	68	3	tr	tr	806

SS, sandstone; LS, limestone; n, number of clasts; other abbreviations as table A1

Piedra River gravels are mainly sandstone, with lesser volcanic rocks, with andesite and ash-flow tuff in about equal abundance. Gravel in the San Juan River below the Piedra River confluence thus contains abundant sandstone, although still dominated by andesite.

Los Pinos River gravels are dominated by quartzite, with abundant metamorphic rocks, volcanic rocks and calico rocks in about equal amounts, and small amounts of plutonic rocks, mainly granite.

Gravel in the San Juan River below the confluence of Los Pinos River is still dominated by volcanic rocks, although quartzite has now become a significant constituent. Sandstone has diminished greatly, calico is present in small amounts, and traces of plutonic rocks occur.