



## **THREE GLACIERS FLOOD Arkansas River, Colorado**

### **OVERVIEW**

Huge boulders litter the Upper Arkansas River Valley in Colorado. The size of the boulders indicates they were not deposited by normal river processes, and the topography and landforms preclude glacial transport. These boulders were deposited by a catastrophic flood, far bigger than any witnessed here in historic times, that I call the Three Glaciers Flood. Three glaciers flowed down to the Arkansas River – one glacier pushed the river out of its channel, and the other two crossed the river and rammed into granite walls on the other side of the valley. The glaciers formed an ice dam that blocked the Arkansas River and created a large lake above the dam. When the ice dam broke, the entire lake drained catastrophically and the outburst tore down the valley as a wall of water hundreds of feet high. This actually happened twice, about 20,000 years ago and about 120,000 years ago.

### **UPPER ARKANSAS VALLEY**

The Upper Arkansas Valley in central Colorado contains the headwaters of the Arkansas River, which drains the Sawatch Range on the west and the Mosquito Range on the east [Fig. 1]. The river hugs the east side of the valley, flowing in unconsolidated sediments except for three narrow canyons where the river has cut down into granitic rocks - at the Three Glaciers damsite, at Elephant Rock Canyon just north of Buena Vista, and at Brown's Canyon near Salida [Fig. 1].

Bounding walls of the Upper Arkansas Valley are almost entirely metamorphic and igneous rocks, most commonly granite, of Precambrian age [more than 540 million

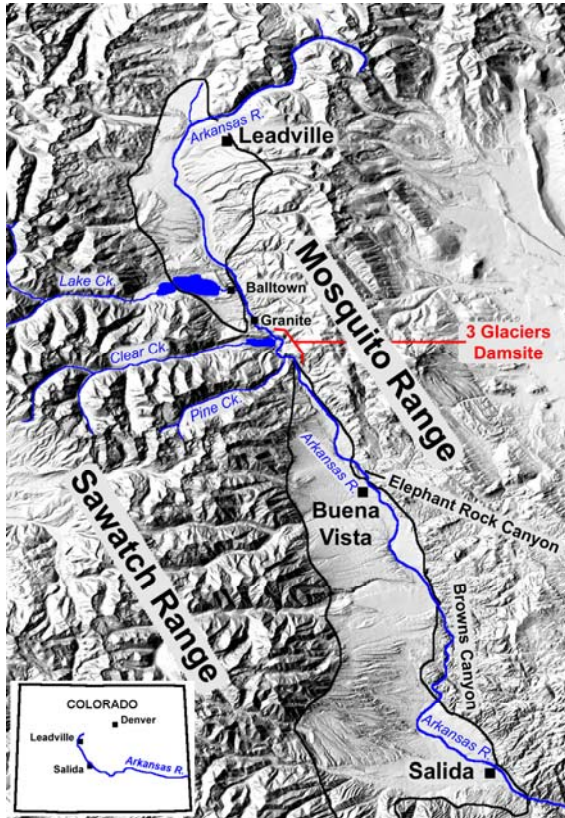


Figure 1—Upper Arkansas Valley in Colorado. Black line shows the boundary of unconsolidated deposits of valley fill with solid bedrock, which also fairly well defines the valley floor. Glaciers flowed down from 14,000 ft peaks of the Sawatch Range.

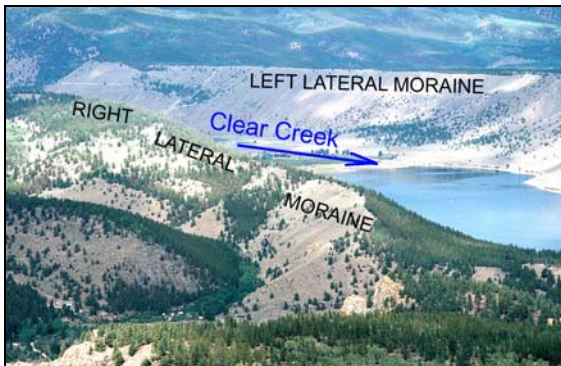


Figure 3—View to the northwest shows both lateral moraines of the Clear Creek glacier.

None of the glaciers from the Mosquito Range reached the valley floor, except for a few small glaciers near Leadville that were too small to block the river. Numerous glaciers flowed into the Upper Arkansas Valley from the Sawatch Range to the west, but only three were capable of

years old]. The valley floor contains thick sediments deposited in the last 20 million years.

We can read the story of the Three Glaciers Flood mainly from two types of deposits - moraines built by glaciers, and boulders carried by floodwaters. Alpine glaciers [aka valley glaciers because they are restricted to individual valleys] are flowing streams of ice that carry large amounts of mud, sand, pebbles, cobbles, and boulders, some of impressive size. Ice melts at the edges of the lower parts of the glacier, along the sides and at the snout, and the entrained debris is dumped there in unsorted piles called till. Over time the glacier forms ridges of till called moraines - lateral moraines along the two sides and an end moraine loop at the snout [Fig. 2A]. After glaciers retreat, moraines record the former positions of the glaciers [Fig. 2B, Fig. 3].

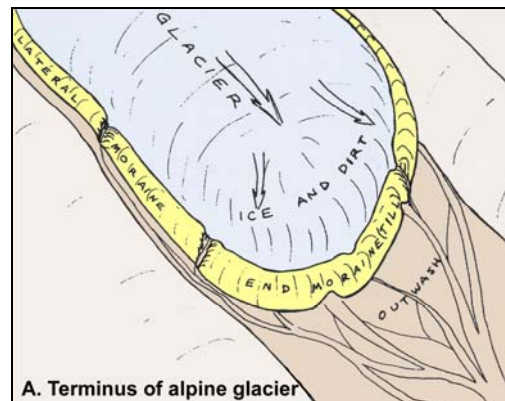


Figure 2A—An alpine glacier builds moraines around the edges of the glacier.

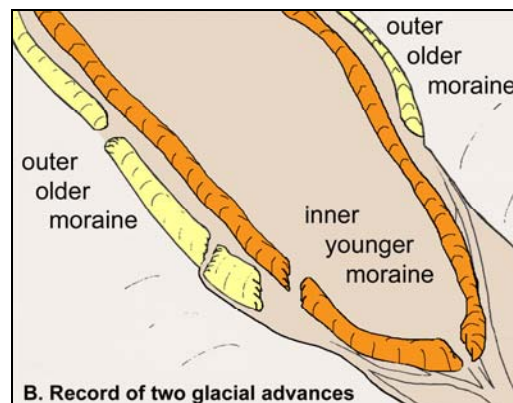


Figure 2B—After glaciers melt, remaining moraines mark the former positions of the glaciers.



blocking the valley. Glaciers advanced down each of three contiguous tributary valleys that drained the east flank of the Sawatch Range - from north to south, these were the Lake Creek glacier, the Clear Creek glacier, and the Pine Creek glacier [Fig. 4].

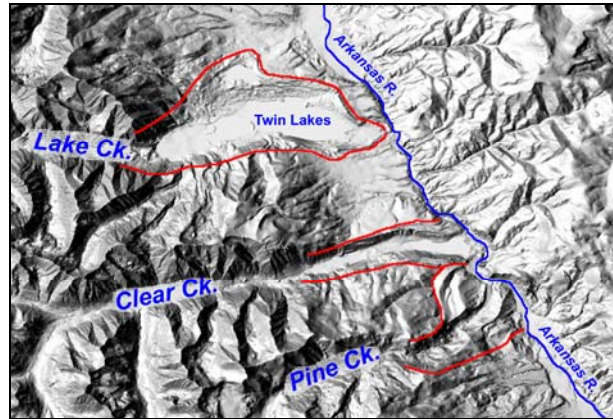


Figure 4—Three glaciers flowed down tributary valleys and reached the Arkansas River. Red lines show the boundaries of moraines left by each glacier.

## THE FIRST FLOOD

### The Dam

The glacier flowing down Lake Creek reached the Arkansas River, which at the time was in a gravel channel considerably west of the current channel. The ice advanced quicker than the river could melt it, and the glacier pushed the river to the east, onto granite bedrock, but it did not actually stop the river flow.

The Clear Creek and Pine Creek glaciers, however, pushed the Arkansas River up against a steep wall of granite and managed to dam the river's flow when the glaciers rammed into the granite wall on the other side of the valley. The tremendous pressure on the granite wall gouged out concave hollows on the far wall, later enhanced by floodwaters pouring through, that I call whamout zones [Fig. 5]. As the flowing ice piled up at the granite wall, it thickened and spread out upriver and downriver, forming a bulbous mass that from above had a tulip shape [see Pine Ck. moraines in Fig. 4]. The Pine Creek glacier spread out so much that it effectively merged with the Clear Creek glacier, and the combined glaciers set up a formidable ice dam.

We don't know exactly how high the dam was, because the end moraines and parts of the lateral moraines were destroyed by the ensuing flood. From the remaining lateral moraines, however, we can estimate the height by projecting the elevation of the moraine crests down to the river [Fig. 6]. This suggests the moraine on the upriver side was 470 ft high, at an elevation of 9350 ft. The glacier was higher than its moraines, of course, but how much higher is uncertain. A dam elevation of about 9400 ft is a reasonable estimate.



Figure 5—Pine Creek whamout carved out of granite wall; view up Arkansas River, Pine Creek out of view behind hill on left.

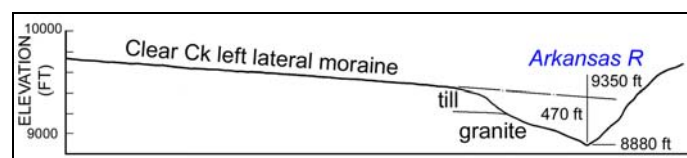


Figure 6—Profile of Clear Creek left lateral moraine [see Fig. 3] and the Arkansas River looking upriver. The end of the moraine was torn away by the flood, but projection of crest shows it reached the Arkansas River at 9350 ft.

## The Lake

The dammed Arkansas River backed up behind the glacial dam and created Three Glaciers Lake, which was more than 500 ft deep at the dam and extended 14 miles up the Arkansas Valley to the Malta substation, just below Leadville [Fig. 7]. There is, unfortunately, no direct evidence of the lake elevation, such as shorelines, but there are two indirect lines of evidence.

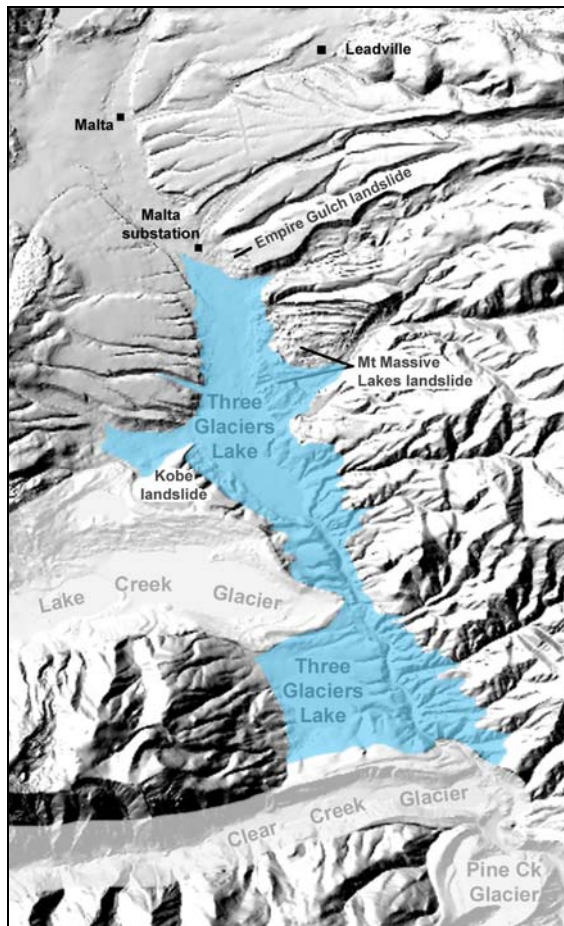


Figure 7—Three Glaciers Lake impounded by the glacial dam.

A second line of evidence is provided by landslides caused by the lake. Three landslides along the shore of Three Glaciers Lake [see Fig. 7] most likely were caused by reversed hydraulic gradients in the saturated sediments when the dam failed and the lake surface dropped catastrophically. The Kobe landslide has a crown scarp at 9400 ft [Fig. 9], and the Mt. Massive Lakes and Empire Gulch landslides, which lack clearly defined scarps, show hummocky landslide topography between 9300 ft and 9500 ft [Fig. 10].

The Lake Creek glacier was flowing into Three Glaciers Lake, and like many such glaciers flowing into the sea today, it calved off icebergs. Being normal glacial ice, they carried with them boulders, and when the icebergs melted, the boulders ended up on the lake bottom. These ice-rafted boulders could have dropped out individually as the iceberg melted, or, if the iceberg was blown aground along the shore, they would have formed a cluster of boulders. Figure 8 shows just such a cluster of ice-rafted boulders, sitting on the surface today just north of Lake Creek at an elevation of 9384 ft [by GPS]. A second, smaller cluster 1500 ft to the north shows a GPS elevation of 9402 ft.



Figure 8—Cluster of ice-rafted boulders marks the shoreline of Three Glaciers Lake.





Figure 9—View north of Kobe landslide. Crown scarp is marked by line of trees from lower right corner to upper left. Rolling topography and closed depressions are typical of landslides.



Figure 10—View east of Mt. Massive Lakes landslide, which produced the closed depressions now holding the lakes.

### The Dam Failure

How did the dam fail? No evidence is available to indicate the mechanism of dam failure, but from the huge boulders transported miles downstream, it is clear that the flood resulted from catastrophic failure and instantaneous dumping of the lake. A likely mechanism is flotation: lake level would have risen behind the ice dam to the point where it was at 90% of the thickness of the ice, at which point the ice dam would have floated [slowly pour water into a glass containing a single ice cube, at the 90% level the ice cube floats]. As soon as the glacier got high-pressure water under it, it would have been torn apart in seconds, and the lake just dumped into the valley below.

### The Flood

The broad, flat floor of the Arkansas River Valley below Pine Creek saw a wall of dirty water hundreds of feet high ricochet off the Pine Creek whamout and tear down the valley. As the valley widens to the south, depth of the floodwater would have diminished, but two miles below Pine Creek it was still deep enough to leave a four-foot boulder 160 ft up on the side of the valley [Fig. 11].

Erosion was severe in the damsite area. When floodwaters tore out the moraines of Pine Creek, they undercut the downstream lateral moraine enough to cause a huge landslide. In addition to scouring out the whamouts, floodwaters ripped out parts of the river bottom, creating a steep gradient in the Clear Creek area and an extremely steep gradient at Pine Creek, where the Arkansas River today drops 50 ft in a distance of 1300 ft, or more than 200 ft/mi.



Figure 11—Flood boulder two miles below ice dam. Distinctive boulder came from either Lake Creek glacier or Clear Creek glacier or moraine. Flood left boulder 160 ft above the valley bottom.

The flood caused surprisingly little erosion in the wider Arkansas River Valley. It did clean off the unconsolidated stream deposits, but most of the tremendous energy of the flood was spent on transporting the huge load of rocks from the washed-out moraines of the two glaciers, including flood boulders big as a house [Fig. 12]. The rocks were spread

out over the valley bottom [Fig. 13], covering it to a depth of 50 ft just below Pine Creek and thinning downstream to about 20 ft at Elephant Rock, 10 miles south. When one looks today at a 50-ft-thick section of boulders, one usually thinks in terms of the eons of time required to deposit it; these 50 ft of flood boulders were deposited in minutes.



Figure 12—Flood boulder carried five miles downriver.



Figure 13—Aerial view to north of flood boulders on valley floor. Large flood boulder at top measures 45 ft long by 24 ft wide by 15+ ft high. Flood boulders removed by erosion left of the scarp and partially covered by alluvial fan debris in upper right.

## THE LATEST FLOOD

The latest flood was much like the first; in fact, it is hard to find significant differences. The Lake Creek glacier again held the Arkansas River to the east side of the valley, but did not actually dam it. When the glacier retreated, its end moraine formed a low dam across Lake Creek that impounded a lake behind it – the lower of the Twin Lakes. Its upper twin was created when the glacier retreat was stalled a few miles upstream and built another end [recessional] moraine [Fig. 14]. Artificial raising of the lower morainal dam has since connected the Twin Lakes.

The younger moraines of Clear Creek show a projected moraine height of 9360 ft, only 10 ft different from the earlier glacier. A cluster of ice-rafted boulders from this flood [one can judge the age by the amount of weathering of the boulders] on the east side of the valley has a GPS elevation of 9358 ft [Fig. 15].

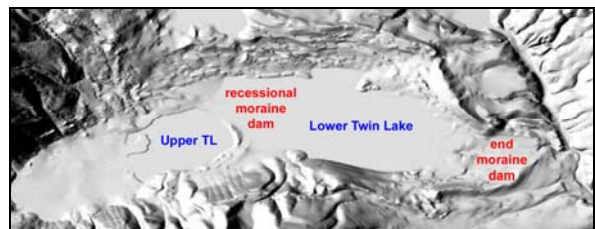


Figure 14—End moraine of Lake Creek glacier formed low dam that impounded Lower Twin Lake; recessional moraine dammed Upper Twin Lake.

During the interval between floods, the Arkansas River had eroded part of the valley below the dam about 50 ft, so when the flood spread out a sheet of flood boulders 20 or 30 ft thick, it left the valley floor with two levels, or terraces, of flood boulders about 30 ft apart [Fig. 16]. When driving US24 or the dirt roads along the Arkansas River, the two terraces of flood boulders are apparent, with the higher, older flood terrace about 50 ft above the modern river level and the younger, lower terrace about 20 ft above. Most of the rapids in the Arkansas River are caused by the very large flood boulders, some of which occupy the total depth of the flood layer [Fig. 17].



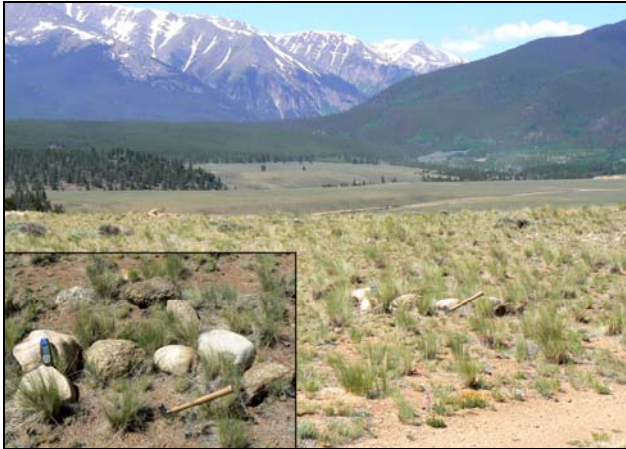


Figure 15—View to southwest of cluster of ice-rafted boulders on old erosion surface east of Arkansas River. The light gray round boulder above end of hammer comes from west of the Arkansas River.



Figure 16—Flood boulders on lower, younger, terrace in foreground; house sits on upper terrace about 30 ft higher.



Figure 17—20-ft flood boulder in the Arkansas River.



Figure 18—Flood boulder measuring 18 ft long by 12 ft wide by 11+ ft high is about 600,000 years old.

## OTHER FLOODS

The nature of these floods is such that they tend to destroy evidence of earlier events. So, while we have a clear picture of the two floods described here, only fragmentary evidence remains of earlier ones. Evidence for an earlier flood is shown in [Figure 18](#). Glenn Scott, the pioneer in flood recognition here [Scott, 1984], found a volcanic ash on top of these boulders that he determined came from an eruption at Yellowstone National Park 600,000 years ago, suggesting the flood was at about this time. A similar deposit at Buena Vista attests to an even earlier flood [[Fig. 19](#)]. Glenn Scott thinks this one tore down the Upper Arkansas Valley as long as 1.4 million years ago.

## THE NEXT FLOOD

Paleoclimate studies have shown that over the last 800,000 years there have been 8 glacial episodes, or *ice ages*, spaced about 100,000 years apart. This climate change is forced by variations in solar energy reaching the Earth as the Earth's orbit changes. The change on a

100,000 year cycle is caused by periodic variations in eccentricity of the orbit – that is, every 100,000 years the Earth's orbit grows more elliptical, with the result that the Earth

is farther from the sun for a part of the year, leading to a cold, glacial episode, or ice age. There is no reason to suppose this pattern will not continue into the future, so we can anticipate the next catastrophic flood at the next glacial maximum in about 80,000 years.

### LEGACY OF THE CATASTROPHIC FLOODS

Rafting and kayaking on the Arkansas River were brought to you by the Three Glaciers Flood. The extreme gradient created at Pine Creek translates into the Class IV-V rapids of Granite Gorge [Fig. 20]. Rapids in The Numbers were created largely by the huge flood boulders laid down by the most recent flood, while the Railroad Bridge section of rapids cuts through flood boulders from the first flood.



Figure 20—Granite Gorge Rapids at Pine Creek. Left: view upriver of start of rapids; Right: highwater 28 June 2008. Pine Creek flows from left through concrete railroad underpass.

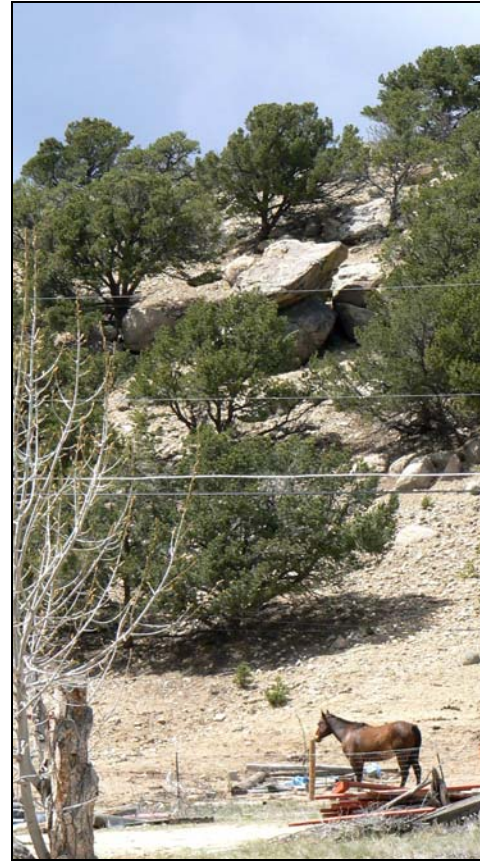


Figure 19—Flood boulder estimated 18 ft long is probably 1.4 million years old.

Flood boulders on the land surface render much of the wide, flat valley floor unsuited for cultivation, so there is little farming in what otherwise would be prime bottomland. The boulders restrict agricultural use to grazing, and this is now being supplanted in several areas by residential development, where modern homes have dramatic boulder landscapes. This is a suitable use for the flood boulder fields, but homeowners must be aware that they definitely are in the 100-thousand-year floodplain.

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#### Some References

- Pierce, K.L., 2003, Pleistocene glaciations of the Rocky Mountains: Developments in Quaternary Science, v. 1, p. 63-76.  
 Scott, G.R., 1975, Reconnaissance geologic map of the Buena Vista Quadrangle, Chaffee and Park Counties, Colorado: U.S. Geological Survey Miscellaneous Field Studies Map MF-657, scale 1:62,500.  
 Scott, G.R., 1984, Pleistocene floods along the Arkansas River, Chaffee County, Colorado, in Nelson, A.R., Shroba, R.R., and Scott, G.R., Quaternary stratigraphy of the Upper Arkansas Valley - A field trip guidebook for the 8<sup>th</sup> Biennial Meeting of the American Quaternary Association, Boulder, Colorado: p. 51-57, *unpublished*.