A stereo picture guide to

Rivers and Streams

by

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2001

You are looking toward the southwest, upstream, at the Sikianni Chief River, a meandering braided stream, in northeastern British Columbia, Canada.

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Viewing Stereo Images

The two small pictures at the top of each page are a stereo pair. To see the image in three dimensions, you need to look at the right image with the right eye and the left image with the left eye. To do this, pick out some prominent feature in the pictures and stare beyond the pictures. The two prominent features, one from each picture, should float together in the center. This center image will be in three dimensions. At first it may not be in focus. You are accustomed to associate convergence of your eyes with focus. If you continue to stare at the center image, your mind will ultimately relent and focus on the center image while your gaze remains parallel, each eye looking at its respective image.

A simple exercise may help prepare you for this unaccustomed way of viewing. With your hands at arm's length in front of your eyes, touch your two index fingers together as you look beyond them. You should see a sausage image between your two index fingers. Your eyes are parallel, the right one looking at the right finger, the left one at the left finger. The two images have floated apart, the right one to the left and the left one to the right to form the sausage. The feeling in your eyes is the one you should try to imitate when looking at the stereo images. Some will master the technique instantly. It will take longer for others. If you don't succeed at first, keep trying at odd times. Try sometime when you are really tired and tend to see double images anyway when you stare at objects. If I could learn to do it, anyone with two good eyes can. I worked at it off and on for over two years before I suddenly learned the knack.

Your eyes are just a few inches apart. With that small separation, you can see in three dimensions for about 1100 feet. Most of these images were taken from a small airplane flying at a speed of about 100 mph. The interval between the two images varied from one second to several seconds, giving an effective eye base of between 100 and several hundred feet. With this eyebase, you can see in three dimensions for miles. These pictures produce spectacular three dimensional views not easily obtainable in any other way.

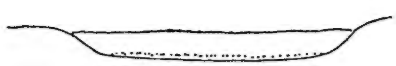
Rivers and Streams

As water flows over the earth's surface, it reacts with that surface in a way that produces a dynamic equilibrium within a system of independent, interdependent and dependent variables.

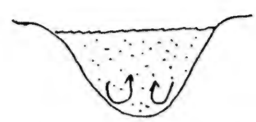
Discharge, the amount of water flowing past a point in a given length of time, and load, the amount of sediment the stream carries, are supplied to the stream by its drainage basin. The discharge and load are independent variables supplied in response to the size, topography, climate, rock types, and structure of the drainage basin.

The stream reacts to produce a channel that will contain the ordinary yearly maximum discharge and load. The width, depth, and velocity are adjusted to accomodate the discharge and type of load. Width, depth, and velocity all increase downstream as the discharge increases, for discharge (Q) = width x depth x velocity. Width, depth, and velocity, then, are interdependent variables. Change one, and the others must change.

Streams that carry dominantly bedload tend to be wide and shallow, for this is the most efficient way the water can roll and bounce the particles along the bottom. Streams that carry dominantly suspended load tend to be deep and narrow, because the upward eddies in the water are more likely to keep the particles in suspension.



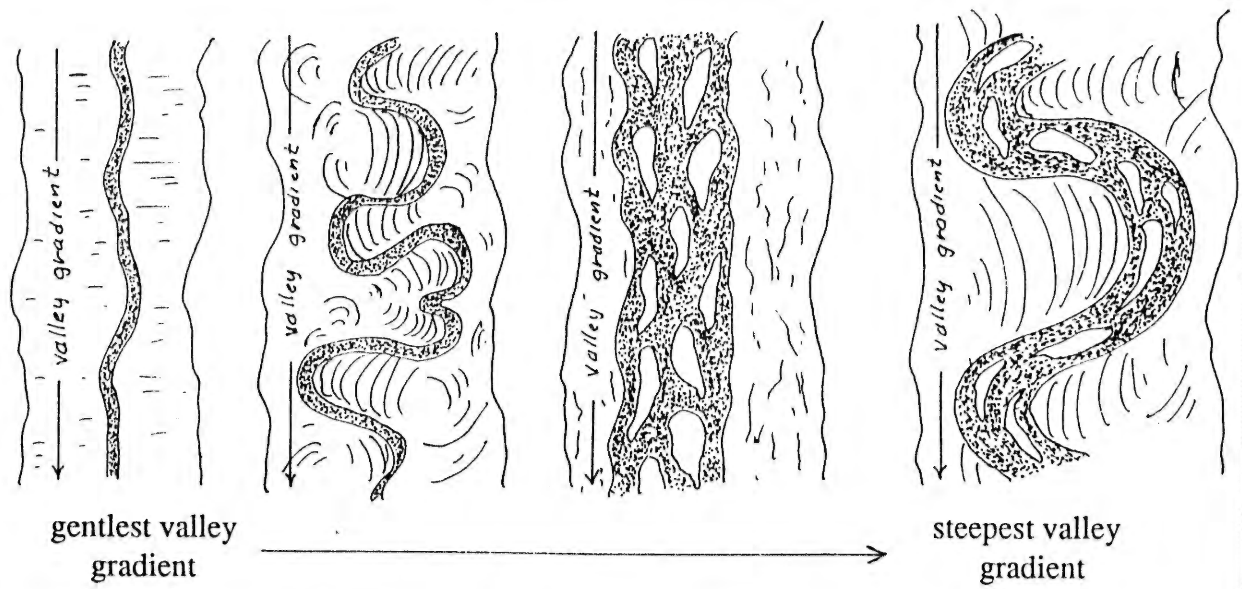
bedload stream



suspended load stream

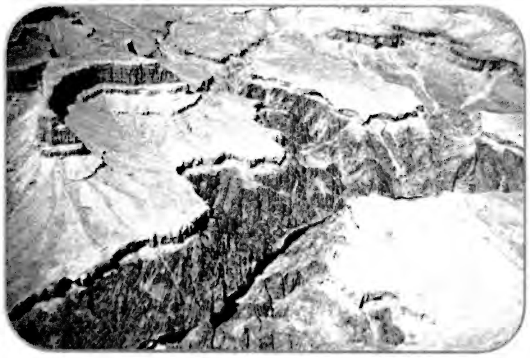
The stream adjusts its gradient to provide for the orderly transportation of its discharge and load. If its gradient is steeper than is required to transport its load, it has excess energy, and it erodes to decrease its gradient until its gradient is matched to the load it must carry with the discharge supplied by its drainage basin. If its gradient is too gentle, it deposits some of its load, increasing its gradient until it can carry the load with the discharge supplied by its drainage basin. The gradient, then is a completely dependent variable of discharge and load.

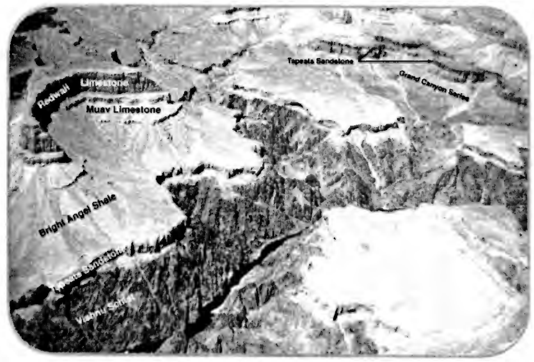
In addition to erosion and deposition, the stream can fine-tune its gradient in a number of ways. It can meander, thereby decreasing its gradient. If the gradient is still too steep, the stream will have the excess energy it needs to erode its banks and split or braid into multiple channels, thereby greatly increasing the amount of water in contact with the stream bed and increasing its frictional resistance to flow. Streams also develop sand waves on the bottom that increase the frictional resistance to flow. For any given river, a straight reach will have the lowest valley gradient, a meandering reach will have an intermediate valley gradient, and a braided reach will have the steepest valley gradient. Some streams with steep valley gradients will both meander and braid, for meandering is the normal pattern produced by water in turbulent flow, and most all natural streams have bed roughness factors that produce turbulent rather than laminar flow.

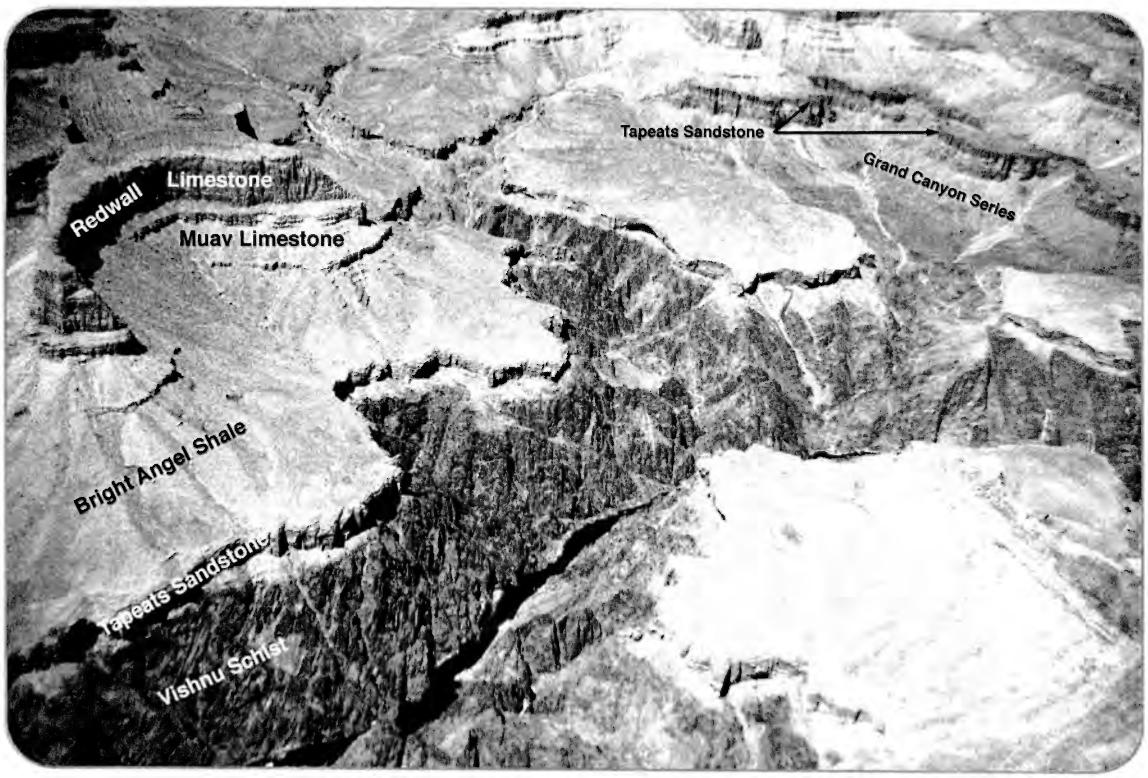


Streams, then, do not simply carve relief on the surface of our globe, but are controlled by the very topography they help shape. Their discharges and loads control them and, in turn, depend upon the characteristics of their drainage basins.

Erosion of the Grand Canyon

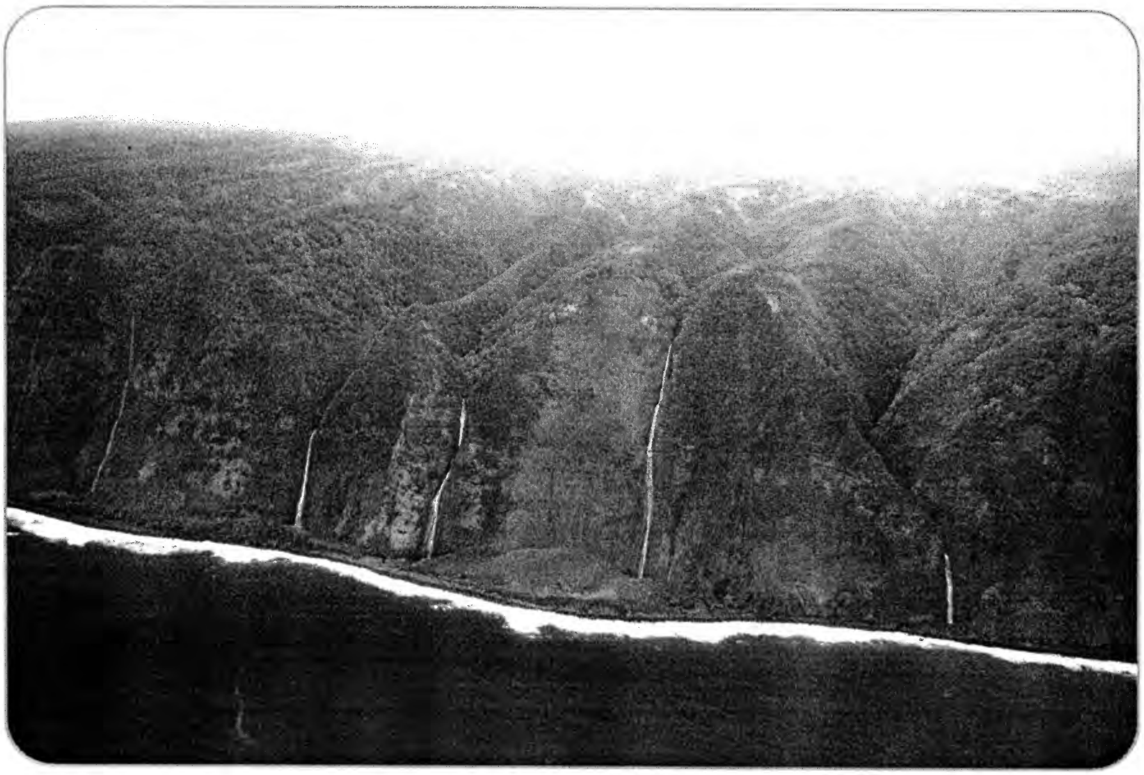






The Colorado River carved the Grand Canyon through 4000 feet of sedimentary rocks and down into the Vishnu Schist. Distant mountains provide water for the river to flow and erode all year through an arid landscape. In contrast, its minor tributaries carry water and erode only after infrequent rains. To reach the river their water must flow down steep gradients and drop over waterfalls that migrate upstream by undermining the resistant rock layers they tumble over.

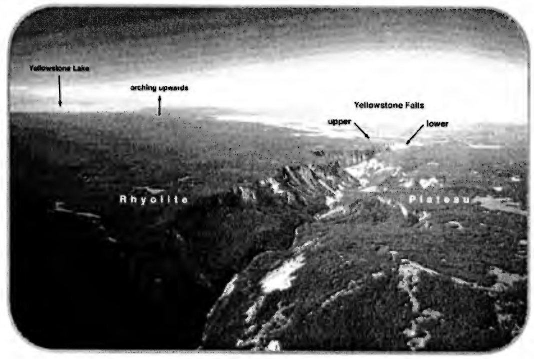
Kohala Coast Waterfalls

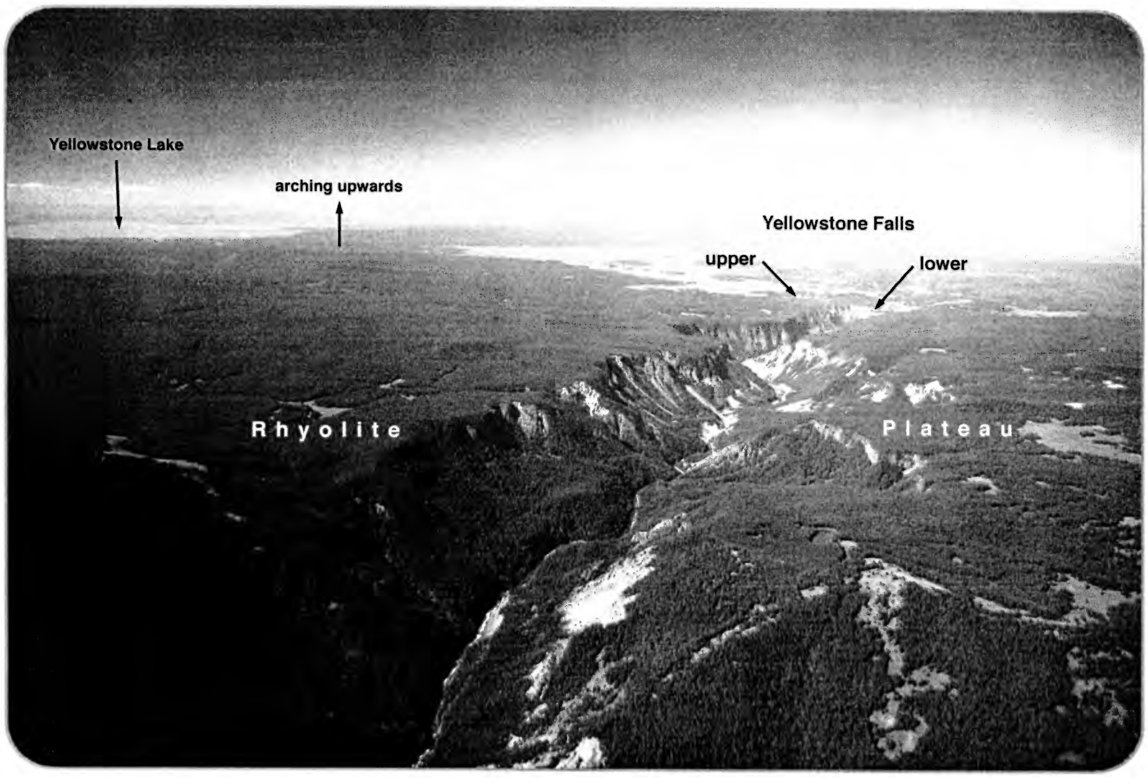


You are looking toward the southwest at the wave-eroded headwall of a gigantic landslide along the Kohala Coast on the northeastern shore of Hawaii. The waterfalls are nickpoints on the streams. They formed when the streams tumbled over the headwall after the basalts slid seaward. The slide mass left a trail of debris on the sea floor for 75 miles as it disappeared into the Hawaiian Deep sometime between 150,000 and 400,000 years ago.* Wave erosion of the headwall keeps pace with retreat of many of the nickpoints, keeping the waterfalls at the edge of the sea.

*Hazlett, R.W., and Hyndman, D.W.,1996, "Roadside Geology of Hawaii", Mountain Press Publishing, Missoula, Montana, p. 113.

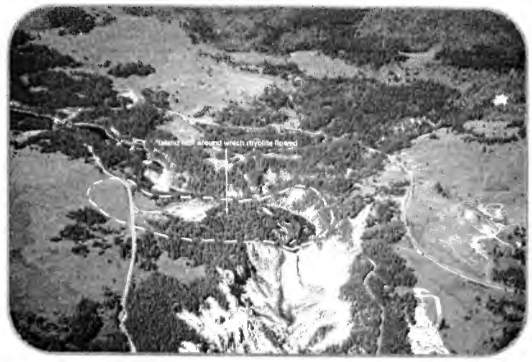
Yellowstone Canyon

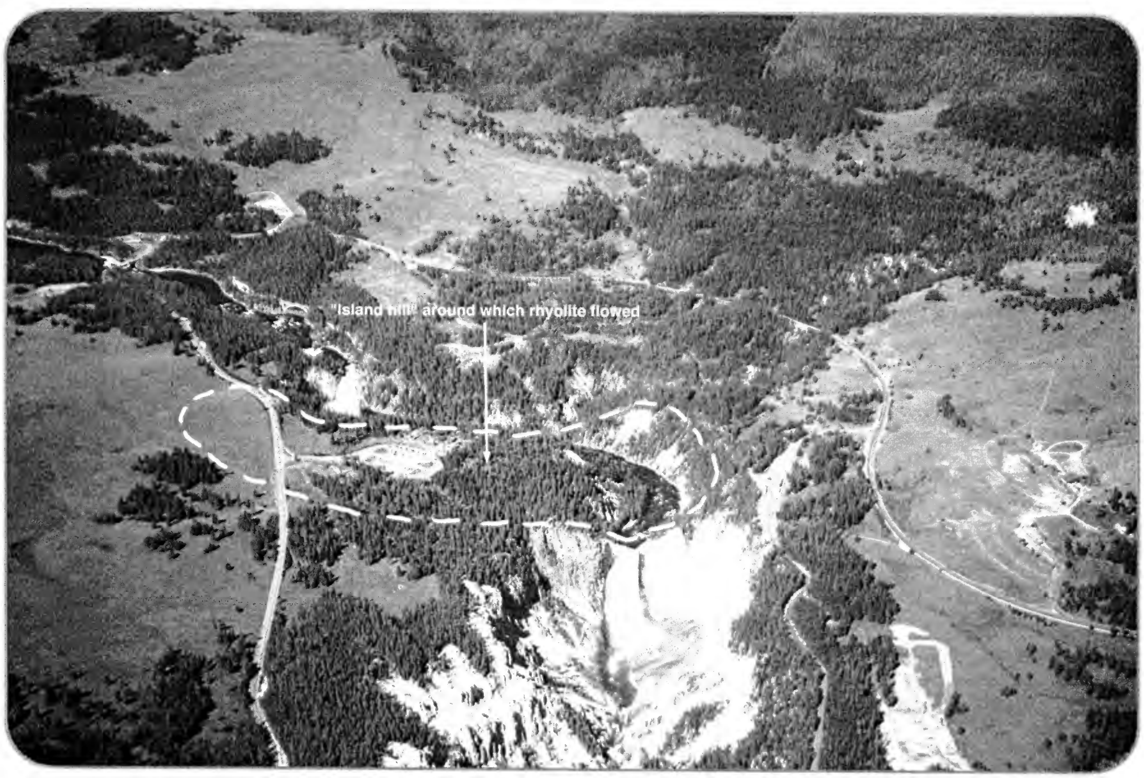




Yellowstone Canyon formed during the retreat of Yellowstone Falls as it tumbled over the edge of the Rhyolite Plateau.

Yellowstone Falls

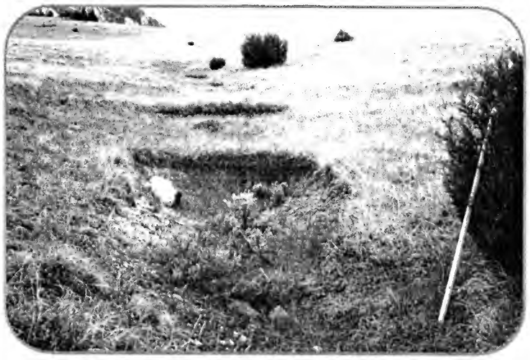




Rhyolite flowed around the volcanic sediments of the "island hill". These volcanic sediments cover a larger area on Richmond's map* than shown by the dashed outline, which encircles only the highest part of the "island". The Lower Falls is about to cut through the edge of the rhyolite flow. It should then retreat rapidly through the soft volcanic sediments of the "island hill" to join the Upper Falls in a single higher waterfall cutting back through the rhyolite on the far side of "island hill".

*Richmond, G.M., 1976, "Surficial geologic history of the Canyon Village quadrangle, Yellowstone National Park, Wyoming", USGS Map I-652 & Bull. 1427.

Headward Migration of Nickpoints



The main process of erosion in this gulch is the headward migration of nickpoints. The gulch is carved in Wolsey Shale on the western flank of North Doherty Mountain in southwestern Montana.

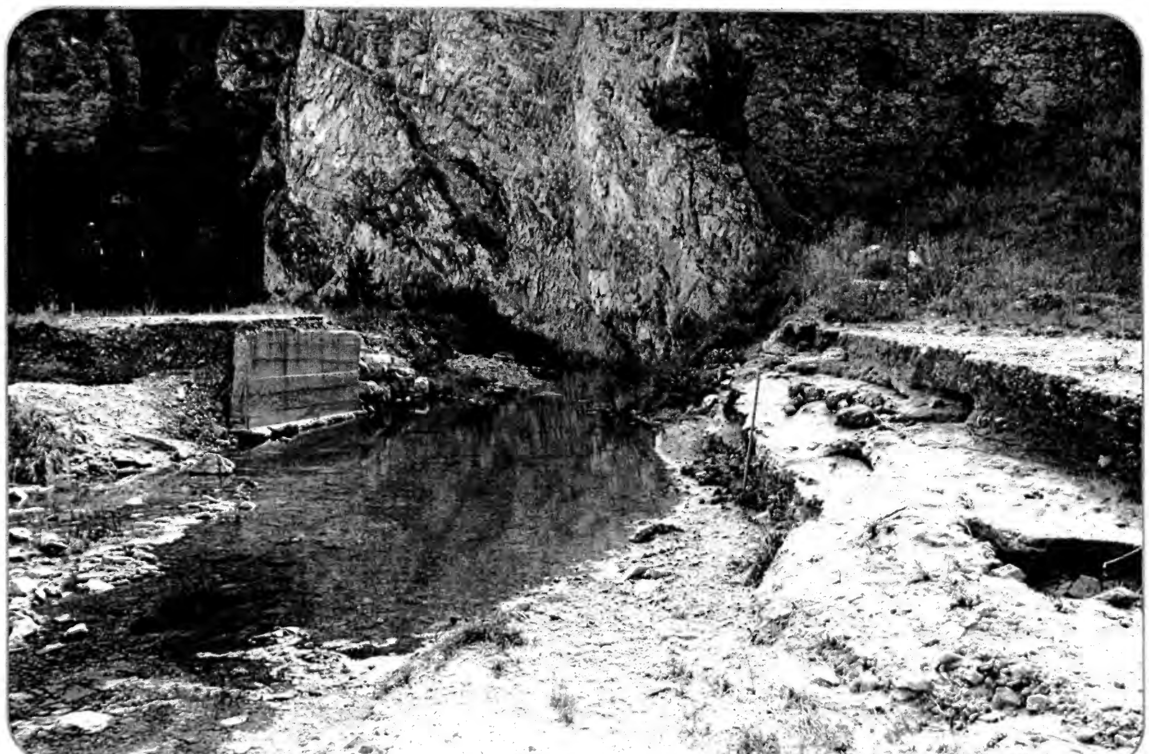
Milligan Canyon Flash Flood

You are looking southward in the direction of flow of Milligan Creek through its canyon, which has been cut into the Madison Limestone. At both the north and south ends of the canyon, the valley broadens where the creek erodes softer rocks. This course of the creek was probably inherited from a higher level course developed on an unconformable covermass of easily eroded Tertiary sediments.

On July 3, 1998 a powerful thunderstorm sent a flash flood through the canyon. On succeeding pages, pictures taken in October of that year document the depth and power of the flood.

Milligan Canyon is about six miles west of Three Forks in eastern Jefferson County, Montana.

Milligan Canyon Flash Flood
Bridge Torn Out

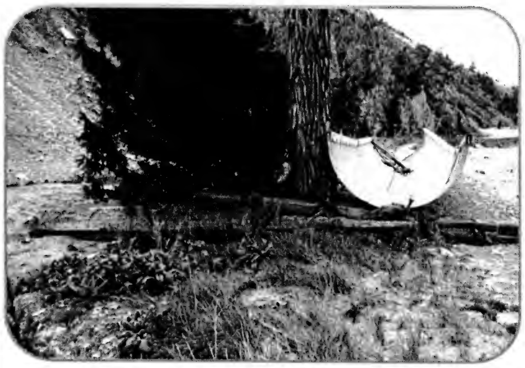


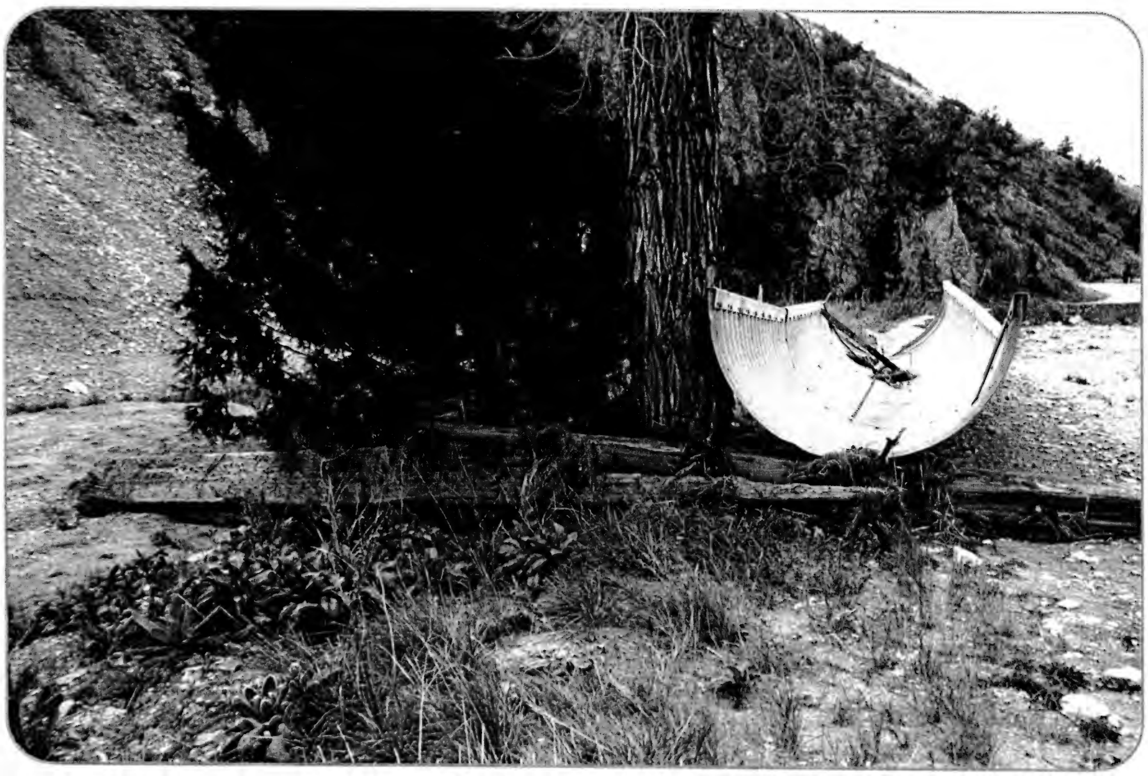
You are looking eastward and upstream at the northern end of Milligan Canyon. The bridge and the southern bridge abutment were washed downstream by flood waters more than six feet deep here. The pogo stick standing where the southern bridge abutment used to be is five feet long, and the flood waters covered the road.

Milligan Canyon Flash Flood
Bridge Abutment Washed Downstream

You are looking upstream at two large chunks of the southern bridge abutment broken and washed downstream by the Milligan Canyon flood. A piece of culvert washed up onto the road against a tree is visible in the background and is shown in closer view on the next page. The pogo stick is five feet long.

Milligan Canyon Flash Flood
Culvert & Bridge Timber Lodged Against Tree





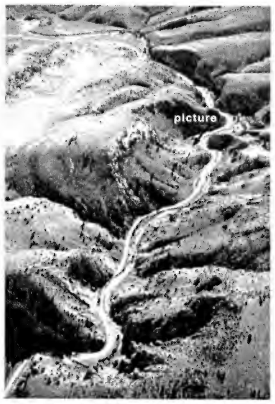
On July 3rd, flash flood waters splintered a bridge timber as it slammed into the base of the tree and washed the culvert over the road against the tree.

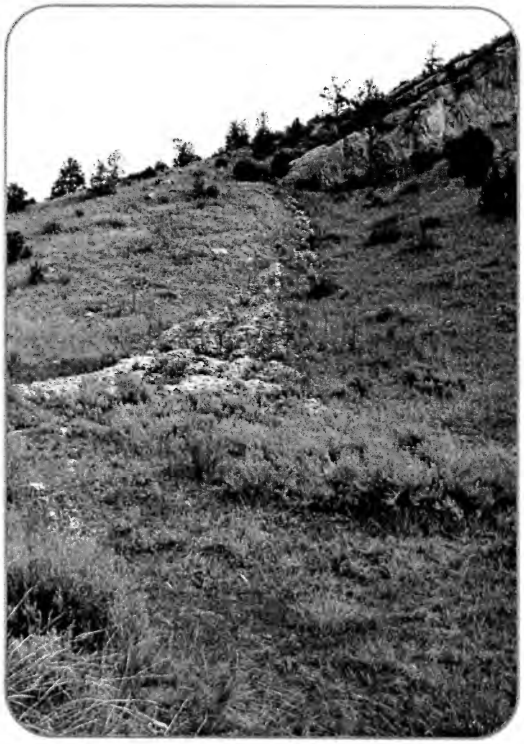
Milligan Canyon Flash Flood
Depth of Flood Water

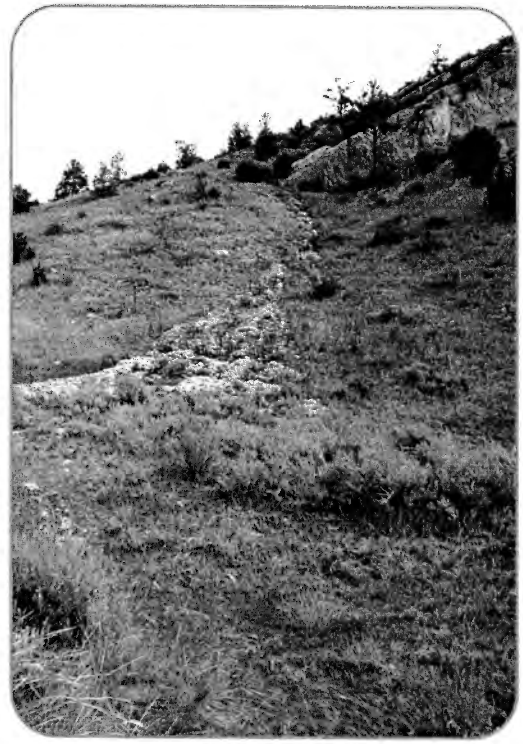
The debris wrapped around the aspen trees indicates the approximate height of the flood waters. The trees are growing in the normally dry stream channel.

Milligan Canyon Flash Flood
Potholes Eroded in Road

Eddies in the flood waters on July 3rd, washed out potholes in the road.



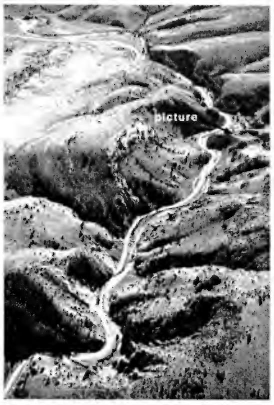


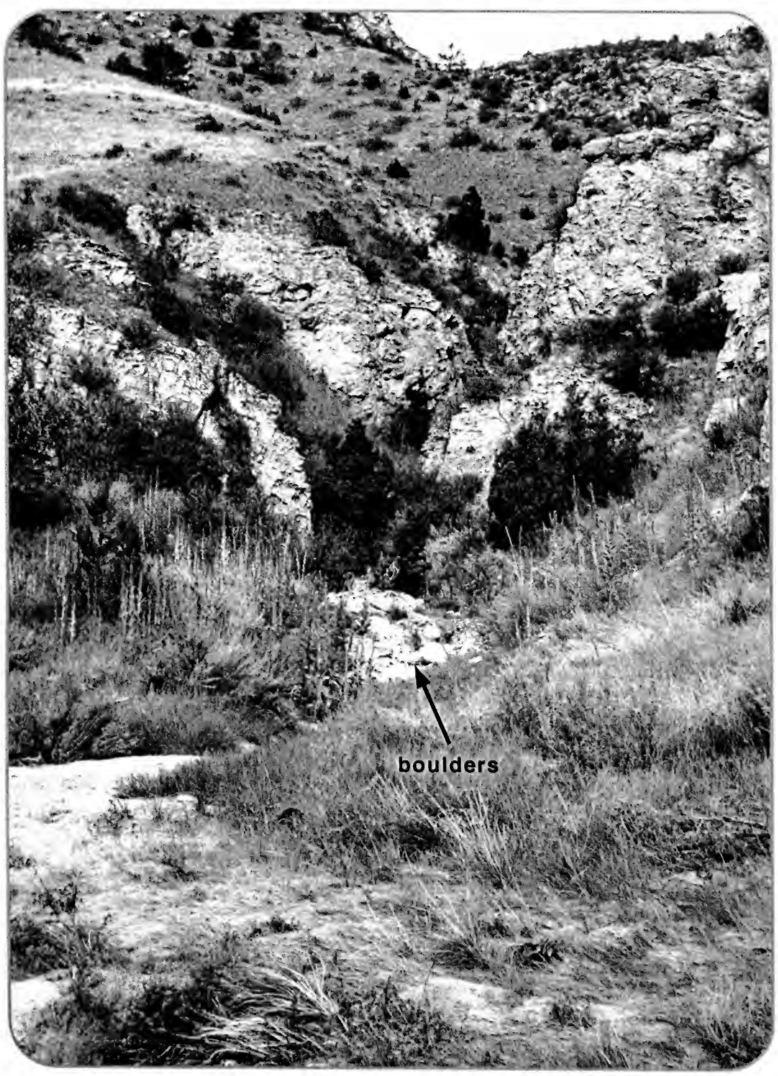


Milligan Canyon
Flash Flood

A Debris Flow Fan

White arrows mark the end of a fan of rocks and debris washed down the slope by the torrential rains that caused the July 3rd flash flood down Milligan Canyon.





Milligan Canyon Flash Flood

Boulders Washed out of Tributary Canyon

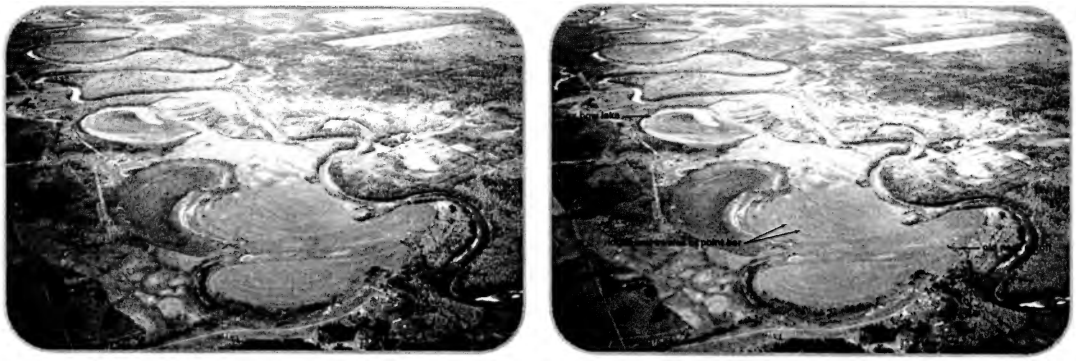
Boulders of limestone that washed down a tributary canyon during torrential rains on July 3rd accumulated on the floor of Milligan Canyon behind a bedrock salient that protected them from the full impact of the flash flood.

Milligan Canyon Flash Flood

Culvert Crumpled Against Trees

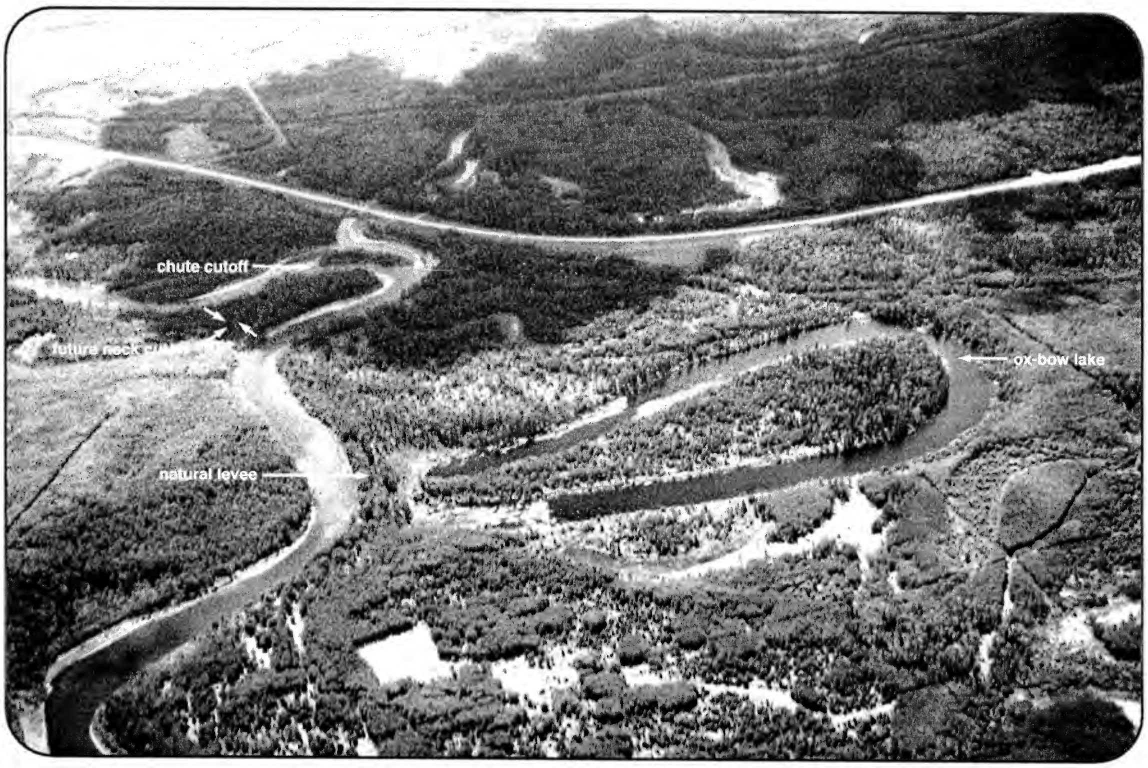
Flood waters crumpled this culvert against the aspen trees during the flash flood down Milligan Canyon.

Meanders of the Pembina River



You are looking southwestward at meanders of the Pembina River west of Edmonton, Alberta, Canada. Old point bars and filled ox-bow lakes record positions formerly occupied by the river. The meanders migrated by eroding the outsides of the bends while depositing inclined convex sheets of sand as ridges during high water and as swales during low water on the insides of the bends. For most rivers this migration ultimately produces a floodplain that is two to three times the width of the meander belt.

Ox-bow Lake and Chute Cutoff



You are looking toward the southwest at an ox-bow lake and a chute cutoff along the North Saskatchewan River in Alberta, Canada near Rocky Mountain House. The natural levee was built across the neck cutoff of the looping meander bend as the river topped its banks during floods. Sediment carried over the natural levee during floods slowly fills the ox-bow lake. The river cut across its point bar during a flood to create the chute cutoff. The two opposing meander bends below the chute cutoff should continue to erode on the outsides of their bends and join to form a neck cutoff and another ox-bow lake, this one containing the chute cutoff.

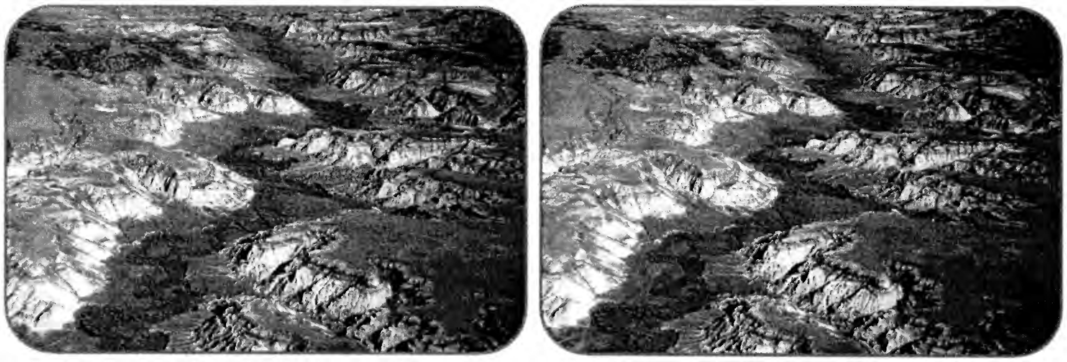
Meander Bend Landslide

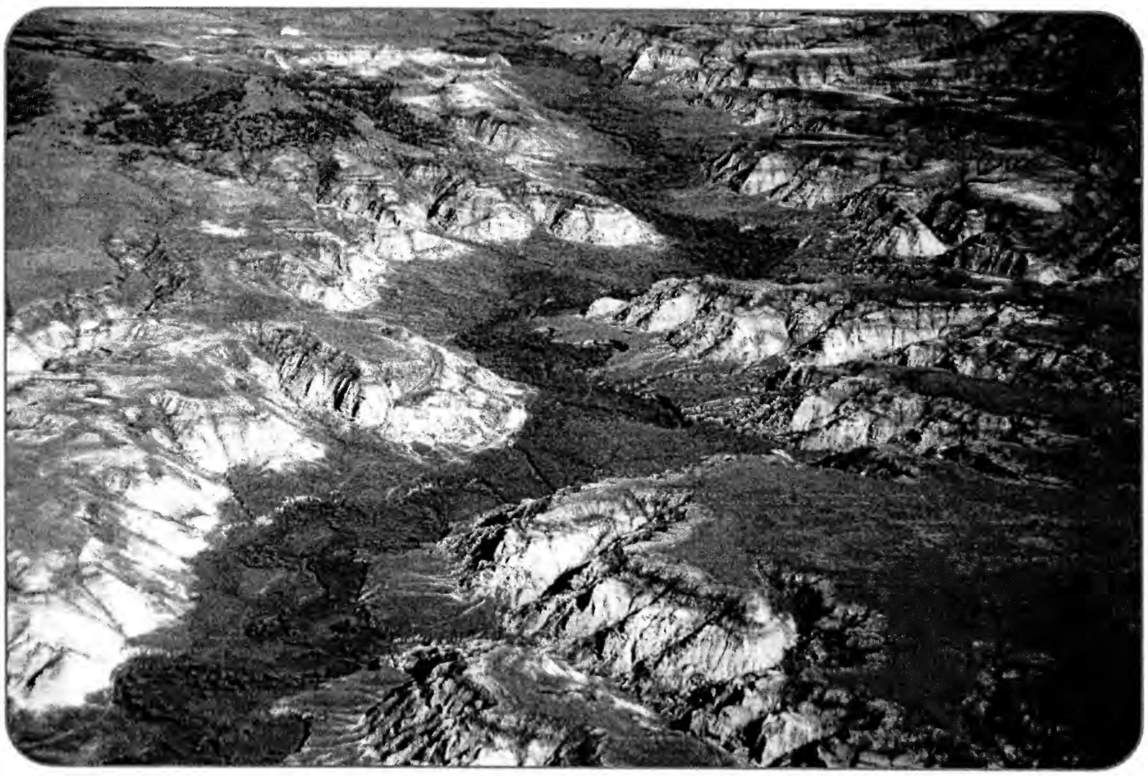
You are looking southward at a landslide on the outside of a meander bend in the Belly River just west of Lethbridge, Alberta, Canada. The bank on the outside of the meander bend is made of cohesive (clayey) sediment overlying sand at river level. The river undercuts the bank by eroding the sand, and the cohesive sediment slides down into the river.

Milk River - Underfit Stream

You are looking westward at the Milk River Valley just west of Harlem in north-central Montana. Because its floodplain is seven to eight times the width of its meander belt, it is an underfit stream occupying a floodplain that was constructed by a larger river. This may have been an ancestral course of the Missouri River, but the Milk River also had greater discharge when the glaciers melted about 16,000 years ago.

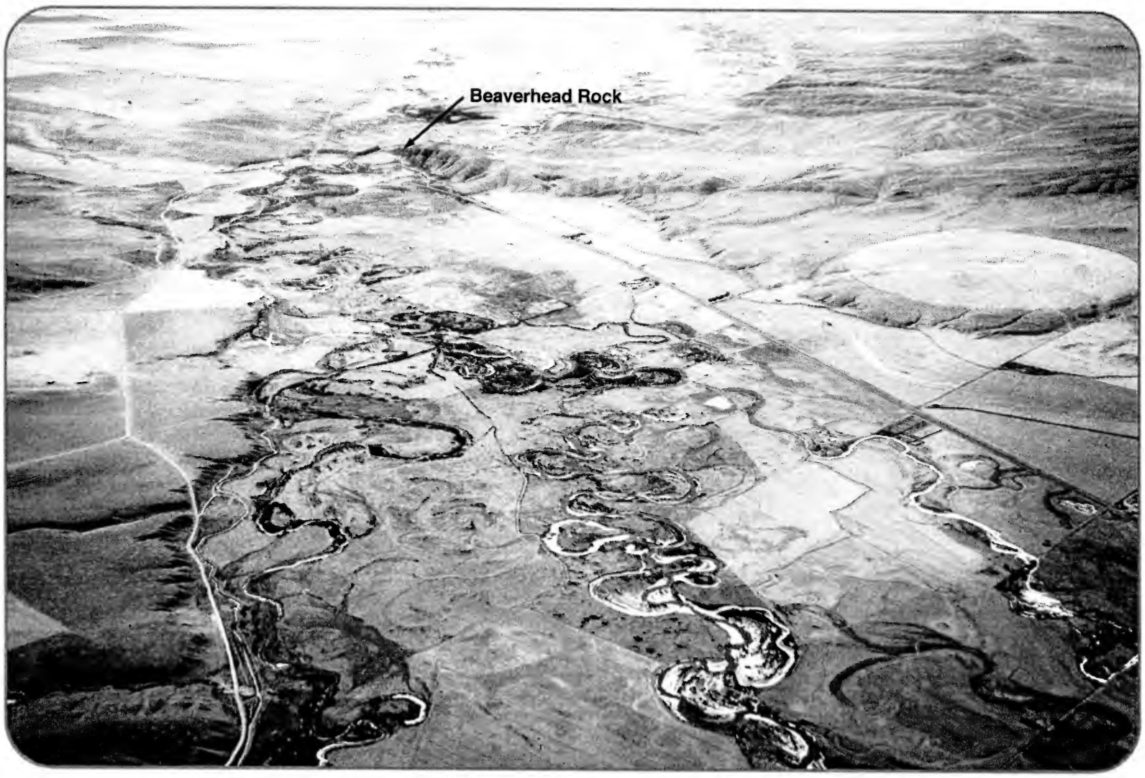
Underfit Stream in Glacial Sluice





You are looking southeastward in north central Montana southeast of the Bears Paw Mountains. A small meandering stream has carved a floodplain within a larger meandering valley cut by an ancestral river of greater discharge supplied by melting glaciers about 18,000 years ago.

Beaverhead River
Abandoned Meander Belts

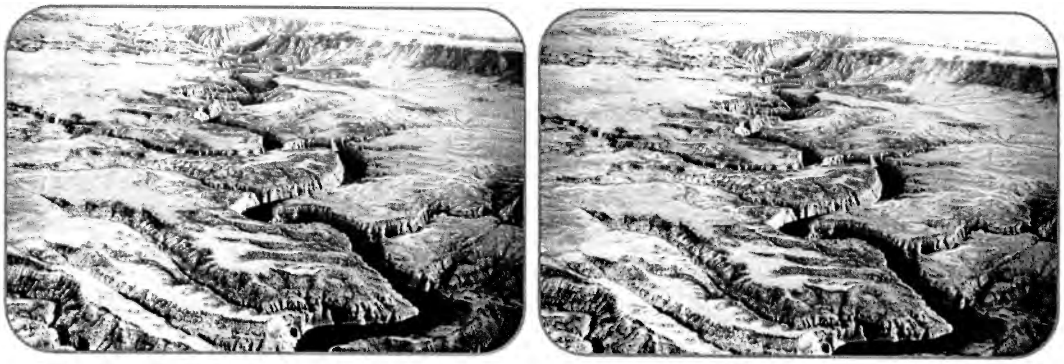


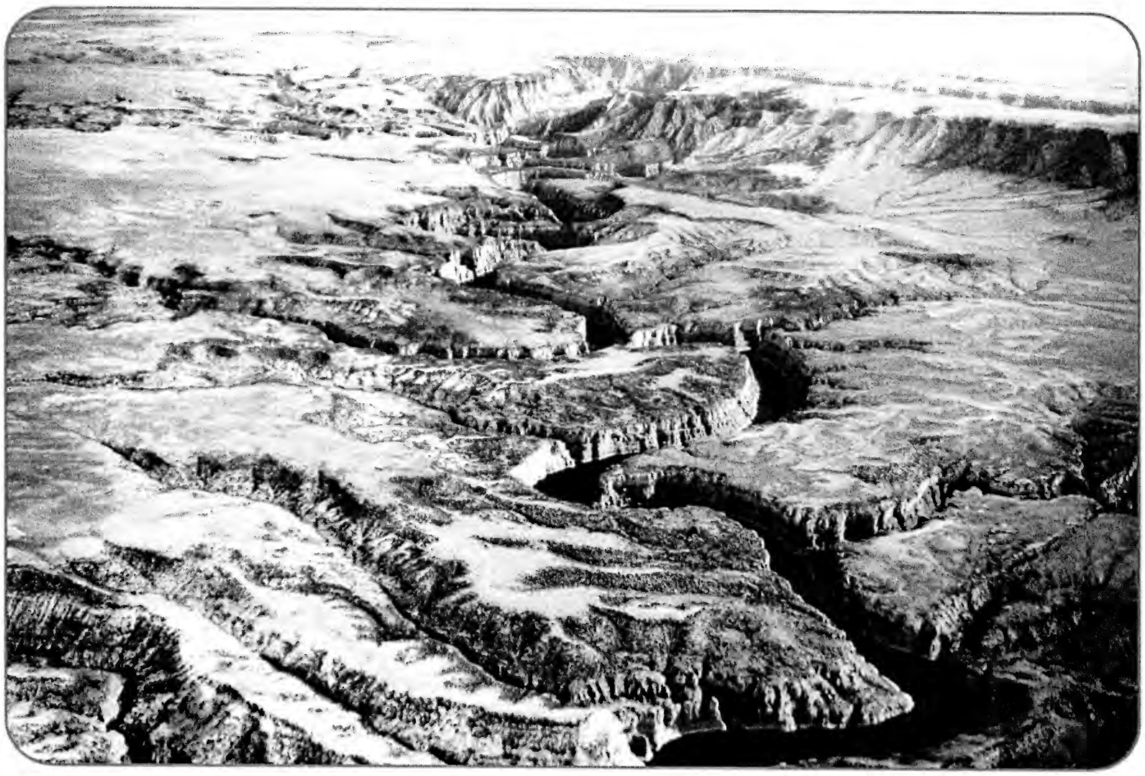
You are looking southward at the Beaverhead River south of Twin Bridges, Montana. During floods the Beaverhead River abandons entire meandering reaches to form and occupy new meandering channels. Its present meandering reach is flanked by older, abandoned meandering reaches.

Salmon River - Ingrown Meanders


You are looking southward at ingrown meanders of the Salmon River south of Salmon, Idaho. The meanders are termed "ingrown" because they have migrated as they cut into the bedrock. Meanders that have cut vertically into the bedrock are termed "entrenched" or "incised".

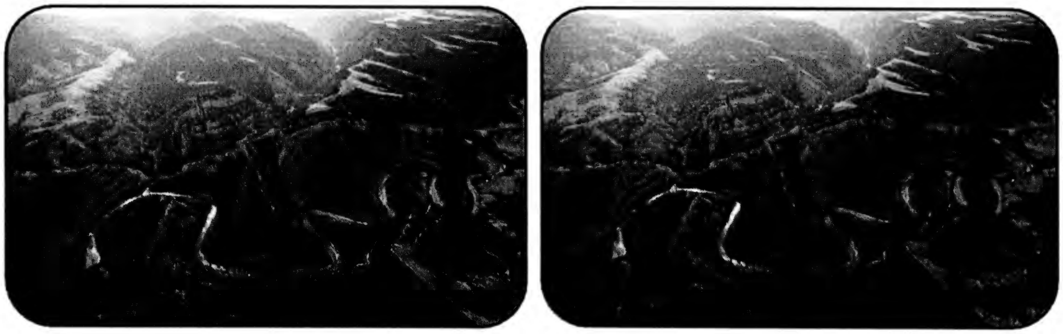
Big Horn River - Incised





You are looking toward the northeast at meanders of the Big Horn River that have incised into Paleozoic rocks where the river crosses the Pryor Mountains. The river has backed up into a sinuous lake behind Yellowtail Dam, partially filling the canyon with a lake that is wider than the original river.

Smith River - Ingrown Meanders

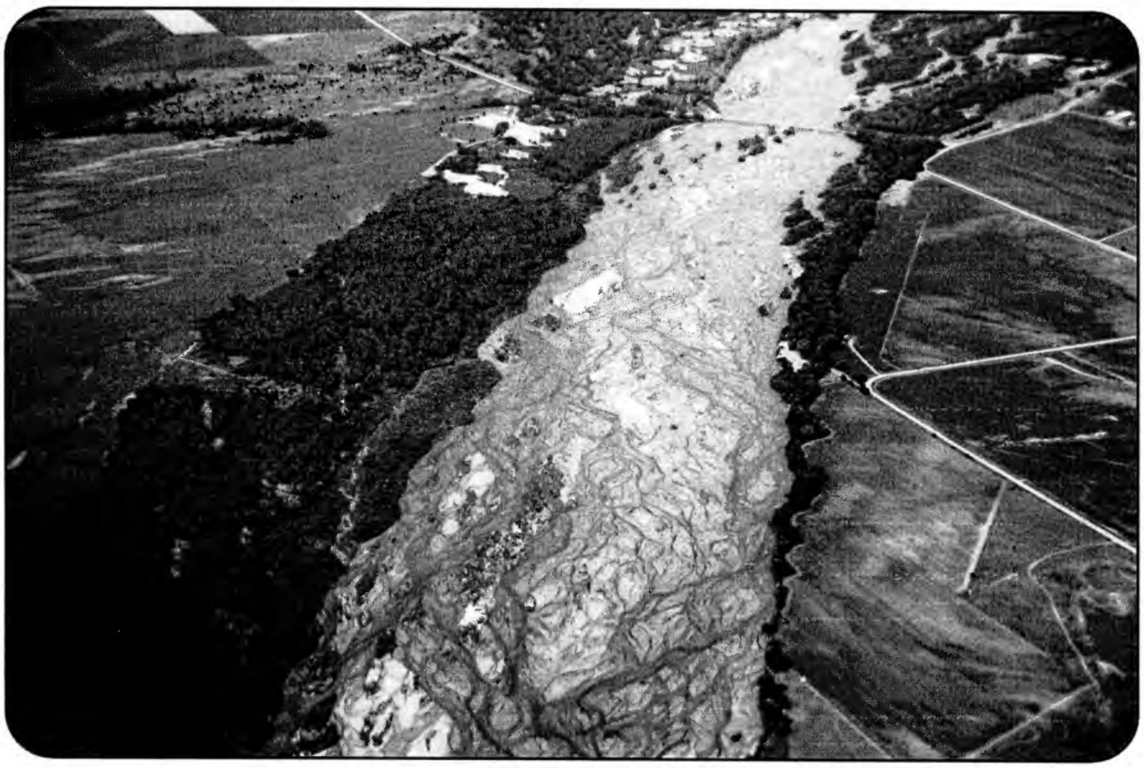


You are looking toward the east at ingrown meanders of the Smith River where it crosses the Little Belt Mountains in Montana. The wave length of the meanders is considerably more than ten times the river's width, probably because they were cut about 16,000 years ago when melting glaciers supplied the Smith River with greater discharge than it has now.

Toad River - Braided

You are looking south at the Toad River in northern British Columbia, Canada. It is a classic braided stream showing rills on the bars that result from a preponderance of currents that flow at about 45 degrees to the alignment of the river. Sand accretes on the downstream ends, sides, and upstream ends of its bars. Some of its anabranches meander, depositing point bars around the insides of their bends. Picture taken in June, 1985.

Platte River - Braided



You are looking toward the northeast at the braided Platte River near Grand Isle, Nebraska. All braided streams have only two attributes in common: (1) bedload, and (2) easily eroded banks. They may be aggrading, degrading, or graded. Braiding increases the wetted perimeter of the stream and thereby increases the frictional resistance to flow. It is one of the most powerful tools a stream has to control its discharge and load. Picture taken June 18, 1981.

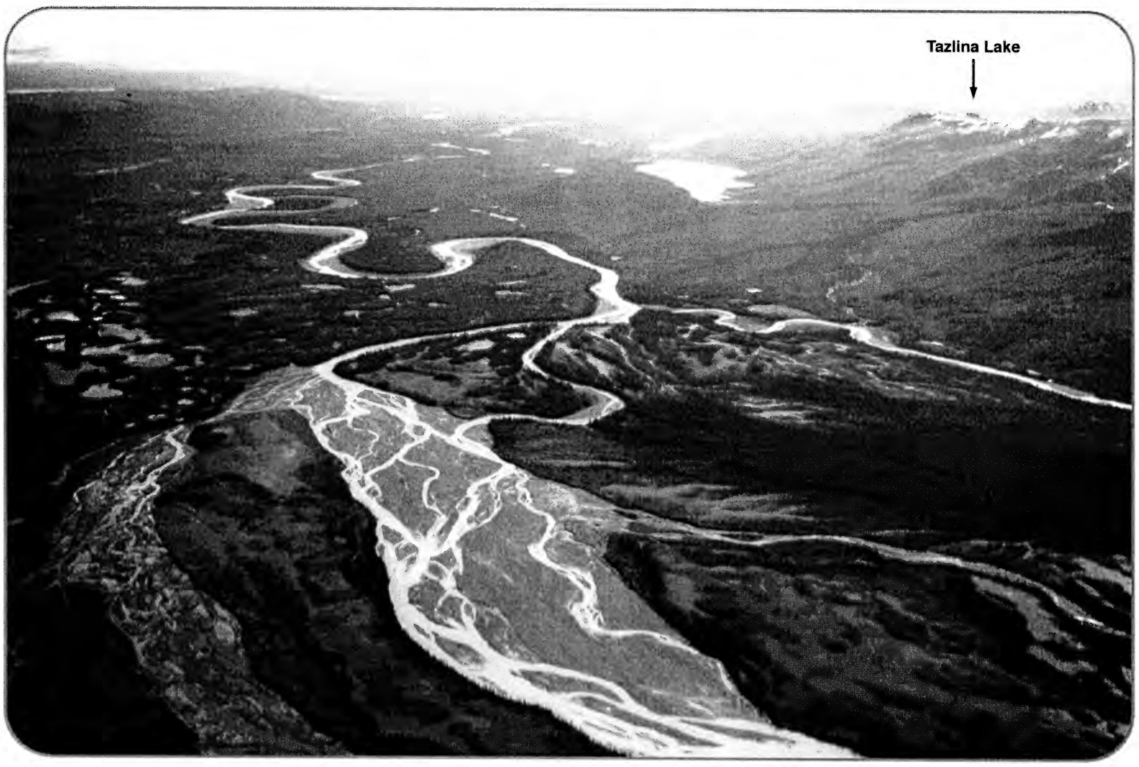
Wise River - a Degrading Braided Stream

You are looking southward up Wise River in southwestern Montana. Wise River is a braided stream that is actively cutting its valley into bedrock. The triangular facets, in the shadow along the eastern side of the valley, formed as the river cut through the ridges that descend from the mountain.

Donjek River - A Degrading Braided Stream

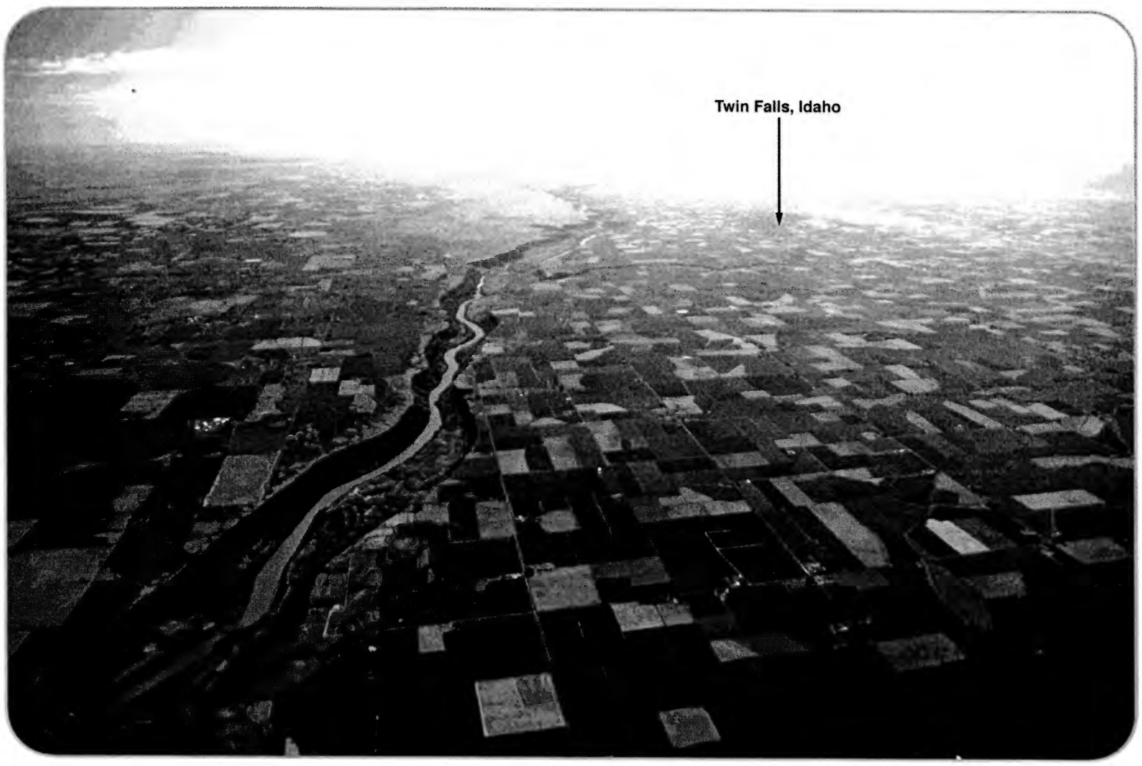
You are looking toward the northeast at the braided Donjek River in Canada's Yukon. The river drains the eastern flank of the St. Elias Mountains that arc along the shores of the Pacific Ocean. It flows northeastward across the Shakwak Trench (the Denali Fault) to join the Yukon River, thence flowing north before turning west across Alaska to empty into the Bering Sea. In this picture the Donjek River cuts through the mountains bordering the northeastern side of the Shakwak Trench. It is a braided degrading stream.

Nelchina River changes from Braiding to Meandering



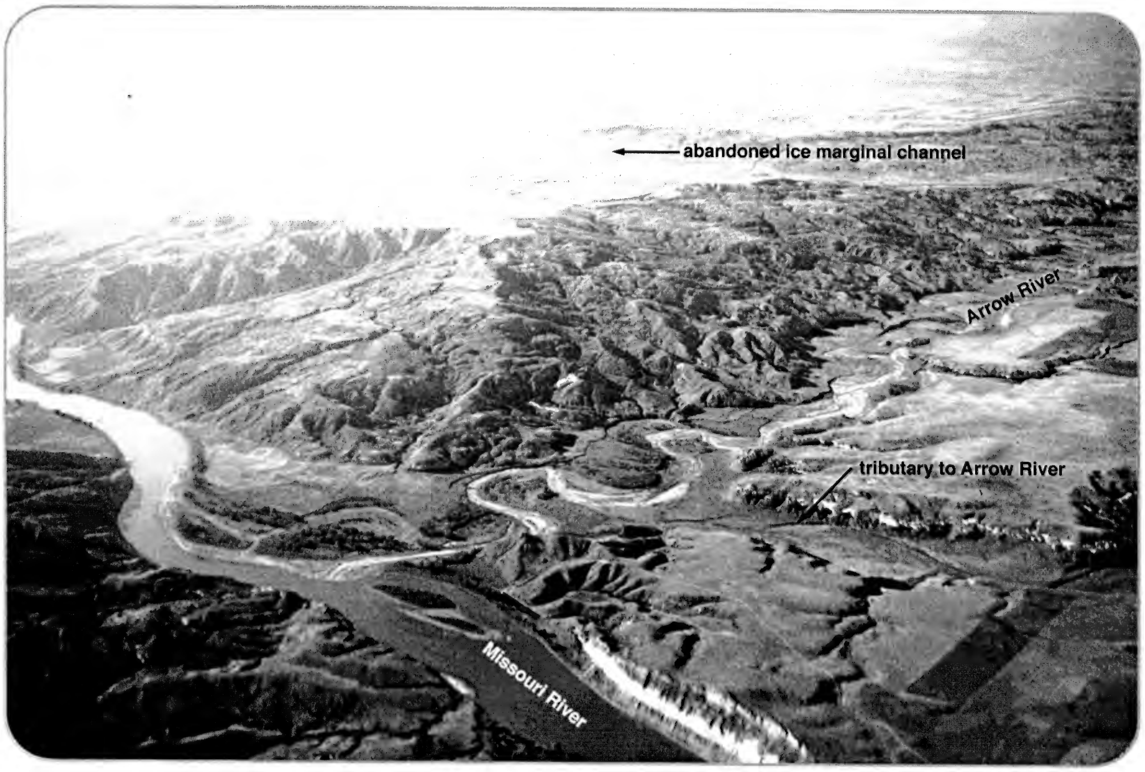
You are looking toward the northeast at the Nelchina River as it drains the Nelchina Glacier in the Chugach Mountains of Alaska a short distance to the south, just beyond the right edge of the picture. The river changes from braided on the steep valley gradient in the foreground to meandering on the gentler valley gradient in the Copper River Basin. The river is building a delta into Tazlina Lake.

Snake River - Gently Sinuous and Incised



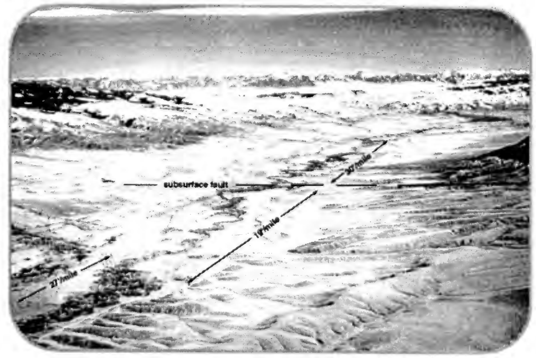
You are looking eastward at the canyon carved by the gently sinuous Snake River in the nearly flat volcanics of the Snake River Plain.

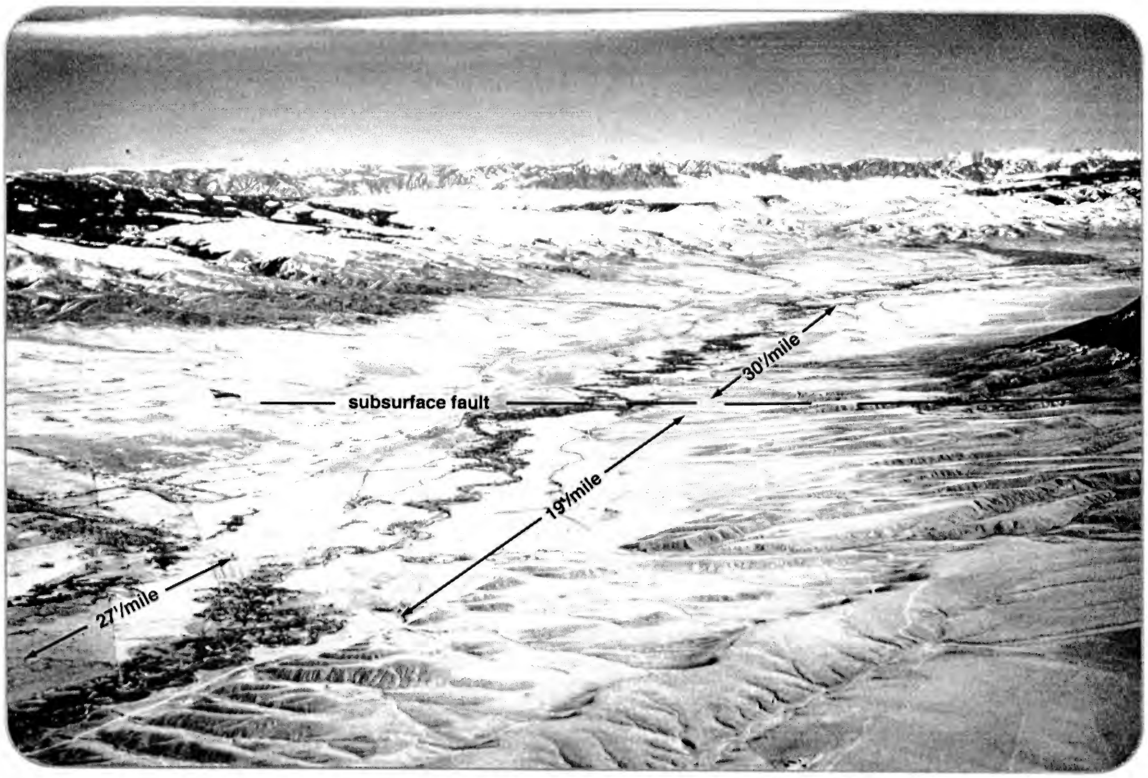
Valley Gradients and Patterns of Missouri & Arrow Rivers



You are looking toward the southeast at the junction of the Arrow and Missouri Rivers. The Missouri and the small tributary of the Arrow River flow eastward on gentle valley gradients; therefore, they are sinuous. By contrast, the Arrow River descends from the Little Belt Mountains on a steep valley gradient, and it must both meander and braid to control its discharge and load. The abandoned ice-marginal channel is an ancestral course of the Missouri. The Missouri's present course, approximately parallel to the abandoned channel, is also presumed to have formed along the leading edge of the glacier.

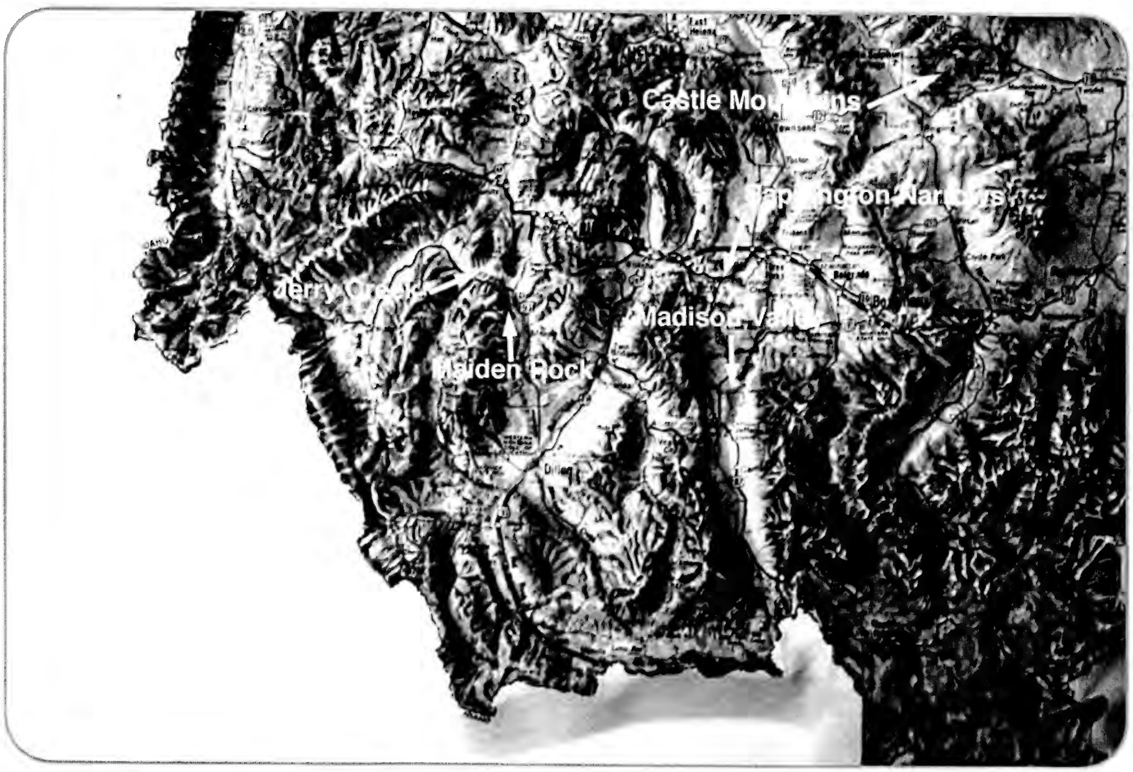
Ruby River Meander Patterns & Valley Gradient Changes





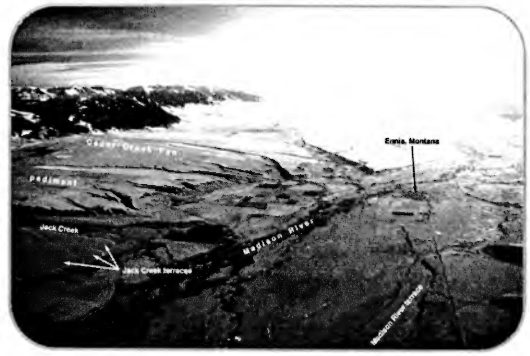
In this eastward view, the valley gradient of the Ruby River changes from 30' per mile to 19' per mile and then steepens again to 27' per mile in a downstream direction. The river changes pattern from tightly meandering to sinuous where the gradient changes across the fault and then changes back to tightly meandering where the gradient increases to 27' per mile. The near side of the fault dropped, and the river constructed the minimum gradient it needed for its discharge to carry its load across that reach. The fault continues southward along the western flank of the Ruby Mountains in SW Montana, and may join with the fault along the western side of the Tobacco Root Mountains to the north. The position of the fault under the valley was confirmed by a gravity survey run by Dr. Charles Wideman's Montana Tech students in 1981.

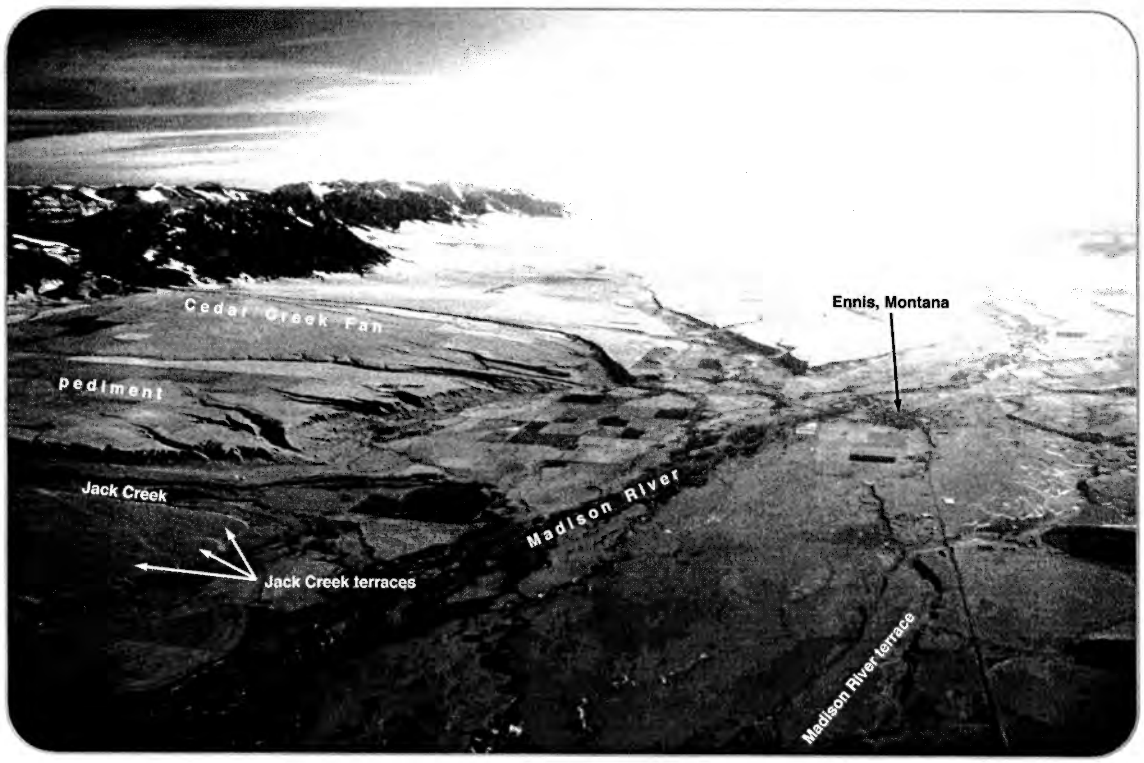
Index Map



Index map showing the locations of some of the pictures on the following pages. Immediately following is a series of pictures taken while flying southward up the Madison Valley.

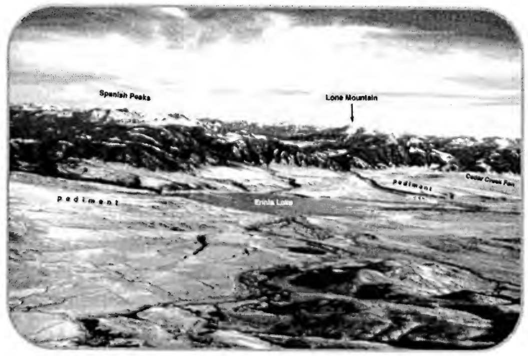
Landforms in Northern Madison Valley

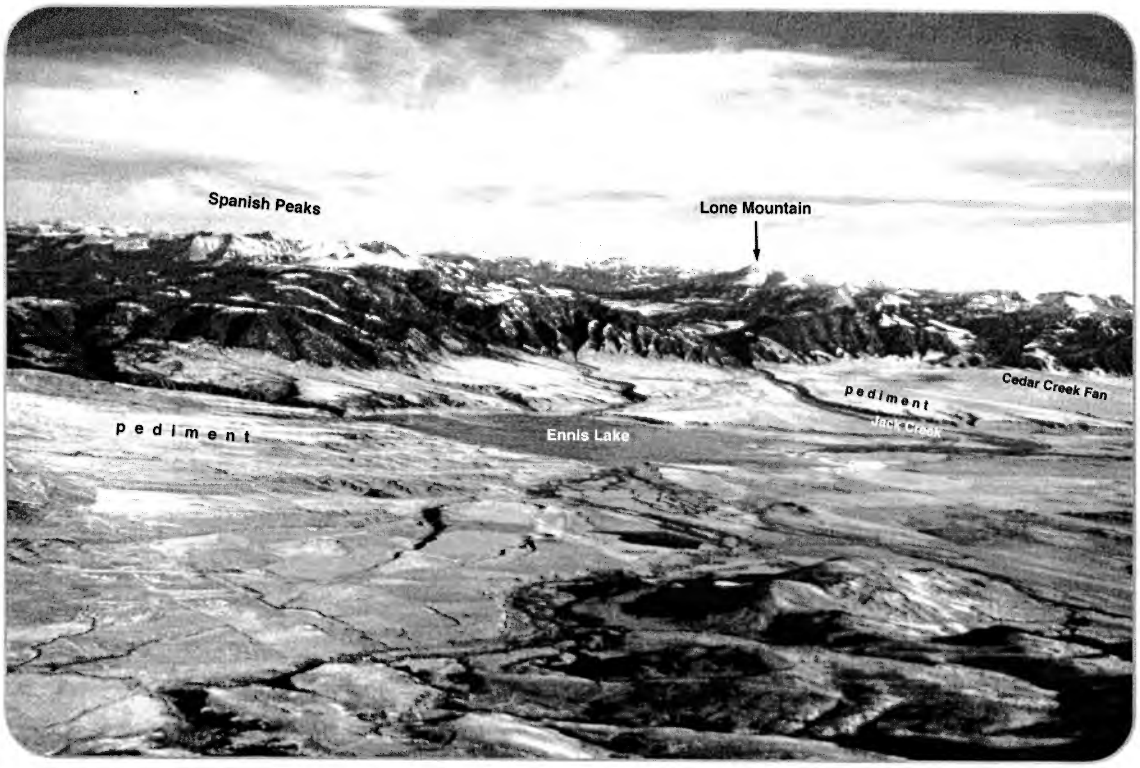




You are looking southward up the Madison River Valley just north of Ennis, Montana. Numerous upstream terraces have merged with the Madison River floodplain to leave the single terrace labelled in the lower right part of the picture. The Cedar Creek alluvial fan has spread over the pediment remnant bordering Jack Creek which, in turn, has incised through the pediment and the terraces that border it.

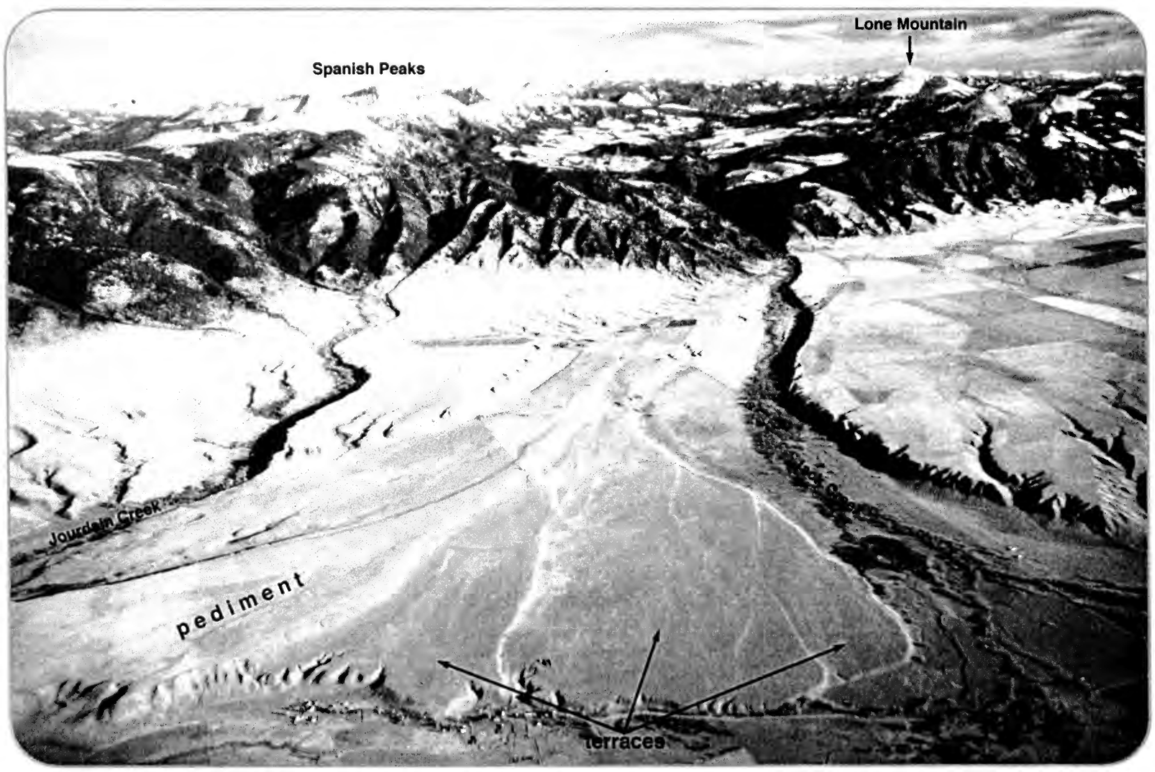
Northern Madison Valley
Pediment and Cedar Creek Alluvial Fan





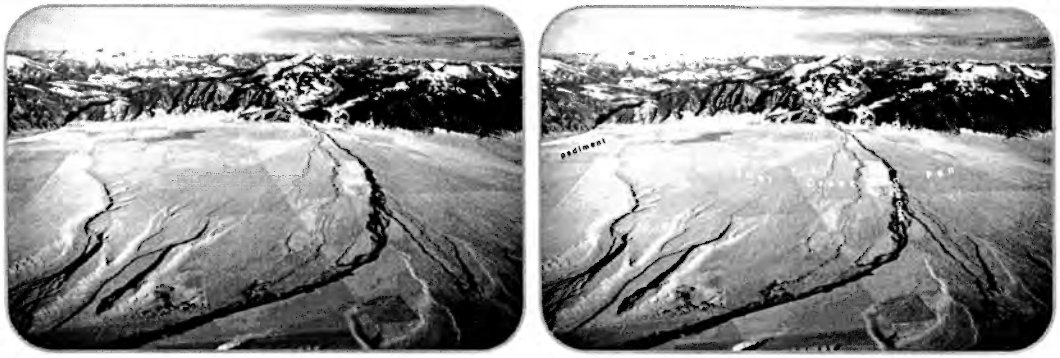
You are looking toward the southeast across the pediments that border the northern end of the Madison Valley in southwestern Montana. To the south the Cedar Creek alluvial fan buries the pediment which probably developed during the last interglacial interval, about 70,000 years ago.

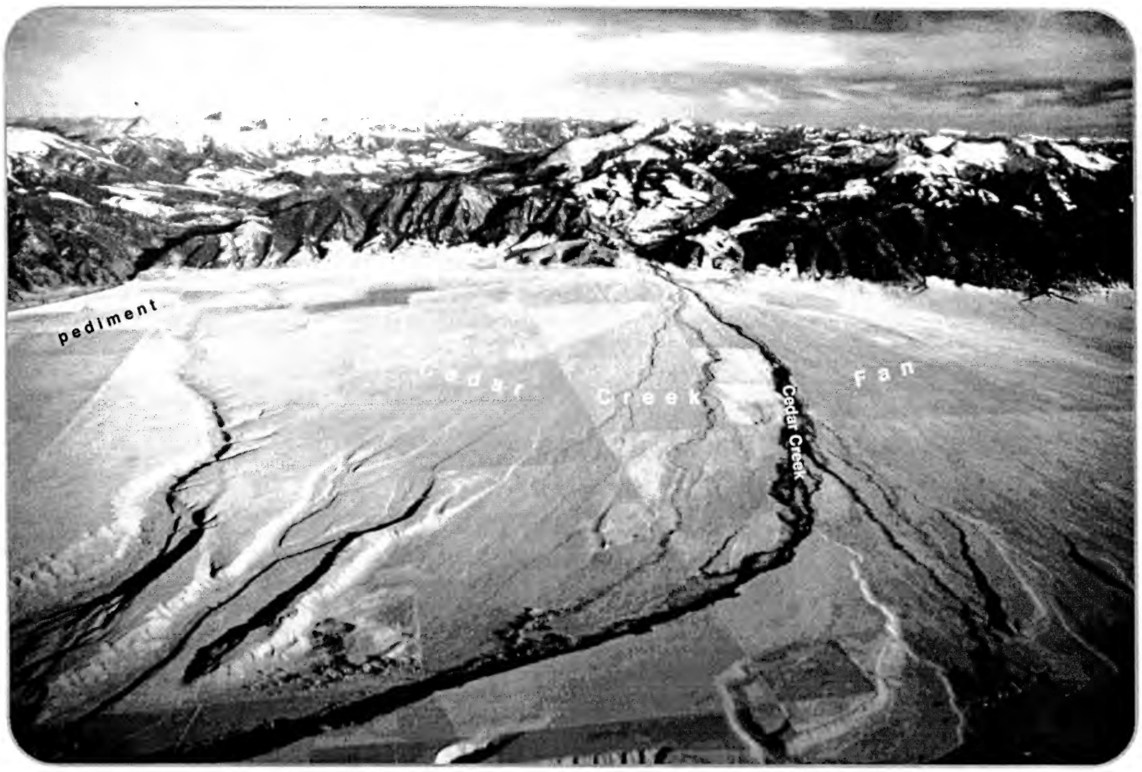
Northern Madison Valley
Terraces Bordering Jack Creek



You are looking toward the east at the terraces bordering Jack Creek, a tributary of the Madison River, in the northeastern corner of the Madison Valley, SW Montana. According to Bill Locke of MSU, calcite rinds on the bottoms of cobbles have similar thicknesses on all three terraces. Perhaps this indicates that the terraces formed rapidly near the end of the Pleistocene as the ancestral Madison River, fed by the melting of the glaciers, cut rapidly into the bedrock that extends across the river's exit at the northern end of the Madison Valley.

Northern Madison Valley
Cedar Creek Alluvial Fan



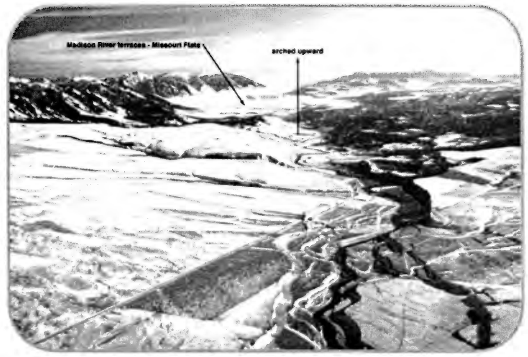


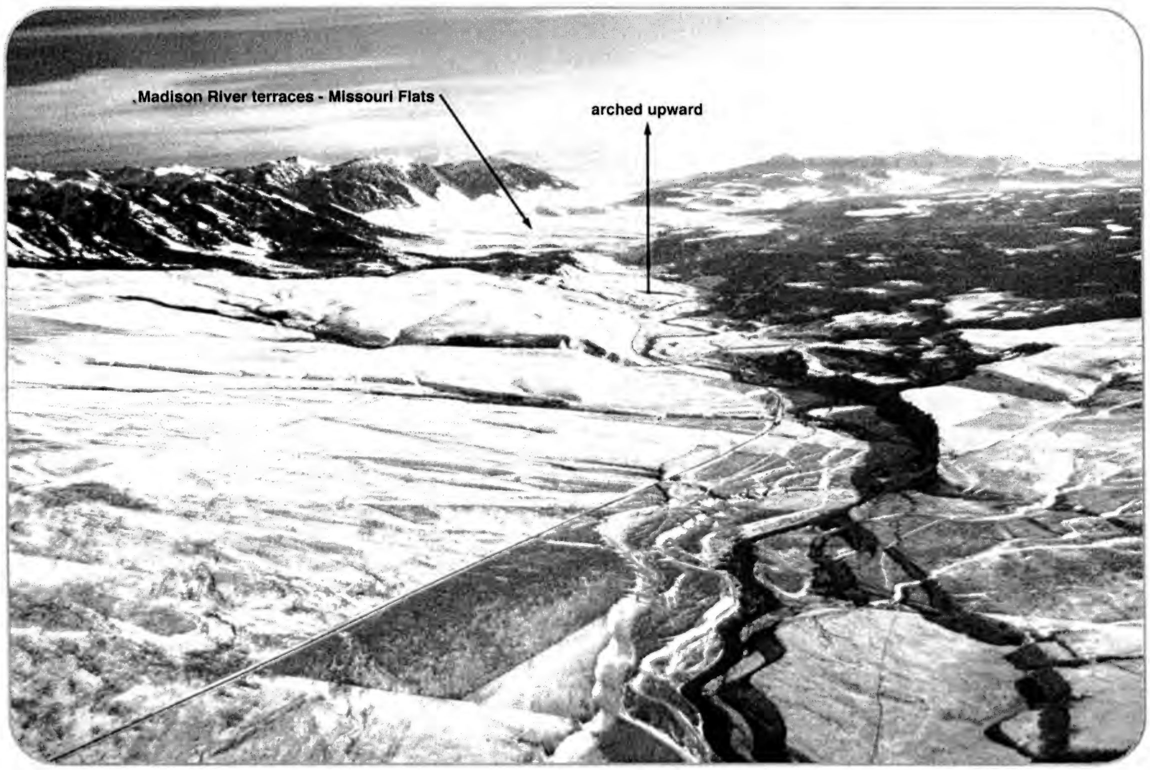
You are looking eastward at the Cedar Creek alluvial fan on the eastern side of the Madison Valley in southwestern Montana. Cedar Creek deposited the fan over the pediment when the fault bordering this part of the Madison Range dropped the eastern side of the Madison Valley. Since then, the Madison River has continued to deepen its course, and in response, Cedar Creek has incised into its alluvial fan. Smaller tributaries of the Madison River have also eroded headward and incised into the fan, as shown nicely in the lower left part of the picture.

Mid Madison Valley
Terraces

You are looking southward up the terraced Madison River Valley. The heavier white arrow points downstream where the lowest terrace merges with the modern floodplain. The two lighter arrows point to odd, breached channels that parallel the side of the valley. How did they form? Are they cut into a terrace? Could an ice dam that formed on the floodplain block the tributary valley, forcing the tributary's water to flow parallel to the ice dam and carve the channels?

Middle Madison Valley
Terraces

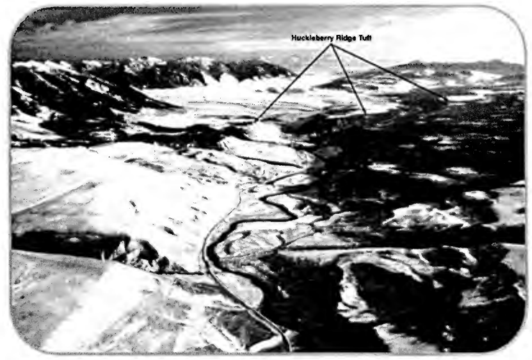


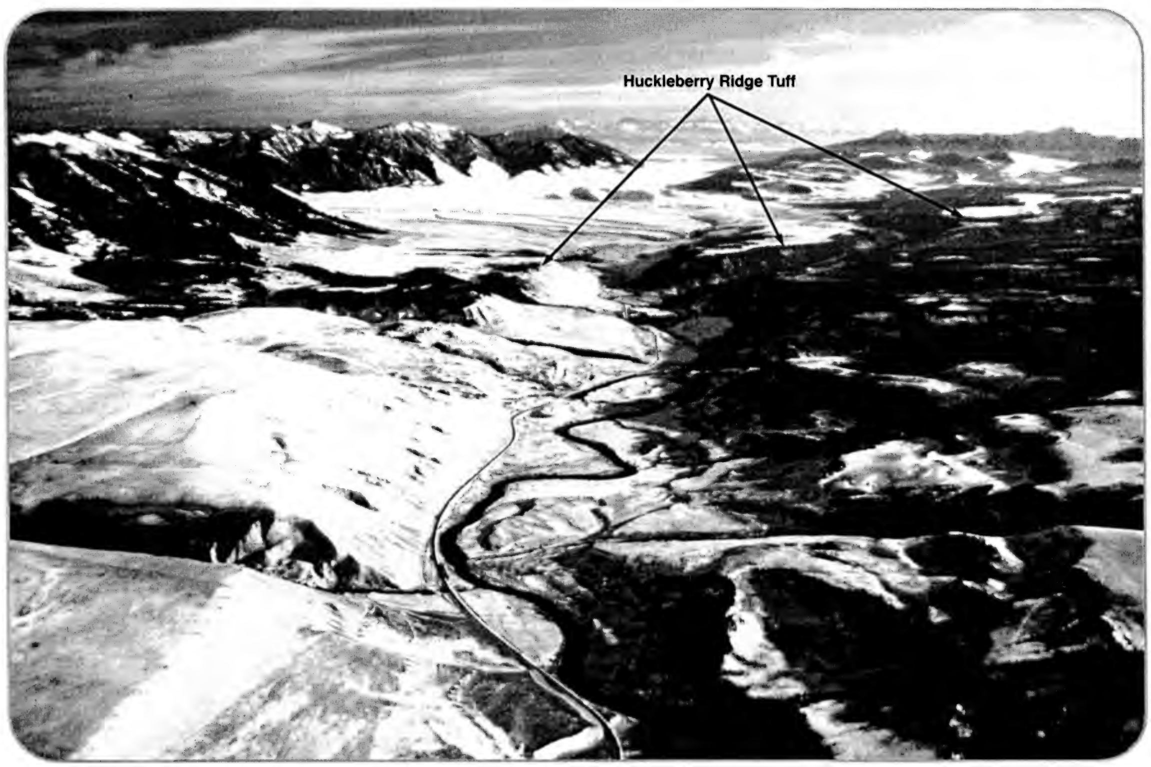


You are looking southward, upstream, at the Madison River in the Madison Valley of south-western Montana. The river has well developed terraces on the alluvium in the foreground. Terraces are poorly developed where bedrock is being arched upward* in the middle distance. Beyond that, terraces are well developed again on alluvium in the Missouri Flats area.

*arched upward from: O'Neill, J.M., Leroy, T.H., Stickney, M.C., and Carrara, P.E., 1995, "neo-tectonic Evolution and Historical Seismicity of the Upper Madison Valley and adjacent Madison and Gravelly Ranges in the Cliff Lake 15' Quadrangle, Southwest Montana": GSA Abstracts with Programs, Rocky Mountain Section.

Madison River
Bedrock Reach





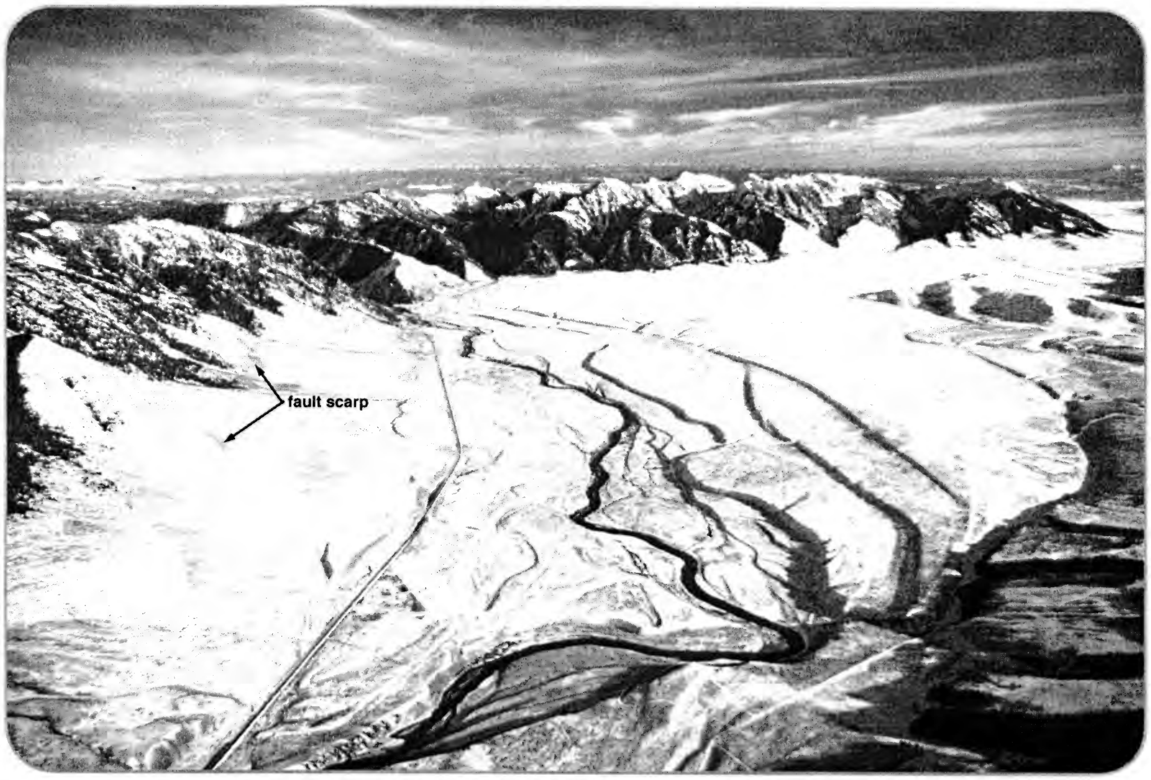
You are looking southward at the reach of the Madison River where it cuts through the two million year old Huckleberry Ridge Tuff into Mesozoic-age rocks. The Huckleberry Ridge Tuff was originally deposited as a series of ash flows that retained enough heat to form a welded tuff as the glass shards fused together. It filled these valleys as a nearly flat-lying sheet that has been arched upward on the western flank of the Gravelly Mountains to reach an elevation of 9,600 feet near the mountain's crest.*

*O'Neill, J.M., Leroy, T.H., Stickney, M.C., and Carrara, P.E., 1995, "Neotectonic Evolution and Historical Seismicity of the Upper Madison Valley and adjacent Madison and Gravelly Ranges in the Cliff Lake 15' Quadrangle, Southwest Montana": GSA Abstracts with Programs, Rocky Mountain Section.

Missouri Flat
Terraces & Huckleberry Ridge Tuff

You are looking southward where the four terraces of the Madison River in the Missouri Flats area enter into the bedrock-incised reach. The Huckleberry Ridge Tuff was erupted from the Island Park Caldera two million years ago. It has been dropped along the fault at the Madison Range mountain front while being arched up onto the Gravelly Range to the west.

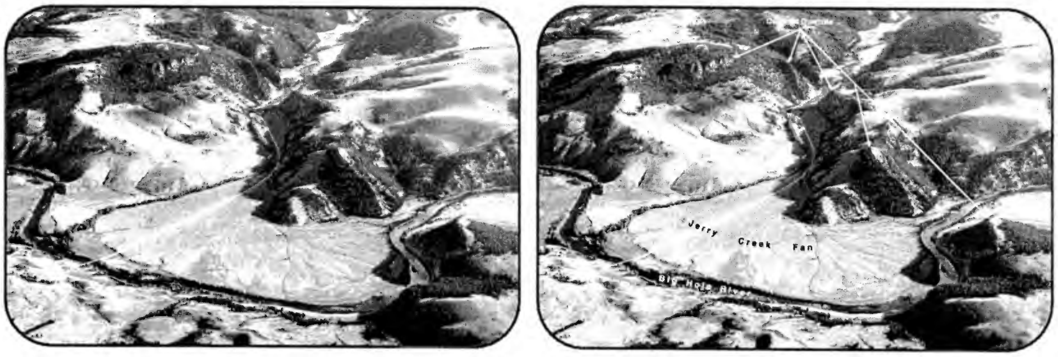
Missouri Flat Terraces



You are looking southeastward, upstream, at the Madison River terraces in the Missouri Flats area of southwestern Montana. The terraces are developed where the river emerges from its canyon onto the alluvium filling the half-graben of Missouri Flats. If the dip of the Huckleberry Ridge Tuff, outcropping in the lower right corner of the picture, is projected to the fault scarp along the mountain front, it would be buried by about 1000 meters of alluvium.* The Huckleberry Ridge Tuff is about two million years old. An average movement on the fault of two to three meters would produce a recurrence interval for the faulting of about 4000 to 6000 years.

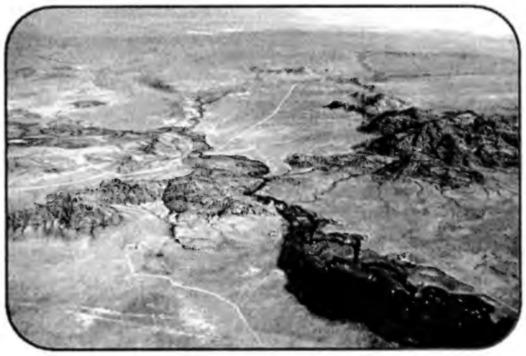
*Weinheimer, C.J., 1979, "The Geology and Geothermal Potential of the Upper Madison Valley between Wolf Creek and the Missouri Flats, Madison County, Montana", M.S. Thesis Montana State University.

Jerry Creek Alluvial Fan



You are looking northward at an alluvial fan built by Jerry Ceek onto the floodplain of the Big Hole River in southwestern Montana. Presumably, the lower level of the Big Hole River floodplain and the lack of gradient across it caused Jerry Creek to drop its load and build the fan into the Big Hole River valley. The valleys of both Jerry Creek and the Big Hole River narrow dramatically where they are superimposed across the folded Quadrant Quartzite.

Sweetwater River - Superimposed



You are looking northward at the Sweetwater River in central Wyoming. The granite mountains are the rugged peaks that stick up through Miocene and Pliocene sediments. Until just a few million years ago, the sediments completely covered the mountains. The Sweetwater River developed its course on these sediments. Uplift caused it to cut downward across the underlying granite as erosion exumed the tops of the buried mountains. The superimposed river valley is wide where it flows across the easily eroded sediments and narrow where it crosses the granite.

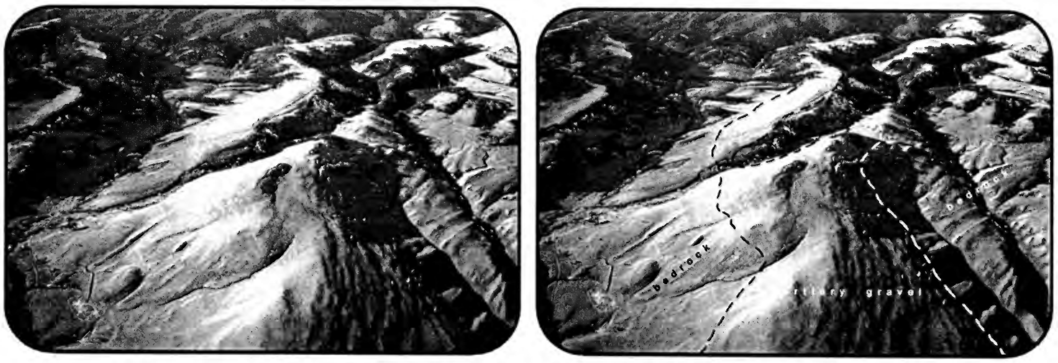
Big Hole River's Superimposed Course

You are looking northwest, upstream, at the Big Hole River in the Maiden Rock area of southwestern Montana. The Big Hole River emerges from its bedrock canyon west of Divide to carve a broad floodplain in the gravel-filled graben. It then forsakes the easily eroded gravel to cut a meandering canyon through bedrock. In the foreground it emerges from Maiden Rock Canyon to carve a broad floodplain on the gravels of the Melrose Valley. The gravels buried the mountains at Maiden Rock, and the river, meandering on that high-level broad gravel plain, began to cut down when the Rocky Mountains rose isostatically somewhere between one million and five million years ago. As the river cut down, its meandering course was superimposed on the buried mountains beneath the gravel.

Jefferson River Superimposed at Sappington Narrows

You are looking toward the southeast at Sappington Narrows north of Harrison in southwestern Montana. The Quadrant sandstone and other Paleozoic and Mesozoic rocks were folded, thrust-faulted and eroded near the end of the Cretaceous. They were buried by Tertiary sediments that covered this landscape. Isostatic uplift between one million and five million years ago rejuvenated the rivers, and the Jefferson River cut down from its Tertiary surface across the buried outcrops of hard rock, creating Sappington Narrows.

Angular Unconformity below Tertiary Gravel

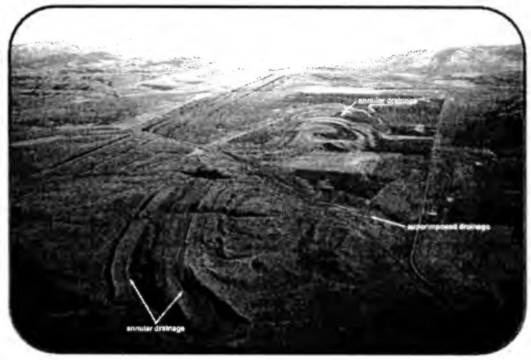


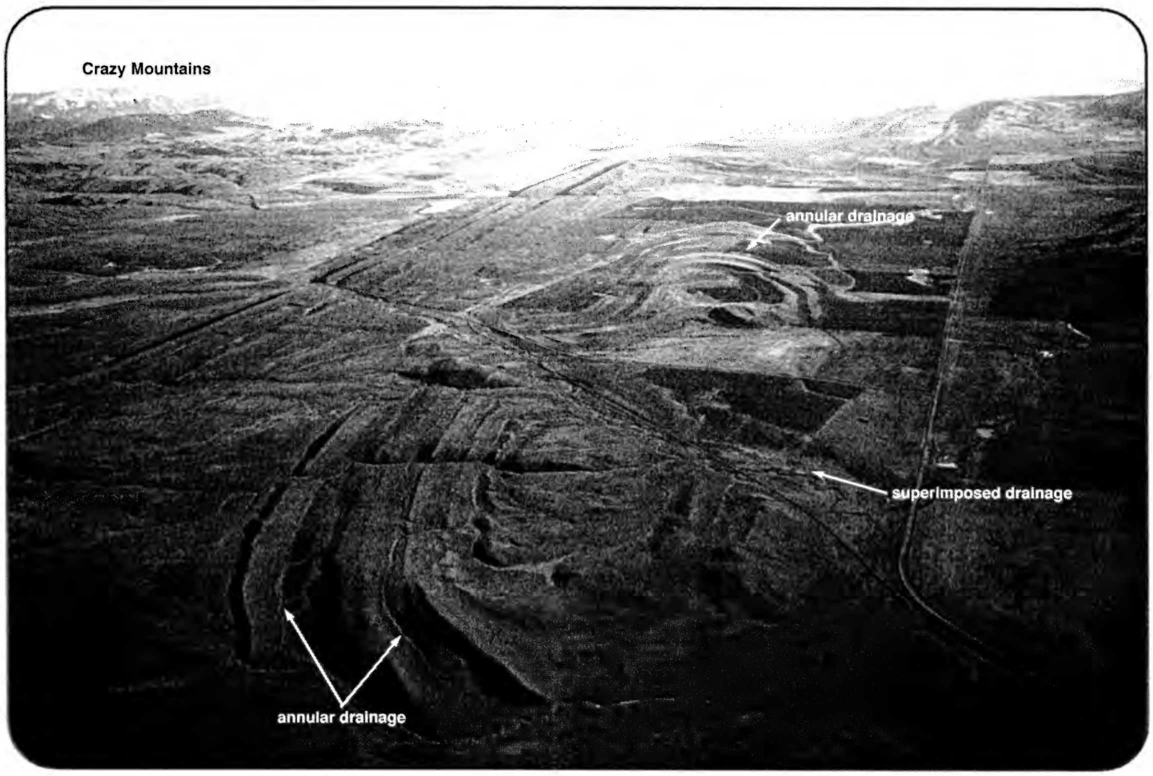
You are looking northward along the southern margin of the Castle Mountains in central Montana. Tertiary gravels unconformably overlie Mesozoic sedimentary rocks that were folded and eroded before the gravels were deposited across their edges.

Angular Unconformity below Tertiary Gravel

You are looking eastward at Tertiary gravel unconformably overlying folded and eroded sedimentary rocks south of the Castle Mountains in central Montana.

Stream Superimposed Across Anticline





You are looking southward at a stream superimposed across a small anticline from an unconformable covermass of Tertiary sediment that buried the anticline. Small annular drainages have developed on the less resistant layers after the anticline was exposed. This area is near Ringling in central Montana.