

# Topographic Map Analysis of Mountain Passes Crossing the Continental Divide Between Colorado River Headwaters and North and South Platte River Headwaters to Test a New Geomorphology Paradigm, Colorado, USA

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## Abstract

Detailed topographic maps are used to identify and briefly describe named (and a few unnamed) mountain passes crossing high elevation east-west continental divide segments encircling south- and southwest-oriented Colorado River headwaters and linking the Colorado River drainage basin (draining to the Pacific Ocean) with the North and South Platte River drainage basins (draining to the Platte, Missouri, and Mississippi Rivers and Gulf of Mexico). Previous researchers following commonly accepted geomorphology paradigm rules have not explained how most, if any of these mountain passes originated. A recently proposed geomorphology paradigm requires all Missouri River drainage basin valleys to have eroded headward across massive south- and southeast-oriented floods, which implies south- and southeast-oriented floods flowed from what are today north-oriented North Platte River headwaters across the continental divide, the present-day south- and southwest-oriented Colorado River headwaters valley, and then across what is now the continental divide a second time to reach east- and southeast-oriented South Platte River headwaters. Paradigms are rules determining how a scientific discipline governs its research and by themselves are neither correct nor incorrect and are judged on their ability to explain observed evidence. From the new paradigm perspective, a stream eroded each of the passes into a rising mountain range until the uplift rate outpaced the erosion rate and forced a flow reversal in what would have been the upstream valley. The passes and the valleys leading in both directions from the continental divide are best explained if diverging and converging south- and southeast-oriented flood flow channels crossed rising mountain ranges. While explaining observed drainage patterns and erosional landforms such an interpretation requires a fundamentally different regional middle and late Cenozoic glacial and geologic history than what previous investigators using the accepted paradigm perspective have described.

**Keywords:** Barbed Tributary, Blue River, Drainage Basin, Drainage Divide, High-Level Erosion Surface, Never Summer Range, Rabbit Ears Range, Topographic Map Interpretation

## 1. Introduction

### 1.1 Statement of Problem

Thomas Kuhn (1970) suggests scientific paradigms are rules defining how a scientific community governs its research and are selected based on their ability to explain observed evidence. Kuhn further says most scientific research is “normal science” in which an accepted paradigm is fleshed out and not questioned, but paradigms also identify anomalous evidence (evidence the paradigm cannot explain). Scientists, according to Kuhn, deal with anomalous evidence in three ways. First, the accepted paradigm eventually explains the anomalous evidence and the paradigm continues without interruption. Second, the anomalous evidence is described and catalogued and shelved for future study. Third, the anomalous evidence leads to a new paradigm with a fundamentally different set of rules (which are capable of explaining the anomalous evidence) and then to a battle over which paradigm should be used. During such paradigm battles the competing paradigms should not be used to judge each other (the paradigms are fundamentally different sets of rules, which by themselves are neither correct nor incorrect). Instead the competing paradigms should be judged on their ability to explain evidence with Occam’s Razor, which in science according to Anderson (2002, p. 57) says “what can be done with fewer [assumptions] is done in vain with more,” being used to compare how well each of the two fundamentally different paradigms explains evidence.

North America's east-west continental divide (see Figure 1) follows high Rocky Mountain ridges as it loops around south- and southwest-oriented Colorado River headwaters (flowing to the Pacific Ocean) while to the north and west are north-oriented North Platte River headwaters and to the north, east, and south are north-, east-, and southeast-oriented South Platte River headwaters. Today the north-oriented North Platte River flows into central Wyoming before turning in a southeast direction to reach western Nebraska and southeast- and east-oriented South Platte River headwaters turn in a north-northeast direction to leave the Rocky Mountains and then to flow in a northeast direction to join the North Platte River and to form the east-oriented Platte River with its water eventually reaching the Gulf of Mexico. Many North and South Platte River drainage route features, including their direction changes, and the mountain passes linking Colorado River and North and South Platte River headwaters represent anomalous evidence that has been mapped and catalogued and left for future geomorphologists to explain.

A recently proposed geomorphology paradigm (new paradigm) has emerged and requires all Missouri River drainage system valleys to have been eroded headward across massive south- and southeast-oriented floods (Clausen, 2018). The North and South Platte Rivers are included in the Missouri River drainage system and the new paradigm requires immense south- and southeast-oriented floods to have crossed their entire drainage basin areas, which implies immense south- and southeast-oriented floods also crossed the Colorado River headwaters area. From the accepted geomorphology paradigm (accepted paradigm) perspective such an interpretation is unlikely, and probably impossible, but one paradigm should not be used to judge a competing paradigm. To date, the accepted paradigm has led to continuing controversies as geomorphologists have tried to explain North and South Platte River and Colorado River drainage routes, high-level Rocky Mountain erosional surfaces, and other erosional landform features. The study reported here analyzes detailed topographic map evidence to determine whether or not the new paradigm, which requires the Rocky Mountains to have been rising as massive south- and southeast-oriented floods flowed across them, can explain evidence such as the Colorado River-Platte River drainage divides and the mountain passes that link the two opposing drainage systems any better than published accepted paradigm interpretations.

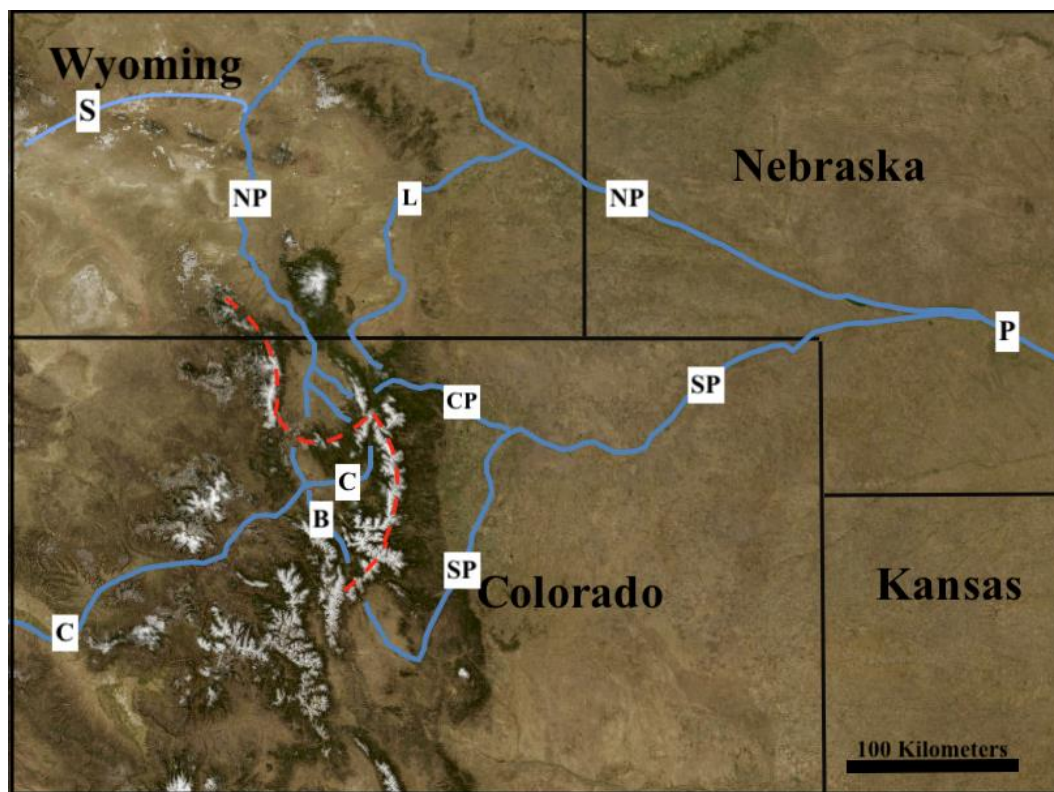


Figure 1. Modified United States Geologic Survey (USGS) National Map website imagery showing Colorado River (C) headwaters between North Platte (NP) and South Platte (SP) River headwaters and Blue River-B, Cache la Poudre River-CP, Laramie River-L, Platte River-P, and Sweetwater River-S. Dashed red line shows the continental divide in this paper's study region

### 1.2 Geographic Setting

North-oriented North Platte River headwaters (seen in figure 1) flow into and through a mountain-surrounded structural basin known as North Park to reach Wyoming. The Michigan (north) and Illinois (south) Rivers are the unlabeled northwest-oriented North Platte River tributaries shown in North Park. North Park is located between the Sierra Madre and Park Ranges (west), Medicine Bow and Never Summer Ranges (east), with the Rabbit Ears Range to the south. The North Platte River has cut canyons into structural uplifts where it leaves North Park and at various points along its north- and southeast-oriented Wyoming route. Southeast-oriented South Platte River headwaters flow through South Park, another mountain-surrounded structural basin, before turning in a north-northeast direction to enter deep canyons and eventually reach the Great Plains. Between North and South Parks, south- and southwest-oriented Colorado River headwaters flow through Middle Park, another mountain-surrounded structural basin, to reach Gore Canyon where the river flows through the Gore Range. Gore Canyon floor elevations are in the 2200-meter range while Gore Range elevations to the south exceed 3500 meters and to the north exceed 3200 meters, although abandoned valleys cross the Gore Range both to the south and the north of Gore Canyon. Numerous mountain passes of varying depths cross the Park, Rabbit Ears, and Never Summer Ranges and link north-oriented North Platte River headwaters valleys with Colorado River tributaries and cross high mountain ridges to link north-, east- and southeast-oriented South Platte River headwaters and tributary valleys with the Colorado River headwaters and tributary valleys.

### 1.3 Previous Work

Critical to the study reported here are paradigm neutral United States Geological Survey (USGS) detailed topographic maps covering this paper's entire study region (available at the USGS National Map website). Drainage routes are shown and water eroded landforms such as valleys, drainage divides, asymmetric drainage divides, water gaps, barbed tributaries, erosional escarpments, abandoned valleys, and mountain passes (and wind gaps) are easily identified and interpreted. While detailed topographic maps are excellent tools for identifying stream capture evidence and reconstructing former drainage routes, previous investigators have focused most of their attention on the region's high-level erosion surfaces (referred to as peneplains in earlier work). Bradley (1987) in a Colorado Front Range erosion surface literature review notes how Davis (1911) recognized remnants of a high-level Rocky Mountain peneplain or erosion surface (at about 11,500 feet or 3505 meters) above which some of Colorado's highest mountains now stand. Lee (1923, p. 2) comments "Davis believes that only two main cycles of erosion are represented in the Rocky Mountains in Colorado—an older one resulting in the formation of a peneplain and a younger one during which the canyons and cirques were excavated." Lee then proposes that two erosion surfaces are present with the lower erosion surface having an elevation of between 9,000 and 9,500 feet (2743 and 2896 meters).

Little (1925, p. 497) observes "for practical purposes... the peneplains of the Front Range may be considered as cut wholly across pre-Cambrian granites, gneisses, and schists, with the former especially abundant" and then includes a table comparing how twelve different reports interpreted the number of Front Range peneplains and the ages and names assigned to each of the suggested peneplains. That table demonstrates by the mid 1920s researchers were disagreeing about the number and nature of Front Range erosion surfaces and those controversies continue today with many Colorado geologists (e.g. Chapin and Kelley, 1997) considering the high-level Rocky Mountain erosion surface to be late Eocene in age. In Wyoming, just to the north of this paper's study region Mears (1993) in a literature review notes most Wyoming geologists consider the high-level Rocky Mountain erosion surface to be late Miocene in age.

Early workers did not have good quality topographic maps and while more recent researchers have had such access, they have used other types of evidence when reconstructing the former drainage routes. For example, Hunt (1969, p. 70) comments "In Oligocene time, the ancestral headwaters of the Colorado River discharged westward... from the Park Range and possibly from the Front Range.... This course is recorded by river gravels under the tuffaceous beds and lava, thought to be of early Pliocene age.... The gravels are at an altitude of 10,400 feet [3170 meters], but part of this high altitude is due to 2,000 feet [610 meters] or more of late Tertiary or Quaternary uplift." After implying the uplift forced the Colorado River onto its present route Hunt continues (p. 71) "The present course of the Colorado River through Middle Park, across the Gore Range... clearly is younger than the lavas and sedimentary rocks in the basins and apparently became established by being superimposed across the structures at the very end of Miocene time or the beginning of Pliocene time. The canyons, though, seem to be antecedent."

Fan et al. (2014, p. 547) suggest "When and how the central Rocky Mountains (Rockies) ... gained modern topography remains a controversial question" and then suggest "the region underwent differential uplift to form relief similar to that of today before the earliest Oligocene time." Addressing evidence located in Wyoming (just

to the north of this paper's study region) Flanagan and Montagne (1993, p. 597) comment "The depth and timing of Wyoming's basin fill remains a controversial subject. The essential question is whether Wyoming's foreland basins were filled volumetrically with more Cenozoic sedimentary material between late Eocene and Pleistocene and then substantially excavated or whether the material in the basins today is the maximum sediment fill deposited in the basins throughout the Cenozoic" and add, "the superposition of river systems suggest that these rivers were flowing across basins filled with sedimentary material to elevations of approximately 9,000 ft. (2700 m)."

Chapin and Kelley (1997, p. 101) comment that following the Laramide orogeny the Rocky Mountain erosion surface developed during the Eocene "by the coalescence of pediments and was protected from dissection by a combination of volcanic cover and alluvial aprons that bordered the range. Change to a significantly wetter, stormier climate beginning in the early Pliocene led to excavation of the protecting piedmont sediments and allowed incision of the deep canyons that now cross the surface," but do not provide the former drainage route details. Wohl (2008, p. F01007), in a discussion of lower elevation Cache la Poudre River drainage areas, uses evidence presented by Anderson et al. (2006) and Crowley et al. (2002) to suggest the Colorado "Front Range has been relatively tectonically quiescent since the early Tertiary." McMillan et al. (2006) suggest Oligocene and Miocene sediments filled intramontane basins and partially buried the mountains before regional uplift raised the mountains and initiated the Oligocene and Miocene basin sediment fill excavation. Such an interpretation according to Pelletier (2009, p. 4) requires the intramontane basins of the southern Rocky Mountains to "have undergone up to 1.5 km of erosion from the middle Miocene to the present."

The new paradigm is based on detailed topographic map evidence and requires large south- and southeast-oriented floods to have flowed across rising mountain ranges from the North Platte River drainage basin across what are now Colorado River headwaters to reach South Platte River headwaters. To date new paradigm publications are limited and document how the new paradigm explains previously unexplained northern Missouri River drainage basin topographic map evidence (some are summarized in Clausen, 2018). The new paradigm requirement forces recognition of a fundamentally different glacial history (than described by workers who have used the accepted paradigm) in which a thick continental ice sheet created and occupied a deep "hole" by eroding the underlying continental bedrock and by causing crustal warping that raised mountain ranges and plateau areas as immense melt water floods flowed across them. Landform evidence supporting the new paradigm interpretation in the deep "hole" floor area is given in Clausen (2019a) while subsequent papers (Clausen, 2019b) and (Clausen, 2019c, p. 410) demonstrate "how prior to a drainage reversal that caused the melt water floods to flow back into the deep 'hole' space, south-oriented melt water floods flowed across the east-oriented Sweetwater River drainage basin and the Great Divide Basin to reach the southwest-oriented Colorado River. Further... the east-oriented Sweetwater River drainage basin is located along a deep "hole" rim segment, with the deep "hole" rim in Montana, Wyoming, and northern Colorado following the present-day east-west continental divide."

## 2. Research Method

The new paradigm discussed here was constructed after many attempts to solve previously unsolved drainage history and erosional landform origin problems and was developed during two separate three-year systematic studies of detailed topographic maps covering the entire Missouri River drainage basin (and several adjacent drainage basins). The goal of these studies was to determine how drainage divides (between streams large enough to be shown on the maps) originated. The first study used large mosaics of (hard copy) detailed topographic maps and was done during the 1999-2001 time period. The unexpected results were fundamentally different from anything in the published literature and could not be easily demonstrated to skeptical reviewers. That first study was repeated during the 2011-2013 time period using National Geographic TOPO digital maps and software and resulted in more than 500 detailed research notes in blog format describing origins for approximately 4000 different Missouri River drainage basin drainage divides which can be found at [geomorphologyresearch.com](http://geomorphologyresearch.com).

The map interpretation techniques used to determine drainage divide origins first identify low points (or divide crossings or mountain passes in the case of this paper) located along a drainage divide. These low points (unless there is reason to believe otherwise) are interpreted to be where water once flowed in one direction or the other across what is now a drainage divide. Valleys draining in opposite directions from the identified drainage divide low point are interpreted to have first originated when water flowed across the drainage divide and the drainage divide is interpreted to have originated when flow in one of those valleys was reversed (or otherwise changed) so as to no longer cross the drainage divide. Reasons for the flow reversal or direction change are then sought. In some cases, uplift at a rate faster than the rate of water erosion explains why the flow was reversed, although in other situations stream capture, where a deeper valley beheaded the flow route crossing the drainage divide, accounts for the flow reversals and drainage divide formation. Where numerous closely spaced streams once crossed a drainage divide the present-day opposing drainage routes suggest the multiple streams may have been

diverging and converging channels in a flood-formed anastomosing channel complex.

The study reported here used detailed topographic maps and tools available at the United States Geological Survey (USGS) National Map website and began by identifying and listing in Tables 1 and 2 the named (and a few unnamed) Colorado mountain passes located along the North Platte River-Colorado River and Colorado River-South Platte River drainage divide segments making up the North American east-west continental divide. Listed pass floor elevations were determined by use of the spot elevation tool and where possible checked against published pass floor elevations. Listed pass depths are approximate and are based on nearby continental divide high point elevations. Each listed pass links valleys on either side of the continental divide and was interpreted to have been eroded by water flowing in one direction or the other. Listed passes were analyzed as described in the results section below to determine how the passes were eroded and how the present-day drainage system evolved as mountain uplift dismembered the previous drainage system.

### 3. Results

#### 3.1 Passes Along the North Platte River-Colorado River Drainage Divide (in Colorado)

Named mountain passes (on detailed topographic maps) and a few unnamed mountain passes identified in sequence (from the Wyoming border southward and eastward toward the Colorado River headwaters) along Colorado's North Platte River-Colorado River drainage divide segment of the east-west continental divide are listed in Table 1. Each of the listed passes links a North Platte River tributary valley with a Colorado River tributary valley. The passes are notched into what today are high mountain ridges and the depths indicate in approximate numbers how much higher (in meters) nearby ridges are than the pass floor. Today it is difficult to imagine how water could have flowed across the ridges as long and steep climbs on both sides are now needed to reach the passes, yet water flowing across what is now a major drainage divide must have eroded each pass (glaciers subsequently further modified some passes). The first three passes are in the Park Range located to the west of North Park and link North Platte River tributaries with Elk River tributaries (the Elk River flows to the Yampa River, which flows to the Green River, which flows to the Colorado River). The middle eight passes are located in the Rabbit Ears Range (south of North Park) and the final passes are in the Never Summer Range (southeast and east of North Park). The listed passes and numerous other unnamed and unlisted passes indicate that prior to regional and mountain range uplift multiple streams of water flowed in one direction or the other across the Park, Rabbit Ears, and Never Summer Mountain Ranges.

Table 1. Named and a few unnamed Colorado mountain passes (with floor elevations and depths in meters) linking Colorado River tributary drainage routes with North Platte River drainage routes

Pass Name	Floor elevation	Pass depth	Colorado drainage valley	North Platte drainage valley	Pass orientation
1. Unnamed pass	2995	450-550	N Fork Elk River	Encampment River	N-S
2. Red Dirt Pass	3520	130-150	Gold Creek	Shafer Creek	NE-S
3. Ute Pass	3345	250-300	Gold Creek	Bear Creek	NW-SE
4. Buffalo Pass	3146	50-200	Fish Creek	Summit Lake outlet	NE-SW
5. Rabbit Ears Pass	2873	100-350	Muddy Creek	Grizzly Creek	E-W
6. Muddy Pass	2655	350-750	Little Muddy Creek	Grizzly Creek	N-S
7. Arapahoe Pass	2729	150-270	Diamond Creek	Indian Creek	NE-SW
8. unnamed pass	2903	100-300	Lindsey Creek	Indian Creek	NE-SW
9. Troublesome Pass	3056	400-450	Haystack Creek	Willow Creek	N-S
10. Willow Creek Pass	2944	400-600	Pass Creek	Snyder Creek	N-S
11. Illinois Pass	3047	150-350	Trout Creek	Illinois River	N-W
12. unnamed pass	3093	150-350	Willow Creek	Illinois River	N-S
13. Bowen Pass	3430	200-300	Bowen Gulch	Illinois River	W-SE
14. Baker Pass	3432	300-400	Baker Gulch	S Fork Michigan River	N-S
15. Thunder Pass	3450	300-350	Lulu Creek	Michigan River	N-S

Pass number 1 in Table 1 (seen in Figure 2), while not named on the map, links north-oriented Encampment River headwaters (draining to the North Platte River) with the west-oriented North Fork Elk River valley (draining to the Elk, Yampa, Green, and Colorado Rivers). A Tweto (1976) geologic map shows glacial deposits in both valleys, but more prevalent in the north-oriented valley. To the north of Figure 2 a 370-meter deep 10-kilometer long and

west- and north-oriented valley diverges from and then converges with the comparably deep north-oriented Encampment River valley with only a 35-meter high drainage divide separating the two valleys. Other valleys also diverge from and then converge with the north-oriented Encampment River valley. These diverging and converging valleys suggest large and prolonged diverging and converging streams of water carved deep valleys into what must have been rising mountains. The “T” intersection in Figure 2 suggests water first flowed in a south direction at an elevation nearly as high as the adjacent mountain tops and was captured by headward erosion of the west-oriented North Fork Elk River valley and continued to flow in a south direction as the pass valley was eroded. Continued regional and mountain uplift eventually forced a reversal of flow to create what is today the drainage divide and the north-oriented Encampment River.

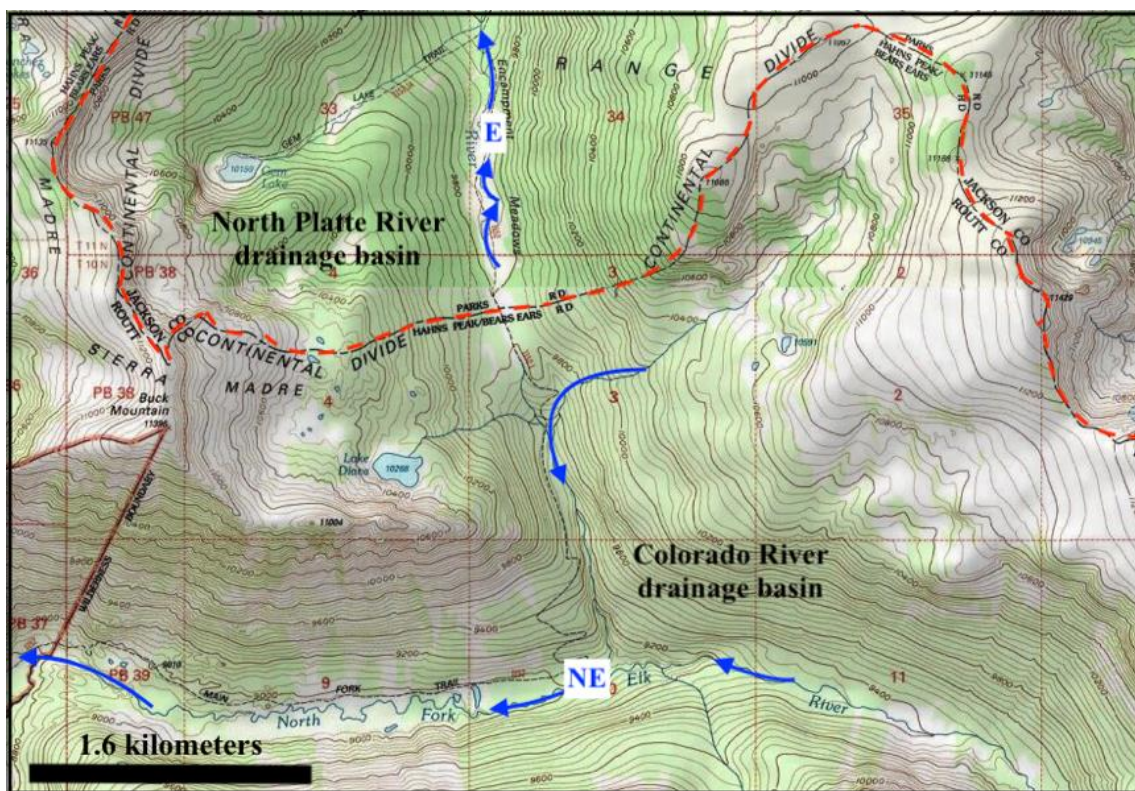


Figure 2. Modified topographic map from USGS National Map website showing an unnamed (on topographic maps) mountain pass (number 1 in Table 1) across the east-west continental divide (dashed red line) linking north-oriented Encampment River (E) flowing to the north-oriented North Platte River with west- and south-oriented North Fork Elk River (NE) with its water eventually reaching the Colorado River. The contour interval is 40 feet (12 meters)

Red Dirt and Ute Passes provide further evidence for south-oriented flow across the high-level surface now preserved along ridge tops. Red Dirt Pass is located on a southeast-oriented continental divide segment and links northeast-oriented Shafer Creek headwaters (flowing to the North Platte River) with south-oriented Gold Creek headwaters (in the Colorado River drainage basin) while Ute Pass is located almost directly south of Red Dirt Pass on a southwest-oriented continental divide segment and links south-oriented Gold Creek headwaters with southeast-oriented Bear Creek which flows to the north-oriented North Platte River as a barbed tributary (the south-oriented Gold Creek headwaters valley makes a turn to the southwest and west just to the north of Ute Pass). Present-day drainage routes can be explained if headward erosion of a west-oriented Gold Creek valley (from the Middle Fork Elk River valley in the Colorado River drainage basin) captured south-oriented water that had been flowing across Red Dirt Pass (from the present-day North Platte River drainage basin), next along the south-oriented Gold Creek headwaters alignment (now in the Colorado River drainage basin), then across Ute Pass, and finally back into the present-day North Platte River drainage basin where it flowed along the southeast-oriented Bear Creek alignment to join south-oriented water flowing on the present-day north-oriented North Platte River alignment. To cross Red Dirt Pass such south-oriented water must have flowed on a surface equivalent to what are

now some of the region's highest ridge tops and there must have been sufficient volumes of water over prolonged periods of time to carve what are today deep valleys into rising mountains before the continued uplift forced a reversal of flow to create what is today the north-oriented North Platte River drainage system.

Buffalo Pass (number 4 in Table 1) links northeast- and east-oriented Chedsey Creek flowing to the north-oriented North Platte River with southwest-oriented Fish Creek flowing to a north-oriented Yampa River segment. To the north of where Fish Creek joins it the Yampa River turns in a west direction and eventually joins the south-oriented Green River with its water then reaching the Colorado River, while to the south a large through valley links the north-oriented Yampa River headwaters valley with a south-oriented Colorado River tributary valley and suggests the north-oriented Yampa River headwaters are flowing in what at one time was a major south-oriented flow route. Gravels described by Madole (1991) indicate the Yampa River headwaters have flowed in a north direction since Rocky Mountain glaciation meaning the south-oriented drainage that eroded Buffalo Pass, passes number 1-3, and probably the other Table 1 passes must have predated glaciation in what are now high Rocky Mountain regions.

Rabbit Ears Pass is located between south-oriented Muddy Creek (flowing to the Colorado River) and southeast- and northeast-oriented Grizzly Creek (flowing to the North Platte River) and is probably best explained by flow that diverged from the upper Muddy Creek valley and then moved along the southeast-oriented Grizzly Creek headwaters alignment to reach and erode Muddy Pass to reach and flow along the Little Muddy Creek alignment to converge with the Muddy Creek route again. Regional (and Rabbit Ears Range) uplift dismembered the diverging and converging flow routes with headward erosion of the northeast-oriented Grizzly Creek valley capturing the dismembered southeast-oriented Grizzly Creek headwaters.

Passes across the west-to-east oriented Rabbit Ears Range include Muddy Pass (number 6 in Table 1) and proceed eastward to Illinois Pass (number 11) with passes 12-15 being in the Never Summer Range. The Rabbit Ears and Never Summer Ranges were local volcanic centers in what was an extensive Middle Tertiary volcanic field (Stevens, 1975) and it is possible some passes represent low points between constructional landforms. However, all listed passes in Table 1 link North Platte River tributary valleys with south-oriented valleys draining directly to the Colorado River strongly suggesting that all passes were water eroded. Based on present-day topography it is difficult to imagine how streams flowing in one direction or the other could have crossed what is now a high drainage divide. However, diverging and converging streams of water must have eroded deep valleys into the rising Rabbit Ears and Never Summer Mountain Ranges until the uplift rate outpaced the erosion rate with the water first being channeled to flow into what are now the deeper pass valleys while at the same time forcing reversals of flow to create what eventually became North Platte River headwaters drainage routes. It is possible diverging and converging streams of water crossed what are now the Rabbit Ears and Never Summer Ranges not only as uplift was occurring, but also as volcanic activity was underway.

### *3.2 Passes along the South Platte River-Colorado River Drainage Divide Segment*

Named passes (on USGS detailed topographic maps) along the South Platte River-Colorado River drainage divide are identified in Table 2 and Figure 3 provides a modified topographic map from the USGS National Map website showing how the continental divide loops around the south-oriented Colorado River headwaters and locations of Baker Pass and Thunder Pass (14 and 15 in Table 1), La Poudre Pass and Milner Pass (16 and 17 in Table 2), Cameron Pass (X1 in Figure 3, floor elevation 3,132 meters, depth of 350-450 meters), Forest Canyon Pass (X2, floor elevation 3450 meters, depth 150-300 meters), and Chapin Pass (X3, floor elevation 3400 meters, depth 225-375 meters). Cameron Pass links a south-oriented Michigan River tributary with north-oriented Joe Wright Creek and Forest Canyon and Chapin Passes link the northeast-oriented Cache la Poudre River headwaters valley with southeast-oriented Big Thompson River headwaters (both rivers use different routes to reach the South Platte River).

To the north of Figure 3 Joe Wright Creek has been dammed to form Chambers Lake, which in addition to having an outlet in the Joe Wright Creek valley leading to the north- and east-oriented Cache la Poudre River (which flows to the South Platte River) also has an outlet to the north-oriented Laramie River, which flows to the North Platte River (see Figure 1). Workman et al (2018) show Cameron Pass located along a north-south oriented fault line although erosion of the Cameron Pass valley and the diverging Chambers Lake outlet routes are easiest to explain if after mountain uplift blocked south-oriented flow across Baker and Thunder Passes south- and east-oriented water turned in a north direction to further erode the Cameron Pass valley and then at the present-day Chambers Lake location to split into diverging channels with one channel leading to the Laramie River and the other channel to the Cache la Poudre River. Mountain uplift eventually blocked flow to the Laramie River valley and soon thereafter through Cameron Pass to create the west- and northwest-oriented Michigan River drainage system leading to what was then newly reversed flow along what is now the north-oriented North Platte River alignment.

La Poudre Pass links the south-oriented Colorado River headwaters valley with lower gradient northeast-oriented La Poudre Pass Creek, which flows to the north- and east-oriented Cache la Poudre River. Milner Pass is 178 meters higher than La Poudre Pass and links northeast- and north-oriented Cache la Poudre River headwaters with a short south-oriented Colorado River tributary valley. Map evidence seen in Figure 3 (and better seen in more detailed topographic maps) suggests that while regional and mountain uplift was occurring channels of south-oriented water diverged so as to follow what are now the north-oriented Cache la Poudre River and La Poudre Pass Creek valleys to reach an actively eroding south-oriented Colorado River headwaters valley until such time as mountain uplift outpaced erosion on the Milner Pass route and all south-oriented flow was forced to flow along what is today the northeast-oriented La Poudre Pass Creek route. Continued south-oriented flow on the La Poudre Pass Creek route further eroded the La Poudre Pass valley while approximately 178 meters of additional uplift occurred and the deep south-oriented Colorado River headwaters valley eroded 5-6 kilometers northward from the Milner Pass location. Northwest oriented and barbed Colorado River tributaries suggest the Colorado River headwaters valley (and the northeast-oriented Cache la Poudre River headwaters valley) also eroded headward across southeast-oriented flow channels that had once moved water to the southeast-oriented Big Thompson River headwaters.

Wohl (2008) interprets a Madole et al. (1998) map to suggest “Pleistocene glaciers extended down Poudre Canyon to 2325 m,” which is lower than any areas seen in Figure 3. Text accompanying the Madole et al map (which does not address evidence for glaciation in the North Platte River or Colorado River drainage basins) suggests the Cache la Poudre valley glacier “was about 45 km long and as much as 600 m thick.” Topographic map evidence seen in Figure 3 and in more detailed topographic maps supports the Madole et al. interpretation and also suggests valley glaciers also once filled most valleys seen in Figure 3. While glaciers probably streamlined, deepened, and otherwise altered valleys and mountain ridges seen in Figure 3 almost all valleys (including the mountain passes) were eroded prior to the glaciation.

Table 2. Mountain passes (with floor elevations and depths in meters) linking Colorado River headwaters and tributary valleys with South Platte River headwaters and tributary valleys

Pass Name	Floor elevation	Pass depth	Colorado valley	drainage	South Platte valley	drainage	Pass Orientation
16. La Poudre Pass	3101	700-800	Colorado River		La Poudre Pass Creek		NE-SW
17. Milner Pass	3279	400-500	Beaver Creek		Cache La Poudre R.		NE-SW
18. Sprague Pass	3569	100-200	Tonahutu Creek		Spruce Creek		NE-SW
19. Ptarmigan Pass	3709	100-150	Ptarmigan Creek		Fern Creek		NE-SW
20. Andrews Pass	3645	200-350	Hallett Creek		Andrews Creek		NE-SW
21. Stone Man Pass	3812	200-500	North Inlet		Glacier Creek		NE-SW
22. Boulder Grand Pass	3681	300-350	East Inlet		North St Vrain Creek		E-W
23. Buchanan Pass	3610	300-350	Buchanan Creek		Middle St Vrain Ck		E-W
24. Pawnee Pass	3825	120-200	Pawnee Lake outlet		Blue Lake outlet		E-W
25. Arapaho Pass	3629	300-400	Arapaho Creek		Middle Boulder Creek		N-SE
26. Devils Thumb Pass	3580	80-180	Cabin Creek		Jasper Creek		NW-SE
27. Rollins Pass	3559	100-200	Ranch Creek		S Fk Mid Boulder Ck		NE-SW
28. Berthould Pass	3449	400-450	Fraser River		Hoop Creek		NNE-SSW
29. Vasquez Pass	3565	300-400	Vasquez Creek		Clear Creek		N-S
30. Jones Pass	3796	100-150	Jones Creek		W Fk Clear Creek		E-W
31. Loveland Pass	3655	350-400	Clear Creek		N Fk Snake River		N-S
32. Argentine Pass	4025	180-220	Peru Creek		Leavenwork Creek		W-E
33. Webster Pass	3700	160-220	Snake River		Handcart Gulch		N-S
34. Georgia Pass	3531	500-600	S Fk Swan River		Michigan Creek		N_S
35. French Pass	3672	300-400	French Gulch		French Creek		N-S
36. Boreas Pass	3499	450-500	Indiana Creek		N Tarryall Creek		N-S
37. Hoosier Pass	3517	500-600	Blue River		Mid Fk S Platte River		N-S



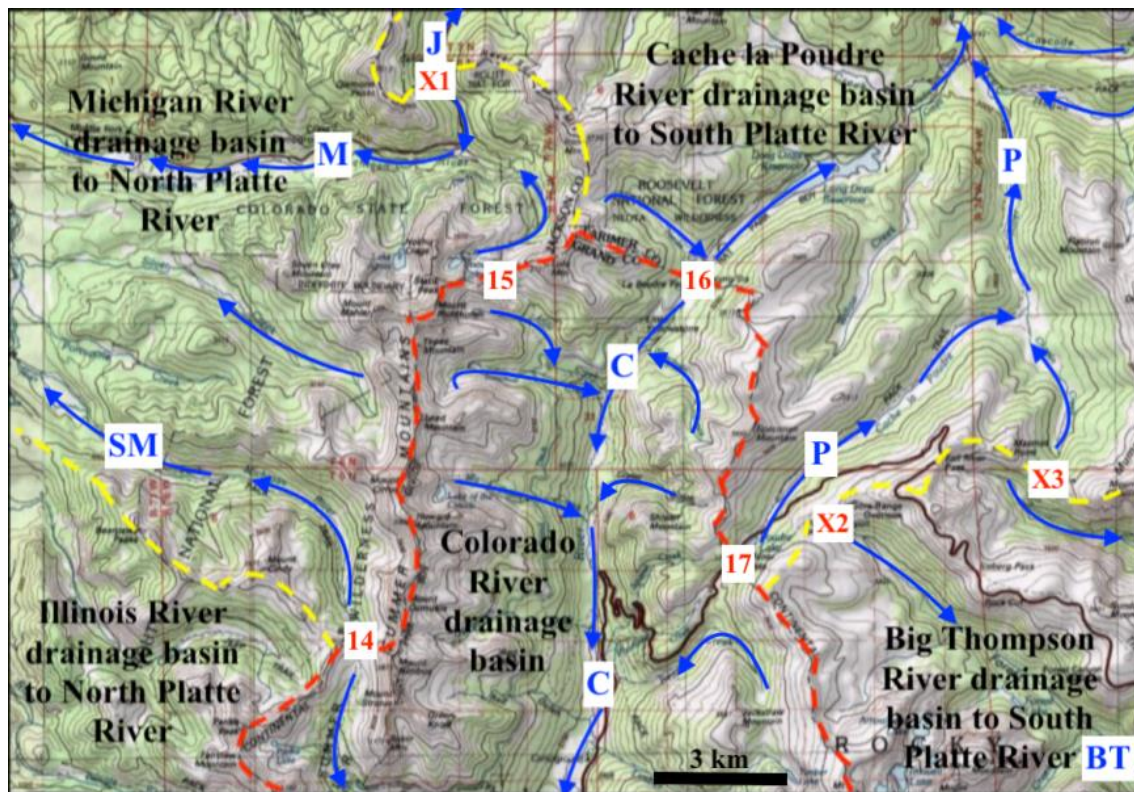


Figure 3. Modified topographic map from USGS National Map website showing drainage divides in Colorado River headwaters area. Dashed red line shows the continental divide and dashed yellow lines show other drainage divides. Blue letters identify rivers BT-Big Thompson River, C-Colorado River, J-Joe Wright Creek, M-Michigan River, P-Cache la Poudre River, and SM-South Fork Michigan River. Red numbers are passes listed in Tables 1 and 2. X1 is Cameron Pass, X2 is Forest Canyon Pass, and X3 is Chapin Pass. Contour interval is 50 meters

Erosion of the deep La Poudre and Milner Pass valleys is best explained by prolonged floods of south-oriented water coming from outside the study region that flowed across what are now Cache la Poudre drainage basin areas with elevations today in excess of 3279 meters into what must have been an actively eroding Colorado River headwaters valley while at the same time the region and mountains were being uplifted by as much as 800 meters or more. Eventually regional and mountain uplift outpaced erosion on the La Poudre Pass route and forced a reversal of flow so as to create what is today the north-oriented Cache la Poudre River drainage route seen in Figure 3, (which diverging and converging abandoned valleys now link with the north-oriented Laramie River valley). Headward erosion of a deeper east-oriented Cache la Poudre River valley captured the newly reversed flow and subsequent to the Cache la Poudre River flow reversal (in Figure 3 map area) significant regional and mountain uplift must have continued to produce the present-day La Poudre and Milner Pass elevations. While difficult to imagine today the north-oriented Cache la Poudre River headwaters valleys originated as south-oriented flood flow routes.

Other passes listed in Table 2 are to the south of Figure 3 and are listed in sequence from the north to the south. In addition to the named passes there are numerous unnamed (on the topographic maps) passes suggesting that at one time dozens of streams or diverging and converging flood flow channels crossed what is now the high elevation continental divide. While pass and valley orientations near the continental divide can be significantly different most valleys on the South Platte River side drain to east- or southeast-oriented South Platte River tributaries and many valleys on the Colorado River side drain to northwest- or north-oriented Colorado River tributaries. The north-northeast oriented South Platte River in addition to its southeast-oriented headwaters also has southeast-oriented tributaries, which join the South Platte River as barbed tributaries while southwest-oriented Colorado River segments have many southeast- and northwest-oriented barbed tributaries. The abundance of northwest-southeast oriented drainage routes suggests prior to regional and mountain uplift and to headward erosion of the deep southwest- and south-oriented Colorado River valley (and the north-northeast-oriented South Platte River

valley) numerous southeast-oriented streams or diverging and converging flood flow channels crossed the region and the north-northeast oriented South Platte River valley and subsequently the southwest- and south-oriented Colorado River valley eroded headward into a rising region and rising mountains to capture southeast-oriented flood flow.

Pass orientations appear to reflect the continental divide orientation, which along the South Platte River-Colorado River drainage divide changes frequently and significantly. Sprague, Ptarmigan, Andrews, Stone Man, and Rollins Passes are oriented in northeast to southwest directions and cross discontinuous continental divide segments oriented in a northwest to southeast direction. Boulder Grand, Buchanan, Pawnee, Devils Thumb, and Jones Passes cross discontinuous continental divide segments oriented in more of a north to south direction. Arapahoe, Berthold, Vasquez, Loveland, Webster, Georgia, French, Boreas, and Hoosier Passes cross discontinuous continental divide segments oriented in more of an east to west direction. While each pass has unique features close investigation of those unique features suggests multiple northwest to southeast oriented streams or diverging and converging flood flow channels once crossed the region as what is now the east-west continental divide was being formed.

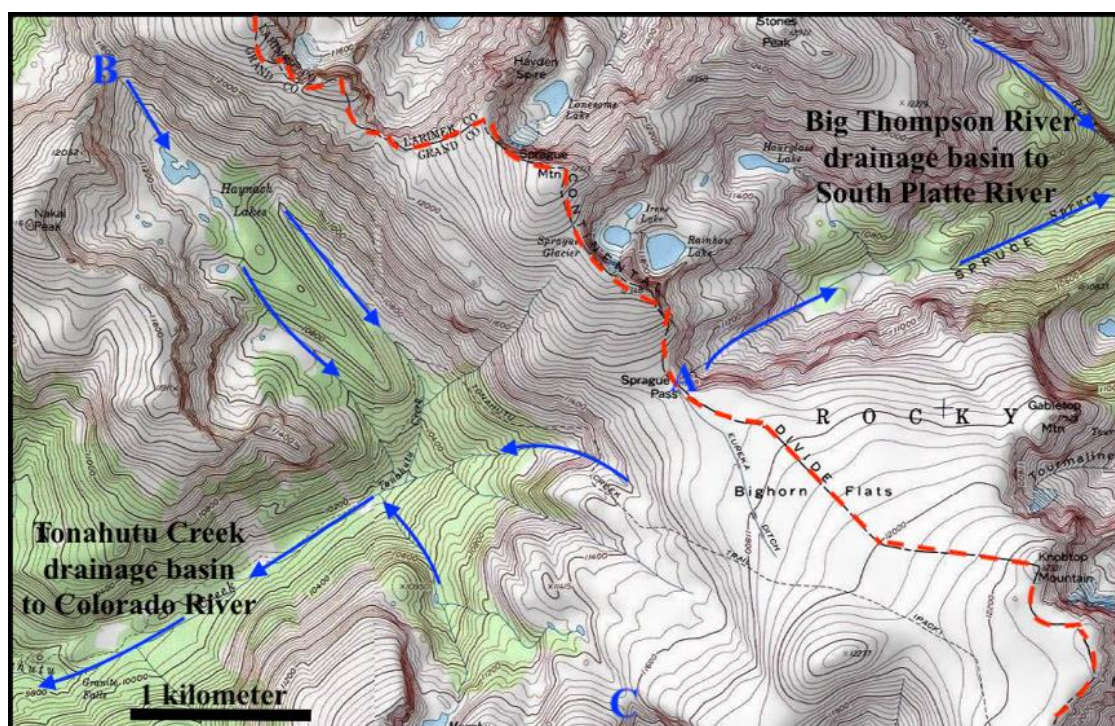


Figure 4. Modified topographic map from USGS National Map website showing the Sprague Pass area. Sprague Pass is at location A and locations B and C are passes discussed in the text. The red dashed line follows the continental divide. The contour interval is 40 feet (12 meters)

Sprague Pass (seen in Figure 4) has a northeast-southwest orientation and links the northeast-oriented Spruce Creek valley with a southwest-oriented Tonahutu Creek valley segment, which at first glance does not support erosion by southeast-oriented water. However, to the southwest of Sprague Pass Tonahutu Creek begins as a southeast-oriented stream at a 200- to 300-meter deep northwest-to southeast oriented pass (at location B in Figure 4). To the northwest of that pass is the (unseen in Figure 4) southeast- and southwest-oriented headwaters valley of Onahu Creek. A pass similar to the pass at location B links the southeast-oriented Onahu Creek headwaters valley with the northwest-oriented Timber Creek headwaters valley, with Timber Creek turning in a southwest and then northwest direction to join the south-oriented Colorado River as a barbed tributary. Looking in the other direction location C identifies a 200-meter deep pass linking a northwest-oriented Tonahutu Creek tributary valley with the south-oriented Ptarmigan Creek valley, which flows to northwest- and southwest-oriented North Inlet. Such passes similar to those at locations B and C suggest headward erosion of southwest-oriented Colorado River tributary valleys systematically dismembered a large southeast-oriented stream or river flowing adjacent to and roughly parallel to the present-day continental divide. To the east of Figure 4 Spruce Creek joins the southeast-

oriented Big Thompson River headwaters which flow in a similar southeast-oriented valley before turning in an east direction, although to the southeast of that turn the north-northwest oriented Aspen Brook valley is linked by Wind River Pass with the south- and southeast-oriented Tahosa Creek valley. In other words, the continental divide segment seen in Figure 4 once separated two or more large southeast-oriented streams or rivers and a southwest-oriented stream of water diverging from the channel on the South Platte River side to the channel on the Colorado River side probably eroded Sprague Pass.

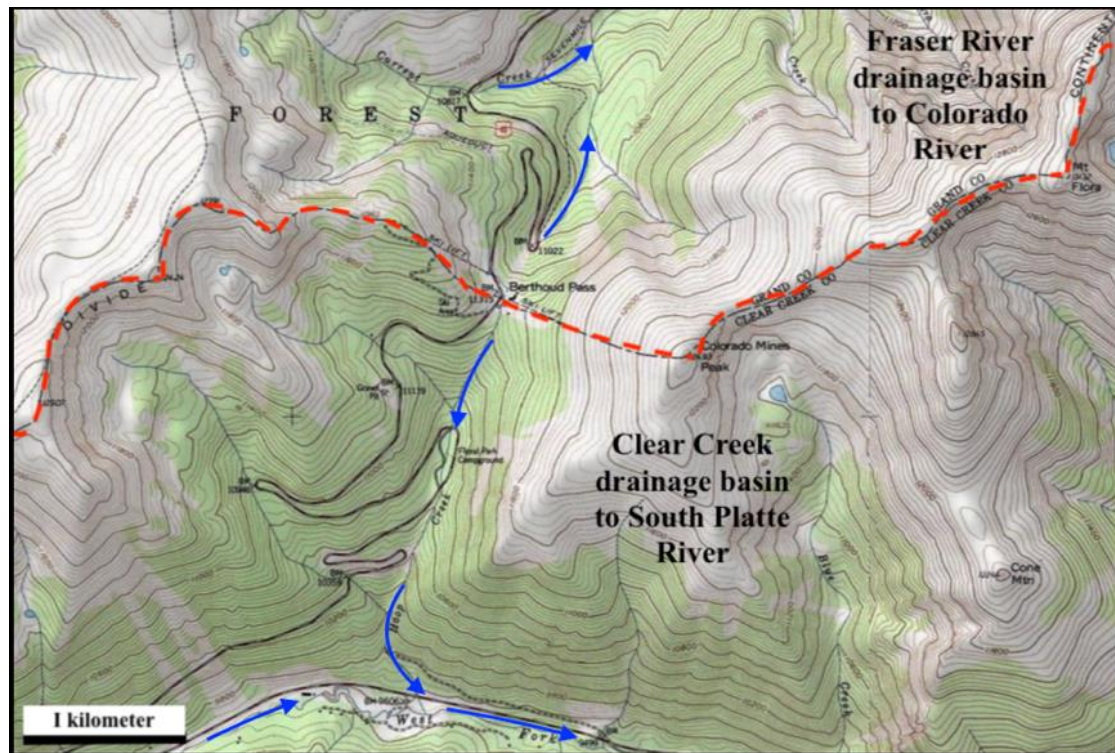


Figure 5. Modified topographic map from USGS National Map website showing the Berthould Pass area. The dashed red line follows the continental divide and blue arrows emphasize present-day drainage directions. The contour interval is 40 feet (12 meters)

While the number of passes along the continental divide's South Platte River-Colorado River drainage divide segment is more than this finite paper can discuss the named and unnamed passes can be used to reconstruct what must have been large streams of water that once flowed adjacent to and across what is now the continental divide. Figure 5 illustrates Berthould Pass, which has a north-northeast to south-southwest orientation with a south-southwest stream to the south draining into an east-southeast oriented stream. Drainage to the north of Figure 5 leads to the northwest-oriented Fraser River, which joins the south- and southwest-oriented Colorado River as a barbed tributary (although immediately downstream from that confluence the Colorado River makes a short northwest-oriented jog). To the north of where the Fraser River joins the Colorado River is south-southeast oriented Willow Creek, which begins at Willow Creek Pass (number 10 in Table 1) and which once may have also been fed by water crossing the continental divide at other unnamed Rabbits Ears Mountain passes. [Willow Creek now joins the Colorado River upstream from the Fraser River, but highway 125 follows a north-south oriented through valley linking the Willow Creek valley with the Fraser River mouth.] In other words, present-day drainage routes suggest a hypothesis that south-southeast oriented water from what is now the North Platte River drainage basin crossed what is now the continental divide at Willow Creek Pass and flowed across what is now the deep southwest-oriented Colorado River valley and then along what is now the northwest-oriented Fraser River alignment and to cross what is now the continental divide at Berthould Pass and then to flow in a southwest direction along the alignment of are now the northeast-oriented West Fork Clear Creek headwaters. That south-oriented stream or river was then dismembered as uplift raised the mountains and region and headward erosion of deep valleys systematically captured the flow from the southeast to the northwest and diverted the water in other directions.

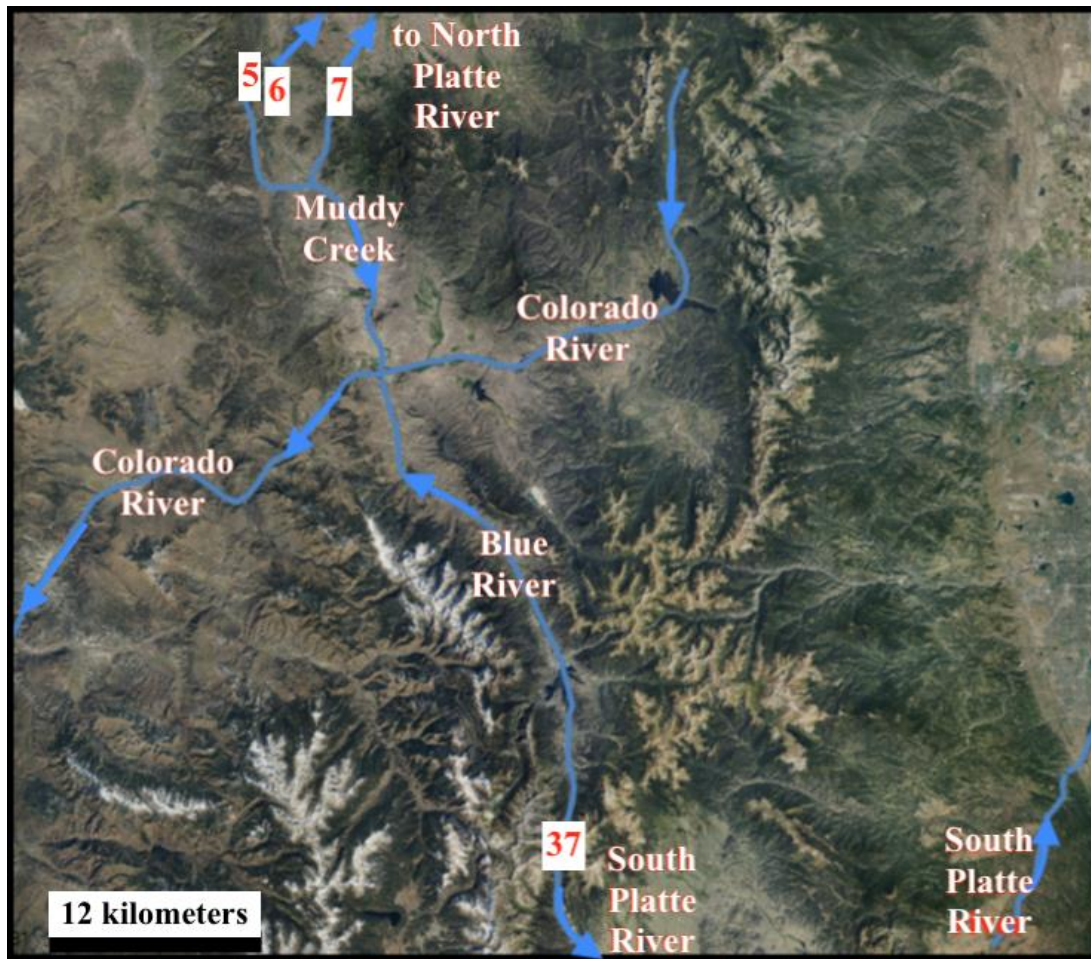


Figure 6. Modified imagery from USGS National Map website showing how south-southeast oriented Muddy Creek and north-northwest oriented Blue River drainage routes link Rabbit Ears (5), Muddy (6), and Arapahoe (7) Passes across the North Platte River-Colorado River drainage divide with Hoosier Pass (37) across the Colorado River-South Platte River drainage divide. Southeast-oriented drainage from Hoosier Pass flows to the South Fork South Platte River. Note north-northeast South Platte River in the Figure 6 southeast corner

Easier to observe evidence illustrating how Colorado River tributary routes link passes across the North Platte River-Colorado River divide with passes across the Colorado River-South Platte River divide is seen in Figure 6 where south-southeast oriented Muddy Creek and the north-northwest oriented Blue River link Rabbit Ears, Muddy, and Arapahoe Passes in the north with Hoosier Pass across the Colorado River-South Platte River divide to the south. While not shown (in Figure 6) Boreas, French, and Georgia Passes are to the northeast of Hoosier Pass and link northwest-oriented Blue River tributary valleys with southeast-oriented South Platte River tributary valleys. The passes leading from the North Platte River drainage basin to the southeast-oriented Muddy Creek valley and from the Blue River drainage basin to the South Platte River headwaters suggest south- and southeast-oriented diverging and converging channels from what is now the north-oriented North Platte River drainage basin initially moved water across what must have been rising mountains ridges into the southeast-oriented South Platte River headwaters area. Colorado River valley headward erosion, probably aided by regional and mountain uplift, captured the south-southeast oriented flow, which reversed flow on the beheaded channels to create what are today the north-northwest oriented Blue River drainage system and the Colorado River-South Platte River drainage divide. Subsequently water continued to flow from the North Platte River drainage basin across Rabbit Ears, Muddy, and Arapahoe Passes and along the Muddy Creek alignment to the newly formed Colorado River valley until mountain and regional uplift ended flow across Rabbit Ears Pass first, Arapahoe Pass second, and finally Muddy Pass and to a reversal of flow in the North Platte River valley.

One previous investigator who did observe a relationship between the passes and the Colorado tributary valleys

was Eaton (1986) who commented on similarities between this paper's study region and the mid-Atlantic ridge. Eaton (p. 179-180) discusses axial valleys and drainage and in regard to the Blue River and Hoosier Pass orientation and notes "Major faults and Neogene movement flank the Blue river... The valley is half graben that has been largely stripped of its sedimentary fill. Near-source Neogene conglomerates are preserved as small patches faulted against Precambrian bedrock." While a case can be made that regional faults have determined the locations of some passes and drainage routes the faults alone do not provide a complete explanation. Massive erosion also occurred and the question needing to be answered is did that erosion take place as massive southeast-oriented floods crossed rising mountains (i.e. as in the new paradigm interpretation) or did the erosion take place more gradually as many previous investigators have suggested (i.e. as in the accepted paradigm interpretation)?

#### 4. Discussion and Conclusion

Mountain passes (and other low points along drainage divides), drainage route and valley orientations, and stream capture evidence (e.g. elbows of capture and barbed tributaries) are clues to the existence and nature of a previous regional drainage system. Reconstructing former drainage systems is similar to solving a giant sudoku puzzle. Like in a sudoku puzzle all clues are important and the correct solution, once found, can be easily checked by any investigator willing to do so. The numerous high elevation mountain passes crossing North Platte River-Colorado River and Colorado River-South Platte River drainage divide segments of North America's east-west continental divide and barbed tributaries flowing to the south- and southwest-oriented Colorado River headwaters (as discussed here) provide a selected set of easy-to-observe (on detailed topographic maps) evidence that previous investigators (following accepted paradigm rules) have yet to explain and which is consistent with the new paradigm prediction that immense south- and southeast-oriented floods once flowed from the present-day north-oriented North Platte River headwaters area across rising mountain ranges and what is now the south- and southwest-oriented Colorado River headwaters area and then across more rising mountain ranges to reach east- and southeast-oriented valleys leading to the north-northeast oriented South Platte River valley, although many questions remain.

Questions arising from the new paradigm's ability to explain the Platte River-Colorado River drainage divide mountain pass origins include where did the floodwaters originate and why did mountain ranges rise as immense south-oriented floods flowed across them? The new paradigm rule forces recognition of a large continental ice sheet thick and heavy enough to deeply erode the underlying bedrock and to cause crustal warping so as to create and occupy a deep "hole" with at least some of what is today the east-west continental divide in northern Colorado being a segment of that deep "hole's" southwest rim. Such an ice sheet could have produced prolonged and immense south-oriented melt water floods, however, accepted paradigm rules do not recognize a North American continental ice sheet that deeply eroded the underlying bedrock and that caused crustal warping so as to create and occupy a deep "hole," nor do accepted paradigm rules permit melt water from any recognized North American continental ice sheet to have reached Colorado, much less to have flowed across what are now high Colorado continental divide segments. In other words, the two paradigms lead to fundamentally different North American middle and late Cenozoic geologic and glacial histories and the new paradigm by successfully explaining the listed mountain pass and discussed drainage feature origins is also challenging the accepted paradigm's middle and late Cenozoic regional geologic and glacial history interpretation. A full discussion of the two alternate middle and late Cenozoic regional geologic histories is beyond this paper's scope, although investigators need to be aware the new paradigm successfully explains drainage divide and drainage system evidence the accepted paradigm has yet to explain.

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#### Conflict of interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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