National Cooperative Soil Survey Conference

Field Tour Guide Book

June 25-29, 2001

View from Trail Ridge Road at Rainbow Curve

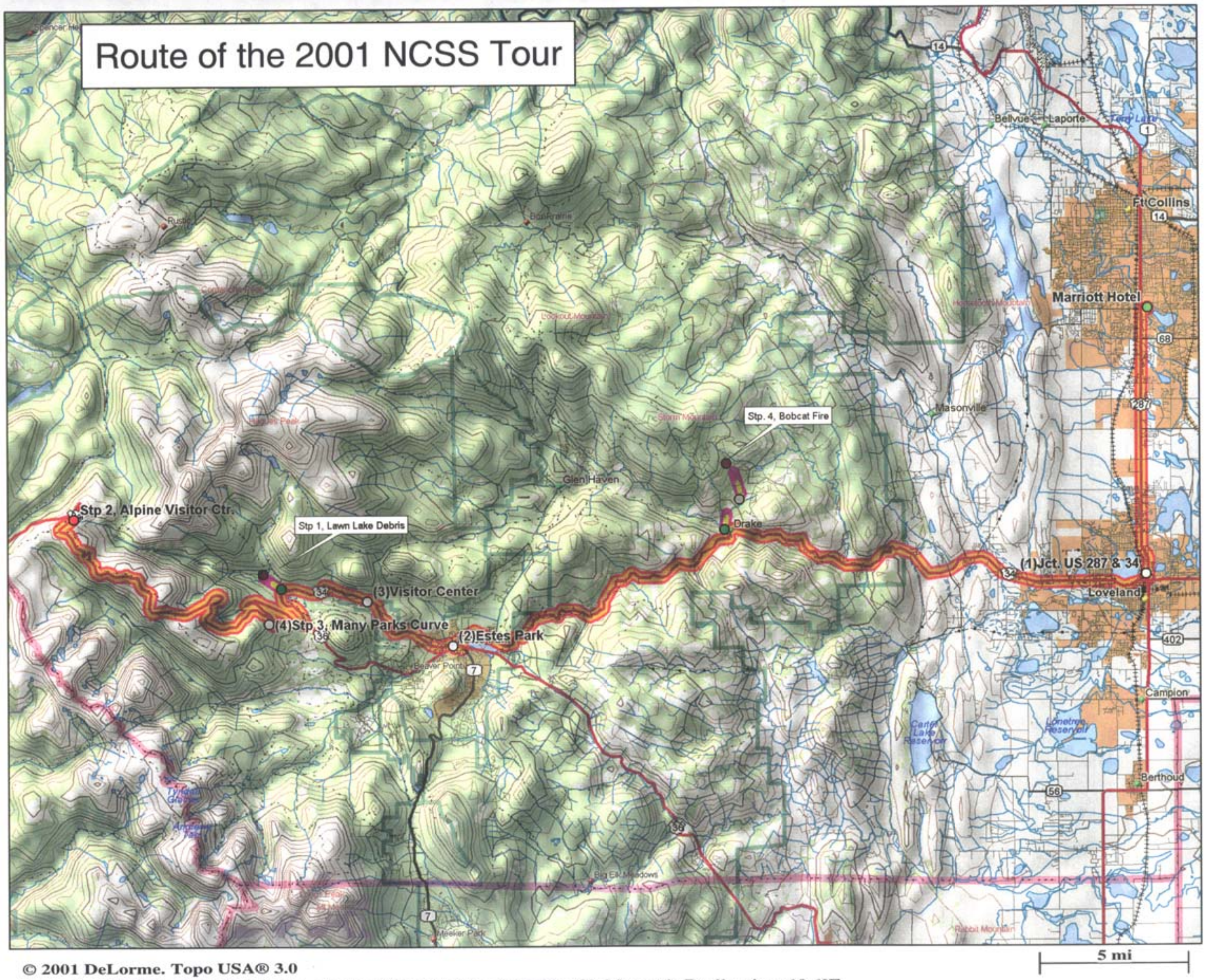
Photo: © Justin Gould

Photo: @ Tedd Huffman

Bobcat Gulch Fire,
June 12, 2000

NCSS Conference 2001
Field Tour -- Colorado Rocky Mountains
Wednesday, June 27, 2001

7:00 AM	Depart Ft. Collins Marriott
8:30	Arrive Rocky Mountain National Park **Lawn Lake Flood Interpretive Area** (elevation 8,640 ft)
8:45	"Soil Survey of Rocky Mountain National Park" - *Lee Neve, Soil Survey Project Leader, Natural Resources Conservation Service*
9:00	"Correlation and Classification of the Soils" - Thomas *Hahn, Soil Data Quality Specialist, MLRA Office 6, Natural Resources Conservation Service*
9:15-9:30	"Interpretive Story of the Lawn Lake Flood" - *Rocky Mountain National Park Interpretive Staff, National Park Service*
10:00	Depart
10:45	**Arrive Alpine Visitors Center** (elevation 11,796 ft)
11:00	"Research Needs in the National Parks" - Pete *Biggam, Soil Scientist, National Park Service*
11:05	"Pedology and Biogeochemistry Research in Rocky Mountain National Park" *- Dr. Eugene Kelly, Colorado State University*
11:25 - 11:40	"Soil Features and Geologic Processes in the Alpine Tundra"- *Mike Petersen and Tim Wheeler, Soil Scientists, Natural Resources Conservation Service*
	Box Lunch
12:30 PM	Depart
1:00	**Arrive Many Parks Curve Interpretive Area** (elevation 9,620 ft.) View of Valleys and Glacial Moraines, Photo Opportunity
1:30	Depart
3:00	**Arrive Bobcat Gulch Fire Area**, Arapaho-Roosevelt National Forest
3:10	"Fire History and Burned Area Emergency Rehabilitation Efforts" - Carl *Chambers, U. S. Forest Service*
3:40	"Involvement and Interaction With the Private Sector"- *Todd Boldt; District Conservationist, Natural Resources Conservation Service*
4:10	"Current Research on the Fire" - Colorado *State University*
4:45	Depart
6:00	Arrive Ft. Collins Marriott



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Scale: 1 : 275,000 Zoom Level: 9-5 Datum: WGS84 Map Rotation: 0° Magnetic Declination: 10.6°E

Navigator's Narrative

Tim Wheeler

Between the Fall River Visitors Center and the Lawn Lake Alluvial Debris Fan:

This Park, or open grassy area, is called Horseshoe Park and is the tail end of the Park's largest valley glacier. The glacier reached depths of 1,500 feet and extended from Fall River Pass at the Alpine Visitor Center down to the east end of Horseshoe Park. As the glacier melted, it left a terminal moraine that dammed the valley and created a lake. Both Bull Lake- and Pinedale-age moraines have been identified. Finely grained mud and sand eventually filled in the lake. The present upper soils are loamy, often for several feet. This and other open, grassy parks in the national park exist today because the upper soil texture allows the grasses to compete successfully with the trees. The stream gradient in the location of the former lake is gentle, so the Fall River meanders through the park.

The alluvial debris fan at our first stop is the result of the dam at Lawn Lake bursting on July 15, 1982. A wall of water 25 to 30 feet high rushed down Roaring Creek. A new lake, which will be out of our view, was created along the Creek.

At Deer Ridge Junction (where we turn right onto Trail Ridge Road to proceed up to the alpine ecosystem):

The junction of this road and the road we are turning right onto is known as Deer Ridge Junction. We are turning onto Trail Ridge Road. The Trail Ridge Road section of U. S. Highway 34 begins at this junction and continues past the Alpine Visitor Center and over the Continental Divide and down toward the town of Grand Lake near the south west corner of the Park.

The junction is near the upper reach of the ponderosa parkland in Rocky Mountain National Park. The ponderosa pine is within the zone where the soil mappers used a frigid temperature regime and an ustic moisture regime. The ponderosa canopy in this lower montane ecosystem is occasionally thick enough on a few north-facing slopes to be a woodland ecosite, but generally the ponderosa community is more savanna like with rather open canopy and common, small, grassy parks. The understory is typically a grassland community. Note that when not capitalized, the term "park" refers to areas of grass communities within surrounding areas of woodland communities. This English term resembles the term used by French speakers for mountain-enclosed meadows.

Steep, northerly facing slopes of the lower montane zone have a Douglas fir and lodgepole pine canopy that is common to the upper montane zone. On topography with ridges running east and west, the climate and plant community of the next higher climatic zone fingers down along steep, north facing slopes into the climate zone below it. As with upper montane plant communities fingering down into the elevations common to the lower montane, the subalpine zone still above us fingers down on north-facing slopes into the lower elevations of the upper montane zone.

Just about one-third of a mile beyond the Junction we move into the upper montane zone, where the tree canopy is dominated by Douglas fir and lodgepole pine. The soil mappers applied the cryic temperature regime to this zone.

We our now moving up through a narrow valley called Hidden Valley. Ahead the upper Valley formerly included a recreational center for downhill skiing. To our right is the top of the lateral moraine we observed from stop 1. The Valley is squeezed between the bedrock-controlled landforms on our left and the moraine on our right. As we wind above and away from the moraine, the road will pass through places such as spur ridges with thin soils over granitic or gneiss bedrock and other places with deeper soils formed in colluvium and slope alluvium.

Trail Ridge Road climbs to 12,183 feet, going through all of this national park's ecosystems. The road is closed each winter to vehicle traffic by drifts that may be more than 35 feet deep. Nordic skiers enjoy use of the road during the winter, however. First opened in 1932, Trail Ridge Road is the highest continuous paved road in the United States.

A NRCS Snotel site name "Willow Park" is located west of the road near the head of this valley. Deep and persistent snow packs are characteristic, particularly on north-facing slopes. Snotel data indicates that the average maximum snow depth is in April when the average water content of the snow is nearly 20 inches. The snow cover frequently persists well into June.

After climbing up sufficiently to be able to see back toward stop 1 and the mountains above and beyond it:

As you look back towards and above our first stop, you can see the Mummy Range. The Range is so named because early visitors imagined the peaks to resemble a mummy from a distance. Mummy Mountain on the right is the head of the mummy.

Mount Ypsilon is the peak with the noticeable glacial dissection on its eastern face. It is named for the fissures on this deeply dissected face. The fissures hold snow late into the summer, and the snow filled fissures spell the letter 'Y', or the Greek letter ypsilon.

Between Many Parks Curve and Rainbow Curve:

We will be moving from the upper montane zone into the subalpine zone between the Many Parks Curve visitor viewpoint we just passed and the visitor viewing point known as Rainbow Curve.

The tree canopy of the subalpine zone is dominated by Engelmann's spruce and subalpine fir. This zone lies approximately between 9,000 and 11,000 feet in the Park.

As approach Rainbow Curve viewing point:

The Rainbow Curve viewing point is at an elevation of 10,829 feet. It is known for the spectacular rainbows that can be viewed from here after summer thunderstorms. Pikas and marmots live in its boulder field. Keep an eye out – you may get a glimpse of a pika or marmot as we travel through the alpine tundra ahead.

From here we can see the krummholtz, which is Finnish for “crooked wood”. We will pass through a narrow krummholtz region as we move into the alpine tundra zone. The krummholtz is a subalpine-alpine tundra ecotone, or transition or tension zone. Notice the clumps of stunted Engelmann spruce and subalpine fir. Mike Petersen will talk more about the krummholtz at our next stop and explain why the trees of the krummholtz are stunted.

Tree limit is roughly where mean summer air temperature is about 50 degrees Fahrenheit. The treeline elevation varies, however, because of varying patterns of deep snow, which delays the summer growing season, variations in exposure to drying winds, and variations in soil wetness, temperature, and depth to bedrock. In Rocky Mountain National Park, the treeline varies from about 11,000 to 12,000 feet.

As we drive through the alpine tundra toward the Alpine Visitor Center:

Trail Ridge Road is named for the ancient Ute trail that crosses the alpine tundra on this ridge. The Road partly follows this trail. Ute and Arapaho Indians as well as prehistoric people of unknown name used the trail. Their artifacts record a human presence in the mountains as much as 11,000 years ago. Aboriginal fire rings are most common at tree line. Also near tree line are the inconspicuous remnants of prehistoric rock-walled game drives that enabled these people to harvest large animals.

The winds up here have a drying effect beyond that we are familiar with at lower elevations because moving snow and ice particles blast the trees and any plant not closely hugging the ground. Although the average annual precipitation on the alpine tundra is over about 30 inches, the ground surface receives added UV radiation, resulting in an unusual degree of potential evapotranspiration relative to the average temperatures. Periods of drought can come in summer or winter. Wind speeds can exceed 150 miles per hour in either summer or winter, and speeds exceeding 200 miles per hour have been recorded on some peaks of the Park. UV radiation is twice what it is at sea level. Sunlight is 50 percent more intense than at sea level.

Notice that most plants in this zone grow close to the ground to help escape the effects of the severe winds. The main exception, which we do not see an example of from this vantage point, is the alpine willow communities growing in wetter soils of the concave drainageways of the tundra. Small plants are also adapted to the short growing season of about six to eight weeks with air temperatures about 20 degrees cooler in the growing season than in the Estes Park, which is at an elevation of approximately 8,500 feet. Small plants that hug the ground also can survive in the typical tundra soil with a high rock fragment content and low available water capacity.

The soil mappers working up here and other Colorado mountain areas are well acquainted with the extra potential to get sunburned followed by cool spells as the clouds move over above. You frequently add and remove clothing layers as you work.

The growing season on the alpine tundra of northern Colorado is about six to eight weeks, and air temperatures are about 20 degrees cooler in the growing season than in the Estes Park, which is at an elevation of approximately 8,500 feet. Small plants that hug the ground have the advantage up here on exposed sites where the soils have a high rock fragment content and therefore have a rather low available water capacity and where evaporation rates are high due to the sun intensity and high winds.

If you watch closely, you will notice the surface rock patterns. In some places you can see small fragmental spots or polygons of cobble and stone size rock fragments. The shape of these patterns changes in other areas to long stripes running up and down the slope. In other places, you will see angular fragments spread irregularly over the mineral soil surface. The latter are known as fel fields. Mike Petersen will discuss patterned ground at our stop at the Alpine Visitor Center.

You are looking across and over the valley housing the upper waters of the Big Thompson River as you view the mountain peaks to our left. You can see some examples of stripes on the steep slopes of the these peaks on the south side of the Big Thompson. Notice the glacial cirque headwalls of the side glaciers that were tributaries of the main valley glacier that formed the present valley the Big Thompson River runs through today. The deep valley is known as Forest Canyon. The valley glaciers extended a maximum of about 5 to 6 miles.

The tundra plants are mainly perennials. Many of them contain the pigment anthocyanin, which converts sunlight into heat. Many plants have waxy or hairy surfaces to reduce loss of water.

As approach the Lava Cliffs viewing point:

On your right is the headwall of a glacial cirque that exposes volcanic tuff. The source of the rock is volcanoes that repeatedly erupted 28 million to 26 million years ago in the area of today’s Never Summer Mountains that lie along the west edge of the Park. Much later, glaciers carved into the mountain to expose the tuff.

As approach Many Parks Curve on the return trip from the Alpine Visitor Center:

We are going to stop briefly at Many Parks Curve. From the viewing platform, you will look down at several parks. The long, forested ridges separating these parks are lateral moraines that formed along the sides of glaciers about 150,000 to 12,000 years ago. Even older glaciers existed here, but subsequent glaciation and erosion has obliterated most evidence of the older glaciers.

u.s. 34

loveland ganby via rocky mountain national park

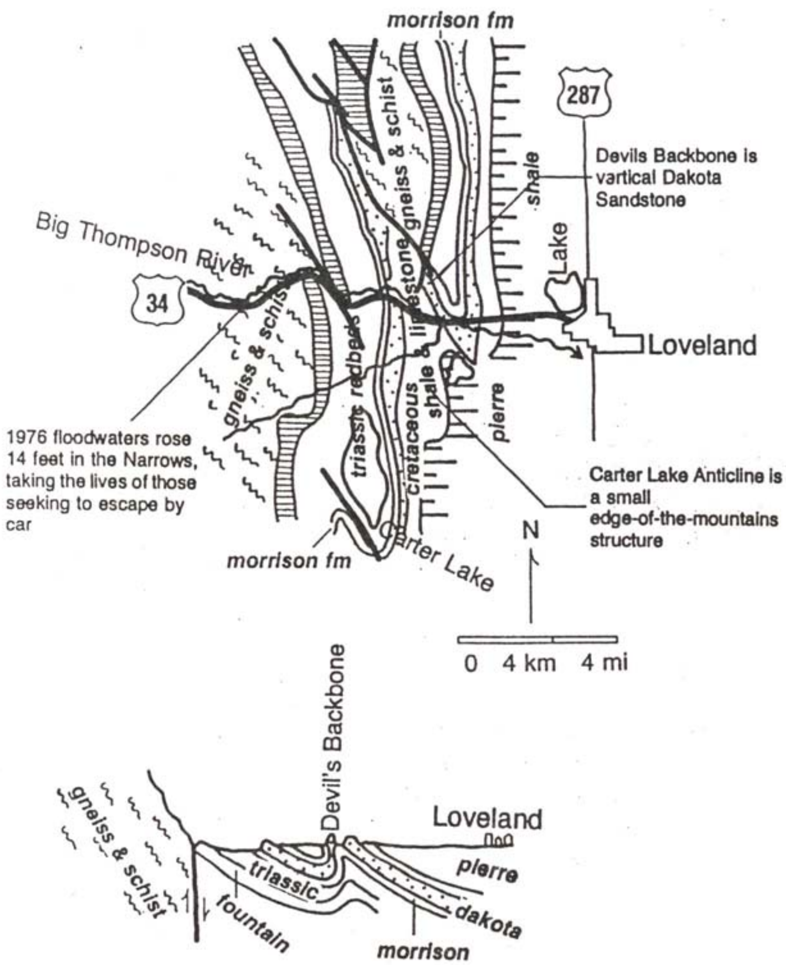
(92 miles)

The mountain front west of Loveland shows well the complex folding and.faulting that in many places edges the Rockies. Loveland lies on dark gray Cretaceous Pierre Shale that weathers into soil and is rarely exposed. A few miles west of town, older Cretaceous rocks come to the surface where they turn up along the edge of the Front Range.

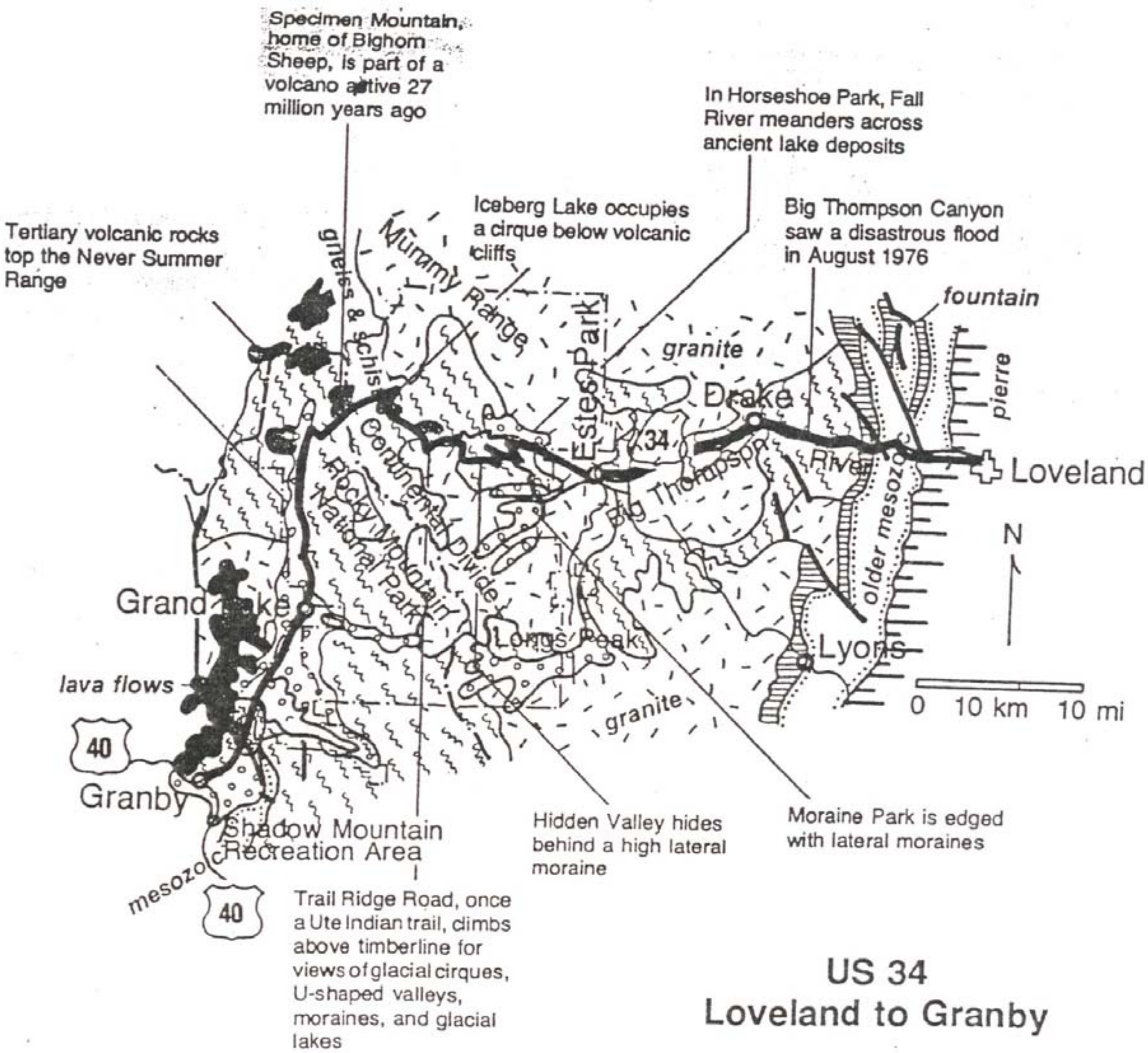
Near Mile 88 the Dakota Sandstone swoops up into a prominent hogback, with a valley of Jurassic shale and another hogback of older Lyons Formation, pink Triassic sandstone, beyond. Then the Dakota turns down again, vertically, so it appears as a vertical wall called the Devils Backbone. Farther west the sequence repeats once more: Dakota Hogback (Mile 86), Jurassic shale, Triassic Lyons Sandstone. Finally, not as steeply dipping as the Cretaceous rocks, the Pennsylvanian Fountain Formation surfaces by the river. Just beyond it and across another fault, Precambrian rocks wall the canyon of the Big Thompson River.

Before 1976, Big Thompson Canyon sheltered hundreds of pleasant pine-shaded homes and cabins, motels, and picnic areas. The river, fed by high-country streams from Rocky Mountain National Park and the region north of it, rose during the night of July 31,1976, when heavy rains fell in that area, and swept the canyon with a disastrous flash flood. Homes, motels, cabins, trees, cars and trucks, bridges, a small dam, and U.S. 34 were wiped out by raging waters so savage that they moved twenty-foot boulders and huge blocks of concrete. In spite of flood warnings at least 139 people died, many of them while trying to outrun the flood by driving down the canyon. At the Narrows near the canyon mouth, where it didn't even rain, the stream rose 14 feet in just a few minutes. You’ll see evidences of the floods rampage as you drive up the canyon, reminders that nature has not finished shaping these mountains. And you’ll wonder why so many homes and cabins have been rebuilt close to the river.

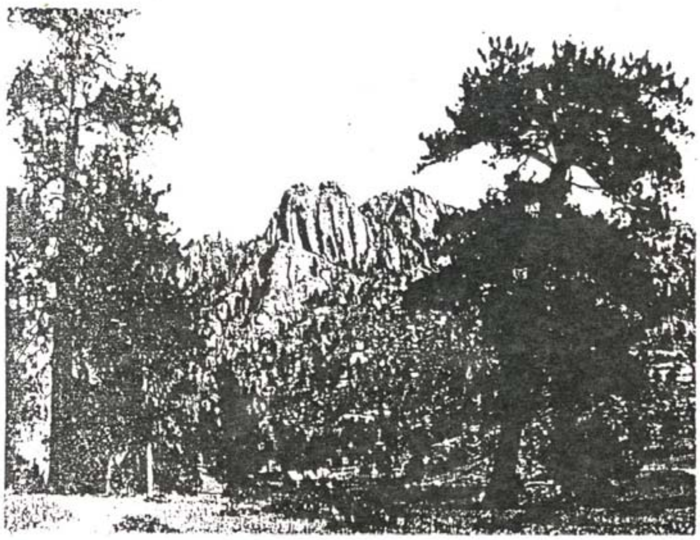
The canyon walls are of metamorphic rock, banded gneiss and shiny schist more than 1750 million years old, broken, fractured, and penetrated by pegmatite dikes, some with large mica crystals. Near the upper end of the canyon these rocks alternate with patches *of pink* and dark red granite until finally granite predominates. It weathers quite differently than the metamorphic rocks, forming rounded boulders and domes rather than craggy cliffs. The canyon widens, and the highway emerges onto rolling granite hills that merge into Estes Park in the heart of the Front Range.



Detail of geology west of Loveland along U.S. 34



US 34
Loveland to Granby



The Twin Owls tower over the peaceful valley of Estes Park, sparsely settled when this photograph was taken in 1916. These and other granite domes form because granite expands slightly when freed of overlying rock, causing a set of joints paralleling large exposed surfaces. Weathering processes then work along the joints, and freezing and thawing spall off curving slabs of rock.
W.T. LEE PHOTO, COURTESY OF USGS

Through Estes Park with its borders of high granite domes looks like a wide glacier-carved valley, it is below the lower limit of Ice-Age glaciation and is really a deep stream-eroded canyon like the one you have driven through, filled in with thick deposits of gravel and rock. Lake Estes, man-made, serves as a staging point for western-slope water brought by tunnel under Rocky Mountain Park and the Continental Divide to the eastern slope. The tunnel portals can be seen across the valley.

There are two east entrances to Rocky Mountain National Park. Stay on U.S. 34 for this itinerary, or take Colorado 66 to the Visitor Center and Moraine Park. The routes rejoin.

Above Estes Park, U.S. 34 is once more confined within a narrow canyon carved in Precambrian granite. In a few miles the canyon opens into a glacial valley almost precisely at the8000-foot elevation considered the lower limit of Pleistocene glaciation in Colorado. Three glacial stages are represented: You enter the valley across the lowest, oldest terminal moraine, so deeply weathered and decayed that it is hardly recognizable. Just below the checking station is a moraine from the second glacial episode, covered with gray-brown soil and dark with pines and spruce. The moraine of the last glacial age is half a mile beyond the checking station, where the highway curves and begins to climb. Note the sandy soil on this moraine and the fresh-looking boulders, probably deposited less than 10,000 years ago.

Horsehoe Park above this moraine became a lake as the last glacier melted; it is floored with lake-deposited mud and sand.

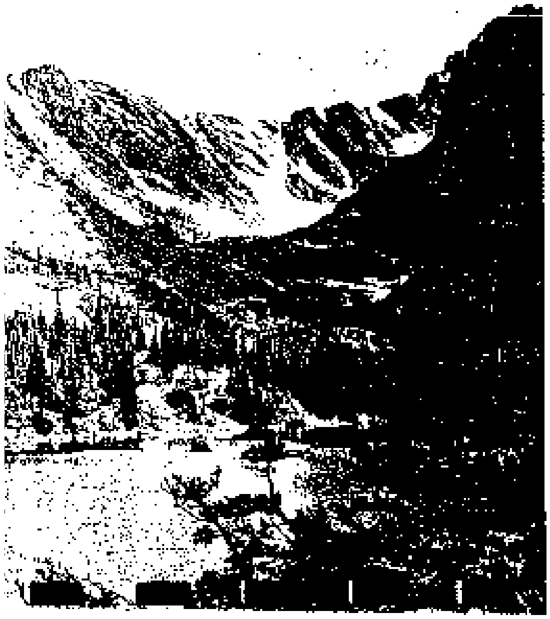
At the head of Horseshoe Park you can take the old Fall River Road (unpaved), following the nature guide available where it begins to climb. Many geologic features are described. Or continue on U.S. 34 with this itinerary. Routes rejoin at Fall River Pass.

As seen from the Fall River road, sediments deposited in moraine-dammed lakes flatten the floor of the U-shaped glacier-cut valley of Fall River.
JACK RATHBONE PHOTO

Beyond the junction with Colorado 66, U.S. 34 becomes. Trail Ridge Road, following an old Ute trail across line mountains. Views of Horseshoe Park and of Moraine Park to the south show that the trail climbs a narrow ridge between two broad glaciated valleys. Picture these green parks as they were 10,000 years ago, filled with creeping tongues of ice cut by arcuate crevasses and streaked with rock and sand, terminating at high-piled rocky moraines. Frigid winds blew downslope from icy peaks to the west, and little vegetation--only low-growing tundra plants and willows - grew near here.

Looking down on Fall River in Horseshoe Park you can see that it meanders now in tight loops on the flat valley floor, for there isn't much gradient to tell it which way is downhill. For more than a mile Horseshoe Park is hidden from view by a long lateral moraine (the one that also hides Hidden Valley).

The core of the Front Range exposed along Trail Ridge Road is mostly gneiss and schist, metamorphic rock like that in Big Thompson Canyon. In places it is intruded by younger granite. Granite forms Longs Peak towering to the south. Some geologists think that this peak's flat top is remnant of the flat erosion surface formed at the end of Precambrian time, 650 million years ago. (In Glenwood Canyon such a surface is covered directly by Cambrian rocks. Or the surface may have formed as the Ancestral Rocky Mountains were eroded away 275 million years ago.



Ice Age glaciers scooped out the cirque and U-shaped valley of Loch Vale in Rocky Mountain National Park.
JACK RATHBONE PHOTO

Above timberline along Trail Ridge Road, even today's climate is arctic. Trees cannot grow, and short-seasoned midsummer wildflowers toss in chilly winds. Freezing nights and frigid winters leave other marks: shattered rocks broken and tipped at drunk angles, barren jagged surfaces known as felfields, and patterned ground marked by constant frost-heaving of soil and stones.
W.T. LEE PHOTO, COURTESY OF USGS

As the highway climbs higher, many other glacial features become visible: a broad glaciated upland cut by glaciated cliffs; cirques, cirque lakes, and hanging valleys; even some small "living" glaciers, distinguished from snowfields by the lip-like piles of their terminal moraines.

From Forest Canyon Overlook, a five-minute walk, look down 2500 feet into Forest Canyon, a steep-walled glacially gouged trough. Before the Ice Ages, the Big Thompson River probably followed as tortuous a course here as in its lower reaches today. But glaciers have trouble negotiating turns, so they straighten the valleys in which they flow, grinding off spurs and smoothing curves.

Across the canyon little lakes stairstep up hanging valleys, filling hollows scooped from bedrock by now-vanished glaciers. At the head of Hayden Creek, named for a pioneer American geologist, an icefield nestles in a small cirque once occupied by a glacier.

Stop at Fall River Pass to look down into the cloverleaf cluster of three cirques that head Fall River Canyon. Exhibits in the Visitor Center explain many alpine geologic and biological features.

Northwest across the Cache LaPoudre Valley from Medicine Bow Curve rises red-tinted Specimen Mountain, the only remnant of a volcano in the park. It was active around 27 million years ago, and at that time was certainly much higher and probably much more conical. Soft yellowish ash from its eruptions is visible in roadcuts near Poudre Lake.

In this lake, biologic processes work today to accomplish geologic ends. Dammed by a moraine and a small beaver dam, the lake is filling with marsh grass and other vegetation and will eventually become a mountain meadow. The peat-like material that is filling it may someday become coal.

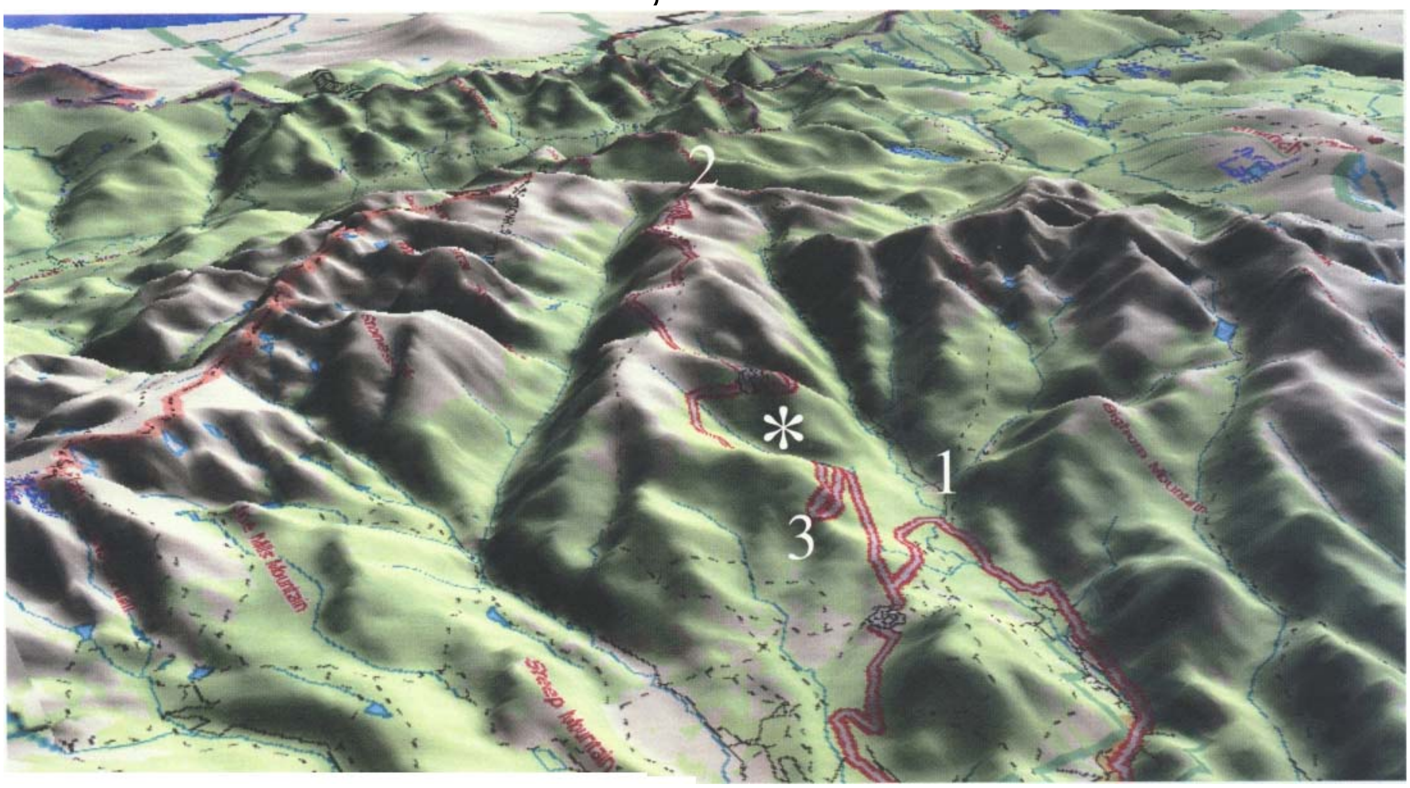
At Farview Curve, look down into the Kawuneeche Valley where the young Colorado River meanders lazily through a long, straight, glaciated valley occupied in Ice-Age time by a succession of glaciers. From glacial meltwater the stream gathered strength and sped southwest, joining other rivers and streams, to carve Glenwood Canyon, Glen Canyon, and ultimately Grand Canyon in Arizona. Across the valley decomposing igneous rocks in the Never Summer Range add a touch of brilliance to the landscape. Iron minerals cause the color, though there is not enough iron for profitable mining.

Grand Lake, half a mile east of the road, is a natural lake dammed by the lateral moraine of the former Kawuneeche Valley glacier and the terminal moraine of a glacier that came down Paradise Creek. Shadow Mountain Reservoir and Lake Granby, man-made reservoirs, store Colorado River water that is eventually tunneled to Lake Estes and east slope cities. Mountains west of the river here are topped with Tertiary volcanic rocks; they and broad, high river terraces bury most of the band of upturned sediments we would otherwise expect to find on this side of the Front Range.

INTRODUCTION TO THE PARK

Tour Stops in Rocky Mountain National Park

June 27, 2001



1. Lawn Lake
2. Alpine Visitors Center
3. Many Parks Curve

* Willow Park SNOTEL Site

WELCOME TO ROCKY MOUNTAIN NATIONAL PARK!

Four hundred fifteen square miles of rock-ribbed wildness, Rocky Mountain National Park truly is a land of superlatives.

Here, more than 110 of the peaks that soar above 10,000 feet elevation have names - Cirrus, Chiefs Head, Isolation, Mummy and Storm, to name just five. A few other high points remain unnamed, perhaps awaiting their turn.

At least 60 mountains in Rocky exceed 12,000 feet, topping off at 14,255 feet on the football field-sized summit of Longs Peak. The mountains provide Rocky Mountain National Park with its sense of wonder and inspiration. The great peaks comprise the essence of the "wild, fantastic views" that thrilled noted British visitor Isabella Bird more than a century ago.

Today, Rocky Mountain's sky-scraping summits overlook growing Front Range towns with surging populations. Each year, three million people visit the park, many driving its roads and hiking a trail system that if linked together, would stretch from Denver almost to Santa Fe. But despite the changes around and within, Rocky remains a bastion of preservation. And there's more to this park than the rocky pinnacles of great mountains.

There is the alpine tundra, the land above the trees. More than 100 square miles of the park lie above treeline. Trail Ridge Road and Old Fall River Road offer easy summer access to this windswept ecosystem where the views seem to span forever.

There also is the Continental Divide, which runs northwest to southeast through the park on its course from Alaska to Panama. Every drop of snowmelt or rainwater to the west of the Great Divide flows toward the Pacific Ocean; every drop to the east toward the Gulf of Mexico and the Atlantic Ocean.

There are lakes, about 150 of them. Some occupy pastoral, forested settings. Others are perched on almost inaccessible shelves high in the park's wilderness, remaining frozen almost year round.

Throughout Rocky Mountain National Park, the unforgettable sound of rushing mountain waters breaks the wilderness silence. The high country gives rise to small streams and great rivers, notably the Colorado, the Cache la Poudre and the Big Thompson. Some of the park's more than 450 miles of streams tumble down waterfalls, which bear such names as Ouzel, Timberline and Thunder.

Also preserved within the park boundaries are some of Colorado's more pristine forests. Great stands of ponderosa pine, Douglas-fir, lodgepole pine, aspen, subalpine fir and spruce adorn the mountains below treeline. The forests are interspersed with mountain meadows that fill with colorful wildflowers during the brief high country summer.

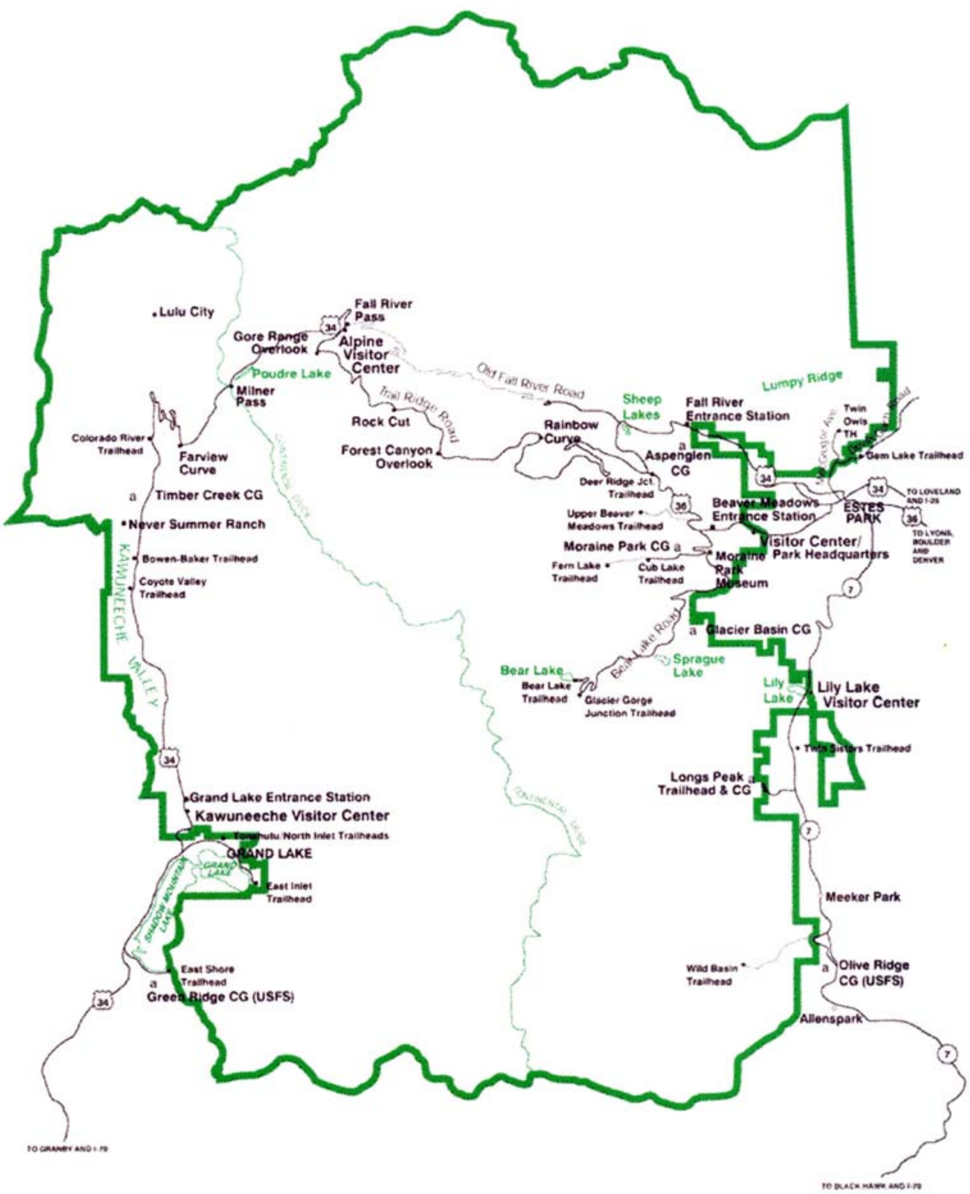
Roaming these mountains is an amazing array of wildlife. Rocky Mountain ranks as one of America's premier wildlife watching destinations, showcasing herds of majestic elk, sure-footed bighorn sheep, hardy ptarmigan and soaring birds of prey.

People, too, are a part of the Rocky Mountain National Park wilderness. Today, hikers walk trails once followed by Native American hunters centuries ago. Trappers sought beaver in streams throughout the region. The failed efforts of prospectors are remembered at the ghost town of Lulu City on the park's west side. The Moraine Park Museum and the Never Summer Ranch recall the early days of the tourism industry.

Today, nature reigns supreme in Rocky Mountain National Park, from the highest summits to the lowest valley floors. The park is a wild preserve where people - in their own special ways - experience nature in all its splendor. Rocky is a place where families enjoy picnics at the water's edge. It's a park where daring mountaineers pit their skills against vertical cliffs of granite.

No matter what you're seeking, those "wild, fantastic views" are out there awaiting discovery.

'ark Map


Lulu City
Fall River Pass
Gore Range Overlook
Alpine Visitor Center
Poudre Lake
Old Fall River Road
Milner Pass
Trail Ridge Road
Rock Cut
Forest Canyon Overlook
Rainbow Curve
Sheep Lakes
Fall River Entrance Station
Lumpy Ridge
Twin Owls TH
Gem Lake Trailhead
Colorado River Trailhead
Farview Curve
Timber Creek CG
Aspenglen CG
Deer Ridge Jct. Trailhead
Upper Beaver Meadows Trailhead
Beaver Meadows Entrance Station
ESTES PARK
TO LOVELAND AND I-25
TO LYONS, BOULDER AND DENVER
Never Summer Ranch
Moraine Park CG
Visitor Center/ Park Headquarters
Bowen-Baker Trailhead
Fern Lake Trailhead
Cub Lake Trailhead
Moraine Park Museum
Coyote Valley Trailhead
KAWUNEECHE VALLEY
Glacier Basin CG
Bear Lake Road
Sprague Lake
Bear Lake
Bear Lake Trailhead
Glacier Gorge Junction Trailhead
Lily Lake
Lily Lake Visitor Center
Twin Sisters Trailhead
Longs Peak Trailhead & CG
Grand Lake Entrance Station
Kawuneeche Visitor Center
Tonahutu/North Inlet Trailheads
GRAND LAKE
East Inlet Trailhead
Meeker Park
East Shore Trailhead
Green Ridge CG (USFS)
Wild Basin Trailhead
Olive Ridge CG (USFS)
Allenspark
TO GRANBY AND I-70
TO BLACK HAWK AND I-70

HISTORICAL ROCKY A GLIMPSE BACK IN TIME

Early Inhabitants

During the Ice Age when massive glaciers were grinding the landscape, shaping the meadows and peaks, Rocky was an inhospitable land. It was not until some 11,000 years ago that humans began venturing into its valleys and mountains.

Native Peoples

Spearheads broken in the fury of a mammoth's charge and scrapers discarded along a nomad's trail tell us little about the area's early native peoples. We do know that even though it was never their year-round home, the green valleys, tundra meadows, and crystal lakes became favored summer hunting grounds for the Ute tribe. In setting up their camps, they made use of the straight and slender lodgepole pine as tepee poles. Until the late 1700s, the Utes controlled the mountain territories. But the Arapaho, venturing west from the Great Plains in search of bigger game, drove the Utes beyond the Continental Divide.

Tepee rings and other signs of summer camps were still evident by the time the first settlers arrived, but few vestiges of those times remain today, other than the large river boulders that Native Americans carried to the top of Oldman Mountain, the site of their ceremonial vision quests.

Early Explorers and Settlers

The U.S. government acquired the park's original 358.5 square miles in the huge Louisiana Purchase of 1803. But French trappers and the Spanish explorers before them seem to have skirted the current park boundaries in their wilderness forays. Even Major Stephen H. Long and his expedition forces avoided these rugged barricades in 1820. Long was never closer than 40 miles to the peak named for him.

Published in 1843, *Scenes in the Rocky Mountains* described the explorations of Rufus Sage from Connecticut. It was the first account of Rocky's wonders to reach unbelieving easterners. Sage spent four years roaming the Rockies, basing his explorations from Fort Lupton, north of present-day Denver. For a month, Sage hunted deer in the area now known as Estes Park.

The first settler in the area was Joel Estes, a Kentuckian with wandering ways. Scouting for game one fall, he and his son climbed a high promontory that gave them a view of a breathtakingly beautiful valley. In 1860, Estes moved his family into a new home in the area now known as Estes Park. It is said that his wife Patsy swept the cabin's floor with the wings of eagles.

Winters proved too harsh for cattle, so six years later the Estes family sold out for a yoke of oxen. The Estes cabin was soon converted into guest accommodations in 1867, and from then on the number of visitors to this area grew steadily.

A Mountain Mecca

The Rockies continued to attract the adventurous, including the great explorer John Wesley Powell, who conquered the summit of Longs Peak in 1868. Just five years later, Anna Dickinson became the first woman to succeed in the climb.

Isabella Bird, an Englishwoman whose extensive travels and writings earned her the first female membership in the Royal Geographic Society, visited Estes Park in the fall of 1873. She fell in love with the area and, incidentally, with Jim Nugent, a well-educated mountain man whose violent death is shrouded in mystery. Bird's book, *A Lady's Life in the Rocky Mountains*, attracted many people to the area, as did Frederick Chapin's *Mountaineering in Colorado*. So while much of the West was attracting homesteaders, the Rockies were also establishing themselves as a tourist mecca.

About that time, an English earl, Lord Dunraven, arrived and laid questionable claim to 15,000 acres as his private game preserve. He also built the fine Estes Park Hotel.

By 1874, a stage line ran between Estes Park and Longmont by way of North Saint Vrain Canyon.

Miners and Homesteaders

Because large veins of silver and gold had been discovered in other areas of the Rockies, miners considered the area a land of opportunity and headed here in droves during Colorado's gold rush of the late 1870s. Lulu City, in what is now the northwest part of the park, in 1880 was a booming mining town with a raucous reputation. Three years later, it was nearly deserted because the region's mineral riches were far less than dreamed. It cost the area dearly.

When the miners and first settlers arrived, there seemed no end to the supply of game. Bear, deer, wolves, and elk were abundant. To feed the boom town demand, commercial hunters went to work. A single hunter could deliver a weekly supply of three tons of assorted big-game meat.

The rousing boom times yielded to an industrious homesteading period. Ranchers and farmers felt that the real wealth of the Rockies lay in its water. They fought over rights to it (finally running the greedy earl out of town) and built ambitious canal systems to transfer water from the wetter western slopes to the drier eastern plains. The Grand Ditch in the Never Summer Range in the park intercepted the stream source of the Colorado River and diverted it for use for cattle and crops. Though homesteading proved no more profitable than mining in this land, another new enterprise showed promise. Dude ranches began attracting city dwellers in quest of an original adventure.

Protecting the Rockies

In 1903, F. O. Stanley, inventor of the Stanley Steamer automobile, came to Estes Park for his health. Impressed by the beauty of the valley and grateful for the improvement in his health, he decided to invest his money and his future there. In 1909, he opened the elegant Stanley Hotel, a classic hostelry exemplifying the golden age of touring.

Rockies Geology

The diverse landscape at Rocky Mountain National Park, created over billions of years, displays some of nature's finest handiwork. Natural forces have created geologic features that provide a fascinating glimpse into the mysteries of the park's evolution and clues to the continuing changes that shape the future of this dynamic environment.

The park's geologic history contrasts sharply with strata of areas such as the Grand Canyon, where the deeper you go, the farther back in time you travel. At Rocky, some of the most ancient rocks lie atop the highest peaks, lifted thousands of feet by incredibly powerful mountain-building forces within the earth. Much of this ancient rock, however, has been removed from the mountaintops by various natural forces, including the powerful sculpting of massive glaciers. The glaciers were formed by huge snowdrifts, compacted into ice by their own great weight, and contained tons of loose rock temporarily frozen within. They slowly scraped and scoured the bedrock, chiseling mountain summits into peaks. The glaciers continued sliding down the slopes along pathways of steep, V-shaped canyons carved over millions of years by the steady flow of streams. The glaciers wore away the sides of some of these canyons, forming broad, U-shaped valleys.

Though the geologic origins of the park date back nearly two billion years, the shapes of the lofty peaks that characterize the park today are relatively young. The glaciers that gouged the granite faces of Longs Peak, Sundance Mountain, and Tanima Peak were formed approximately 10,000 to 15,000 years ago during the last major ice age.

About 13,000 years ago, rising temperatures brought about other changes. As the glaciers melted, the rocks they had carried were strewn along the edges and terminations of their paths, forming moraines, or ridges of rock debris. A terminal moraine, formed at the foot of a glacier, often creates a natural dam that obstructs the flow of winter runoff, creating lakes.

Through a natural process called eutrophication, sediment and organic material accumulate, and a moraine-dammed lake evolves into a meadow. Many of the park's meadows, such as Horseshoe Park and Moraine Park, are examples of this process.

Although the last major glacial period ended more than 10,000 years ago, remnants of five active glaciers remain in the park. Residing on north-facing slopes, they date back to the minor ice age that began about 4,000 years ago. Evidence of this recent glacial activity is most apparent today, but more ancient natural history is also visible.

The Roots of the Rockies

It is difficult to imagine that the Rocky Mountains were once underwater, but some two billion years ago, the entire area was covered by an ancient inland sea. Over time, various natural forces above and below the earth created the mountains we see today.

The transition from ocean to mountain range began when numerous rock and soil particles, worn away by weathering in neighboring lands, were carried by winds and rains into the sea. As particles accumulated on the sea bottom, they compacted into layers of sediment tens of thousands of feet thick. The sediment also included volcanic layers, which formed when lava flows invaded the seabed during a violent volcanic period.

Largely due to Stanley's efforts, the Estes Park Protective and Improvement Association was established to protect local wildflowers and wildlife and to improve roads and trails: "Those who pull flowers up by the roots will be condemned by all worthy people, and also by the Estes Park Protective and Improvement Association," they warned. It was the start of a conservation ethic that has become increasingly important and complex.

National Park Status

Even more important to the future of the area was Enos Mills, who came to the Longs Peak area in 1884 when he was 14 years old. A dedicated naturalist, he wrote eloquent books about the area's natural history. Not long after his arrival, Mills bought the Longs Peak Inn and began conducting local nature trips.

In 1909, Mills first proposed that the area become the nation's tenth national park to preserve the wildlands from inappropriate use. It was his vision that you would arrive here years later to experience the wonderful Rocky Mountain wilderness he knew. "In years to come when I am asleep beneath the pines, thousands of families will find rest and hope in this park," he proclaimed.

Unleashing his diverse talents and inexhaustible energy, he spent several years lecturing across the nation, writing thousands of letters and articles, and lobbying Congress to create a new park that would stretch from the Wyoming border south to Pikes Peak, covering more than 1,000 square miles. Most civic leaders supported the idea, as did the Denver Chamber of Commerce and the Colorado Mountain Club. In general, mining, logging, and agricultural interests opposed it. The compromise drafted by James G. Rogers, the first president of the Colorado Mountain Club, was the establishment of a smaller park (358.3 square miles). On January 26, 1915, under President Woodrow Wilson, it was declared Rocky Mountain National Park.

The park has since grown to more than 415 square miles. In 1990, it gained an additional 465 acres when Congress approved expansion of the park to include the area known as Lily Lake. The National Park Service, the Conservation Fund, and some diligent legislators successfully halted land development in this area adjacent to the park's boundary. It now is an important buffer zone that helps protect the migratory routes of wildlife in the park.

Today, the park stands as a legacy to those pioneers who looked beyond its harvestable resources to its more lasting values.

Sediments up to 15 miles deep underwent tremendous temperature and pressure changes. The layers hardened, crystallized, twisted, and transformed into metamorphic rock. These dark gray contorted bands of rock can be seen today along Trail Ridge Road and on the west side of the park.

Approximately one billion years ago, a huge mass of molten magma rose from beneath the older metamorphic rock layer. The magma "baked" into pink granite, forming the rock that is now typical of the east side of the park.

An extensive period of erosion followed, and by about 530 million years ago a sea covered the area. Over the next few million years, the same natural processes built mountains. As mountain streams cut through the layers of marine sediment, the area gradually became a vast island with 2,000-foot peaks about 100 miles from the sea. Approximately 250 million years ago, the peaks of these "Ancestral Rockies" were slowly reduced to low hills as erosion caused bedrock to break down into boulders, rocks, pebbles, and finally sand. Then the bordering plains were covered by huge sand dunes on which the area's first reptiles roamed.

Age of the Dinosaurs

At that time, dinosaurs appeared on the earth to dominate the landscape for the next 185 million years. During this "Age of the Dinosaurs," another uplift of land lowered the coastline, and the dunes receded with it. Broad floodplains between low mountains and the dunes became tropical plains inhabited by dinosaurs. The last seas continued to ebb and flow, until they finally began to drain away.

Today

The rise of the Rocky Mountains about 70 million years ago foreshadowed the demise of inland seas and signaled the end of the dinosaurs. The park's current mountain range dates back to that uplift, though ongoing mountain building and volcanic eruptions have shaped and refined the Rockies we know today. About 25 million years ago, the Never Summer Mountains on the west border of the park were the locus of three volcanic eruptions that spread lava and ash over the landscape. Much of that volcanic material has been eroded away, but traces are left in the northwest corner of the park at Specimen Mountain, Lava Cliffs, and Milner Pass on Trail Ridge Road.

Points of Interest

Longs Peak is the highest peak in the park, cresting at 14,255 feet. It can be seen from many vantage points on roads inside the park, as well as from many backcountry hiking trails. South of Estes Park on Hwy. 7 is a pullout area with a fine view of the east face, a 1,000-foot sheer cliff called the Diamond.

Trail Ridge Road takes you back in time on this route over the park's high mountain ridges. Here are remnants of the most ancient rocks in the park, recognizable by the marbled gray, white, and black bands of minerals in gneiss (pronounced "nice") and schist, which is darker and more finely grained.

Horseshoe Park is named for the glacial moraines (rock debris) that rim the valley in the shape of a horseshoe. A giant alluvial fan spreads into the upper end of Horseshoe Park, where the Lawn Lake Dam burst on July 15, 1982, sending a torrent of water and huge boulders down the Roaring Fork River.

Old Fall River Road is a one-way road from Endovalley to the Alpine Visitor Center. It crosses Chiquita Creek, where there is a good view of Hanging Valley. Geologists believe that this canyon and the Fall River Canyon were once on the same level. However, the carving action of the Fall River Glacier scraped the main gorge so deeply that the side canyon was left hanging high up on the wall. Across the creek, you can see pits in granite rock, ground out by the swirling waters of the glacier.

Glacier Gorge has one of the park's best examples of a classic glacier-carved, U-shaped valley, which is visible from Bear Lake and Fall River Valley. The sharp peak of The Spearhead in Glacier Gorge shows the results of glaciers moving down more than one side of a mountain. Moraine Park's long, wooded slope at its south edge is a classic example of the lateral moraine, rock rubble that forms at the side of a glacier. The area also provides good opportunities for short hikes.

Kawuneeche Valley is a long, broad glacial valley formed by water and ice erosion along a major fault zone. Looking south from Farview Curve, you can see the young Colorado River meandering along it. Over the past several hundred thousand years, the valley has been widened and its walls steepened by several glaciers fed from the Never Summer Mountains across the valley and the Milner Pass area. The Colorado gathers strength and speed here before flowing through Glenwood Canyon in Colorado, Glen Canyon in Arizona, and, ultimately, the Grand Canyon in Arizona.

Grand Ditch is a water diversion project located alongside the Never Summer Mountains. Construction was begun in 1890 and completed in 1936. The 16.2-mile system delivers an average of 20,000 feet of water annually over the Continental Divide to the eastern plains of Colorado.

ANNUAL CLIMATE CONDITIONS
ESTE S PARK & GRAND LAKE

The high country of Rocky Mountain National Park is noted for extreme weather patterns. Shaped by elevations, slope, and exposure, these patterns can change rapidly.

Temperatures are often moderate at elevations below 9,400' (2,865 m). At higher points, like Bear Lake, Trail Ridge Road, or Longs Peak, it may snow even in July.

A wide variation between day and nighttime temperatures is also typical of mountain weather.

Summer days in July and August often reach the 70's or 80's and drop into the 40's at night. All temperatures given are in Fahrenheit.

Based on ten years of precipitation data, Estes Park receives approximately 13.10" of moisture every year. Grand Lake receives about 19.95" yearly. This precipitation comes in the form of rain or snowfall through the year.

CLIMATE AND WEATHER WHAT'S A DIFFERENCE?

Climate is a general term to express broad patterns--for example. Colorado's climate is sunny with warm summers and cold winters.

Weather applies to specific movements of air masses, levels of precipitation, and temperature fluctuations at specific times of the year.

The Continental Divide runs northwest to southeast through the center of the park atop the high peaks. This accounts for two distinct weather patterns--one typical of the east side near Estes Park and the other associated with the Grand Lake area on the park's west side.

Winter
(December, January, February, March)

Lower elevations on the east slope of Rocky Mountain National Park are usually free of deep snow. At higher elevations, arctic conditions prevail. Sudden blizzards, high winds, and deep snowpack are common. The west side of the park experiences more snow, less wind, and clear cold days during these months.

Most high country overnight trips require gear suitable for -35 degrees or below. Skiing and snowshoeing conditions are best in January, February, and March.

Spring
(April and May)

Spring comes to the montane environs--elevations 8,000' to 9,500' (2,438 - 2,895 m)--in late April, although snowfall is not uncommon at this time of year. Unpredictable weather alternates between warm and cold, wet and dry.

In June, spring is just reaching

ESTES PARK (7,522')

	HIGH TEMP	LOW TEMP	PRECIP.	SNOW
January	39	16	0.37	4.6
February	41	17	0.45	6.3
March	45	21	0.86	7.8
April	53	27	1.28	3.8
May	62	34	2.02	0.5
June	73	41	1.76	0.1
July	78	46	2.21	0.0
August	77	45	1.86	0.0
September	70	38	1.17	0.5
October	60	30	0.81	1.0
November	46	23	0.60	3.8
December	40	18	0.47	5.7

the subalpine country -- 9,500' to 11,500' (2,895 - 3,505 m), while summer is on the plains. Wildflowers begin blooming at lower elevations in late April or early May. Many trails are still snow-covered. In late May, Trail Ridge Road opens for the season.

Summer

(June, July, August)

On the alpine tundra -- 11,500' to 13,000' (3,505 - 3,962 m) wildflowers bloom from late June to early August. Afternoon thunderstorms and wind are normal patterns. Always be prepared for temperature drops of 10-20 degrees Farenheit.

Fall

(September, October, November)

September and October bring clear, crisp air, blue skies, and generally dry weather. An early snowstorm may occur. Aspen leaves start changing colors in mid-September. Elk mating season begins in September and continues through most of October. Trail Ridge Road usually closes for the winter by mid-October.

GRAND LAKE (8,369')

	HIGH TEMP	LOW TEMP	PRECIP.	SNOW
January	31	2	1.68	29.6
February	35	4	1.43	22.5
March	40	10	1.54	19.5
April	49	19	1.88	16.8
May	59	27	1.94	4.7
June	70	33	1.60	0.4
July	75	37	2.06	0.0
August	74	36	2.08	0.0
September	67	29	1.64	1.1
October	57	22	1.28	5.9
November	40	12	1.33	18.9
December	32	3	1.66	27.5

THE ALPINE TUNDRA ECOSYSTEM

It may look barren--but look again! While standing in one spot you could touch a meadow, a marsh, or a rocky desert. Microclimates can spell success for a plant that takes root where a rock shelters it from wind. How many different communities can you recognize?

FELLFIELDS

These "fields of rock," lie on exposed slopes where winter winds blow away the snow. Water and soil are scarce, but lichens--crust-like plants that tolerate extremes of cold and drought--can grow on the rocks. The dominant plants take the shape of "cushions," hugging the ground to avoid wind. As dead leaves and soil collect within a cushion plant, less hardy plants may sprout in this fertile bed. In time, invading plants may replace the cushion, and a fellfield may become a meadow. Moss campion *(Silene acaulis)* is a common cushion plant at Rocky. Nearly half of Rocky's alpine plants grow in tundra lands throughout the northern hemisphere, including Moss campion.

SNOWBED COMMUNITIES

A distinct community forms where wind piles up snow. Late-melting snow shortens the growing season for plants beneath it, but insulates them in winter and yields a bonus of water in spring. Blossoms of the yellow snow buttercup *(Ranunculus adoneus)* often push up through the snow. Look for the snake-like casts of soil left by pocket gophers tunneling under the snow. The gophers eat plant roots. The soil they turn over makes a seedbed for flowers, which begins a new community, the "gopher garden."

ALPINE TURFS AND MEADOWS

Much of Rocky's alpine land is covered with dense turfs of sedges and grasses. Rich soils accumulated here support a bright diversity of wildflowers, whose colors peak in early July. The largest flower on the tundra, the alpine sunflower *(Rydbergia grandi flora)*, grows only in the Rocky Mountains. Its roots store solar energy from ten summers or more before blooming only once. Then the whole plant dies.

KRUMMHOLZ

Alpine tundra begins where trees give up the fight against cold, wind, and a short growing season. At Rocky, this happens near 11,500 feet (3505 m), marked by the low, wind-shaped spruce and fir trees called **krummholz** (German for "crooked wood"). Many of these small, twisted trees have battled over a thousand winters.

THE TREES OF ROCKY

As the Rocky Mountains lifted, erosional forces turned rock slowly into rich soil where plants and trees began to establish their presence. In harsh, mountain environments precipitation increases with elevation, winds become stronger, and the sun's intensity is greater due to the thin mountain air while temperatures decrease. In the Central Rocky Mountains, trees grow between 5500 ft.-11500 ft. (1650 m.-3450 m). At higher elevations trees are excluded by cold temperatures and at lower elevations dry conditions prohibit tree growth. Different tree species dominate areas depending on elevation, precipitation, and length of growing season. Only evergreen trees and a few, hearty deciduous trees thrive in a harsh mountain environment.

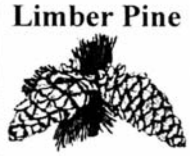
The Montane forest ecosystem, 5500 ft.-9000 ft. (1650 m.-2700 m.), consists of Ponderosa pine forests on warm south-facing slopes, and Douglas-fir forests on cooler, north-facing slopes. Aspen and Lodgepole pine are common, indicating areas of past disturbances from fire, windthrow, flooding, or logging.

Subalpine forests, 9000 ft. to 11500 ft. (2700 m.-3450 m.), are dense, moist communities composed of spire-like Engelmann spruce and Subalpine fir. Lodgepole pine and Aspen may be found in the lower subalpine, and Limber pine are often present throughout. The upper forest consists of spruce and firs that become wind-sculptured tree islands called krummholz.

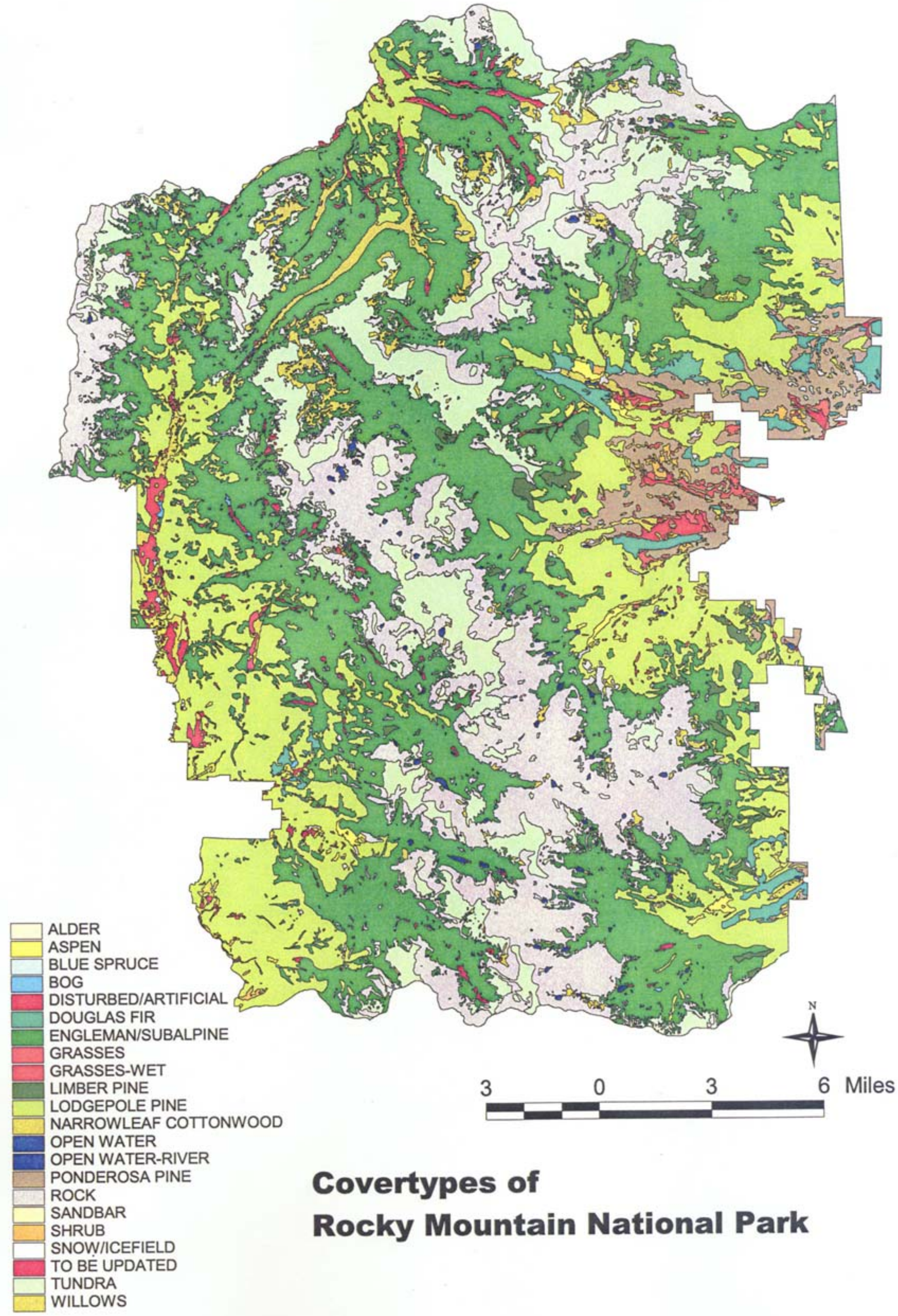
Riparian ecosystems appear as narrow bands of distinctive vegetation along ponds and streams. Blue spruce, Aspen, Narrowleaf cottonwoods, and shrubs dominate these areas. What follows is a list of the commonly found trees in the park and identification information.

Common Name	Scientific Name	Habitat	Characteristics
Ponderosa Pine 	*Pinus ponderosa*	Montane 5600 ft.-9500 ft. (1680 m.-2850 m.)	Mature trees large, with open rounded or flat-topped crown. Height to 100 ft., trunk massive, to 3 ft. diameter. Bark thick, reddish, with vanilla, or butterscotch scent. Needles 3 in. to 7 in. long, in bundles of 2 to 3. Female cones large, woody, with a short spine on each scale. Trees scattered or in clumps, generally uncrowded. Diverse understory, dominated by shrubs and grasses.
Douglas Fir 	*Pseudotsuga menziesii*	Montane 5500 ft.-9500 ft. (1650 m.-2850 m.)	Straight Christmas-tree shape with relatively dense foliage in crown. Height to approximately 100 ft., trunk diameter to 30 inches. Needles 1 in. long, flat, with a rounded tip and a short stalk attaching them to the twig. Female cones 2 in. to 3 in. long, with prominent three-pronged papery bracts protruding from between the cone scales. Relatively dense stands. Sparse understory.

Lodgepole Pine 	*Pinus contorta*	Montane and Subalpine 7800 ft.-11500 ft. (2340 m-3450 m.)	Trees in dense stands are tall and straight, with narrow crowns; in open sites, their crown is broader, resembling ponderosa. Height to approximately 90 ft., trunk diameter to 18 inches. Needles 1 in. to 2 in. long in bundles of two; more of a yellow-green color than those of other conifers. Female cones up to 2 in. long, many remaining closed and attached to the tree for many years. Stands often appearing even-aged, with most of the trees about the same size. Usually sparse understory. Trees in younger stands often nearly all lodgepole; older stands invaded by shade-tolerant spruce, subalpine fir, or Douglas fir.
Rocky Mountain Juniper or Red Cedar 	*Juniperus scopulorum*	Montane 5000 ft.-8000 ft. (1500 m.-2400 m.)	Shaped like pyramids with an irregular to slightly rounded crown. Height to approximately 16 ft. to 49 ft., trunk diameter up to 3.3 ft. Leaves small, scale-like occurring in pairs, pale-green to grayish-green. Cones appear as berry-like seeds, green or purple containing 1 to 3, usually 2 seeds. Bark is thin, reddish-brown to grayish, and scaly. Grows in rock areas, ridges, cliffs, and hillsides.
Quaking Aspen 	*Populus tremuloides*	Montane, Subalpine, and Riparian. 6000 ft.-10000 ft. (1800 m.-3000 m.)	Often grow in clumps or groves. Height 39 ft. to 100 ft., diameter to 23 in. or more. Broad, oval leaves with thin, flattened stem. Smooth, light-colored bark ranging from bone white to tan or greenish. Lush green understory compared to conifer forests. Older groves usually invaded by young conifers. The only common deciduous tree growing on mountain slopes away from riparian zones.
Narrowleaf Cottonwood 	*Populus angustifolia*	Riparian 5000 ft.-8000 ft. (1500 m.-2400 m.)	Small, slender tree with a narrow cone-shaped crown. Height to approximately 60 ft., trunk diameter to 1.6 ft. Leaves, alternate, 2 in. to 3.6 in. long, broadest near the middle tapering to a point, fine toothed along the margin. Bark is smooth, yellowish-green, becomes thicker on older trees with fissured ridges. Occurs along streams, margins of marshy areas, occasionally in roadside ditches.

Colorado Blue Spruce 	*Picea pungens*	Montane and Riparian 7000 ft.-9500 ft.(2100 m.-2850 m.)	Narrow, pyramidal and an open to dense, irregularly cone-shaped crown. Possible silver-blue color or green. Height from 65 ft. to 115 ft., trunk diameter 32 in. Needles rigid, sharp to the touch almost spine-tipped. Cones over 2.4 in. long; bluish color not obvious. Bark is gray and scaly. Occurs in small groves along streams and occasionally in mixed forests.
Englemann Spruce 	*Picea engelmannii*	Subalpine 9000 ft.-11500 ft. (2700 m.-3450 m.)	Straight trunk and dense crown having a narrow conical shape. Height to approximately 100 ft., trunk diameter to 30 in. Needles attached singly to twig, 1 in. long, 4 sided, with sharp tip. Bark in plate-like layers, relatively thin, reddish on protected side of tree, otherwise gray. Female cones 1 in. to 2 in. long with very papery scales, tan to reddish, mostly clustered in upper third of tree. Thick forest of tall trees with narrow crowns and a dark green color. Upper forest margins ragged and fragmented into wind-sculpted tree islands. Dense understory with immature spruces and firs usually abundant.
Subalpine Fir 	*Abies lasiocarpa*	Subalpine 9000 ft.-12000 ft.(2700 m.-3600 m.)	Crown often narrower, more spine-like than Engelmann spruce; foliage extremely dense. Height to approximately 80 ft., trunk diameter to 28 in. Needles attached singly to twig, flat, with rounded tips and soft to the touch; often arc upward so that the tips point skyward. Bark typically thin, smooth, and silvery, with horizontal markings; shallow, vertical furrows common on older bark.
Limber Pine 	*Pinus flexilis*	Subalpine 7000 ft.-11000 ft. (2340 m.-3450 m.)	Gnarled and twisted in windy sites; in more protected areas, crown broad, symmetrical and often flat-topped. Typically a small tree, 15 ft. to 30 ft. tall, with a trunk diameter to 18 in.; trees frequently with multiple trunks. Older bark gray and platelike; thin and smooth on younger branches, often with pinkish color at windy sites. Needles 1 in. to 2 in. long in bundles of four or five. Female cones large, often several inches long with thick, woody scales; cones bear seeds approximately 3/8 in. long in fall.

Sources: John Emerick's "Rocky Mountain National Park: Natural History Book", 1995, Robert Rinehart Publishers, Niwot, CO. John Emerick's "From Grasslands to Glacier", 1992, Johnson Printing, Boulder CO. Jack L. Carter's "Trees and Schrubs of Colorado", 1988, Johnson Books, Boulder, CO. Thomas S. Elias's "Trees of North America", 1987, Gramercy Publishing Company, New York, NY. Ruch Ashton Nelson's "Rocky Mountain Plants", 1992, Roberts Rinehart Publishers, Niwot, CO.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GRASSES-WET
LIMBER PINE
LODGEPOLE PINE
NARROWLEAF COTTONWOOD
OPEN WATER
OPEN WATER-RIVER
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Rocky Mountain National Park

Rocky Mountain National Park - Geology Information Needs

Glaciology of Long's Peak Boulder Field

Geologists and climbing guides have suggested that the Boulder Field may be a dry glacier, a bed of slowly moving ice disguised by a covering of talus and scree. In 1937, the 12-year old Boulder Field Inn had to be dynamited due to a two-foot wide crack that had spread through the building. Currently there are two privies and ten campground pits (with rock walls) at the Boulder Field. Information gained from core sampling and surface profiling may aid park engineers and managers in designing and using camping and toilet facilities at the Boulder Field. The academic answers to be discovered are also of value to park interpretation.

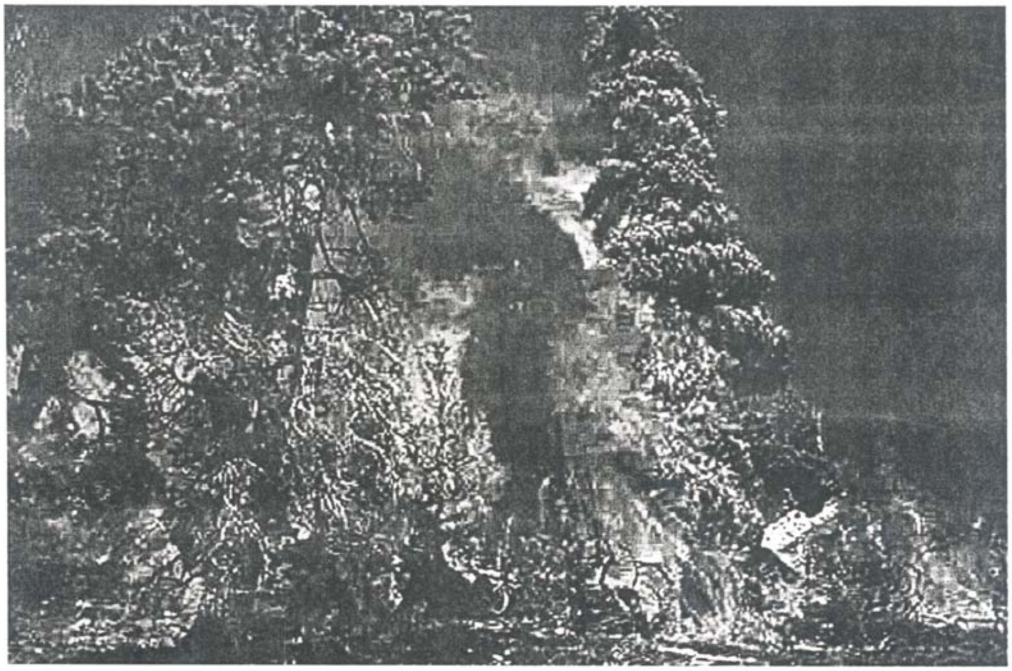
Conduct Geomorphological Investigations

Understanding the process and timing of the creation prehistoric and modern land forms are important for archeological, biological, and geological research. Unfortunately, the cycles of glaciation and related cut and fill episodes are sketchy, broadly described, lack fine scale definition, only roughly dated, drawn from areas outside the park, or are overly generalized.

The purpose of this project is for detailed studies along the major drainages from their respective high point(s), and in each park/valley on both sides of the park. It is expected that core samples will be taken and that the cores which will be subject to a complete soil/biotic analysis. The information derived from within the park will be compared with information from the surrounding area. A technical report and associated databases will be prepared. The report must be prepared in such a manner that individuals with no training or background in geomorphology will be able to understand and use the information derived.

The National Park Service

Fire Management at Rocky Mountain National Park



Fire has been an essential and natural part of the Rocky Mountain ecosystem for thousands of years. The fire management program at Rocky Mountain National Park encompasses approximately 182,596 acres that are susceptible to fire. The presence of fire within Rocky Mountain National Park habitats is one of the significant factors contributing to the perpetuation of plants, animals and healthy park ecosystems.

Lightning has always been, and remains, the main cause of wildland fires. But most lightning strikes do not ignite fires; rather they will smolder, then self-extinguish. On average, Rocky Mountain National Park experiences three to seven lightning caused fires each year.

Fire naturally thins the forest, recycles nutrients into the soil, releases seeds for new plant growth, and creates meadows. All of these are critical to forest health and natural cycles of growth and decomposition. Thanks to recent research in fire ecology we are now realizing that many plant and animal species actually benefit from the rejuvenating effects of fires burning regularly through their habitat. Without fire, forests would not be able to support the abundance of bird and mammal communities.

Despite the evidence that fire is a necessary element, over most of the past century people have feared and suppressed it whenever possible. As a result of this exclusion of fire, there has been an unnatural fuel buildup (downed or diseased trees, pine needles, and grasses) in our parks and forests. This now presents extreme hazards to the health of trees, soil, and wildlife, and to people living in these areas and to the taxpayer that has to pay for the fighting of catastrophic wildfires.

In order to help restore natural processes, the National Park Service has used and will to continue to use prescribed fires to reintroduce fire into the ecosystem where possible. Prescribed fire is the deliberate and carefully planned periodic burning of a selected site to reduce the risks of unnaturally heavy fuel buildup and the potential for devastating wildfires and the loss of life and property. In the past 5 years at Rocky Mountain National Park, the National Park Service has treated over 500 acres with prescribed burns. The National Park Service is also proactive in reducing hazardous fuel loads through prescribed burning and mechanical removal of fuel within the park's boundaries especially adjacent to private land and near park structures.

The overall program goad is to strengthen the concept of total fire management by increasing the safe and effective use of prescribed fire, maintaining and utilizing our strong fire suppression capabilities working closely with our neighboring agencies, and supporting mobilization of resources to wildland and prescribed fires. Firefighter and public safety are the highest priority in all fire management activities. Fire management is essential to protecting life and property, and is vital to the mission of the National Park Service at Rocky Mountain National Park.

Soil Survey of
Rocky Mountain National Park, Colorado

By Lee A. Neve, Natural Resources Conservation Service Field work by Dave Alstatt, Jim Borchert, Jodi Boyce, Lee A. Neve, Michael Petersen, Nathan Storck, Melissa Trenchik, and Tim Wheeler, Natural Resources Conservation Service; and Steve Blecker, Colorado State University. Quality assurance by Thomas Hahn.

United States Department of Agriculture, Natural Resources Conservation Service in cooperation with the United States Department of Interior, National Park Service; and Colorado State University

How This Survey Was Made

This survey was made to provide information about the soils and miscellaneous areas in the survey area. The information includes a description of the soils and miscellaneous areas and their location and a discussion of their suitability, limitations, and management for specified uses. Soil scientists observed the steepness, length, and shape of the slopes; the general pattern of drainage; the kinds of native plants; and the kinds of bedrock. They dug many holes to study the soil profile, which is the sequence of natural layers, or horizons, in a soil. The profile extends from the surface down into the unconsolidated material in which the soil formed. The unconsolidated material is devoid of roots and other living organisms and has not been changed by other biological activity.

The soils and miscellaneous areas in the survey area are in an orderly pattern that is related to the geology, landforms, relief, climate, and natural vegetation of the area. Each kind of soil and miscellaneous area is associated with a particular kind of landform or with a segment of the landform. By observing the soils and miscellaneous areas in the survey area and relating their position to specific segments of the landform, a soil scientist develops a concept or model of how they were formed. Thus, during mapping, this model enables the soil scientist to predict with a considerable degree of accuracy the kind of soil or miscellaneous area at a specific location on the landscape.

Commonly, individual soils on the landscape merge into one another as their characteristics gradually change. To construct an accurate soil map, however, soil scientists must determine the boundaries between the soils. They can observe only a limited number of soil profiles. Nevertheless, these observations, supplemented by an understanding of the soil-vegetation-landscape relationship, are sufficient to verify predictions of the kinds of soil in an area and to determine the boundaries.

Soil scientists recorded the characteristics of the soil profiles that they studied. They noted soil color, texture, size and shape of soil aggregates, kind and amount of rock fragments, distribution of plant roots, reaction, and other features that enable them to identify soils. After describing the soils in the survey area and determining their properties, the soil scientists assigned the soils to taxonomic classes (units). Taxonomic classes are concepts. Each taxonomic class has a set of soil characteristics with precisely defined limits. The classes are used as a basis for comparison to classify soils systematically. Soil taxonomy, the system of taxonomic classification used in the United States, is based mainly on the kind and character of soil properties and the arrangement of horizons within the profile. After the soil scientists classified and named the soils in the survey area, they compared the individual soils with similar soils in the same taxonomic class in other areas so that they could confirm data and assemble additional data based on experience and research.

While a soil survey is in progress, samples of some of the soils in the area generally are collected for laboratory analyses and for engineering tests. Soil scientists interpret the data from these analyses and tests as well as the field-observed characteristics and the soil properties to determine the expected behavior of the soils under different uses. Interpretations for all of the soils are field tested through observation of the soils in different uses and under different levels of management. Some interpretations are modified to fit local conditions, and some new interpretations are developed to meet local needs. Data are assembled from other sources, such as research information, production records, and field experience of specialists.

Predictions about soil behavior are based not only on soil properties but also on such variables as climate, geology, and biological activity (USDI-USGS, 1968). Soil conditions are predictable over long periods of time, but they are not predictable from year to year. For example, soil scientists can predict with a fairly high degree of accuracy that a given soil will have a high water table within certain depths in most years, but they cannot predict that a high water table will always be at a specific level in the soil on a specific date.

After soil scientists located and identified the significant natural bodies of soil in the survey area, they drew the boundaries of these bodies on aerial photographs and identified each as a specific map unit. Aerial photographs show trees, buildings, fields, roads, and rivers, all of which help in locating boundaries accurately.

This survey area was mapped at two levels of detail. At the more detailed level, map units are narrowly defined. Map unit boundaries were plotted and verified at closely spaced intervals. At the less detailed level, map units are broadly defined. Boundaries were plotted and verified at wider intervals. The detail of mapping was selected to meet the anticipated long-term use of the survey, and the map units were designed to meet the needs for that use.

Conventional soil survey techniques were used for the more detailed level of mapping. Much of the area mapped at this level includes important wetlands and valley areas that are intensively used. These areas were accessible and could be transected efficiently on foot. Soil survey techniques used at the less detailed level were quite different, largely because of the remote and poorly accessible topography. Specially designed geostatistical methods were employed for this area (Cipra, Neve, Petersen, and Wheeler, 1999).

The geostatistical methods were based on data gathered from block transects that were delineated on aerial photographs prior to the fieldwork. These areas were carefully selected to represent significant landforms, aspects, and plant communities. An individual block had dimensions at the ground surface of 1,000 feet by 2,000 feet and was oriented lengthwise downslope. Each block contained five soil description sites and four satellite sites, each of which was randomly located. The five soil description sites comprised one complete pedon described to a depth of 60 inches, and four pedons described to a depth of 30 to 40 inches (or to a root-limiting layer if above those depths). Standard soil pedon data was collected at the five soil description sites, including texture, consistence, pH, horizons, rock fragment content, slope, aspect, parent material, surface layer organic matter content, and vegetation. At the four satellite sites, vegetation, surface layer organic matter content, slope, aspect, and parent material were described.

All soil description sites in the blocks were geographically referenced using global positioning systems and recorded in Universal Transverse Mercator units (UTMs). Data recorded in the blocks allowed soil scientists to identify the typical soils and to describe the composition of the map units. The information was given to Colorado State University and a geostatistical model was developed to analyze the data and provide maps of projected soil components on landforms. The projections were used as a tool to complete mapping in areas that could not be traversed efficiently on foot. Helicopters were used to great advantage in some areas to verify the soil map units that had been predicted by the geostatistical model.

Species of native plants were identified by soil scientists at the sample sites within the block transects. After the vegetative data was compiled, the representative plant community of each soil was correlated to an ecological site described in the U.S. Forest Service system “Plant Associations Of Region Two” (USDA- Forest Service, 1987). A thorough and systematic inventory of the vegetation was beyond the scope of this soil survey. Plant specialists or ecologists were not directly involved in identifying or in correlating the vegetation.

General Soil Properties, Rocky Mountain National Park

The formation of the soils of Rocky Mountain National Park has been strongly influenced by landform and climate. There is a wide range in soil properties from the warmer and drier valleys to the high elevation tundra.

Soils of the low elevation valleys are generally very deep, loamy, and particularly on the east side of the Park, have mollic epipedons. In the floodplains they are poorly or very poorly drained with stratified textures. On stream terraces they are well drained. They formed in alluvium from the nearby mountains.

Soils of the glacial moraines are very deep, well or somewhat excessively drained, and loamy or sandy with a high content of rock fragments. They formed in till derived mainly from granite, gneiss, and schist.

Soils of the subalpine mountain slopes are generally well or somewhat excessively drained, loamy with a high content of rock fragments, and have ochric epipedons. Depth to the underlying bedrock ranges from shallow to very deep. Typically soil reaction becomes more acid with increasing elevation, as the climate becomes cooler and more moist. These soils formed mainly in material weathered from granite, gneiss, and schist.

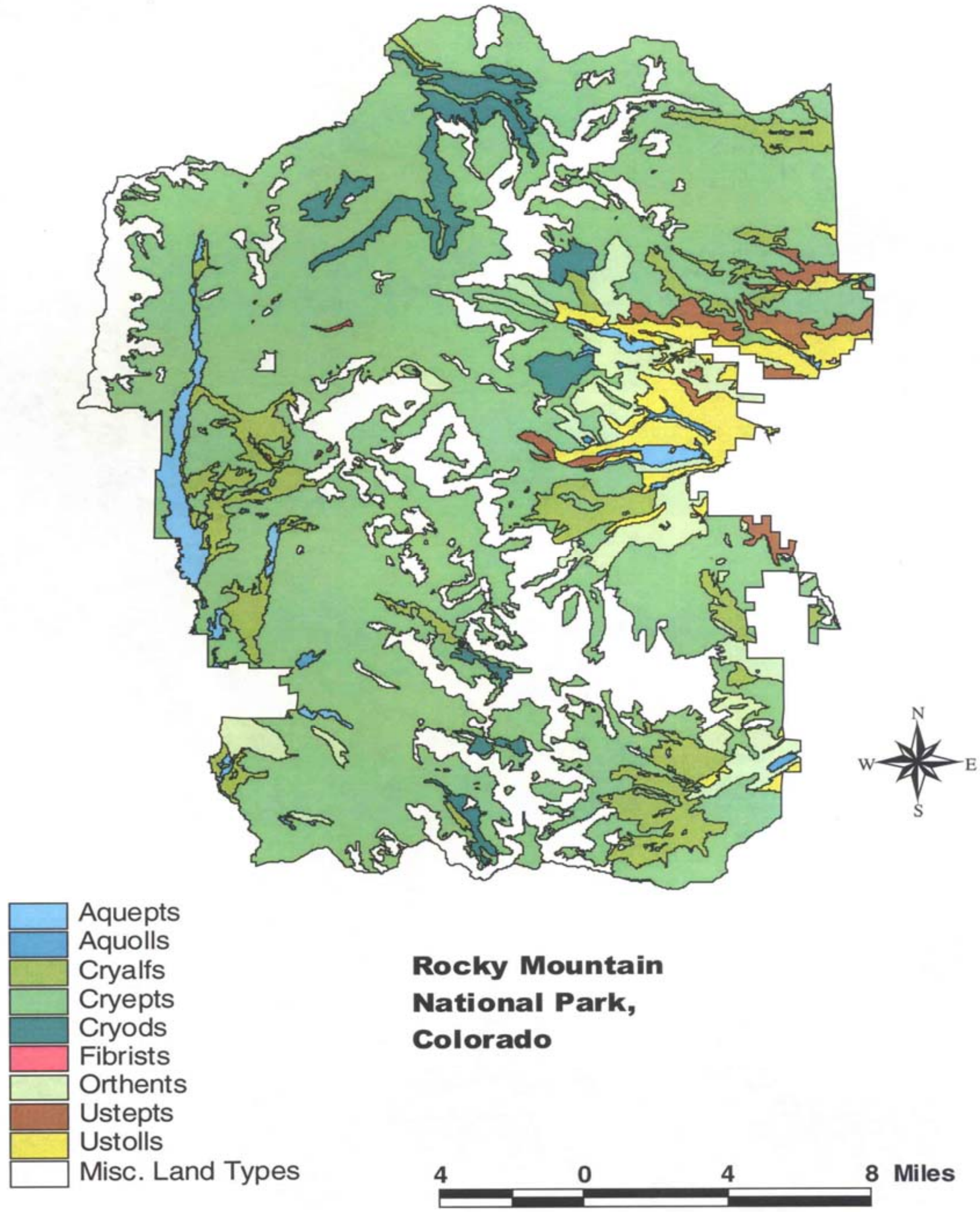
Soils of the alpine mountains and ridges are generally well drained, loamy with a high content of rock fragments, strongly acid, and have umbric epipedons. These soils formed mainly in material weathered from granite, gneiss, and schist. Poorly drained soils are common in landscape depressions and drainageways.

Relationships Between Soil Moisture/Temperature Regimes and Vegetation

Temperature Regime	Moisture Regime Subclass	Elevation Range (feet)	Average Annual Precipitation (in)	Potential Native Vegetation 1/
Cryic	Typic Udic	9,000 – 12,500	24 - 40	Alpine clover/golden avens, Kobresia/golden avens/rock sedge, Subalpine fir-Engelmann’s spruce/grouse whortleberry
Cryic	Ustic Udic	8,000 - 10,000	16 - 24	Lodgepole pine/kinnickinnick, Lodgepole pine/common juniper Lodgepole pine/elk sedge
Frigid	Typic Ustic	7,500 – 9,100	16 - 22	Ponderosa pine-Rocky Mountain Douglas fir/mountain muhly, Ponderosa pine/mountain muhly, Ponderosa pine/antelope bitterbrush, Needleandthread/mountain muhly

1/ As identified and defined in “Plant Associations of Region Two”, USDA-Forest Service, 1987, Edition 4.

Dominant Soil Suborders



Rocky Mountain National Park, Colorado

Representative Soil Series of the Subalpine and Alpine Zones in Rocky Mountain National Park
Thomas Hahn, Soil Data Quality Specialist, NRCS, Lakewood, Colorado

The soil series described in the following sections represent the primary pedogenic features of the alpine and subalpine zones of Rocky Mountain National Park.

The **Fallriver series** is the most extensive soil in the subalpine zone. It formed under a dense coniferous forest, mainly of Engelmann's spruce and subalpine fir. The forest vegetation does not favor accumulation of organic carbon in the surface layers, and an ochric epipedon results. The sandy textures of the parent materials and the high average annual precipitation promoted intensive leaching of basic cations, hence these soils are acid. Clay illuviation is not evident. The climate has promoted weathering of iron and aluminum oxides, which have accumulated in the subsoil. These accumulations are not sufficient for a spodic horizon, however.

The **Ypsilon series** is not as extensive as Fallriver, but is significant because it represents the next step of pedogenesis. The Ypsilon series is very similar to Fallriver, but its horizons are more strongly expressed. Albic and spodic horizons formed in this soil. It formed on landform positions that are slightly cooler and more moist, commonly on north- and east-facing mountain slopes.

The **Mummy series** typifies soil development in the alpine tundra. The grass and forb vegetation and the cold soil temperatures favor the accumulation of organic matter in the surface horizons and result in an umbric epipedon. This soil is strongly leached and base saturation is low. As in the forested Fallriver and Ypsilon, illuvial clay has not accumulated significantly. Accumulations of sesquioxides are not sufficient for a spodic horizon.

Fallriver Series

Depth class: Very deep
Drainage class: Somewhat excessively drained
Parent material: Till and colluvium from granite, gneiss, and schist
Landform: Glaciated mountain slopes and moraines
Landform position: Backslopes and footslopes
Slope: 10 to 55 percent
Elevation: 9,000 to 11,800 feet
Average annual precipitation: 24 to 40 inches
Average annual air temperature: 36 to 40 degrees F
Frost-free period: 20 to 50 days

Taxonomic class: Loamy-skeletal, isotic Typic Dystrocryepts

Typical pedon

Fallriver extremely cobbly sandy loam, in an area of Fallriver extremely cobbly sandy loam, 10 to 45 percent slopes, about 3.6 miles north of Grand Lake in Rocky Mountain National Park; USGS Allens Park topographic quadrangle; latitude 40 degrees, 18 minutes, 08 seconds, N; longitude 105 degrees, 49 minutes, 11 seconds W, NAD 1927.

Oe--0 to 2 inches; moderately decomposed plant material.

E2--14 to 19 inches; light gray (10YR 7/2) very cobbly coarse sandy loam, dark grayish brown (10YR 4/2) moist; weak medium subangular blocky structure; soft, very friable, nonsticky and nonplastic; few coarse and medium and many very fine and fine roots; 25 percent gravel and 15 percent cobbles; very strongly acid (pH 4.8); clear wavy boundary.

Bs1--19 to 24 inches; brown (7.5YR 5/4) very cobbly coarse sandy loam, strong brown (7.5YR 4/6) moist; weak medium subangular blocky structure; very hard, firm, moderately cemented by iron, brittle, slightly sticky and nonplastic; few medium and coarse and common fine roots; common distinct continuous iron stains on faces of peds; 20 percent gravel and 15 percent cobbles and 5 percent stones; very strongly acid (pH 4.8); gradual smooth boundary.

Bs2--24 to 35 inches; brown (7.5YR 5/4) extremely stony sandy loam, brown (7.5YR 4/4) moist; weak coarse subangular blocky and moderate fine subangular blocky structure; hard, firm, weakly cemented by iron, brittle, slightly sticky and slightly plastic; few fine to coarse roots; few distinct continuous iron stains on faces of peds; 20 percent gravel and 25 percent cobbles and 30 percent stones; very strongly acid (pH 4.7); gradual smooth boundary.

BC--35 to 67 inches; light yellowish brown (10YR 6/4) extremely cobbly loamy coarse sand, dark yellowish brown (10YR 4/4) moist; massive; hard, very friable, nonsticky and nonplastic; few medium roots; 20 percent gravel and 30 percent cobbles and 10 percent stones; very strongly acid (pH 4.7).

Selected NSSL Data for the Ypsilon series (from the above pedon)

Horizo n	Depth (cm)	Organic Carbon	*pH (1:1) H_2O*	*Oxalate Extractable*			*CEC (NH_4OAc)*	Base Sat.
				Al+1/2Fe	*Al*	*Fe*		
E1	16 – 35	.75	4.2	0.10	0.08	0.05	9.4	32
E2	35 – 47	1.17	4.4	0.34	0.18	0.31	12.2	15
Bs1	47 – 76	1.38	4.8	0.62	0.36	0.51	11.7	18
Bs2	76 – 104	1.33	4.9	0.67	0.43	0.48	12.0	20
BC	104 - 168	.65	5.0	0.42	0.31	0.22	4.7	36

Mummy Series

Depth class: Very deep
Drainage class: Somewhat excessively drained
Parent material: Colluvium and till from granite, gneiss, and schist
Landform: Mountains
Landform position: Footslopes and backslopes
Slope: 10 to 60 percent
Elevation: 10,400 to 12,200 feet
Average annual precipitation: 30 to 40 inches
Average annual air temperature: 34 to 38 degrees F
Frost-free period: 10 to 30 days

Taxonomic class: Loamy-skeletal, paramicaceous Humic Dystrocryepts

E--2 to 9 inches; light gray (10YR 7/2) gravelly sandy loam, grayish brown (10YR 5/2) moist; weak fine granular structure; soft, very friable, slightly sticky and nonplastic; many fine to coarse roots; 20 percent gravel and 5 percent cobbles; very strongly acid (pH 4.6); abrupt smooth boundary.

Bs1--9 to 21 inches; light yellowish brown (10YR 6/4) very cobbly sandy loam, yellowish brown (10YR 5/4) moist; moderate fine and medium subangular blocky structure; slightly hard, very friable, slightly sticky and slightly plastic; common very fine roots and few fine roots; few faint patchy clay films on faces of peds; few faint patchy iron stains on faces of peds; 20 percent gravel and 30 percent cobbles and 5 percent stones; very strongly acid (pH 4.8); clear smooth boundary.

Bs2--21 to 35 inches; brown (7.5YR 5/4) very cobbly sandy loam, brown (7.5YR 4/4) moist; moderate medium subangular blocky structure; hard, friable, slightly sticky and slightly plastic; few fine roots; few faint patchy clay films on faces of peds; common distinct continuous iron stains on faces of peds; 20 percent gravel and 30 percent cobbles and 5 percent stones; very strongly acid (pH 4.8); clear smooth boundary.

BC--35 to 63 inches; light yellowish brown (10YR 6/4) very gravelly coarse sandy loam, dark yellowish brown (10YR 4/4) moist; weak fine subangular blocky structure; soft, very friable, slightly sticky and nonplastic; 40 percent gravel and 10 percent cobbles; moderately acid (pH 5.6).

Ypsilon Series

Depth class: Very deep
Drainage class: Somewhat excessively drained
Parent material: Colluvium and till derived from granite, gneiss, and schist
Landform: Glaciated mountain slopes and moraines
Landform position: Backslopes and footslopes
Elevation: 9,700 to 11,000 feet
Slope: 20 to 50 percent
Average annual precipitation: 30 to 40 inches
Average annual air temperature: 35 to 38 degrees F
Frost-free season: 20 to 50 days

Taxonomic class: Loamy-skeletal, isotic Typic Haplocryods

Typical pedon

Ypsilon gravelly sandy loam, in an area of Ypsilon gravelly sandy loam, 20 to 50 percent slopes, about 1.1 miles south of Rainbow Curve in Rocky Mountain National Park; USGS Trailridge topographical quadrangle; latitude 40 degrees, 23 minutes, 04 seconds N; longitude 105 degrees, 39 minutes, 49 seconds W, NAD 1927.

Oe—0 to 6 inches; moderately decomposed plant material

E1—6 to 14 inches; light gray (10YR 7/2) gravelly coarse sandy loam, dark grayish brown (10YR 4/2) moist; moderate fine and medium granular structure; soft, very friable, slightly sticky and slightly plastic; common fine and medium and many very fine and few coarse roots; 20 percent gravel and 2 percent cobbles; very strongly acid (pH 4.9); clear wavy boundary.

Typical pedon

Mummy extremely cobbly sandy loam, in an area of Mummy extremely cobbly sandy loam, 20 to 50 percent slopes, about 1.8 miles southeast of Fall River Pass in Rocky Mountain National Park; USGS Trail Ridge topographic quadrangle; latitude 40 degrees, 24 minutes, 24 seconds N; longitude 105 degrees, 42 minutes, 04 seconds W, NAD 1927.

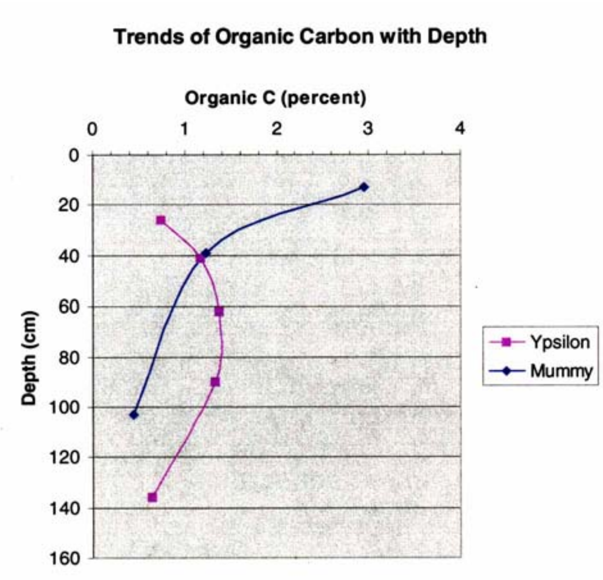
A--0 to 5 inches; dark grayish brown (10YR 4/2) extremely cobbly sandy loam, very dark brown (10YR 2/2) moist; weak fine granular structure; soft, very friable, slightly sticky and nonplastic; many very fine and fine and common medium roots; 15 percent gravel and 30 percent cobbles and 20 percent stones; very strongly acid (pH 4.8); abrupt wavy boundary.

Bw1--5 to 24 inches; brown (10YR 5/3) extremely cobbly sandy loam, dark brown (10YR 3/3) moist; weak fine subangular blocky structure; soft, very friable, slightly sticky and nonplastic; common very fine and fine and few medium roots; 15 percent gravel, 30 percent cobbles and 20 percent stones; strongly acid (pH 5.4); clear smooth boundary.

Bw2--24 to 72 inches; yellowish brown (10YR 5/4) extremely cobbly sandy loam, dark yellowish brown (10YR 3/4) moist; weak fine subangular blocky structure; soft, very friable, nonsticky and nonplastic; common very fine and fine and few medium roots; 20 percent gravel and 30 percent cobbles and 10 percent stones; strongly acid (pH 5.2).

Selected NSSL Data for the Mummy series (not from the above pedon)

Horizon	Depth (cm)	Org. Carbon	*pH (1:1) H_2O*	Base Sat. (NH_4OAc)	*Oxalate Al+1/2Fe*	*CEC (NH_4OAc)*	*Extractable Acidity*
A	0 – 25	2.95	4.2	16	0.58	18.9	11.3
Bw1	25 – 53	1.24	4.7	18	0.70	14.3	10.9
Bw2	53 – 152	.45	5.0	13	0.48	10.3	



Rocky Mountain National Park - Geology Information Needs

Glaciology of Long's Peak Boulder Field

Geologists and climbing guides have suggested that the Boulder Field may be a dry glacier, a bed of slowly moving ice disguised by a covering of talus and scree. In 1937, the 12-year old Boulder Field Inn had to be dynamited due to a two-foot wide crack that had spread through the building. Currently there are two privies and ten campground pits (with rock walls) at the Boulder Field. Information gained from core sampling and surface profiling may aid park engineers and managers in designing and using camping and toilet facilities at the Boulder Field. The academic answers to be discovered are also of value to park interpretation.

Conduct Geomorphological Investigations

Understanding the process and timing of the creation prehistoric and modern land forms are important for archeological, biological, and geological research. Unfortunately, the cycles of glaciation and related cut and fill episodes are sketchy, broadly described, lack fine scale definition, only roughly dated, drawn from areas outside the park, or are overly generalized.

The purpose of this project is for detailed studies along the major drainages from their respective high point(s), and in each park/valley on both sides of the park. It is expected that core samples will be taken and that the cores which will be subject to a complete soil/biotic analysis. The information derived from within the park will be compared with information from the surrounding area. A technical report and associated databases will be prepared. The report must be prepared in such a manner that individuals with no training or background in geomorphology will be able to understand and use the information derived.

THE ALPINE TUNDRA ECOSYSTEM

It may look barren--but look again! While standing in one spot you could touch a meadow, a marsh, or a rocky desert. Microclimates can spell success for a plant that takes root where a rock shelters it from wind. How many different communities can you recognize?

FELLFIELDS
These "fields of rock," lie on exposed slopes where winter winds blow away the snow. Water and soil are scarce, but **lichens**--crust-like plants that tolerate extremes of cold and drought--can grow on the rocks. The dominant plants take the shape of "cushions," hugging the ground to avoid wind. As dead leaves and soil collect within a cushion plant, less hardy plants may sprout in this fertile bed. In time, invading plants may replace the cushion, and a fellfield may become a meadow. **Moss campion** *(Silene acaulis)* is a common cushion plant at Rocky. Nearly half of Rocky's alpine plants grow in tundra lands throughout the northern hemisphere, including Moss campion.

SNOWBED COMMUNITIES
A distinct community forms where wind piles up snow. Late-melting snow shortens the growing season for plants beneath it, but insulates them in winter and yields a bonus of water in spring. Blossoms of the yellow **snow buttercup** *(Ranunculus adoneus)* often push up through the snow. Look for the snake-like casts of soil left by **pocket gophers** tunneling under the snow. The gophers eat plant roots. The soil they turn over makes a seedbed for flowers, which begins a new community, the "gopher garden."

ALPINE TURFS AND MEADOWS
Much of Rocky's alpine land is covered with dense turfs of sedges and grasses. Rich soils accumulated here support a bright diversity of wildflowers, whose colors peak in early July. The largest flower on the tundra, the **alpine sunflower** *(Rydbergia grandiflora)*, grows only in the Rocky Mountains. Its roots store solar energy from ten summers or more before blooming only once. Then the whole plant dies.

KRUMMHOLZ
Alpine tundra begins where trees give up the fight against cold, wind, and a short growing season. At Rocky, this happens near 11,500 feet (3505 m), marked by the low, wind-shaped spruce and fir trees called **krummholz** (German for "crooked wood"). Many of these small, twisted trees have battled over a thousand winters.

PEDOLOGY AND BIGEOCHEMISTRY RESEARCH IN ROCKY MOUNTAIN NATIONAL PARK

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THE $\delta^{18}O$ OF SOIL-RESPIRED CO_2: ISOTOPIC EQUILIBRATION BETWEEN SOIL WATER AND SOIL CO_2

Abstract. Soil respired CO_2 is an important influence on the carbon and oxygen isotopic composition of the atmosphere. The oxygen isotopic composition of this flux can be used to partition gross primary productivity and ecosystem respiration, thereby lending insight to patterns of ecosystem response in time and space and in response to environmental disturbances. We explored the connection between the depth profile of soil water $\delta^{18}O$ and soil CO_2 $\delta^{18}O$ in the field and used a soil diffusion and isotopic equilibration model to calculate the oxygen isotope composition of the CO_2 flux from soil to the atmosphere. Work presented here suggests that soil CO_2 and soil water are sometimes, but not always, in complete isotopic equilibrium, and that the expressed, or "effective" fractionation factor varies as a function of local conditions (from 3.40 to 7.47‰ at the sites studied). Model sensitivity to input was explored, and model output compared to estimates based on large-scale patterns in rainfall as well as to an empirical formulation that does not allow diffusive fractionation to vary with soil conditions. Seasonal average values of the isotopic composition of soil-respired CO_2 were 34.20‰ from the shortgrass steppe sites, 30.27‰ from the lodgepole pine sites, and 27.50‰ from the tundra sites studied. Estimates of ^{18}O in soil respired CO_2 based on a method that does not take into account the competition between equilibration and diffusion deviate significantly from the composition as computed with a full equilibrium-diffusion model. Further, the full diffusion-equilibration model is needed to capture temporal variability in the isotopic composition of the soil flux, which was 8‰ over the course of the growing season at a single location.

CARBON CYCLING IN TERRESTRIAL ECOSYSTEMS

The carbon cycle is a key link between human activities and our environment. When the carbon cycle is altered through fossil fuel use, the climate system responds with implications for plant and animal well-being. Figure 1 shows the relative sizes of the global stocks of carbon that interact on annual to decadal time scales.

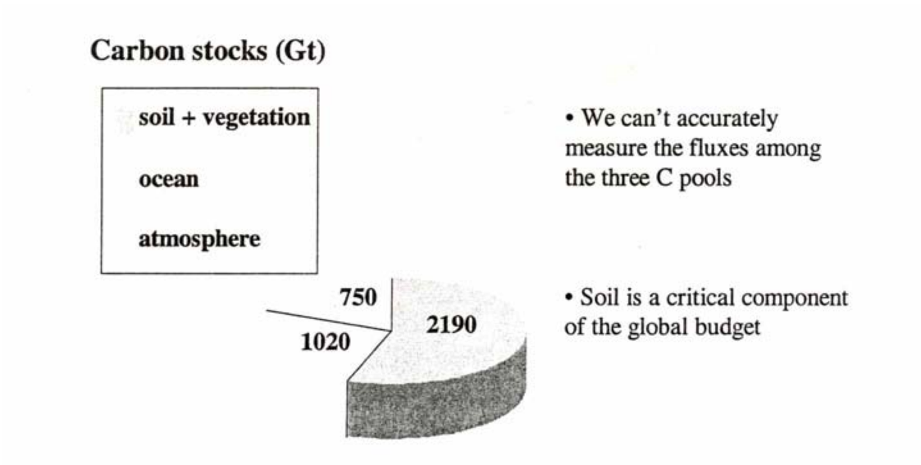


Figure 1. The three components of the short-term carbon cycle. Pie wedges indicate size of pools in Gt (10^{15} g) carbon.

The deep ocean is not included in this figure because it interacts with the atmosphere only on time scales of hundreds to thousands of years. The amount of carbon stored in terrestrial systems, 72% of which is in soils, is over twice that stored in the mixed-layer of the world's oceans, and is nearly three-times more than the amount of carbon in the atmosphere. The fluxes, or transfers, among these three pools cannot yet be accurately measured, but only about half of the carbon emitted every year as a result of fossil fuel consumption and cement manufacture ends up in the atmosphere. The other portion of the emitted carbon (roughly 3.5 Gt, or 10^9 metric tons) enters either the terrestrial or oceanic system. Recently, the use of the ratio of oxygen to nitrogen and $\delta^{13}C$ composition of the atmosphere have allowed quantification of the proportion of emitted carbon entering land versus the ocean. Data suggest that the proportion going to each of these systems changes as a result of changing environmental conditions. The response of soils in particular is critical, because not only do soils store large amounts of carbon, but they are sensitive to changes in temperature and moisture conditions.

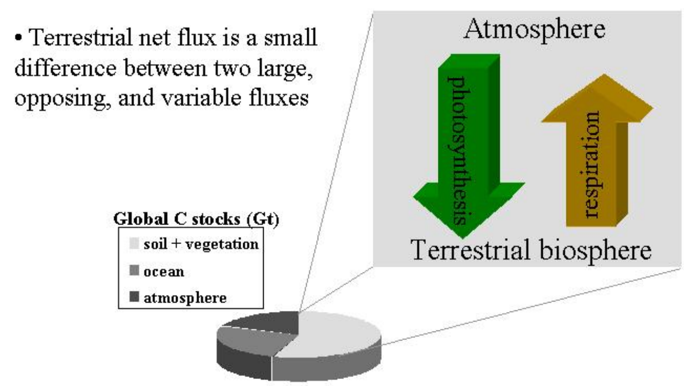


Figure 2. The exchange of carbon between the terrestrial biosphere and the atmosphere. The imbalance between the gross fluxes of photosynthesis and respiration influences the amount of carbon in the atmosphere.

Figure 2 magnifies the terrestrial portion of the global carbon cycle. The gross fluxes of uptake (photosynthesis) and release (respiration) are very large and are not perfectly balanced. Under any given set of environmental conditions in a particular region, the difference can mean a net flux to the atmosphere or net uptake from the atmosphere. It is this net difference between uptake and release that affects the amount of carbon stored in the atmosphere. In order to understand the net exchange of carbon between the terrestrial system and the atmosphere, and in order to make accurate projections about the future size of the atmospheric carbon pool, we must separate the effects of changing environmental conditions on carbon uptake and release by terrestrial systems. Two tools are currently available to do this: eddy covariance, which measures uptake and release at the stand scale, and a direct tracer of CO_2 and water fluxes, ^{18}O.

Site Locations: Six field sites located along the Front Range of the Rocky Mountains in Colorado were selected to represent three separate ecosystems and two soil textures. All other factors considered instrumental in influencing soil properties (aspect, topographic position, and age of parent material) were held as constant as is possible given the constraints of land ownership, soil texture, and ecosystem type. Sites are depicted in Figure 1, and described in Table 1.

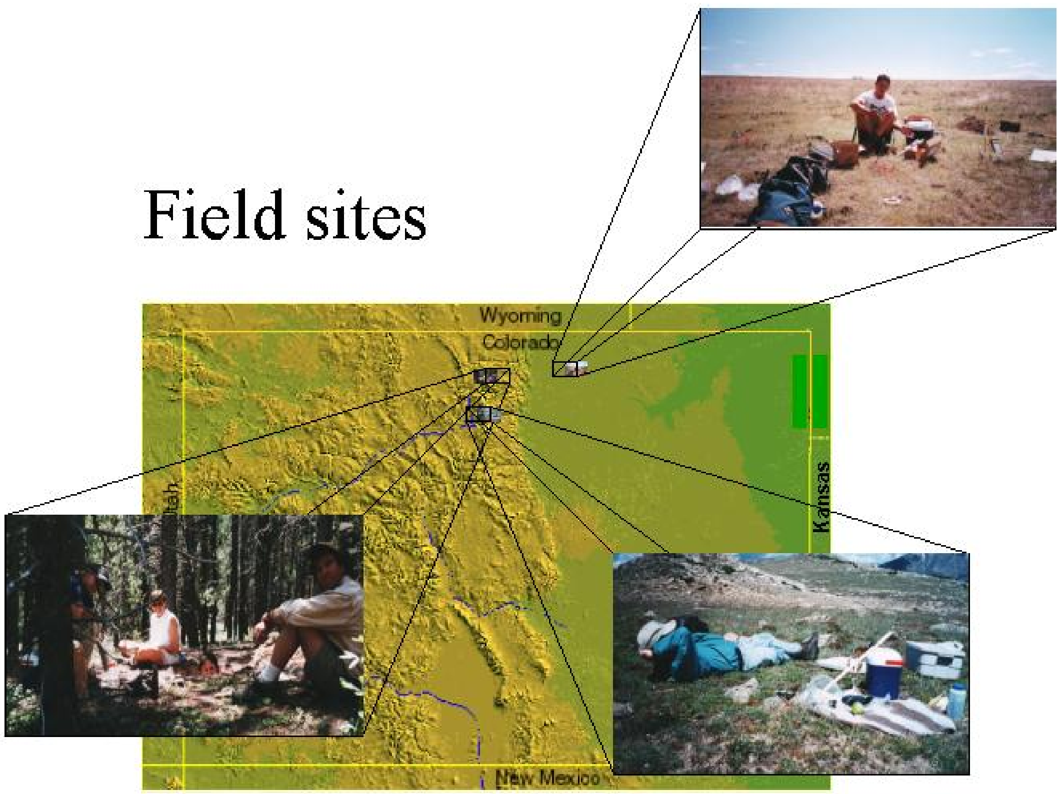


Figure 1. Field sites sampled during this study. Site represent three ecosystems (shortgrass steppe, lodgepole pine, and alpine tundra) on soils of fine and coarse texture. Each photograph represents a textural pair of sites.

Table I.1. Soil data for the CPER-Catena field site. Soil classification: fine, montmorillonitic, mesic Ustic Haplargid.

Horizon	Depth (cm)	Moist color	Sand (%)	Silt (%)	Clay (%)	OC (%)	$\delta^{13}C$ value (‰)
A1	0-4	10YR 3/2	74.3	5.9	19.8	.914	-17.32
A2	4-10	10YR 4/2	49.2	15.7	35.1	.787	-13.58
Bt1	10-23	10YR 4/3	33.9	31.1	35.0	.600	-13.81
Bt2	23-47	10YR 4/2	49.4	17.5	33.1	.292	-13.33
BCk1	47-64	10YR 4/3	46.6	17.8	35.6	.257	-14.20
BCk2	64-100	10YR 5/2	27.5	31.3	41.2	.313	-12.85

Table I.2. Soil data for the CPER-Meteorological Station field site. Soil classification: fine-loamy, mixed, mesic Ustic Haplargid.

Horizon	Depth (cm)	Moist color	Sand (%)	Silt (%)	Clay (%)	OC (%)	$\delta^{13}C$ value (‰)
A	0-10	10YR 3/3	72.0	15.0	13.0	.539	-16.68
Bt1	10-26	10YR 4/2	70.0	11.0	19.0	.536	-14.36
Bt2	26-50	10YR 4/2	64.0	12.0	24.0	.342	-14.80
Bt3	50-66	10YR 4/2	66.0	12.0	22.0	.278	-15.87
BCk1	66-110	10YR 5/2	74.2	17.9	7.9	.588	Na
BCk2	110-130	10YR 5/2	74.3	11.9	13.8	.374	Na

Table I.3. Soil data for the Ballard Road field site. Soil classification: fine-loamy, paramicaceous, Typic Cryoboralf.

Horizon	Depth (cm)	Moist color	Sand (%)	Silt (%)	Clay (%)	OC (%)	$\delta^{13}C$ value (‰)
Oe	3-0						-24.82
E	0-10	10YR 4/3	65.2	24.0	10.8	.800	-24.03
E/B	10-23	10YR 4/4	62.4	24.8	12.8	.497	-23.77
Bt1	23-44	7.5YR 4/4	49.6	17.8	23.6	.363	-23.39
Bt2	44-61	7.5YR 3/4	57.2	18.6	24.2	.312	-22.96
BC1	61-80	7.5YR 4/6	59.2	18.6	22.2	.147	-23.92
BC2	80-102	10YR 3/6	52.4	28.8	18.8	.158	-26.01
Cr	102-115+		79.2	12.0	8.8	.047	

Table I.4. Soil data for the Allenspark field site. Soil classification: loamy-skeletal, mixed, Typic Cryorthent.

Horizon	Depth (cm)	Moist color	Sand (%)	Silt (%)	Clay (%)	OC (%)	δ^{13}C value (‰)
Oe	2-0						-25.19
A	0-7	7.5YR 4/3	61.6	23.4	15.0	1.17	-24.35
E	7-29	7.5YR 4/3	67.6	19.4	13.0	.34	-23.79
E/B	29-45	10YR 5/4	61.6	29.8	8.6	.339	-23.75
BC	45-52	10YR 5/4	76.4	14.8	8.8	.103	-21.81
R	52+						

Table I.5. Soil data for the Iceberg Pass field site. Soil classification: loamy-skeletal, mixed, Typic Cryumbrept.

Horizon	Depth (cm)	Moist color	Sand (%)	Silt (%)	Clay (%)	OC (%)	δ^{13}C value (‰)
A1	0-14	10YR 2/2	73.6	11.4	15.0	6.57	-25.14
A2	14-30	10YR 3/3	63.6	17.8	18.6	1.83	-24.54
Bw1	30-62	10YR 4/4	63.2	28.6	8.2	.495	-23.43
Bw2	62-87	10YR 4/3	63.2	26.6	10.2	.226	-23.04
BC	87-110+	10YR 5/3	62.4	21.8	15.8	.019	-23.81

Table I.6. Soil data for the Tombstone Ridge field site. Soil classification: sandy-skeletal, mixed, Typic Cryumbrept.

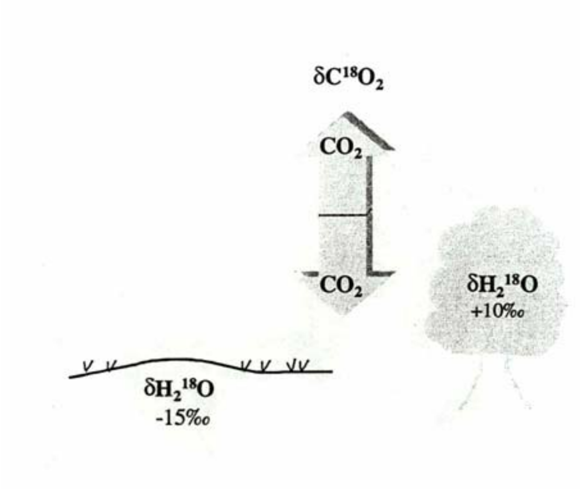
Horizon	Depth (cm)	Moist color	Sand (%)	Silt (%)	Clay (%)	OC (%)	δ^{13}C value (‰)
A	0-19	7.5YR 3/2	83.6	7.4	9.0	3.61	-24.59
Bw1	19-47	7.5YR 4/4	70	20	10.0	.09	-23.89
Bw2	47-69	10YR 4/4	67.6	19.8	12.6	.314	-23.12
BC1	69-87	10YR 4/4	91.2	2	6.8	.027	-22.81
BC2	87-102+	10YR 5/3	67.2	20	12.8	.042	-22.93

Table I.7. Dominant vegetation species at the six field sites.

Site name	Dominant vegetation
CPER Shortgrass steppe, fine soil	(C_4) Blue grama (*Bouteloua gracilis*), buffalograss (*Buchloe dactyloides*), ring muhly (*Muhlenbergia torreyi*); (C_3) western wheatgrass (*Agropyron smithii*), green needlegrass (*Stipa viridula*); (succulents) prickly pear cactus (*Opuntia polyacantha*)
CPER Shortgrass steppe, coarse soil	(C_4) Blue grama (*Bouteloua gracilis*), buffalograss (*Buchloe dactyloides*); (C_3) western wheatgrass (*Agropyron smithii*); (forbs) white stemless evening primrose (*Oenothera caespitosa*); (shrubs) fourwing saltbush (*Atriplex canescens*); (succulents) prickly pear cactus (*Opuntia polyacantha*), yucca (*Yucca glauca*)
Ballard Road Lodgepole pine, fine soil	Rocky Mountain lodgepole pine (*Pinus contorta* var. *latifolia*), kinnikinick (*Arctostaphylos adenotricha*), Rocky Mountain juniper (*Juniperus scopulorum*)
Allenspark Lodgepole pine, coarse soil	Rocky Mountain lodgepole pine (*Pinus contorta* var. *latifolia*) (no understory)
Iceberg Pass* Alpine tundra, fine soil	Alpine avens (*Acomastylis rossii*), alpine primrose (*Primula angustifolia*), alpine bunchgrass (*Deschampsia caespitosa*), alpine clover (*Trifolium dasyphyllum*)
Tombstone Ridge* Alpine tundra-coarse soil	Alpine avens (*Acomastylis rossii*), alpine sedge (*Kobresia myosuroides*), Little clubmoss (*Selaginella densa*), Moss campion (*Silene acaulis*)

- Identified with the help of http://culter.colorado.edu:1030/Niwot/Niwot_Ridge_LTER_vegetation.html

Stable Isotope Geochemistry: We used the oxygen isotopic composition of soil water and soil CO_2 to model the composition of the flux from soil to atmosphere, and to test whether CO_2 fluxes from different ecosystems could be distinguished. We also tested whether ^{18}O in respired CO_2 could be used to partition plant and soil contributions to the terrestrial-to-atmosphere CO_2 flux (this is theoretically possible because the average



$\delta^{18}O$ of soil water is quite distinct from that of leaf water, Figure 3).

Figure 3. The distinct oxygen isotopic values of soil water and plant chloroplast water. Values shown are average values for illustrative purposes only. The isotopic equilibrium reaction that occurs between CO_2 and water controls the $\delta^{18}O$ of atmospheric CO_2.

Our study included measurement of soil properties, soil water, and soil CO_2 at field sites in shortgrass steppe, lodgepole pine, and alpine tundra (RMNP) ecosystems. Data revealed unique patterns of isotopic composition of soil CO_2 efflux across the three ecosystems (Figure 4).

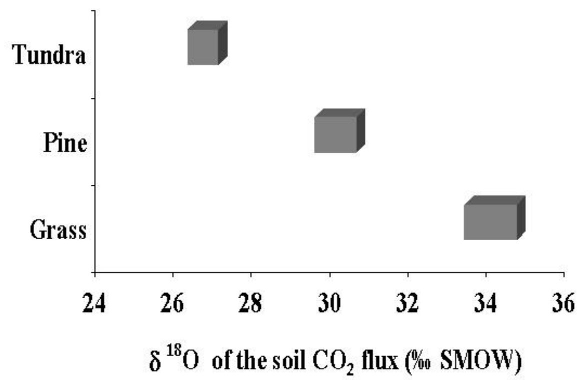


Figure 4. Isotopic composition of soil-respired CO_2 from three ecosystems in northeastern Colorado. Model-derived values are based on field data averaged across the growing season, 1998.

Data also suggest that the technique *is* capable of distinguishing soil-respired versus plant-respired CO_2.

Table 2.1. Characterization of field sites.

Site name	Ecosystem type[&]	Parent material	Elevation (meters)	Location	Slope	Aspect	Climate*
CPER-Catena	Shortgrass steppe	Shale residuum	1646	40°48'N, 104°44'W	<5%	----	MAP 31 cm MAT 9.2°C
CPER-Meterological Station	Shortgrass steppe	Coarse alluvium	1646	40°48'N, 104°44'W	<1%	----	MAP 31 cm MAT 9.2°C
Ballard Road	Lodgepole pine	Mica schist	2720	40°34'N, 105°28'W	17%	105° (SE)	MAP 58.4 cm MAT 7.8°C
Allenspark	Lodgepole pine	Silver plume granite	2651	40°11'N, 105°32'W	22%	42° (NE)	MAP 52.6 cm MAT 4.7°C
Iceberg Pass	Alpine tundra	Biotite schist	3597	40°26'N, 105°45'W	22%	56° (NE)	MAP 191.5 cm MAT -8.3°C
Tombstone Ridge	Alpine tundra	Silver plume granite	3475	40°24'N, 105°41'W	14%	50° (NE)	MAP 180 cm MAT -8.3°C

[&] See Appendix I for details

* 30-yr average when available; data from http://ulysses.atmos.colostate.edu/Access.html

Glossary of Selected Geologic Terms

Cryoplanation - The reduction and modification of a land surface by processes associated with intensive frost action, such as solifluction, supplemented by the erosive and transport actions of running water, moving ice, and other agents.

Cryoturbate - A mass of soil or other unconsolidated earthy material moved or disturbed by frost action, and usually coarser than the underlying material; especially a rubbly deposit formed by solifluction.

Cryoturbation - A collective term used to describe all soil movements due to frost action, characterized by folded, broken and dislocated beds and lenses of unconsolidated deposits.

Frost boil - A small mound of fresh soil material formed by frost action. A type of nonsorted circle commonly found in fine-grained sediment underlain by permafrost, or formed in areas affected by seasonal frost.

Frost bursting, frost riving, frost splitting, frost weathering, frost wedging - the glossary refers the reader to "frost shattering".

Frost churning, frost stirring - the glossary refers the reader to "cryoturbation".

Frost shattering - The mechanical disintegration, splitting, or breakup of a rock or soil caused by the pressure exerted by freezing water in cracks of pores, or along bedding planes. Sometimes referred to a congelifraction.

Garland - this term used as a type of patterned ground is not included in the glossary.

High-center polygon - A polygon whose center is raised relative to its boundary.

Ice wedge - A massive, generally wedge-shaped body with its apex pointing downward, composed of foliated or vertically banded, commonly white, ice.

Ice wedge cast -A filling of sediment in the space formerly occupied by an ice wedge.

Ice wedge polygon - Patterned ground in areas of ice wedges. These polygons are commonly in poorly-drained areas and may be high-centered or low-centered.

Low-center polygon - A polygon whose center is depressed relative to its boundary.

Net (nonsorted) - (not preferred) refer to patterned ground.

Net (sorted) - (not preferred) refer to patterned ground.

Nonsorted circle - A type of patterned ground whose mesh (shape) is dominantly circular and has a nonsorted appearance due to the absence of a boarder of coarse fragments. Vegetation characteristically outlines the pattern by forming a bordering ridge. Diameters commonly range from 0.5 to 3 m. Nonsorted circles include mud boils, earth hummocks, turf hummocks, and frost boils. Nonsorted circles have various origins. Some, such as mud and earth hummocks and frost boils, involve cryoturbation activity and differential heave of frost-susceptible materials. Others, such as mud boils, involve hydraulic pressures and diapir-like displacement of watersaturated sediments.

Nonsorted polygon - (not preferred) refer to patterned ground.

Patterned ground - A general term for any ground surface exhibiting a discernibly ordered, more-or-less symmetrical, morphological pattern of ground and, where present, vegetation. Patterned ground is characteristic of, but not confined to, permafrost regions or areas subjected to intense frost action; it also occurs in tropical, subtropical, and temperate areas. Patterned ground is classified by type of pattern and presence or absence of sorting and includes nonsorted and sorted circles, net, polygons, steps and stripes, garlands, and solifluction features. Inpermafrost regions, the most common macroforms is the ice-wedge polygon and a common microform is the nonsorted circle. Stone polygons generally form on slopes of less than 8 percent, while garlands and stripes occur on slopes of 8 to 15 percent and more than 15 percent, respectively.

Periglacial - (adjective) Pertaining to processes, conditions, areas, climates, and topographic features occuring at the immediate margins of glaciers and ice sheets, and influenced by cold temperature of the ice. The term was originally introduced to designate the climate and related geologic features peripheral to ice sheets of the Pleistocene.

Polygon - A type of patterned ground consisting of a closed, roughly equidimensional figure bounde by more or less straight sides; some sides may be irregular. Refer to patterned ground.
Snowfield - a) A broad expanse of terrain covered with snow, relatively smooth and uniform in appearance, occurring usually at high latitudes or in mountainous regions above the snowline and persisting throughout the year. b) A region of permanent snow cover, as at the head of a glacier; the accumulation area of a glacier.

Solifluction - Slow, viscous downslope flow of water-saturated regolith. Rates of flow vary widely. The presence of frozen substrate or even freezing and thawing is not implied in the original definition. However, one component of solifluction can be creep of frozen ground. The term is commonly applied to processes operating in both seasonal frost and permafrost areas.

Solifluction deposit - A deposit of non-sorted, water-saturated, earthy material locally derived that is moving or has moved down slope en masse, caused by the melting of seasonal frost or permafrost.

Solifluction lobe - An isolated tongue-shaped feature up to 25 m wide and 150 m or more long, formed by rapid solifluction on certain sections of a slope showing variations in gradient. This feature commonly has a steep (e.g., 15 degrees to 60 degrees) front and a relatively smooth upper surface.

Solifluction sheet - A broad deposit of nonsorted, water-saturated, locally derived material that is moving or has moved downslope, en masse. Stripes are commonly associated with solifluction sheets.

Solifluction terrace - A low step with a straight or lobated lobate front, the latter reflecting local differences in rate of flow. A solifluction terrace many have bare mineral soil on the upslope part and 'folded under' organic matter in both the seasonally thawed and the frozen soil.

Sorted circle - A type of patterned ground whose mesh (shape) is largely circular and has a sorted appearance commonly due to a border of coarse fragments surrounding finer material, occurring either singly or in groups. Diameters range from a few centimeters to more than 10 meters. The coarse fragment border may be 35 cm high and 8 to 12 cm wide.

Sorted polygon - refer to patterned ground.

Step- this term sometimes used as a type of patterned ground but is not included in the glossary.
Stripe - A type of patterned ground; one of the alternating bands of fine and coarse surface material, commonly found on steeper slopes. It is usually straight, but may be sinuous or branching.

The above selected terms and definitions are extracted from the glossary contained in Part 629 of the NSSH (430-VI-HSSH, 2001).

Alpine Glaciation: Patterned ground and landforms associated with cryoplanation.

Head wall of a glacial cirque exposing volcanic tuff. Source of rock was volcanoes in the area of the Never Summer Mts.west of the park.


Slope colluvium and alluvium associated with periglaciation adjacent to the Alpine Visitors Center.

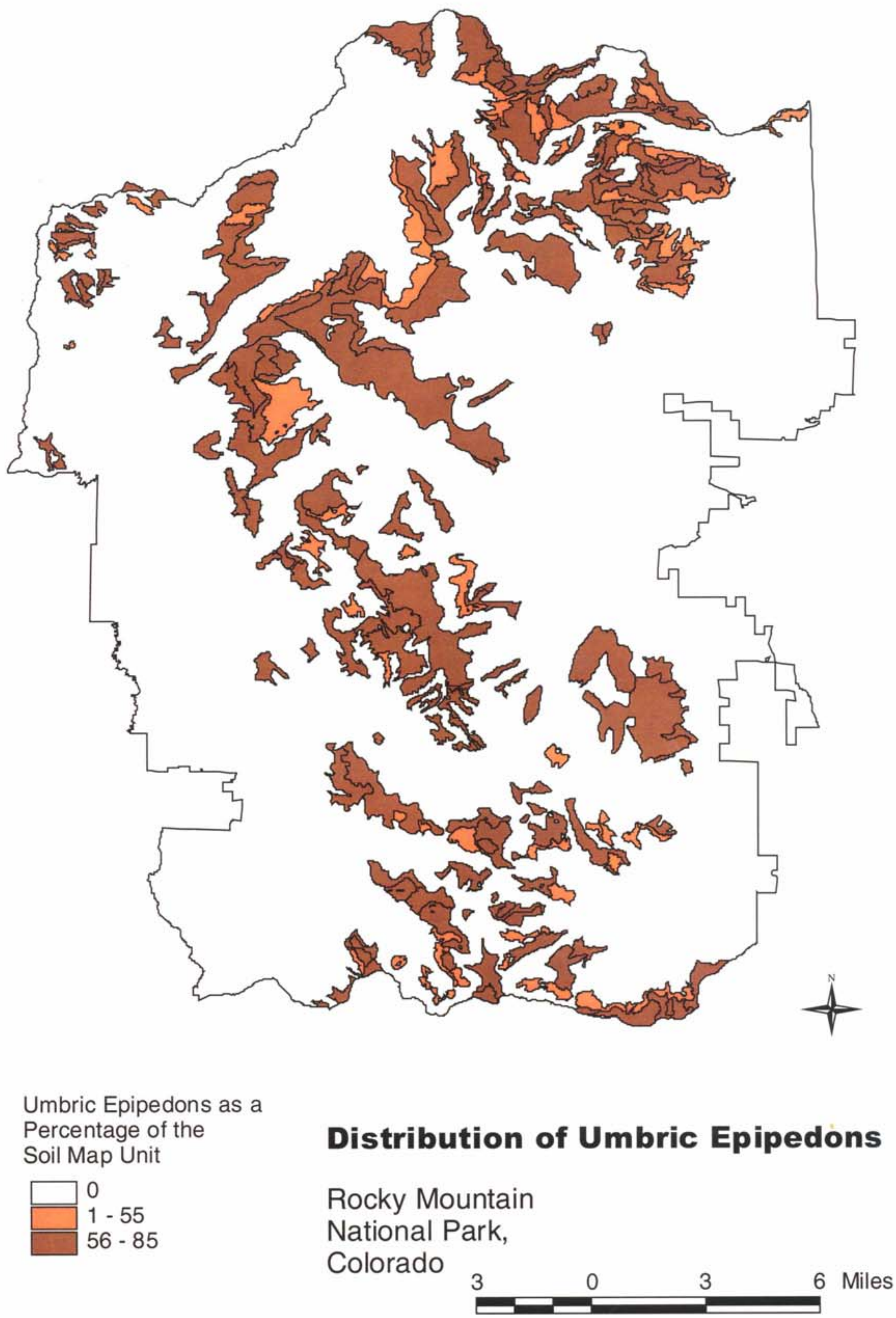
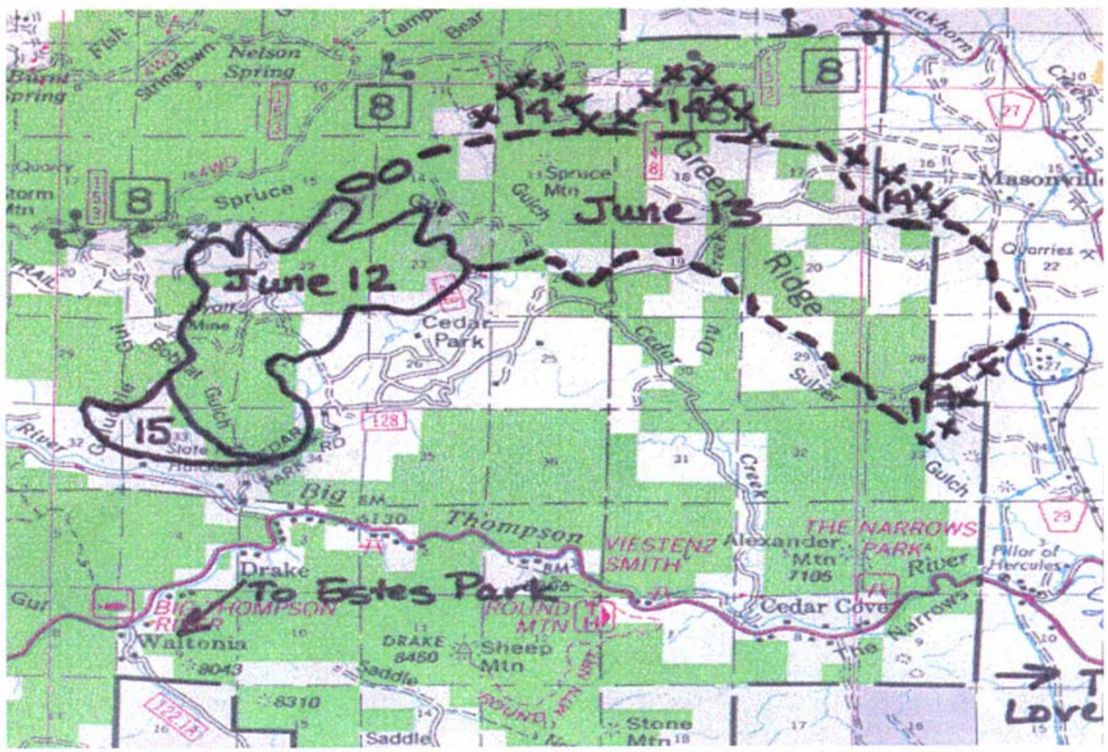

N
Umbric Epipedons as a Percentage of the Soil Map Unit
0
1 - 55
56 - 85
Distribution of Umbric Epipedons
Rocky Mountain National Park, Colorado
3 0 3 6 Miles

Photo taken by CSU graduate student Tedd Huffman shortly after the fire started on Monday, June 12, 2000. That particular day Tedd happened to be researching hydrophobic soils on the Crozier prescribed burn located southwest of the Bobcat Gulch Fire.

Arapaho & Roosevelt National Forests
Pawnee National Grassland
USDA Forest Service

Approximate Map Of The Bobcat Gulch Fire

As of 06/16/00 8:00 am



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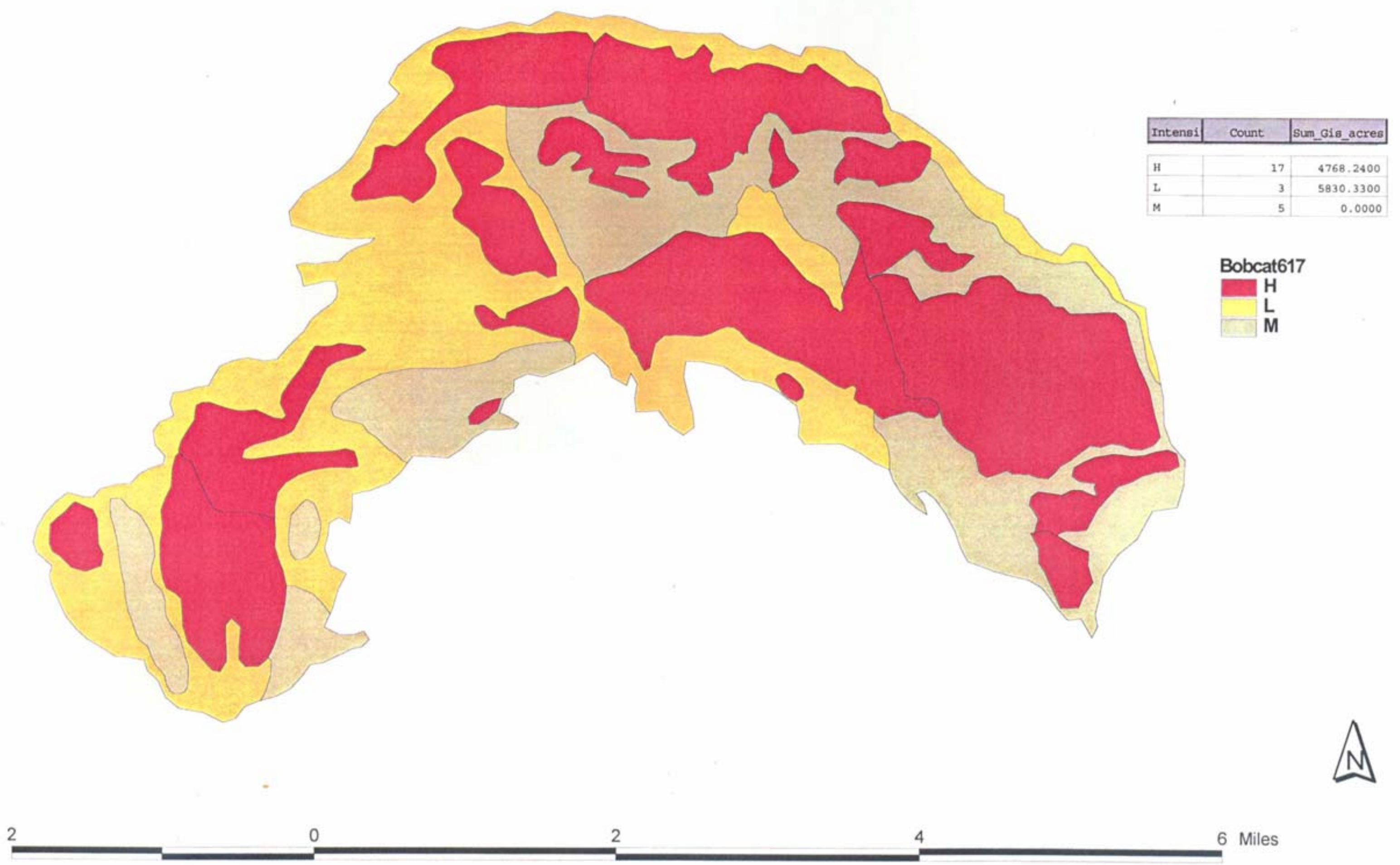
Fire Intensity



Intensi	Count	Sum_Gis_acres
H	17	4768.2400
L	3	5830.3300
M	5	0.0000

GENERAL BOBCAT GULCH FIRE INFORMATION

Date Started: June 12, 2000

Date Contained: June 16, 2000

Date Controlled: June 24, 2000

Ignition Source: Illegal campfire in the Bobcat Gulch Area

Total Acres Burned: 10,599

- **NFS Acres Burned:** 7,295
- **Private Acres Burned:** 3,304

Total Structures Destroyed: 22 (mostly homes)

Suppression Costs: $3.59 million

Fire Intensity (acres):

- **Low:** 431 (4%)
- **Moderate:** 2,643 (25%)
- **High:** 4,769 (71%)

Water Repellent Soils (acres): 4,769 (71%)

Soil Erosion Hazard Rating (acres):

- **Low:** 431 (4%)
- **Moderate:** 5,889 (56%)
- **High:** 4,269 (40%)

Sediment Potential: 8958 cubic yards/square mile (14 cubic yards/ac)

Vegetation: Ponderosa Pine (66%), Douglas Fir (16%), Lodgepole Pine (9%), Grass/Shrub (8%), Aspen (<1%)

Geology: Mostly precambrian gneiss and schist with some precambrian intrusive micaceous granite on Green Ridge

Soils: Depths are mostly shallow and moderately deep. Particle-size classes are mostly loamy-skeletal with some loamy. Mineralogy classes are mostly paramicaceous with some mixed. Dominant parent materials are slope alluvium and colluvium derived from gneiss, schist, and micaceous granite. Dominant temperature regime is frigid with some cryic on north slopes. Dominant subgroups are Lithic Haplustepts, Lithic Haplustalfs, Typic Haplustepts, and Typic Haplustolls. Steep slopes and high mica content make these soils highly erosive.

BOBCAT GULCH FIRE

QUICK FIELD ASSESSMENT OF POST FIRE HYDROPHOBIC CONDITIONS AND EROSION POTENTIALS

This assessment is not based on a statistical analysis. The extremely short time frame needed to produce the burn assessment report precluded any in-depth analysis. However, it is based on 22 years of professional "on-the-ground experience" with working in these, and similar soil types and vegetation. It is also based on the general repetitive pattern I observed on my field visit on June 21, 2000.

My intent for the field visit was to compare hydrophobic conditions in unburned areas to hydrophobic conditions in the burned areas (low, moderate, and high intensity). The general patterns I observed were:

1. Unburned areas with significant conifer cover and associated duff layer showed strong water repellency (>40 seconds) at the top of the mineral soil just below the duff layer (Oi/Oe horizons). This strong repellency extended to .25 inches for some of the sites observed. Below .25 inches there was only weak, or nonexistent, repellency.

2. High intensity burned areas that had significant conifer cover consistently had strong water repellency to a depth of 1 inch. Below 1 inch the results were less consistent but some sites did show moderate or strong repellency below 1 inch. Moderately burned areas showed a similar pattern but the depth of repellency was less.

3. Unburned areas of grasses and shrubs had strong water repellency (>40 seconds) at the top of the mineral soil just below the duff layer (Oi/Oe horizons). This strong repellency extended to .25 inches for some of the sites observed. Below .25 inches there was nonexistent water repellency.

4. High intensity burned areas of grasses and shrubs consistently had strong water repellency to a depth of 0.5 inches. Below 0.5 inches water repellency was nonexistent or weak. Moderately burned areas showed a similar pattern but the depth of repellency was less.

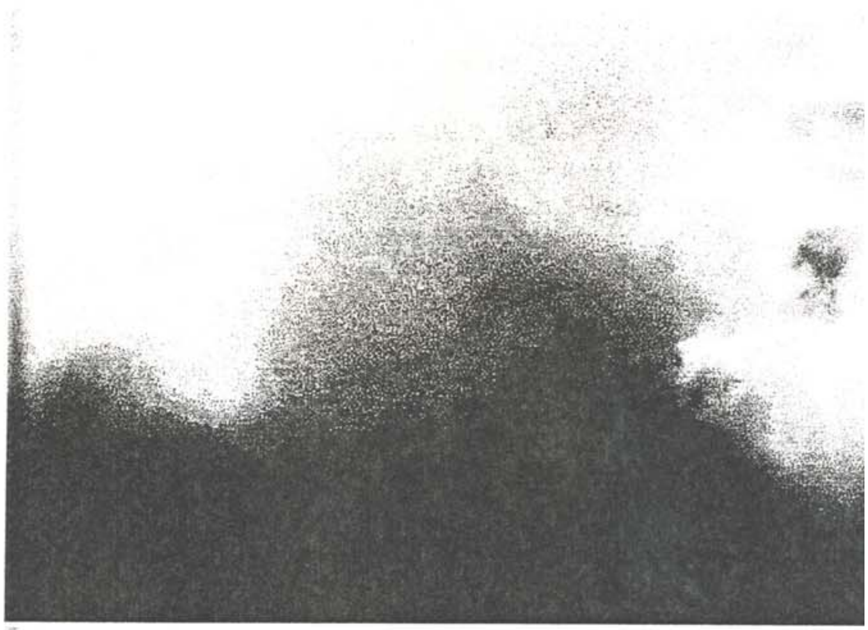
5. The high intensity burn areas had both medium and high classes of water repellency. Since time did not allow for a more detailed and encompassing analysis, I prefer to err on the most limiting side, and state that the high intensity burn areas have a "high" water repellency class. Moderate intensity burn areas will generally have a "moderate" water repellency class. Low intensity burn areas will have a "low" water repellency class.

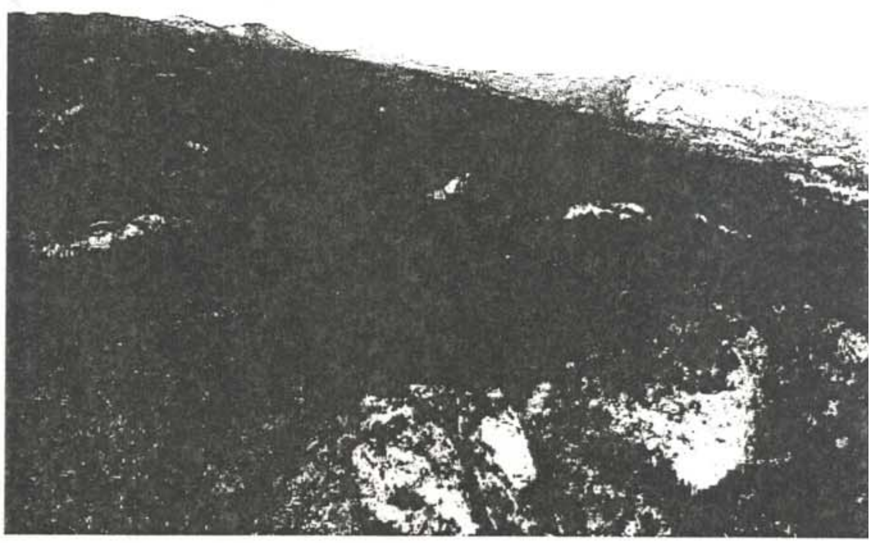
Stating the obvious, moderate and high intensity burns in conifer forest types with significant duff layers will exacerbate hydrophobic conditions. The hydrophobicity is driven deeper into the soil than what was present in pre-fire conditions. I could not find any data on how much hydrophobic conditions increase soil loss rates. I would estimate that a "ball park" figure is a factor of 3 to 5 times. It is very possible the factor could be much higher. Even though hydrophobic conditions add to the erosion problems, more importantly is the loss of ground cover (C factor USLE). The cover factor (C) in burned areas is greatly increased resulting in extremely significant increases in soil loss.

The loss of cover on steep hydrophobic soils with high mica content can potentially result in tremendous soils losses. These losses will pollute watersheds and damage roads. If left unchecked or unmitigated, it will greatly reduce soil productivity and the natural regeneration process.

Fire Behavior of the Bobcat Fire
A Discussion of Contributing Factors

Kelly Close, Poudre Fire Authority
FBAN; Bobcat Fire



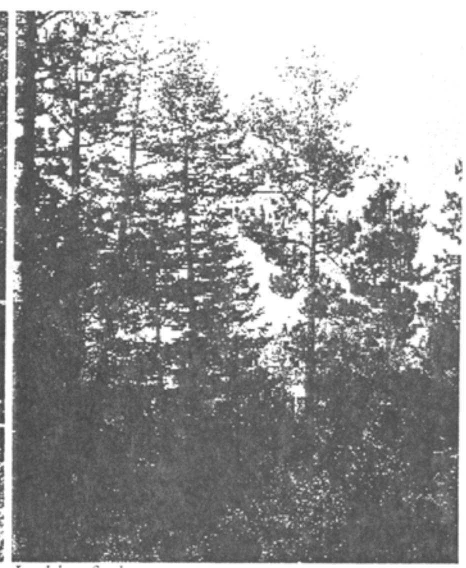


INTRODUCTION

Wildland fire behavior deals with understanding the way wildland fires burn -particularly the factors that influence how intensely they burn and how rapidly they spread. To understand how and why the Bobcat Fire burned the way it did, it§ important to understand the fire environment," or the combination of physical and environmental conditions under which wildland fires can burn. There are three basic components of the fire environment that determine wildland fire behavior - fuels, topography, and weather.

"Fuels" are anything in the wildland that is available to burn and support the spread of fire. It includes grass, brush, trees, leaf and needle litter, and live trees if they are sufficiently dry. Unfortunately, all too often it also includes houses and other improvements - especially if the roof or siding is made of flammable materials. An important component of fuels is their vertical arrangement and continuity across the landscape. Continuous, unbroken expanses of fuels provides a means for fire to spread readily in any direction. “Ladder" fuels, those that provide continuity from the surface fuels to the tree canopies, provide a path for fires to spread from the ground into the tree tops.

Heavy accumulations of surface fuels



Ladder fuels

"Topography" incorporates the influence of the “lay of the land" on fire behavior, and includes elevation, steepness of the slope, and aspect - i.e., the direction a slope faces. Topography influences fire behavior by the way it affects warming and drying from the sun, exposure to wind, and seasonal growth and drying of fuels.

Weather is a critical element in wildland fire behavior. In particular, wind is the one single thing that can change the speed and intensity of fire spread. Temperature and relative humidity are also important, however, because they directly influence how dry fuels become and how readily they burn.

What makes wildland fires burn the way they do? Why was the Bobcat Fire more difficult to control than others?

To understand this, we need to look at the basic ways wildland fires can spread:

- *Ground Fires.* These smolder through decomposing vegetation on the ground. Ground Fires are not as readily apparent because there is little or no visible flame; they creep slowly beneath and at the surface by smoldering combustion.

- *Surface Fires.* These are the most common and familiar type of fire spread. Simply put, surface fires are those that spread through fuels on the surface of the ground (grass, leaf and needle litter, dead branch wood, and brush). They can move rapidly, burn intensely, and change direction quickly as they encounter changes in wind and terrain.

- *Crown Fires.* These are fires that burn in the tree canopies, or "crowns." Crown fires range from single trees `torching" and short-duration fire spreading through small groups of trees, to high-intensity, continuous spread of the fire front through canopies. They are considered a very extreme type of fire behavior, and occur under extreme fuel and weather conditions. Crown fires are the most difficult to control due to their intensity and rapid spread. Typically, this type of fire can only be attacked when encountering a change in fuels or weather that allows the fire to drop back to the surface where firefighters and equipment can attack them. Prolonged drought, very dry fuels, and strong winds often combine to produce these types of fires.

- *Spotting.* This is fire spread by burning materials, or `firebrands, "being lofted from the main fire into adjacent unburned fuels, causing spot fires that can spread the fire more rapidly and present additional control and safety problems. Spotting is a particular problem when torching occurs, and with more intense crown fires. In strong winds, firebrands are commonly cast up to %mile or more from the main fire front, and in very extreme situations, up to a mile. These firebrands can start numerous new fires that spread rapidly and burn intensely, creating a potentially dangerous, volatile situation ahead of the main fire front.

Why did the Bobcat fire spread so fast? And why did it become so intense so suddenly?

To understand where we are now in terms of fire danger and burning conditions, we need to look back to last Fall. The current fire danger situation in Colorado began developing in November, 1999. Snowfall came late, and many ski resorts did not open at the "traditional" time of Thanksgiving Weekend. Though the snowpack in many areas was above-normal at elevations above 9,000 ft., it was far below normal at lower elevations - which includes most of the rapidly-growing wildland/urban interface areas along the front range. As a result, a drying trend set in early in the foothills and lower elevations of the mountains.

During January, the Front Range was unseasonably warm and dry. With lack of significant precipitation, local fire agencies began experiencing intense, fast-moving fires in grass and brush fuels. By February, fires were beginning to show signs of extreme intensity. The warm, dry weather continued into early Spring, and the snowpack at higher elevations began to melt more rapidly than usual. As a result, the snowpack in April and May fell below normal in nearly every location in Colorado, regardless of elevation.

By June, the combined effects of unseasonably warm, dry weather and lack of significant precipitation resulted in unusually high fire danger for this time of year. Fuels are drier, and burning conditions more extreme, than have been recorded in the nearly 4 decades the U.S. Forest Service has been tracking fire weather and fuel moisture.

The end result?   When fires start, they now have great potential to burn intensely and spread very rapidly, consuming everything in their path. With drought-stressed trees and very dry surface fuels, surface fires can readily become crown fires with even moderate winds.

What made this fire so difficult to fight?

Fire intensity and spread rate are the two things most important to gaining control of a wildfire. With lower fire intensities, firefighters and equipment (such as engines and dozers) are able to construct fireline directly on or near the burning edge of the fire. With higher intensities, the heat becomes too great, and fire behavior too extreme, for anyone to safely operate near the active edge of the fire. With continuous surface fuels, fires can quickly spread a great distance, easily outpacing firefighters and equipment trying to suppress them. With adequate ladder fuels, fires readily move into tree canopies, and with wind, can become intense, destructive crown fires. Once a surface fire transitions into a crown fire, there is little that can be done to fight it due to the extreme intensity. In addition, firebrands can be cast great distances ahead of the main fire front, starting new fires in front of the main fire and creating a dangerous situation.

Surface fire beginning to torch.

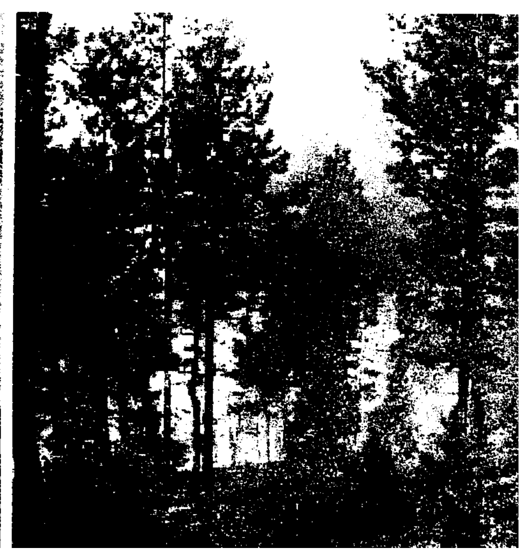
Transitioning to an intermittent crown fire with spotting.

Water drops from helicopters, and retardant drops from air tankers, can be effective in many situations. However, these actions do not put the fire out by themselves; crews must follow up water and retardant drops on the ground by building fireline and taking aggressive suppression actions. If the fire behavior is too extreme, water and retardant drops may not reduce the fire intensity or spread enough for crews to safely and effectively attack the fire on the ground, and if the wind is too strong, water and retardant may not even reach the areas they are needed. With extreme fire behavior, aircraft may not be able to get close enough to the fire to safely fight it, and with very strong winds, helicopters and air tankers may not even be able to fly safely at all.

Many of these situations came together the day the Bobcat fire started. The first crews en route and arriving at the fire noted unusually warm, dry weather that morning. They reported intense burning conditions upon reaching the fire. By 10:00 am, the fire was already torching individual trees and starting spot fires adjacent to where crews were working. The fire was beginning to exceed containment capabilities. Dead fuels and live vegetation were both burning very aggressively, and too intensely for the crews to work directly near the fire. As a result, firefighters were forced to back off from directly attacking the fire for safety reasons. Within an hour, the fire was running through the crowns of small group of trees and starting spotfires well ahead of the main fire front. Retardant drops from an air tanker, though helpful in slowing the fire§ advance in places, could not stop the advance of what had quickly become an extremely dangerous, hot, fast-moving fire.

By early afternoon, the fire had already grown to over a thousand acres, with rapid spread both in surface fuels and tree crowns. Crews reported very intense, volatile burning conditions, and by the end of the first day, the fire had grown to over 2,000 acres - very unusual for this time of year in the Front Range. The fire spread slowed at night, but continued to burn through surface fuels very aggressively, and torch groups of trees, well into the early morning hours. Crews fighting the fire never had a reprieve from aggressive fire behavior through the night, and by daybreak, firefighters were experiencing fatigue.

Fire crossing Rd. 128



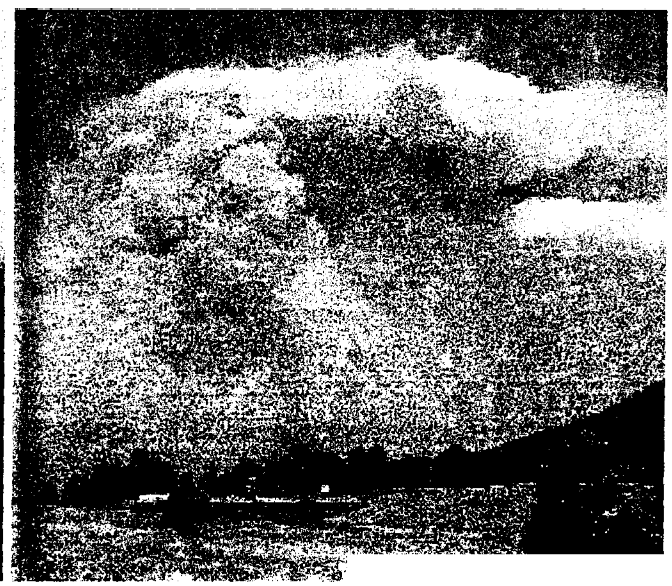
Fire advancing uphill with intense surface fire and torching

June 13, fire activity continued unabated from the night before. By early afternoon, strong winds began developing in the area. With the hot, dry weather already in place, and continuous surface and canopy fuels throughout the area, the stage was set for another rapid fire growth situation and extreme burning conditions. In addition, the now substantial size of the fire, and the fact it§ entire perimeter was still active, provided numerous places from which further fire growth could occur. When the winds developed in the afternoon, they blew from the west. This westerly wind aligned with many of the more prominent ridges and valleys in the area, which channeled the winds and amplified their effect on the fire.

All these factors combined to push the fire into the crowns of trees by early Tuesday afternoon. As the wind increased, the spread through the crowns became more sustained, and the fire behavior more extreme. At approximately 3:30 pm, the fire had spread into Jug Gulch. This was a significant event in that Jug Gulch contained large accumulations of heavy dead fuels.

By this time, the fire was spreading at a rate of over a mile an hour - faster than a person can walk in that terrain. Flame lengths were reported to be from 100-150 feet above the tree tops at the main fire front. A large, strong convective column had developed with heat energy so intense, a thunderhead-type of cloud had begun to form at its top. The intense burning in Jug Gulch and resultant extreme heat increased the frequency of crown fire runs and spotting, and further contributed to the development of the now-massive convective column.

Torching, and fire advancing out ofJug Gulch and up the west slope of Spruce Mtn.



Convection column at 4:00 pm, viewed from Cedar Park

Spread was 'pulsing," alternating between very intense surface fires with torching to extended runs through the crowns. Spotting was reported to be from ½ mile to 1 mile ahead of the fire front. Under these conditions, fire crews could do little to stop the advance of the fire. Safety of the firefighters and the public became the primary concern, and in addition to providing for their own safety, crews worked diligently to evacuate residents in the area to safer locations. Those places where surface fuels and continuous tree crown were absent for large areas provided vital "safety zones" for firefighters and residents to retreat when the fire burned through the area.

Fire behavior was similar on June 15 when a strong wind out of the west pushed the fire north and east toward Buckhom Creek.

Once winds subsided, the extreme fire behavior began lessening. Only at that point were firefighters and equipment able to assess the extent of fire spread and be effective in taking aggressive suppression actions.

Crown fire burning from Green Ridge toward Buckhor.

Convection column north of Masonville Cr.

Why did some houses burn and others didn't?

Survivability of some houses had to do with simple luck, but most losses were due to the extreme fire behavior the Bobcat fire was exhibiting. When burning conditions are as extreme as they are currently in the Colorado Front Range, the power of a wildfire can quickly overcome even the greatest suppression capabilities available.

In the event suppression forces cannot safely or effectively work in the vicinity of a structure, that structure is at the mercy of wind, fuels, and topography -the fire environment itself. Several aspects of one key element of the fire environment, fuels, can affect where and how intensely a fire will burn, how extreme the burning conditions may be, and what may be consumed in the path of the fire front. This relates right back to the inter-relationship between fuels and various elements of the fire environment:

- *Surface Fuel Continuity.* Having a relatively continuous bed of fuel, containing any combination of grass, brush, or other flammable materials, provides a route through which a fire can readily burn. The greater the accumulation of fuels, the more intensely a fire can burn and the more likely it will cause torching of trees.

- *Ladder Fuels and Canopy Fuels.* If there is an unbroken path of fuels, dead or live, between the ground and tree canopies, it provides a path along which fire can easily climb into the crowns of the trees. This can lead to torching with little or no wind, and crown fire with even moderate winds under dry conditions. With the strong winds we experienced on the afternoon of June 13, the crown fires burned intensely and rapidly through both surface and crown fuels, consuming virtually everything in the path of the main fire front.

- *Spot Fires.* Spot fires are always a concern with any winds. Once torching and crowning commence, spotting is one of the key concerns due to their ability to start numerous fires a great distance from the main fire front. Spot fires cause the greatest problems where there is a continuous, receptive fuel bed to land and start new ignitions.

In the case of the Bobcat Fire, these all came into play, hindering the fire spread in some areas and accelerating it in others. Where surface fuels were absent or discontinuous, fires were unable to sustain spread for any appreciable distance, nor build up a great deal of intensity. Where surface fuels were plentiful, and as dry as the conditions were (and continue to be), there were large areas through which fires were able to spread readily, and build up speed and intensity.

Where fuel accumulations were particularly heavy, flare-ups caused spotting over short distances and initiated torching where tree canopies extended down to within reach of surface fuels. When torching occurred, the continuous surface fuels continued to provide opportunities for firebrands to ignite new fires downwind, further accelerating the fire's spread. Surface fuels can include houses, particularly those with flammable wood shake roofs and deck extending over flammable surface fuels, and houses that are destroyed in wildland fires typically have flammable roofs or accumulations of receptive fuels near or adjacent to the house.

During the most intense fire runs experienced on the Bobcat Fire, several key factors lined up in a chain of events that led to rapid, intense fire spread. Continuous, dry surface fuels resulted in rapid initial fire spread, quickly outpacing the crews. Ladder fuels with heavy surface fuel accumulations led to torching and short-range spotting. Sustained torching, continuous tree canopies, and strong winds led to crown fire runs within a short time. These in turn caused longer-range spotting and ignition of new fires ahead of the main fire front. Winds blew from the south initially, creating a large fire front that was then spread in a different direction in the afternoon when the winds shifted to blowing from the west.

Where one or more elements in this chain of events was absent (discontinuous surface fuels, absence of ladder fuels, or discontinuous crown fuels), the likelihood of continued extreme fire behavior was greatly reduced or eliminated. In fact, many areas of the fire were showered with firebrands but did not burn! Lack of surface fuels hindered those firebrands from starting new ignitions, and if ignitions occurred, lack of ladder fuels prevented initiation of torching or crown fire.

While weather played a pivotal role in the rapid, intense growth of the fire, it also provided firefighters a much-needed break in gaining the upper hand... and no doubt spared further spread of the fire and loss of structures. On June 15, a dry cold front moved through the area. Ahead of the front, winds were strong out of the west, and conditions were hot and dry. The fire spread to the east and north, again with intense surface fire, torching, crowning, and some spotting. Though the fire increased in size, no structures were in the path of its spread. Then at 3:30 pm, the front passed through the fire area from the north, bringing with it a wind shift to out of the northeast, then north. The fire essentially blew back on itself, and further spread was largely halted. The wind shifts were followed by rain and snow as the front passed, and the firefighters were finally able to gain the upper hand. Construction of fueline was completed and improved on most of the fire's perimeter, and hot areas near the periphery cooled down and mopped up.

SUMMARY

The Bobcat fire dramatically demonstrated the sheer power of a wildland fire burning in heavy fuels under extreme burning conditions, and its ability to quickly surpass the capabilities of even the most capable suppression efforts from the air and ground. In some instances, it also demonstrated how changes in the fire environment, particularly fuels, significantly alter the rate of spread' and intensity, potential for extreme behavior, and destructiveness, of a wildland fire. Two major parts of the fire environment, weather and topography, cannot readily be changed. However, the third part, fuels, can be modified to a significant extent, thus also modifying the fire environment and the potential fire behavior. In a year such as this, where we are setting records for extreme burning conditions, the importance of this must be emphasized.

ANOTHER BAER INCIDENT

A few years ago my then 9 year old son and I had a close encounter, about 4 feet, with a large black bear in northern Colorado. Three warning shots from a handgun safely ended that incident. However, my most recent experience earlier this summer in northern Colorado did not involve real bears or handguns. Instead, I was asked to be a part of the BAER team working on the Bobcat Gulch Fire near Loveland, Colorado.

BAER is a U.S. Forest Service acronym for Burned Area Emergency Rehabilitation. BAER teams are multi-disciplined teams consisting primarily of a soil scientist, hydrologist, forester, range conservationist, ecologist, economist, biologist, and an engineer. Other disciplines are involved as needed. The Bobcat Gulch Fire, and the High Meadow Fire southwest of Denver, occurred June 2000. Each fire burned about 11,000 acres of both private and federal lands. The NRCS became involved in the rehabilitation process because private lands were burned. Myself and Tim Wheeler, soil scientist on the Colorado state soils staff, provided the soils expertise to the BAER teams for the Bobcat Gulch and High Meadow Fires.

Our primary objective, quoted from the BAER handbook, was to alleviate emergency conditions following the fire, to help stabilize soil; to control water, sediment, and debris movement; to prevent permanent impairment of ecosystem structure and function; and to mitigate significant threats to health, safety, property, and downstream values. Our secondary objective was to coordinate and provide direction for the rehabilitation of disturbance caused by suppression activities, such as fire lines, roads, heliports, and camps. Our overall goal was to complete the Burned-Area Report in as short a time as possible. This report would be submitted to the agency heads who would then use the report to request emergency rehabilitation funds. The team averaged 14 hour work days starting 6 AM on Tuesday, June 20th and finishing the report at 7 PM on Saturday, June 24th.

As soil scientist for the team I was charged with:

1. pulling together whatever existing soil survey information was available,
2. assessing the extent and degree of hydrophobic soils,
3. creating maps and acreage figures for soil map units, hydrologic groups, and runoff potential,
4. estimating erosion potential,
5. assisting other team members with identifying what treatments were needed and where they should be applied, and
6. completing the soil sections of the Burned-Area Report.

About 70% of the Bobcat Gulch Fire occurred in the Roosevelt-Arapahoe-Routt National Forest soil survey area (CO645). The other 30% occurred in the Larimer County Area soil survey (CO644). The Roosevelt-Arapahoe-Routt National Forest soil survey area is uncorrelated and uncertified. The Larimer County Area soil survey is correlated and certified. Fortunately, both surveys had been digitized, so I did not have to create the spatial layers for each survey area. My next challenge was to merge these spatial layers into one seamless join. With the help of a very skilled USFS GIS person I was able to make an "acceptable" join between the survey areas. The differences in mapping intensity and slope breaks proved to be the major issues with joining. Although both surveys are considered Order 3, the USFS survey was mapped more broadly than the NRCS survey. In addition, slope breaks did not match between the surveys. The USFS used predetermined slope breaks of 0-15%, 15-40%, 40-150% while the NRCS survey used breaks that reflected the actual slopes that occurred for a map unit. Predetermined slopes breaks were very problematic when it came to calculating erosion potentials.

My next task was to ensure that the erosion factors (T, K and LS factors) were populated in the databases for the all the soil map units in the fire area. Overall there were 16 map units with 6 from the Larimer soil survey and 10 from the Roosevelt-Arapahoe-Routt soil survey. Total soil components was 31. Slope-length factors (LS) were not populated for any component. The 6 map units from Larimer had all the other critical erosion factors populated. At that time, the map units from the USFS survey did not have the erosion factors populated. With the assistance of Eric Winthers, soil scientist on the USFS Region 2 staff here in Lakewood, we were able to derive all the erosion factors for the USFS map units and complete the database population.

As usual, determining slope lengths took a little more effort than coming up with the other erosion factors. Fortunately, I had a digital soils layer to work with. Again, I employed (begged) the assistance of Eric Winthers and his GIS specialist, Brett Suddarth. Using Arc View software we were able to drape the soils layers over a digital topographic quad layer. Being able to view the soil polygons and the topography allowed me to select 3 to 5 polygons from each map unit and actually measure slope length. I averaged these measurements to come up with an average slope length for each map unit. Now, I had all the erosion factors except the C (cover) factor.

High intensity burn area on Green Ridge. Total consumption of all surface organic material. The two pedons with strongly repellent layers at 6 inches were in this area.

From some Colorado Tech Guide information I found some information on C factors for ponderosa pine forests. Ponderosa pine was the dominant forest type in the burn area. My next question was what C factors should I use for the different burn intensity levels of low, moderate, and high? I began researching materials about using the Universal Soil Loss Equation (USLE) and the Revised Universal Soil Loss Equation (RUSLE). In the extremely short time I had available to me, I could not find any information about C factors related to burn intensity. However, I did come across some information about using C factors on construction sites. In sites where the vegetation and surface rocks have been bladed off a C factor of 1.0 was used. In a high intensity burn area pretty much all of the surface organics has been consumed, leaving nothing but an ash layer. Considering this, and the definitions of low and moderate burn intensities, I assigned C factor ratings of 0.1, 0.4, and 0.8 respectively. Since I had an acreage figure for all soil map units by burn intensity I was now ready to calculate some erosion potentials.

My calculations were based on using the dominant component in the map unit. I do not consider my figures to be precise. However, I have confidence in their "relative" accuracy in estimating pre-fire and post-fire erosion potentials. Pre-fire erosion potentials were about 19 tons/ac/yr while post-fire erosion potentials were 54 tons/ac/yr. This represents almost a three fold increase in erosion potential. Initially, these figures seemed high to me. However, given the steep slopes and long slope lengths, these figures are probably in the ball park.

As soil scientist on the team I was charged with assessing the degree and extent of hydrophobic soils in the burn area. Hydrophobic conditions are created when the surface organics, primarily ponderosa pine duff layers in this case, are consumed by fire. Vapors from the burned organics permeate the soils, and upon cooling, leave a waxy coat on soil particles. This waxy coat repels water. The more coarse-textured the soils the deeper the vapors penetrate. The dominant soils in the burn area are shallow and moderately deep, loamy-skeletal, paramicaceous soils derived from gneiss, schist, and micaceous granite. Vapors readily permeated these soils.

Because of the extremely short timeframe for completing the burned area report, I was not able to do an extensive and statistically sound evaluation of the hydrophobic conditions. My field procedure consisted of driving across the entire width of the fire and periodically stopping to test for hydrophobicity. I collected information on unburned areas as well as from low, moderate, and high intensity burned areas. Testing for hydrophobic layers involves placing a drop of water on dry soil and observing how long it takes to be absorbed into the soil. According to the guidelines outlined in the USFS BAER handbook a layer is weakly repellent if it takes less than 10 seconds for the water drop to be absorbed; moderately repellent if it takes 10 to 40 seconds; and strongly repellent if it takes longer than 40 seconds.


Author testing for hydrophobic soil conditions.

Hydrophobic conditions can occur naturally in pre-fire conditions. In fact, all the unburned sites I tested I found a thin, about 0.25 inch thick, hydrophobic layer right at the contact between the surface organics and the mineral soil. I have found this to be the norm for the forests I have worked in the Southwest.

My findings showed the moderate and high intensity burned areas had exacerbated hydrophobicity. These areas consistently had moderately and/or strongly repellent layers below 0.5 inches. Two pedons I tested in the most intensely burned area, located within the drip-line of two large ponderosa pines, were strongly repellent at 6 inches. The depth of repellency was directly related to fire intensity and the thickness of the original organic layer. About 45% of the 11,000 acre fire was covered by what the USFS defines as water repellent soils.

Even though 45% percent was covered by “water repellent” soils, I suspect the post-fire runoff potentials are not that much greater than the pre-fire runoff potentials. My rationale is that strongly repellent layers occurred in the top 0.25 inches of the mineral soil surface in the pre-fire state. In the post-fire state strongly repellent layers, on the average, extended to a depth of 0.5 to 1 inches below the mineral soil surface in the moderate and high intensity burn areas. I reason that as long as the upper part of the mineral soil surface was strongly repellent, the bottom depth (total thickness) of that strongly repellent layer would not affect the runoff potential in the short term. It is the top of the repellent layer that affects runoff.

A much more significant impact to erosion potentials, and runoff, was the loss of surface cover. About 45% percent of the area was classified as high burn intensity. These areas had nearly all of the surface organics removed with many trees being totally consumed. About 25% of the area was classified as moderate burn intensity. These areas had partial consumption of the surface organics with most trees still intact. Stating the obvious, it is moderate and high intensity burn areas that have the greatest erosion potentials. Even though these areas occupy 70% percent of the fire area, they account for 94% of the potential erosion. Areas of high and moderate burn intensity that had potential to impact municipal water supplies and damage vital roads were targeted for most of the rehabilitation treatments and practices. The major treatments were reseeding, contour tree felling, and road stabilization measures. All other areas were left to regenerate naturally.

Extreme heat caused this granite boulder to exfoliate. The chemistry of the rock was also altered by the intense heat. The exposed faces reacted to 10% HCL indicating calcium carbonate is present. Normally, this granite would not react to acid.

I was fortunate to assist with some of the reseeding efforts on the private lands. This was a very rewarding experience. During the reseeding efforts many of the people whose homes were destroyed personally thanked us for all that we were doing. There were 22 structures destroyed by the fire. It was also refreshing to work with the local NRCS field office staffs on such a worthwhile effort.

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Natural Resources Conservation Service
Field Office

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Friday, June 23, 2000
To: Nyle Jodre, Economist, Lakewood State Office
From: Todd Boldt, District Conservationist, Fort Collins FO
Subject: Bobcat Fire, Municipal & Agricultural water users
The following is a summary of the meeting I had with the municipal and agricultural water users who might be affected by the Bobcat Fire. The meeting was held on June 23, 2000 at 2:00 PM at Northern Colorado Water Conservancy District Office in Loveland.

Attendees:
City of Greeley Water Resources Department and Waste Water Treatment Department. City of Fort Collins Water Resources
Greeley & Loveland Irrigation Company Northern Colorado Water Conservancy District City of Loveland Waste Water Treatment
Big Thompson Water Commissioner
Big Thompson Soil Conservation District Big Thompson Water Users Association USGS

I presented information to the group on the fire in terms of BAER team make up and duties, location of the fire, acres of public and private land, tire intensity areas, runoff potential, erosion potential, and increased flood hazard. I asked for their input on how serious potential problems might be to their operations, including water diversions and water treatment. I also asked if the potential problems were a concern what would be the costs to them. I also discussed the opportunities available to them through EWP and that the Big Thompson SCD has offered to be the local sponsor.

The water users are very concerned about potential impacts to their systems. The following is a summary broken down by entity. <u>*These figures are based* on *a per year cost*</u>

Greeley & Loveland Irrigation Company (GLIC)

Debris damages to 2 structures, Barnes & GLIC:	2 @ $50,000	**$100,000**
Ditch Cleaning		
Barnes: 3 miles long, affect 1 mile.	5280' @	**$528.000**
GLIC: 0.5 mile, affect all	2640' @ $100/ft	**$264,000**

Affects on *other Watershed Agricultural Diversions & Ditches*	**$1,900,000**

- Assumes some siltation of the 14 ditch systems from the mouth of the Big Thompson canyon to I-25.

Debris removal on 14 structures:	14 @ $25,000	**$350,000**

- 9 on Big T, 5 on Buckhorn

The Natural Resources Conservation Service works hand-in-hand with the American people to conserve natural resources on private lands.
AN EQUAL OPPORTUNITY PROVIDER AND EMPLOYER

Northern Colorado Water Conservancy District

If Dilley Diversion affected: NCWCD loses the ability to "skim" free water and will forgo its entitled decree of 5,000 AF.	5,000AF @ $60/Af	**$300,000**
City of Loveland If Dilley Diversion affected: City of Loveland loses it's Entitled decree to 3000 AF of water per year.	3000 AF @ $382/AF	**$1,146,000**
Water Treatment; City of Loveland. Treating sediment, hauling additional sludge, additional chlorine for smoky taste. Total organic carbons are a concern due to their affect on filtering and reduction in capacity.		**$100,000**
Idylwilde Reservoir: Concerns about the loss of Power generation is minimal. The main concern is The affect on the turbines and sediment filling the Reservoir. They did not have a good number to put in.		**$unknown**
City of Greeley		
Sediment in Lake Loveland: The lake can hold 12,000AF. They will have to drain I O,000AF to clean out the sediment.	10,000AF @ $382/AF	**$3,820,000**
Water Treatment, City of Greeley @ Boyd Lake. They treat 10,000 AF per year. They are concerned about sediment, hauling Additional Sludge, additional chlorine treatment of smoky taste. TOC's are a concern due to there affect on filtering and reduction in capacity Manganese and its red staining affects are a concern. This is an aesthetics problem for their customers.		**$100,000**

City of Fort Collins
No affect unless the Hansen Feeder Canal is impacted by runoff from the green ridge area. Northern has cross drains and underdrains on every major tributary that drains to the Hansen. They do have some small tributaries that drain directly into the Hansen. There is a concern about debris impacting the cross and under drains and causing overflow into the Hansen. If this occurs or the small tributaries carry ash and sediment into the canal. Horsetooth Reservoir will be affected. Horsetooth provides a lot of the city of Fort Collins drinking water. The representative from Fort Collins felt that overall they will not be affected. Therefore no dollar amount will be entered for Fort Collins.

Irrigated Cropland
There was some discussion on the affects of sediment on the irrigated cropland in the area served by the irrigation companies in the area. Some affect may occur if headgates are damaged and water can not be diverted. There are approximately 32,000 acres of irrigated land in this area. At our standard cost of $200/acre. That comes to ***$6,400,000*** of loss crop production.

TOTAL POTENTIAL DAMAGES: $15,008,000

Other Comments:

Steve Anderson of the Big Thompson SCD voiced his concern about the SCD's ability to cover the 25%. The other entities expressed a desire to contribute to the SCD to help offset the costs. They all want treatment costs and what their expected shares of the costs will be ASAP. There were questions about what qualifies as in-kind services and how does that impact Big T's projected out of pocket expense. The group also ***strongly recommended*** that the Colorado Water Conservation Board, Colorado State Soil Conservation Board and the governor's office be contacted to discuss state funding for the SCD's share. NCWCD wanted to know if they installed monitoring equipment in the burn area, if that could be considered in kind services. Northern is willing to put $20,000 into the burn area. Another question related to how long hydrophobic soils persist after a fire. They also wanted to know what the soils were in the Buffalo Creek fire. I would like the answers to these questions ASAP, please. Finally, the USGS representatives stated that a major source of sediment was from the stream channel in the Buffalo creek fire. They also offered any assistance we would need for aerial photos, monitoring, sedimentation calculations and hydrology modeling. I think it would be wise to use their expertise and develop a partnership with them. They also expressed concern about the impacts of phosphorous loading into the domestic and irrigation systems. They think it might impact algae growth and cause them additional costs in water treatment.

Above--Area of moderate and high intensity burn rehabbed with contour tree felling, straw waddles, and hand seeding. Below--Area of high intensity burn rehabbed by mulch and seeding. Pictures taken one year after fire by Todd Boldt, NRCS.

Bobcat Fire Monitoring

Lee H. MacDonald and John D. Stednick - Principal Investigators

I. DETAILS OF THE FIRE

- The Bobcat Fire near Drake, CO burned 10,600 acres of public and private lands in June 2000, this was the largest recorded wildfire on the Arapaho-Roosevelt National Forest.

- USDA-Forest Service Burned Area Emergency Rehabilitation (BAER) funds and a research grants from U.S. EPA have been supporting work on: 1) strength and persistence of hydrophobic soils, 2) runoff and erosion from small plots using a rainfall simulator, 3) effectiveness of BAER treatments to reduce runoff and erosion, 4) sediment production on the hillslope scale, and 5) monitoring runoff and water quality at the watershed scale.

II. Graduate Student Projects

- **Edward Huffman** (strength and persistence of hydrophobic soils)
- **Juan de Dios Benavides-Solorio** (runoff and erosion from small plots and hillslopes)
- **Joe Wagenbrenner** (effectiveness of BAER treatments to reduce runoff and erosion)
- **Matt Kunze** (monitoring precipitation, runoff, and water quality at the watershed scale)

In press, Hydrological *Processes*

Strength and Persistence of Fire-induced Soil Hydrophobicity under Ponderosa and Lodgepole Pine, Colorado Front Range

Edward L. Huffman[*1], Lee H. MacDonald[2], and John D. Stednick[2]
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Abstract

Fire-induced soil hydrophobicity is presumed to be a primary cause of the observed post-fire increases in runoff and erosion from forested watersheds in the Colorado. Front Range, but the presence and persistence of hydrophobic conditions has not been rigorously evaluated. Hence the goals of this study were to: (1) assess natural and fire-induced soil hydrophobicity in the Colorado Front Range, and (2) determine the effect of burn severity, soil texture, vegetation type, soil moisture, and time since burning on soil hydrophobicity.

Five wild and prescribed fires ranging in age from 0 to 22 months were studied. Each fire had four study sites in ponderosa pine forests that had been burned at high, moderate, and low severity, respectively, and three sites in unburned areas. Additional sites were established in lodgepole pine stands and an area with unusually coarse-textured soils. At each site soil hydrophobicity was assessed in two pits using the water drop penetration time (WDPT) and the critical surface tension (CST). Measurements were made at the mineral soil surface and depths of 3, 6, 9, 12, 15, and 18 cm.

In sites burned at moderate or high severity the soils were often strongly hydrophobic at 0, 3, and 6 cm. Unburned sites or sites burned at low severity were typically hydrophobic only at the surface. Although soil hydrophobicity generally strengthened with increasing burn severity, statistically significant differences in soil hydrophobicity were difficult to detect because of the high variability within and between sites. Hydrophobicity also increased with increasing percent sand and was not present when soil moistures exceeded 12-25 percent. There were no significant differences in soil hydrophobicity between ponderosa and lodgepole pine stands, regardless of burn severity.

Repeat measurements on one fire suggest a weakening of fire-induced soil hydrophobicity after three months. Comparisons between fires suggest that fire-induced soil hydrophobicity persists for at least 22 months. Overall, CST values were more consistent and more highly correlated with the independent variables than the WDPT, and the CST is recommended for assessing soil hydrophobicity rather than the more commonly used WDPT.

KEYWORDS: soil hydrophobicity; water repellency; burn severity; soil texture; Colorado Front Range; critical surface tension; ponderosa pine; lodgepole pine

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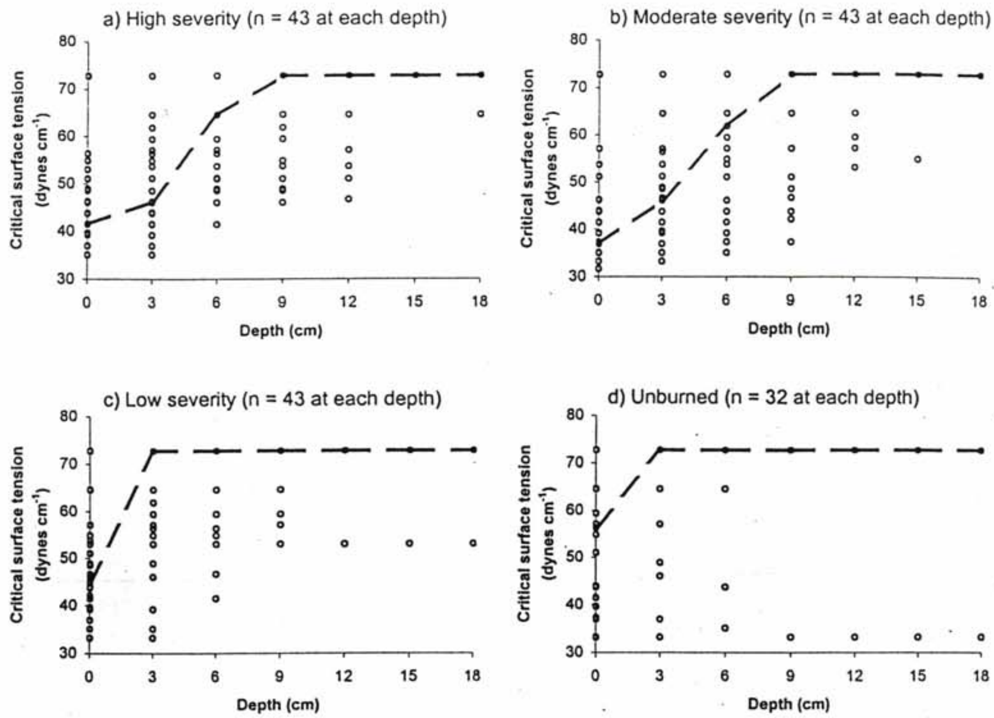

Figure 2. Critical surface tension values for a) high severity, b) moderate severity, c) low severity, and d) unburned sites. Each circle represents the average value at a site. Because so many values are overlapping, the median value for all sites is plotted as a dashed line. A decrease in critical surface tension indicates stronger hydrophobicity.

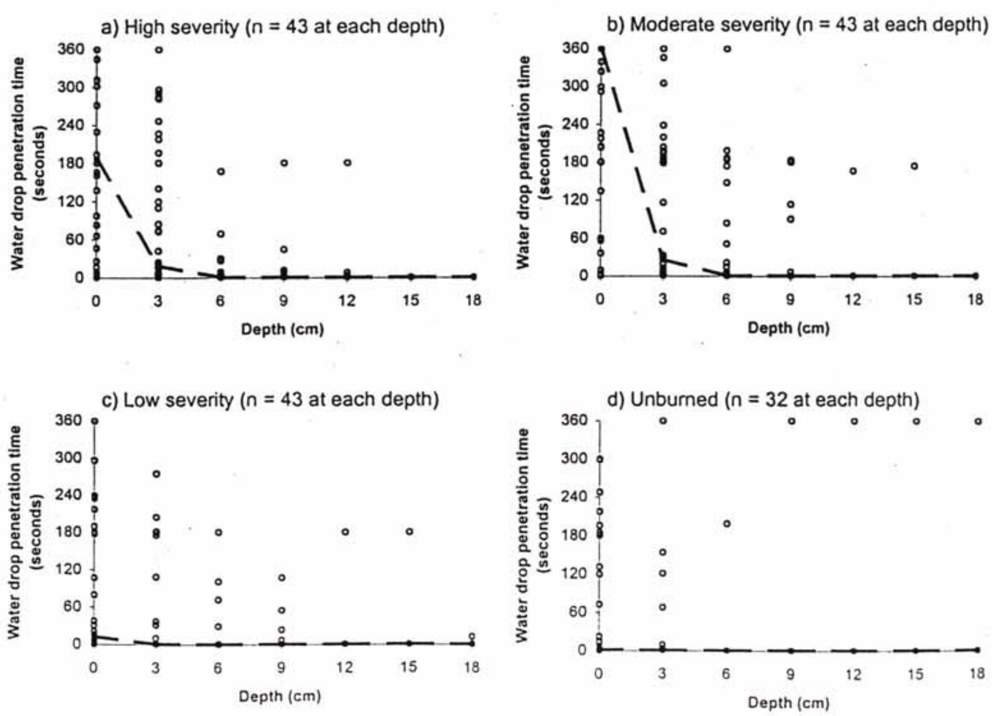

Figure 3. Water drop penetration times for a) high severity, b) moderate severity, c) low severity, and d) unburned sites. Each circle represents the average value at a site. Because so many values are overlapping, the median value for all sites is plotted as a dashed line.

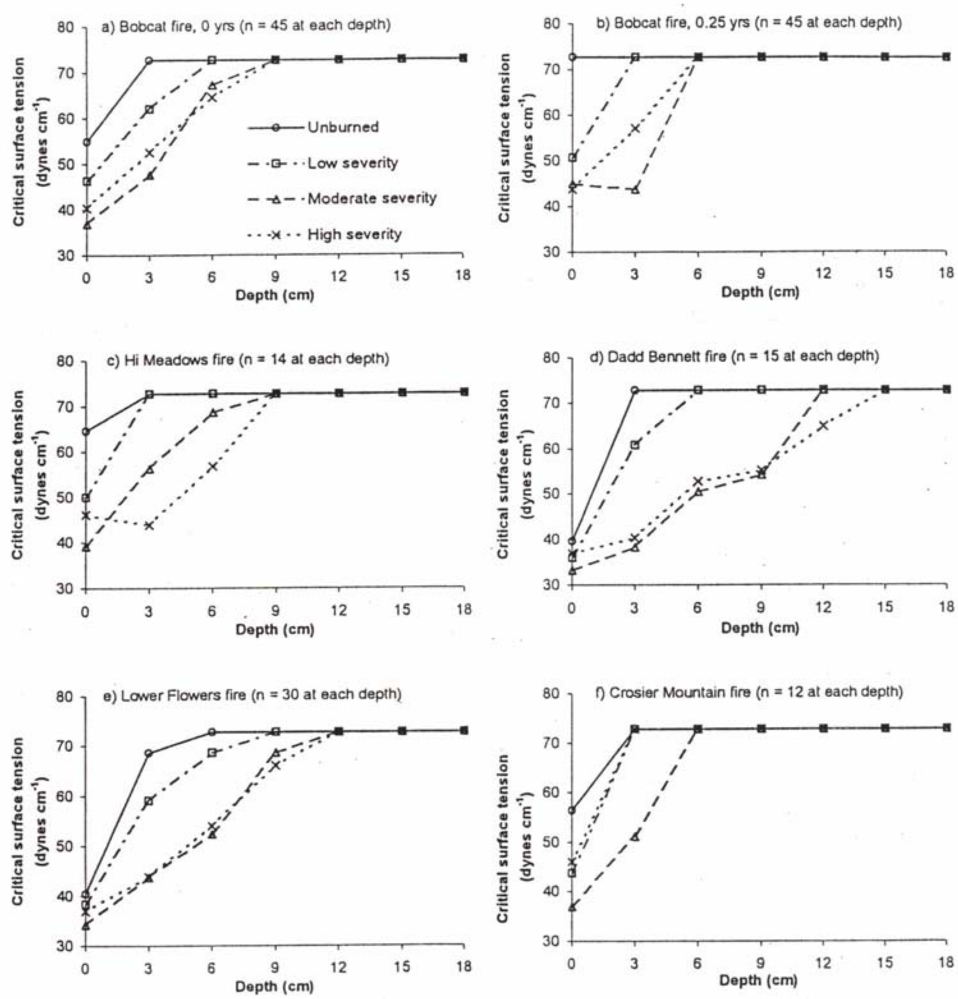

Figure 4. Critical surface tension for high severity, moderate severity, low severity, and unburned sites in the a) Bobcat fire shortly after burning, b) Bobcat fire after 3 months, c) Hi Meadows fire, d) Dadd Bennett fire, e) Lower Flowers fire, and f) Crosier Mountain fire. Each symbol represents the median value at a given depth, and the same legend applies to all six plots.

Table 4. Correlations between each independent variable and measured CST values at depths of 0, 3, and 6 cm. The top number for a given correlation is the correlation coefficient (r) and the number in parentheses is the p-value. Values in bold are significant at $p \leq 0.05$.

Variable	Depth = 0 cm CST	Depth = 3 cm CST	Depth = 6 cm CST
Fire severity	**-0.179**	**-0.308**	**-0.161**
	(0.0235)	**(<0.0001)**	**(0.0418)**
Vegetation type	0.087	-0.025	-0.057
	(0.27)	(0.75)	(0.47)
Time since burning	-0.130	0.108	-0.008
	(0.10)	(0.17)	(0.92)
Surface soil moisture	**0.382**	**0.349**	**0.266**
	(<0.0001)	**(<0.0001)**	**(0.0007)**
Percent > 2mm	0.116	0.016	-0.074
	(0.14)	(0.84)	(0.35)
Percent sand	**-0.295**	**-0.398**	**-0.418**
	(0.0001)	**(<0.0001)**	**(<0.0001)**
Percent clay	**0.175**	**-0.300**	**0.244**
	(0.026)	**(0.0001)**	**(0.0018)**

Table 5. R^2, F, and p values for the overall model to predict the natural logarithm of CST values, and the statistics for each significant variable. The soil moisture at the surface was used for predicting lnCST at 0 and 3 cm, while the model for lnCST at 6 cm uses the soil moisture at 10 cm.

	Depth = 0 cm			**Depth = 3 cm**			**Depth = 6 cm**		
lnCST	**R^2**	**F**	**p**	**R^2**	**F**	**p**	**R^2**	**F**	**p**
Model	0.38	18.87	<0.0001	0.41	21.46	<0.0001	0.30	13.36	<0.0001
Burn severity		16.71	<0.0001		17.68	<0.0001		9.12	<0.0001
Soil moisture		9.78	0.0021		7.57	0.0066		7.0	0.009
Percent sand		12.91	0.0004		22.81	<0.0001		20.61	<0.0001

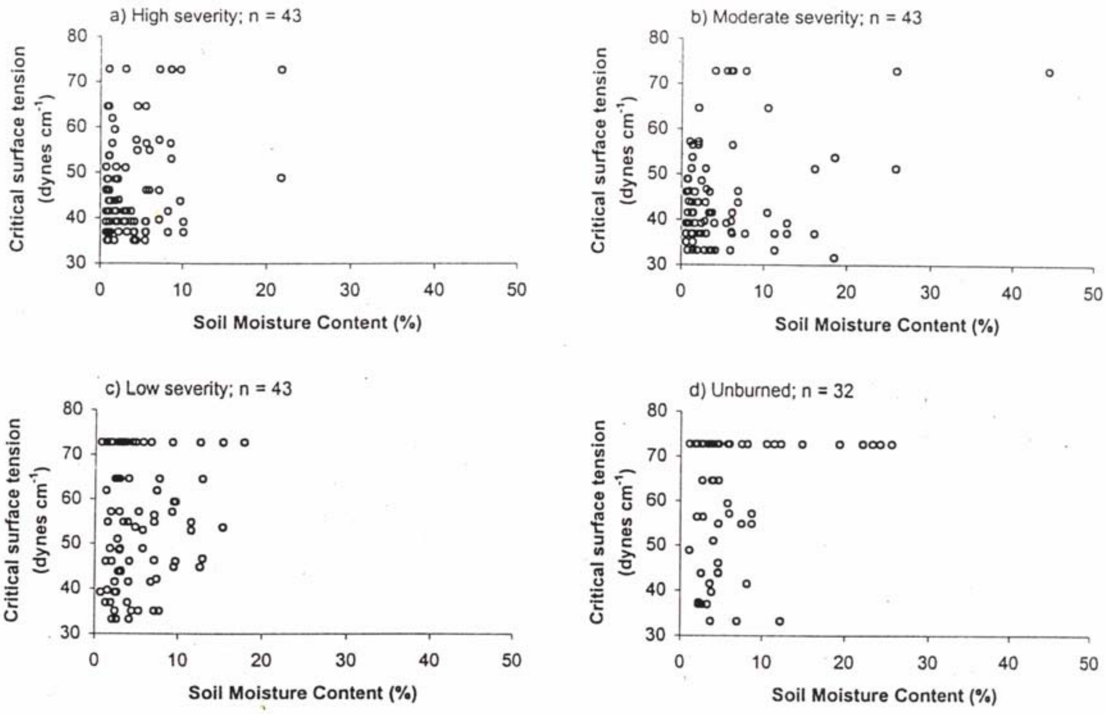

Figure 6. Critical surface tension at the soil surface and 3 cm as a function of surface soil moisture content for a) high severity, b) moderate severity, c) low severity, and d) unburned sites.

CONCLUSIONS

Critical surface tension was less variable than the water drop penetration time when stratified by fire, burn severity and depth. CST was-also better correlated with the variables measured in this study than the water drop penetration time. Since CST is also quicker and easier to measure, the CST should be used for assessing soil hydrophobicity in the field.

In sites burned at high and moderate severity the soils were generally hydrophobic from the soil surface to a depth of 6 cm. In low severity and unburned sites the soils were generally hydrophobic only at the soil surface, and this surface hydrophobicity was generally weaker than in sites burned at high and moderate severity. Soil hydrophobicity was often stronger and deeper in the prescribed fires than the wildfires, but the effect of hydrophobicity on runoff is likely to be less because prescribed fires are usually smaller and have less area burned at high and moderate severity. Three of 161 sites had strong natural hydrophobicity to a depth of 18 cm, and this was associated with fungal mycelia.

Burn severity and percent sand are the most significant predictors of fire-induced soil hydrophobicity in ponderosa and lodgepole forests along the Colorado Front Range. Together with soil moisture, these factors explained approximately 40 percent of the variability in soil hydrophobicity at the soil surface and a depth of 3 cm. Time since burning was not a significant predictor of soil hydrophobicity, and this is probably due to the variability of fire-induced soil hydrophobicity between fires. There was some evidence that hydrophobic soils become hydrophilic when soil moisture levels exceed 12 to 25 percent, and this threshold may vary with burn severity. Fire-induced and natural soil hydrophobicity were not significantly different between lodgepole and ponderosa pine stands.

Repeated measurements suggest that fire-induced soil hydrophobicity weakens within three months after burning. Hydrophobicity measurements 22 months after burning showed little evidence of fire-induced soil hydrophobicity at 3 and 6 cm in site burned at high and moderate severity. However, sites burned at moderate severity 22 months earlier were significantly more hydrophobic at the soil surface than unburned sites.

In press, *Hydrological Processes*

Post-fire Runoff and Erosion from Simulated Rainfall on Small Plots, Colorado Front Range

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Abstract

Wildfires in the Colorado Front Range can trigger dramatic increases in runoff and erosion. A better understanding of the causes of these increases is needed to predict the effects of future wildfires, estimate runoff and erosion risks from prescribed fires, and design effective post-fire rehabilitation treatments. The objective of this project was to determine the relationship between runoff and sediment yields to the site variables of burn severity, percent cover, soil water repellency, soil moisture, time since burning, and slope. To eliminate the variability due to natural rainfall events, we applied an artificial storm of approximately 80 mm hr^{-1} on twenty-six 1 m^2 plots in the summer and fall of 2000. The plots were distributed among a June 2000 wildfire, a November 1999 prescribed fire, and a July 1994 wildfire.

For 23 of the 26 plots the ratio of runoff to rainfall exceeded 50%. Nearly all sites exhibited strong natural or fire-induced water repellency, so the runoff ratios were only 1530% larger for the high-severity plots in the two more recent fires than for the unburned or low-severity plots. The two high-severity plots in the 1994 wildfire had very low runoff ratios, and this probably was due to the high soil moisture conditions at the time of the simulated rainfall and the resulting reduction in the natural water repellency. Sediment yields from the high-severity sites in the two more recent fires were 10-26 times greater than the unburned and low-severity plots. The plots burned at high severity in 1994 yielded only slightly more sediment than the unburned plots. Percent ground cover explained 81% of the variability in sediment yields, and the sediment yields from the plots in the 1994 wildfire are consistent with the observed recovery in percent- ground cover.

KEYWORDS: Fire, rainfall simulator, runoff, erosion, pine forests, Colorado Front Range

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[2] Corresponding author. Phone: (970) 491-6109; e-mail: leemac@cnr.colostate.edu).

Figure 5

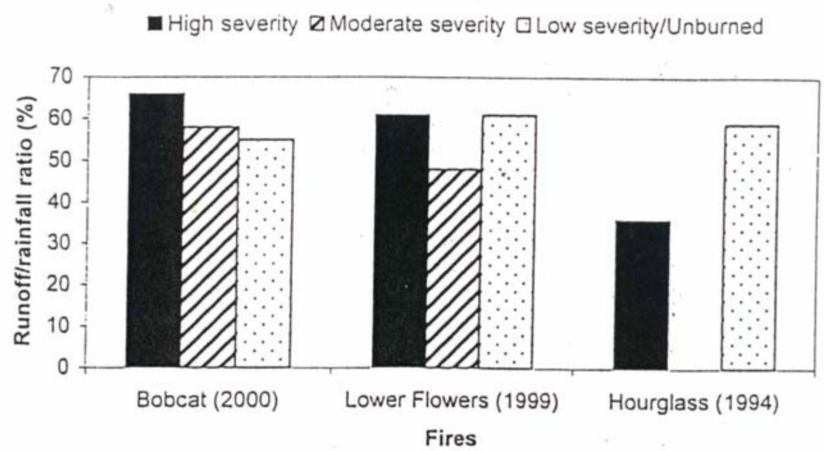

Figure 5. Mean runoff/rainfall ratios by fire and severity.

Figure 9.

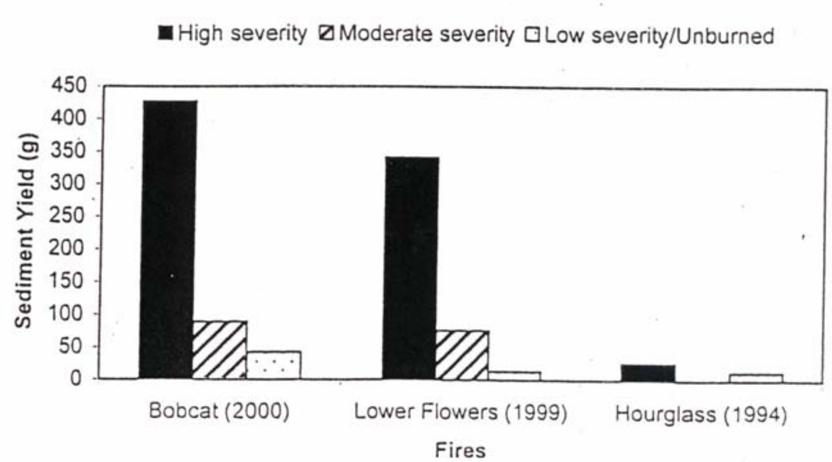

Figure 9. Mean sediment yields by fire and severity.

Figure 10

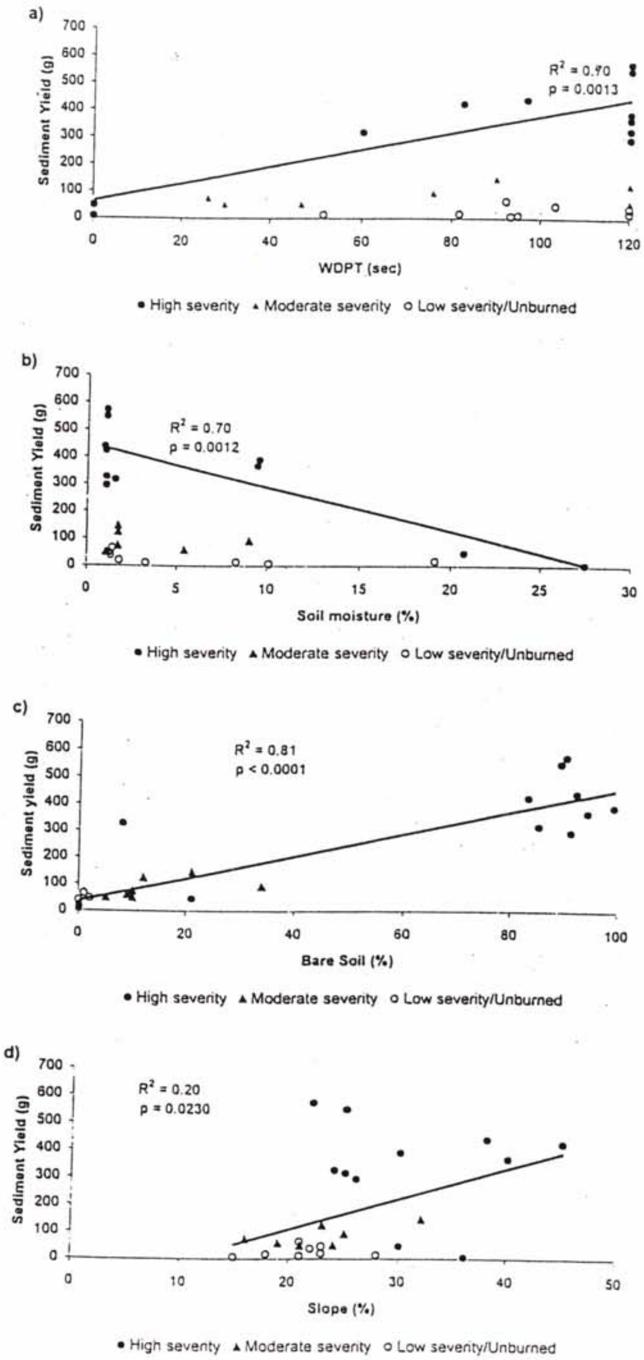

Figure 10. Relationship between sediment yields for each plot and (a) hydrophobicity at 2 cm, (b) soil moisture, (c) percent bare soil, and (d) slope. The regression lines and statistics in (a) and (b) are only for the high-severity plots.

Effectiveness of Burn Area Emergency Rehabilitation Treatments
Interim Report, 23 February 2001

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MacDonald Department of Earth
Resources Colorado State
University Fort Collins, CO

Introduction

The Bobcat Fire burned over 10,000 acres of a predominantly Ponderosa pine ecosystem west of Loveland, Colorado in June 2000. Three emergency rehabilitation treatments were installed by the United States Forest Service (USFS) to reduce the potential impact to downstream water resources. Approximately 650 acres were treated by contour-felling, 850 acres were mulched with straw, and 2800 acres had grass seed applied by aerial seeding.

1. The effectiveness of these common post-fire emergency rehabilitation treatments has not been rigorously tested (Robichaud et al., 2000). This study is attempting to evaluate the effectiveness of these three treatments in the area burned by the Bobcat Fire. The specific objectives are:
2. Determine if sediment production is reduced in contour-felled, mulched, or seeded areas relative to untreated areas.
3. Evaluate the relationship between the amount and intensity of precipitation to the measured sediment yields from each treatment type.
4. Determine if any of the treatments changes the rate at which vegetative cover is established relative to untreated areas.
5. Determine if trenching above contour logs changes the infiltration rate relative to immediately adjacent burned areas, and if the infiltration rate in the trenched and en-trenched areas changes over time.

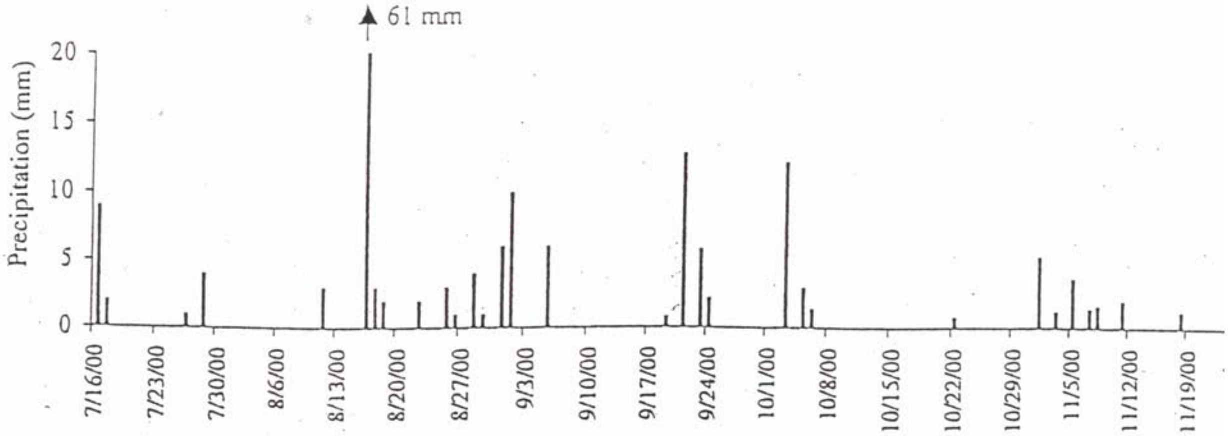
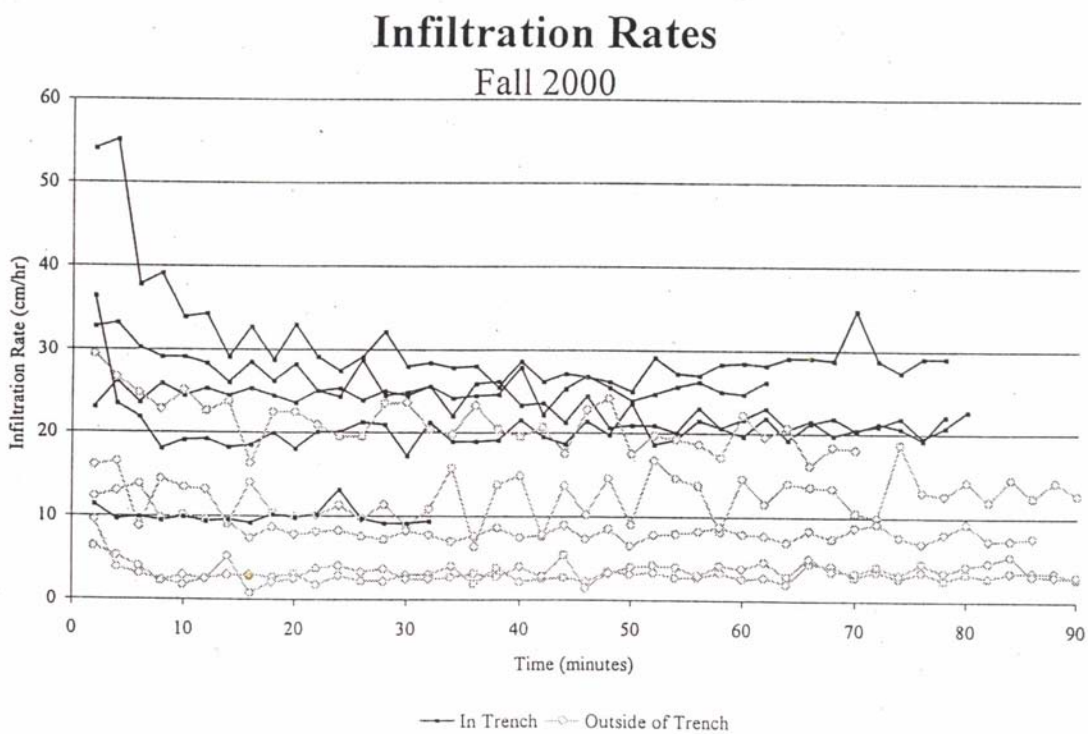
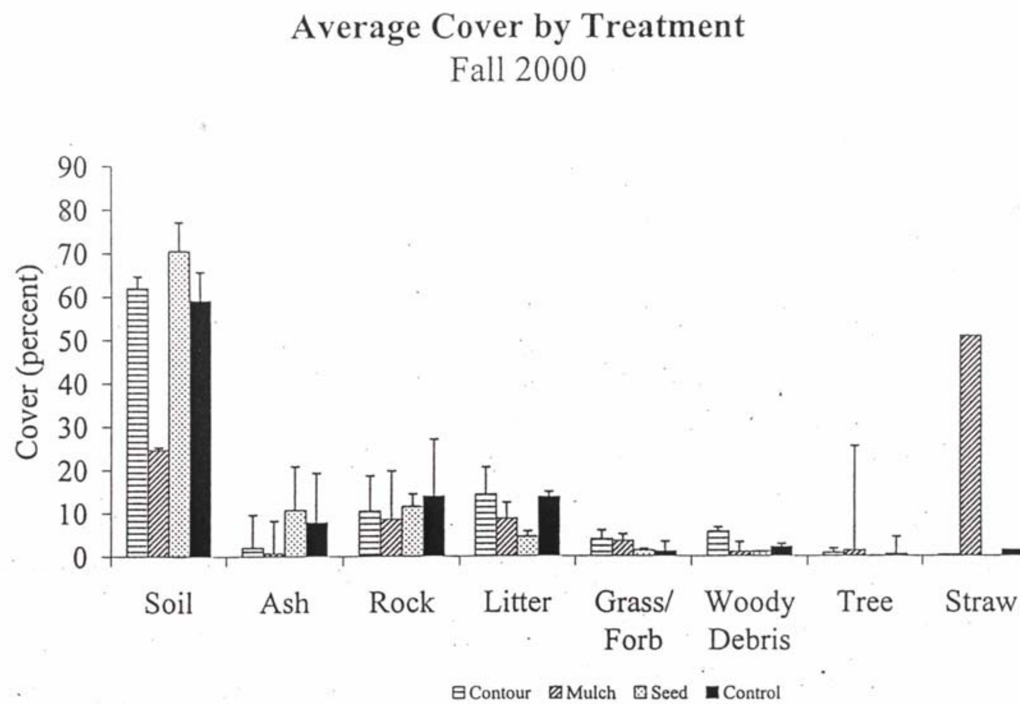
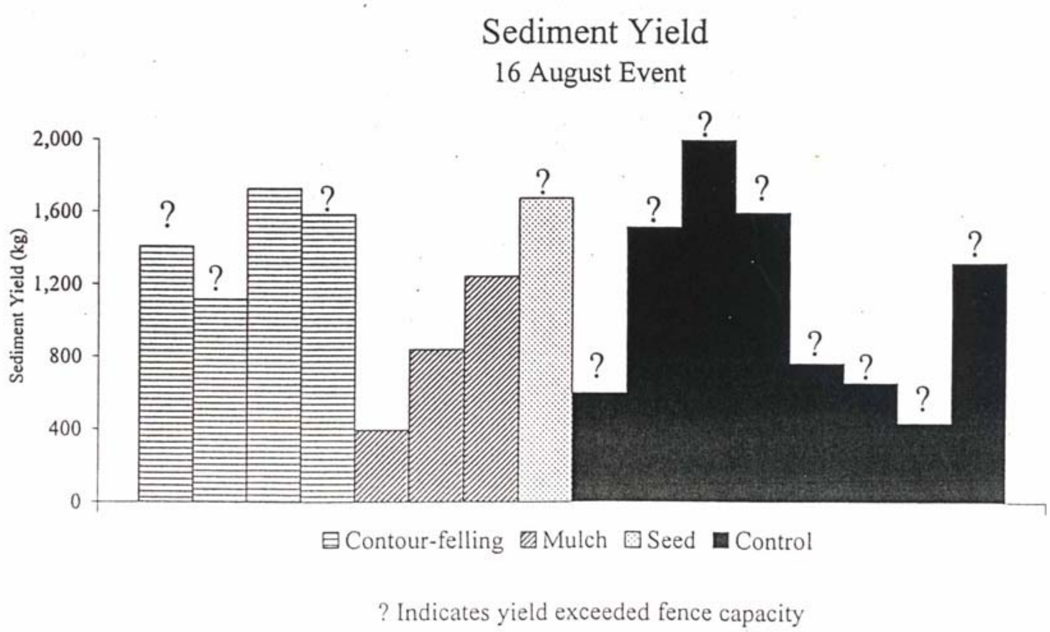
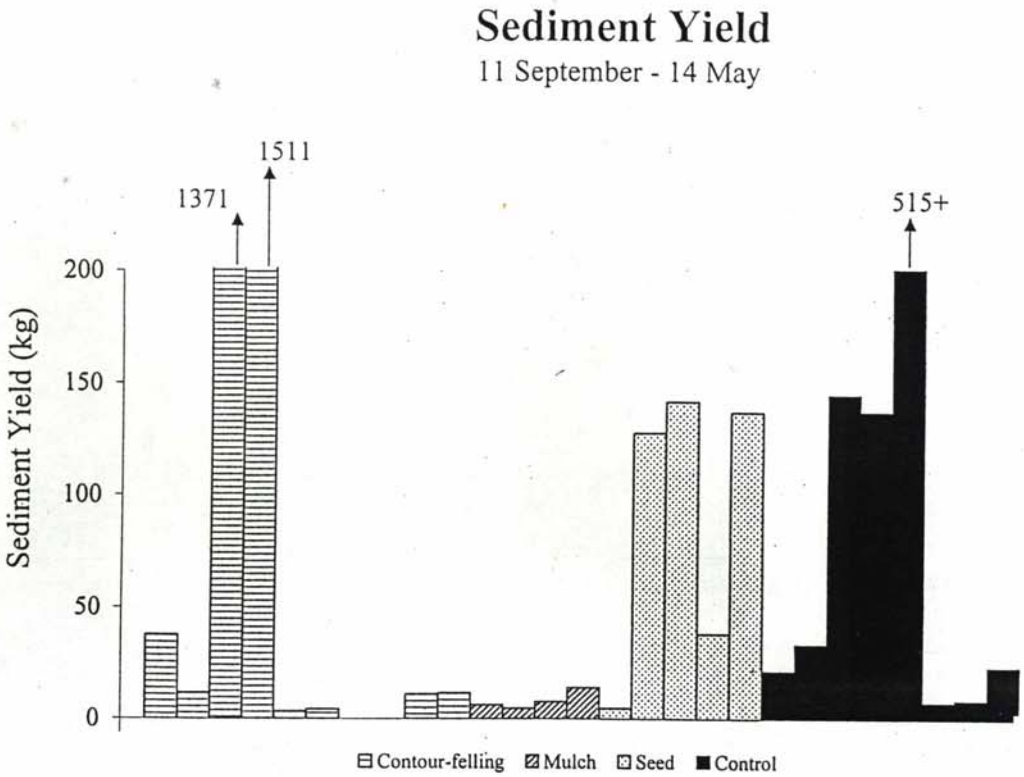


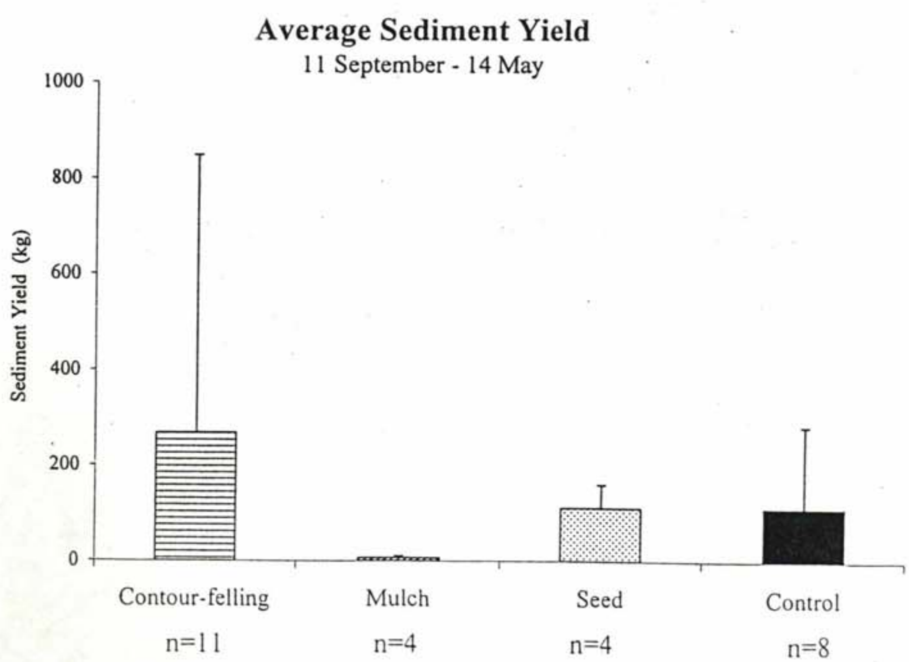
Figure 2: Precipitation in Bobcat Fire area. 16 July to 18 September is from the gauge at Storm Mountain; 19 September through 2 December is from the gauge at Galuchie Ridge.




Average Cover by Treatment
Fall 2000
Cover (percent)
90
80
70
60
50
40
30
20
10
0
Soil
Ash
Rock
Litter
Grass/ Forb
Woody Debris
Tree
Straw
Contour
Mulch
Seed
Control


Sediment Yield
16 August Event
Sediment Yield (kg)
2,000
1,600
1,200
800
400
0
Contour-felling
Mulch
Seed
Control
? Indicates yield exceeded fence capacity





High variation in contour felling yield due to addition of 7 plots in late September and high sediment yield in existing plots during storm on 21 September.

Matt Kunze and John Stednick

Precipitation, Runoff, and Sediment Production at the Watershed Scale

- Measure precipitation over the burn area with 9 recording rain gauges;
- Monitor 2 small watersheds within the burn area (Bobcat Gulch and Jug Gulch);
- Operate a gauging station in each watershed, including continuous measurement of stage, specific conductivity, and water temperature;
- Each station also has an automatic pumping sampler to take water samples at defined time intervals. All samples are currently being analyzed for total suspended solids, and some samples are being analyzed for nutrients, including nitrate-nitrogen and phosphate.

All About Altitude Sickness

Altitude illness is caused by the lack of oxygen in our thin mountain air. Altitude illness can effect anyone, regardless of age or physical condition in altitudes above 6000 feet. The altitude illness seen most commonly is:

Acute Mountain Sickness (A.M.S.)

Acute Mountain Sickness is a mild form of altitude sickness which effects 20% to 30% of visitors to Colorado. The symptoms are headache, nausea, vomiting and trouble sleeping. A.M.S. looks and feels like the "flu". Most people experience the symptoms of A.M.S. in the first three days after arrival. The symptoms usually go away by the fourth day.

The incidence and severity of A.M.S. are related to altitude, speed of ascent, physical exertion and prior acclimatization. Some people are particularly susceptible to A.M.S. and experience similar episodes with each exposure. Symptoms of headache, shortness of breath, anorexia or nausea, weakness dyspnea and "flu-like" malaise may begin 6 to 48 hours after ascent.

Treatment of A.M.S.

Most people with mild A.M.S. get better with no treatment at all. People with moderate or severe symptoms should see a doctor. Things that help:

1. Before your trip, maintain a good work/rest cycle, avoiding excessive work hours and last minute packing.

2. Avoid alcohol, sleeping pills or narcotics, they may decrease ventilation, intensify hypoxemia and make symptoms worse.

3. Drink plenty of fluids.

4. Eat high-carbohydrate foods (rice, pasta, cereal) while avoiding fatty stuff.

5. Avoid heavy exercise. Mild exercise is okay.

6. Diamox (acetazolamide) 125mg. tablets taken twice a day is F.D.A. approved for prevention and treatment of A.M.S. Although it was originally released as a diuretic, it also helps you breath deeper and faster. This allows you to get more oxygen. Diamox is especially helpful with the insomnia and other symptoms of A.M.S.

7. Home oxygen will relieve symptoms. Home oxygen is safe, cheap and easy to use. It can be used at night when symptoms are worse and off and on during the day as symptoms dictate.

8. If nothing else works, you can return to lower altitude. Going to Denver or Colorado Springs will always relieve the symptoms of A.M.S.

Prevention of A.M.S.

People who get symptoms from high altitude can take several steps to prevent symptoms on their next visit to Colorado.

1. "Staging" or changing altitudes helps. If you are coming from sea level, it is better to spend the night in Denver or Colorado Springs. This allows your body to adjust to the altitude and will help you adjust to higher altitudes better.

2. Diamox may be taken one to two days prior to arrival. This will "prepare" your body for our altitude.

3. Do not over-do on your first day or two.

4. Physical conditioning at sea level does not help.

Conclusion

Rapid ascent to high altitude can be uncomfortable for many people and dangerous for some. Headache and other symptoms of acute mountain sickness may be prevented by gradual ascent or by taking Diamox. Pulmonary edema occurs in a small percentage of people who quickly ascent to elevations above 8,000 feet. Those patients need to see a physician for oxygen therapy and descent to lower altitude.

Many Parks Curve – 9,620 feet elevation

Prominent in this fine panorama are several "parks", or mountain – enclosed meadows. The long, forested ridges separating these parks are moraines, great heaps of rock debris that glaciers pushed of deposited along their sides between 150,000 and 12,000 years ago. Even older glaciers existed here, but erosion has obliterated most evidence of their passing. To the west of the viewpoint – and generally behind nearby ridges – lie the headwalls where these glaciers originated and began their journey to the valley floors. Most extended less than five or six miles.

Where people gather, so do the common birds of the Rocky Mountains; the noisy, black-and-white Clark's nutcracker, the blue Steller's jay with its black crest, the quiet gray jay.

Geology of Rocky Mountain National Park

(From "Rocky Mountain National Park, the Story of its Origin," by Glen Kaye, Chief Park Naturalist, 1987.)

THE ROCKIES BEGIN TO RISE

Why are marine fossils so far above the sea? How did this come about? The seas do fluctuate, but not by a tenth as much.

The Late Cretaceous and Early Tertiary Periods in this region were times of major mountain building termed the Laramide Orogeny—the result of continental drift and the complex collision of thick layers of the Earth's crust.

In its slow movement to the west, floating on the Earth's molten mantle, the great North American Plate collided with plates in the Pacific Ocean for millions of years--and in doing so the continental plate began to change. For a long time the major effects of the collision were located near the western margin of the North American Continent; but about 70 million years ago the deformation spread inland and the rocks of what is now Colorado began to fold and fracture due to severe compressional stress. Faults eventually appeared on both sides of the Front Range, and great blocks of Proterozoic basement rock began a fitful rise. In some instances, the movement was nearly vertical. Along the mountain flanks, faulting often caused blocks of rock to tip or overturn, turning the geologic record upside down. A huge block of basement rock in the northeastern corner of the Park was also pushed 7 miles to the west into North Park Basin where it now lies on younger sedimentary rock.

All this, this orogeny, accelerated erosion. Streams erased a mile of overlying sedimentary rock; then they cut again into the Proterozoic basement rock. To the east and west the resulting debris piled on the mountain flanks in thick sedimentary layers, and with each new uplift, the streams cut anew.

In late Cretaceous and Early Tertiary time, volcanoes and volcanic products also appeared within the Front Range. Stocks of igneous rock intruded below volcanoes in the areas adjacent to the Park, andesite breccias were laid down near Granby, and some small dikes were injected into the southeast area of the Park. Subsequent erosion leveled the mountains and narrowed them, so that by about 40 million years ago the Continental Divide stood 8,000 feet above sea level and 3,000-5,000 feet above the surrounding land.

In middle and late Tertiary time there again commenced an uplift of the mountains, and the area was ultimately raised about 5,000 feet. Faulting was accompanied by plutonic and volcanic activity in the northwest corner of the Park, and the features were created that are so prevalent in the area today. The period of igneous activity was brief. It spanned a mere 2 million years, between 28 and 26 million years ago as measured by radioactive decay of potassium to argon. But the products of that period cover 25 square miles.

First to appear were the flows of basalt and trachyandesite near Cameron Pass and the andesite flows on Mt. Richthofen. Later, the Mt. Richthofen stock of granodiorite and monzonite and the Mt. Cumulus stock of granite pushed through the crust of the Earth and cooled near the surface to create the distinctive north-south mass of the Never Summer Range. Both stocks are now exposed by erosion, and each one is several miles across. The Mt. Richthofen granodiorite extends from Static Peak south to Howard Mountain; the slightly younger Mt. Cumulus granite predominates on Mr. Cumulus and Red Mountain.

Shortly thereafter there began a series of eruptions chemically related to granite but often explosive in nature. For a million years these eruptions blanketed the land in ash falls and ash flows, tuffs and volcanic breccias, and latite, rhyolite, and lahar flows. Even obsidian is found near the summit of Specimen Mountain. Collectively, these volcanic deposits are more that 1,200 feet thick. In spreading over the land they buried Milner and La Poudre Passes, and one ash flow surged as far as Iceberg Lake along Trail Ridge Road. There, a cliff of welded tuff is exposed where a small cirque was subsequently carved into it. Volcanic ash is also visible in roadcuts near Poudre Lake.

The source of all these volcanic deposits was probably the stock visible today along the Never Summer Mountains.

Rainwater, of course, continued its inexorable work all the while, and with uplift of the land, the steeply pitched streams cut with fresh vigor through volcanic deposits. Some streams recarved valleys where their original routes lay. Others aligned themselves along readily erodible faults created by the Cretaceous and Tertiary uplifts. The Colorado River, for example, unerringly follows the Kawuneeche Fault. All streams, however moved even more debris to the mountain flanks and beyond—the Tertiary volcanics, the residual Mesozoic and Palozoic sediments, more Proterozoic rock—and the relief increased as great canyons appeared along the northern Front Range. The mountains achieved approximately their present altitudes with this uplift, but in the Continental Divide region they were more rounded than today. Portions of these mountain slopes survive today—on Trail Ridge, on Bighorn Flats and Flattop Mountain, on the summit of Terra Tomah, and on the western flanks of Mount Ida, Taylor Peak, Mt. Alice, and Ogallala Peak. More important, the uplift coincided with the global cooling of the Earth. The Front Range ultimately stood above the elevation of permanent snow, and with this, the conditions for glacier formation were at last attained.

RIVERS OF ICE

In the popular sense, the Pleistocene Epoch, from 2 million to 10 thousand years ago, represents the Ice Age--the time great ice sheets advanced repeatedly over North American and changed the face of the land. Glaciers did their work both earlier and later than this, but the Pleistocene Epoch presents the best products of their activity. The glaciation was not that of continental ice sheets, however, but the work of valley glaciers and mountain ice.

By 2 million years ago, despite continuing erosion, the Front Range was approaching its present height. At the same time the regional snowline, the point at which accumulation equals melting, was lowered due to global cooling. In this environment the snow began accumulating to unprecedented depths, and within decades, perhaps, it completed the transition to ice. Ice began to move as sheet flows on even the slightest slopes and, with extensive freezing and thawing at this lowered snowline elevation, these slopes eventually developed incipient cirques through the downslope movement of earth.

This, at least, is the conjectured beginning of glaciation of the Front Range; no local record of these early glaciers has been found. The products of early glaciation were either weathered to an unrecognizable extent or erased by subsequent stream and glacial erosion. Elsewhere in the Rocky Mountains, however, glaciers began their work about 1.6 million years ago.

East of the Park, the Tahosa Valley, lie the oldest known features of the local glaciation. There are no moraines in these undistinctive deposits, and the boulders within them are so deeply weathered that no striations remain. Such is the alteration that can occur within 200,000 years. The glaciers that followed, however, left a record that is better preserved; two major advances of ice moved down many mountain valleys, only to completely melt away each time. Then repeated minor advances of ice in the last 12,000 years left the increasingly fresh, but smaller, moraines so evident today in the highest reaches of the glacial valleys.

The earlier Bull Lake glaciers generally traveled the farthest. Twice between 150,000 and 130,000 years ago, the glaciers of this period advanced until some were 20 to 25 miles long. Twice they left moraines along their fronts and sides before they melted away. In the Fall River drainage these moraines lie on or just east of Aspenglen Campground—the lowest at an elevation of 8,040 feet. Bull Lake glaciers also left moraines in lower Beaver Meadows, around the base of Deer Mountain, in Glacier Basin, along the drainage of Roaring Fork creek below Longs Peak, at the mouth of Wild Basin, and around Shadow Mountain Lake. These moraines are notably more weathered and possess better-developed soils than younger moraines, suggesting that considerable time elapsed between advances of ice.

As with Bull Lake glaciers, glaciers of Pinedale age also choked the mountain valleys with ice. At time the ice from the Colorado River drainage overflowed Milner and La Poudre Passes, and all but the highest ridges and peaks were buried in white. The ice of today's Chapin Creek and Hague Creek drainages, for example, merged with the ice of the Cache La Poudre and rode over the northern shoulder of Specimen Mountain. Ice from the Never Summer Mountains flowed eastward from a multitude of cirques to join the Colorado River glacier and flow 20 miles to the south. Great rivers of ice from north and East Inlets poured west and carved out their respective canyons. Two major ice tributaries from the Mummy Range also poured south to join the eastward-flowing Fall River Glacier. Ice from Gorge lakes, Hayden Gorge, Spruce Canyon, and Odessa Gorge coalesced as they entered the Big Thompson drainage and flowed into Moraine Park. Glaciers originating in Tyndall Gorge, Chaos Canyon, Loch Vale, and Glacier Gorge likewise merged and advanced down the drainage of Glacier Creek. A dozen sources in Wild Basin fed streams of ice into the growing glacier of the North St. Vrain.

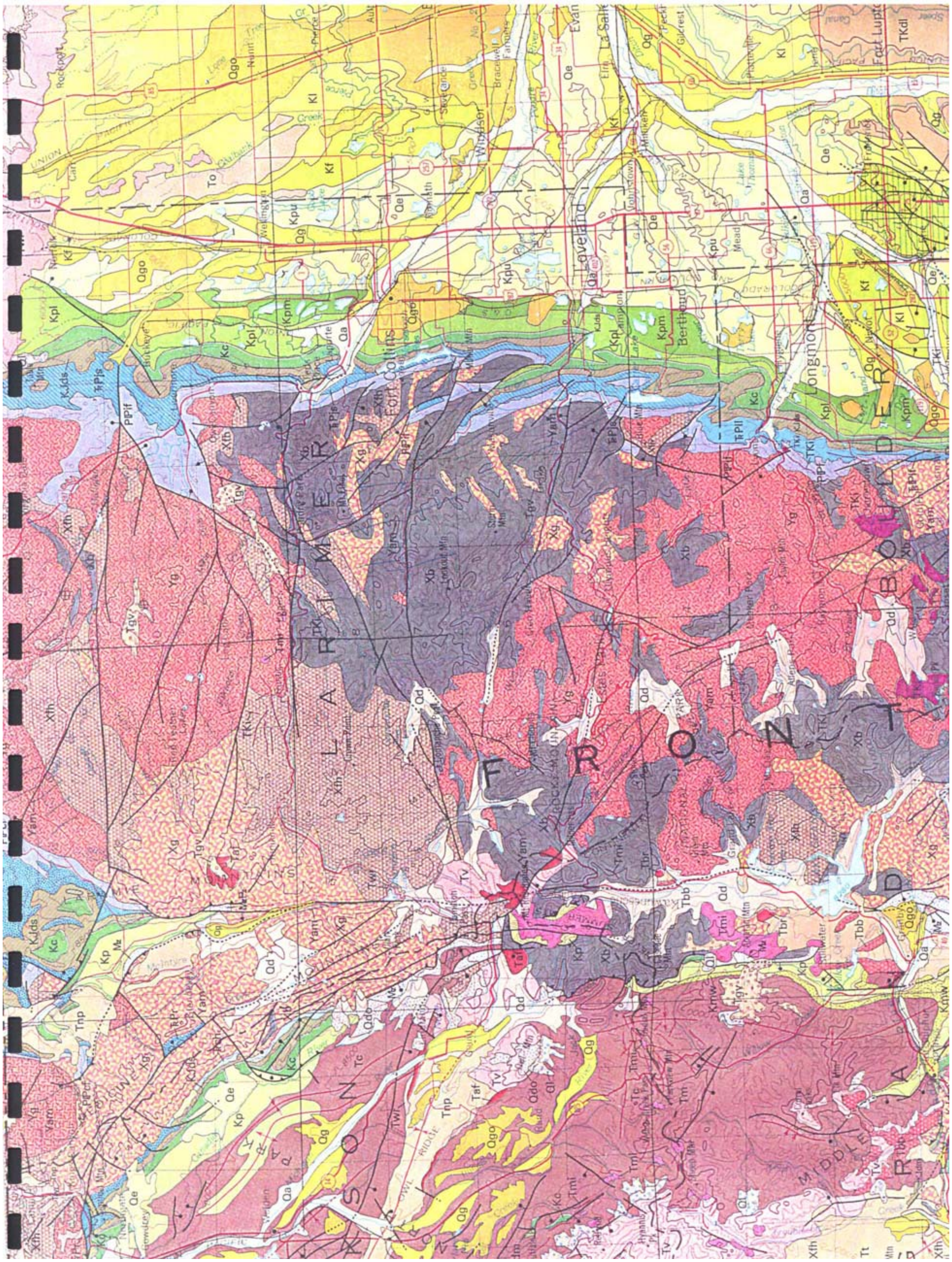
In most cases, Pinedale ice did not extend as far as Bull Lake ice. But in a few instances the younger moraines of Pinedale age lie on those of Bull Lake age, and in Roaring Fork below Longs Peak a Pinedale glacier did push downstream beyond the Bull Lake terminal moraine. Other conspicuous moraines of Pinedale

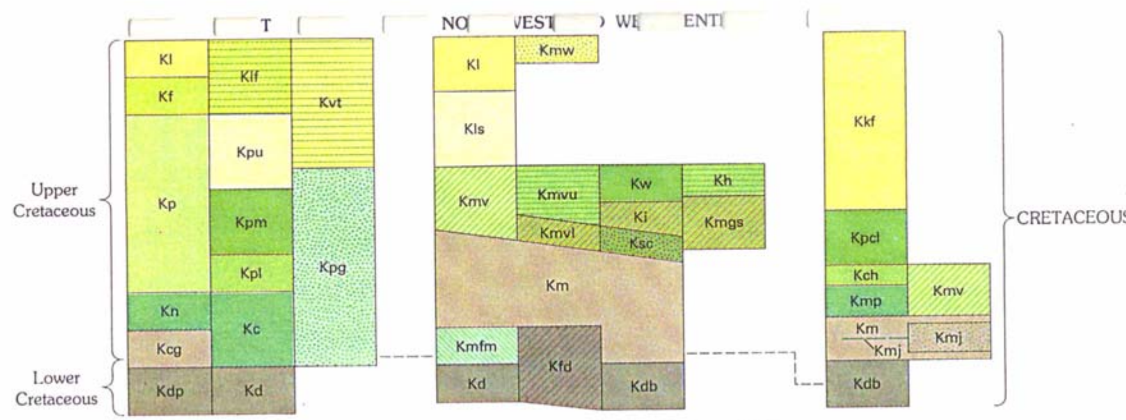
age include the South Lateral Moraine of Moraine Park, the sough lateral moraine of Horseshoe Park (blocking off Hidden Valley), and the moraines of Glacier Creek that embrace Glacier Basin on three sides. In Shadow Mountain Lake the Pinedale terminal moraines of the Colorado River Glacier now stand as distinctive islands.

All these moraines are much less weathered or eroded by streams than Bull Lake moraines, they readily stand out. Pinedale moraines show less soil development, their surfaces are usually hummocky, and striations are sometimes visible on the fresh, morainal boulders. Because of their size and sharpness of lines, these moraines are the most noticeable in the Park. Most of the Park's surface glacial till is of Pinedale age.

During Pinedale glaciation the repeated freezing and thawing and quarrying of rock greatly enlarged cirques, and the glaciers steadily bit into the mountainsides. Cols and aretes became common features where the sides or heads of glacial valleys merged, and cirques frequently left peaks in sharp profile, as in the matterhorns of Pagoda Mountain and Mt. Richthofen. Cirques also advanced into the four sides of Longs Peak, but its old erosional summit—perhaps of Miocene age—still remained. Bull Lake glaciers gave rough definition of the landscape, but Pinedale glaciers sharpened it.

During Pinedale glaciation the high country above and beyond glaciers was also shaped, for permafrost was widespread on the land. Where it existed, water was held to create a saturated earth. In a slow flow (a process called solifluction) and movement due to repeated freezing and thawing (a process called frost creep) this material moved downhill to create the pattern of terraces so noticeable in the tundra today. Rocky patterns in the tundra, including polygons and rock streams, appeared due to seasonal freezing and thawing and the growing failure caused by the melting of massive ground ice. Both solifluction and frost-creep occur today, and some rocky patterns are active, but on a much more restricted basis.


Fort Collins
Loveland
Berthoud
Longmont
Windsor
Wellington



SEDIMENTARY ROCKS OF CRETACEOUS AGE

EAST

Kl	LARAMIE FORMATION—Shale, claystone, sandstone, and major coal beds
Kf	FOX HILLS SANDSTONE
Klf	LARAMIE FORMATION AND FOX HILLS SANDSTONE
Kvt	VERMEJO FORMATION (SHALE, SANDSTONE, AND MAJOR COAL BEDS) AND TRINIDAD SANDSTONE
Kp	PIERRE SHALE, UNDIVIDED
Kpu	Upper unit
Kpm	Middle unit—In Boulder-Fort Collins area, contains Richard, Larimer, Rocky Ridge, Terry, and Hygiene Sandstone Members; elsewhere, shale between zones of *Baculites reesidei* and *B. scotti*
Kpl	Lower unit—Sharon Springs Member (organic-rich shale and numerous bentonite beds) in lower part
Kn	NIOBRARA FORMATION—Calcareous shale and limestone
Kcg	CARLILE SHALE, GREENHORN LIMESTONE, AND GRANEROS SHALE
Kc	COLORADO GROUP—Consists of Niobrara Formation (Kn) and either Benton Shale or Carlile, Greenhorn, and Graneros Formations (Kcg)
Kpg	PIERRE SHALE (Kp), NIOBRARA (Kn), AND CARLILE, GREENHORN, AND GRANEROS (Kcg) FORMATIONS, UNDIVIDED
Kdp	DAKOTA SANDSTONE AND PURGATOIRE FORMATION—Sandstone and shale
Kd	DAKOTA SANDSTONE OR GROUP

NORTHWEST AND WEST-CENTRAL

Kl	LANCE FORMATION—Shale, sandstone, and minor coal beds; Fox Hills equivalent at base
Kmw	WINDY GAP MEMBER (UPPER CRETACEOUS?) OF MIDDLE PARK FORMATION—Andesitic breccia and conglomerate
Kls	LEWIS SHALE
Kmv	MESAVERDE FORMATION, UNDIVIDED—Major coal beds in lower part; Rollins Sandstone Member at base in Delta, Gunnison and Pitkin Counties
	MESAVERDE GROUP OR FORMATION
Kmvu	Upper part—In Moffat and Rio Blanco Counties, sandstone, shale, and coal beds above Sego Sandstone. Along Grand Hogback south of Colorado River, sandstone and shale above coal-bearing sequence
Kmvl	Lower part—Sandstone, shale, and major coal beds

NORTHWEST AND WEST-CENTRAL (Continued)

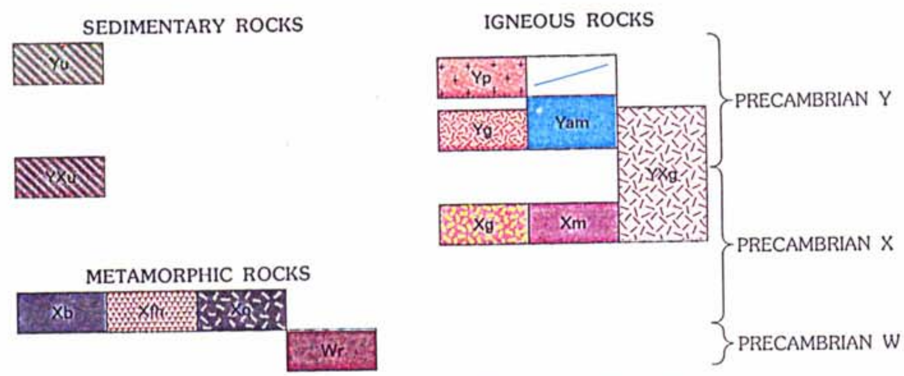
Kw	WILLIAMS FORK FORMATION—Sandstone, shale, and major coal beds
Ki	ILES FORMATION—Sandstone and shale. Trout Creek Sandstone Member at top; coal beds in upper half
Ksc	SEGO SANDSTONE, BUCK TONGUE OF MANCOS SHALE, AND CASTLEGATE SANDSTONE
Kh	HUNTER CANYON FORMATION—Sandstone and shale
Kmgs	MOUNT GARFIELD FORMATION AND SEGO SANDSTONE—Sandstone and shale; major coal beds in lower part of Mount Garfield
Km	MANCOS SHALE—Intertongues complexly with units of overlying Mesaverde Group or Formation; lower part consists of a calcareous Niobrara equivalent and Frontier Sandstone and Mowry Shale Members; in areas where the Frontier and Mowry Members (Kmfm), or these and the Dakota Sandstone (Kfd) are distinguished, map unit (Km) consists of shale above Frontier Member
Kmfm	Frontier Sandstone and Mowry Shale Members and intervening shale zone
Kd	DAKOTA SANDSTONE
Kfd	FRONTIER SANDSTONE AND MOWRY SHALE MEMBERS OF MANCOS SHALE AND DAKOTA SANDSTONE—Locally includes, at base, Burro Canyon Formation (shale and sandstone) or, in western Moffat County, Cedar Mountain Formation (conglomerate and shale)
Kdb	DAKOTA SANDSTONE AND BURRO CANYON FORMATION—Sandstone, shale, and conglomerate

SOUTHWEST

Kkf	KIRTLAND SHALE AND FRUITLAND FORMATION—Shale, sandstone, and major coal beds
Kpcl	PICTURED CLIFFS SANDSTONE AND LEWIS SHALE
Kch	CLIFF HOUSE SANDSTONE
Kmp	MENEFEE FORMATION (SANDSTONE, SHALE, AND COAL) AND POINT LOOKOUT SANDSTONE
Kmv	MESAVERDE GROUP, UNDIVIDED—Sandstone and shale
Km	MANCOS SHALE—Lower part contains Juana Lopez Member (Kmj)
Kmj	Juana Lopez Member—Calcareous sandstone; a thin but persistent unit distinguished only locally
Kdb	DAKOTA SANDSTONE AND BURRO CANYON FORMATION—Sandstone, shale, and conglomerate

IGNEOUS ROCKS OF CAMBRIAN AGE

Єam — Alkalic and mafic intrusive rocks in small plutons, and diabase dikes (age 510–570 m.y.)



SEDIMENTARY, METAMORPHIC, AND IGNEOUS ROCKS OF PRECAMBRIAN AGE

SEDIMENTARY ROCKS

Yu — UINTA MOUNTAIN GROUP (AGE 950–1,400 M.Y.)—Quartzite, conglomerate, and shale

YXu — UNCOMPAHGRE FORMATION (OLDER THAN GRANITES OF 1,400–M.Y. AGE GROUP AND YOUNGER THAN GRANITES OF 1,700–M.Y. AGE GROUP)—Quartzite, slate, and phyllite

METAMORPHIC ROCKS (Age 1,700–1,800 m.y.)

Xb — BIOTITIC GNEISS, SCHIST, AND MIGMATITE—Locally contains minor hornblende gneiss, calc-silicate rock, quartzite, and marble. Derived principally from sedimentary rocks

Xfh — FELSIC AND HORNBLENDIC GNEISSES, EITHER SEPARATE OR INTERLAYERED—Includes metabasalt, metatuff, and interbedded metagraywacke; locally contains interlayered biotite gneiss. Derived principally from volcanic rocks

Xq — QUARTZITE, CONGLOMERATE, AND INTERLAYERED MICA SCHIST

Age probably >2,500 m.y.

Wr — RED CREEK QUARTZITE—Metaquartzite, amphibolite, and mica schist. Present only in small area at Utah border in Uinta Mountains

IGNEOUS ROCKS

Yp — ROCKS OF PIKES PEAK BATHOLITH (1,000–M.Y. AGE GROUP)—Includes Pikes Peak, Mount Rosa, Windy Point, and Redskin Granites and unnamed rocks

Yg — GRANITIC ROCKS OF 1,400–M.Y. AGE GROUP (AGE 1,350–1,480 M.Y.)—Includes Silver Plume, Sherman, Cripple Creek, St. Kevin, Vernal Mesa, Curecanti, Eolus, and Trimble Granites or Quartz Monzonites; also, San Isabel Granite of Boyer (1962) and unnamed granitic rocks

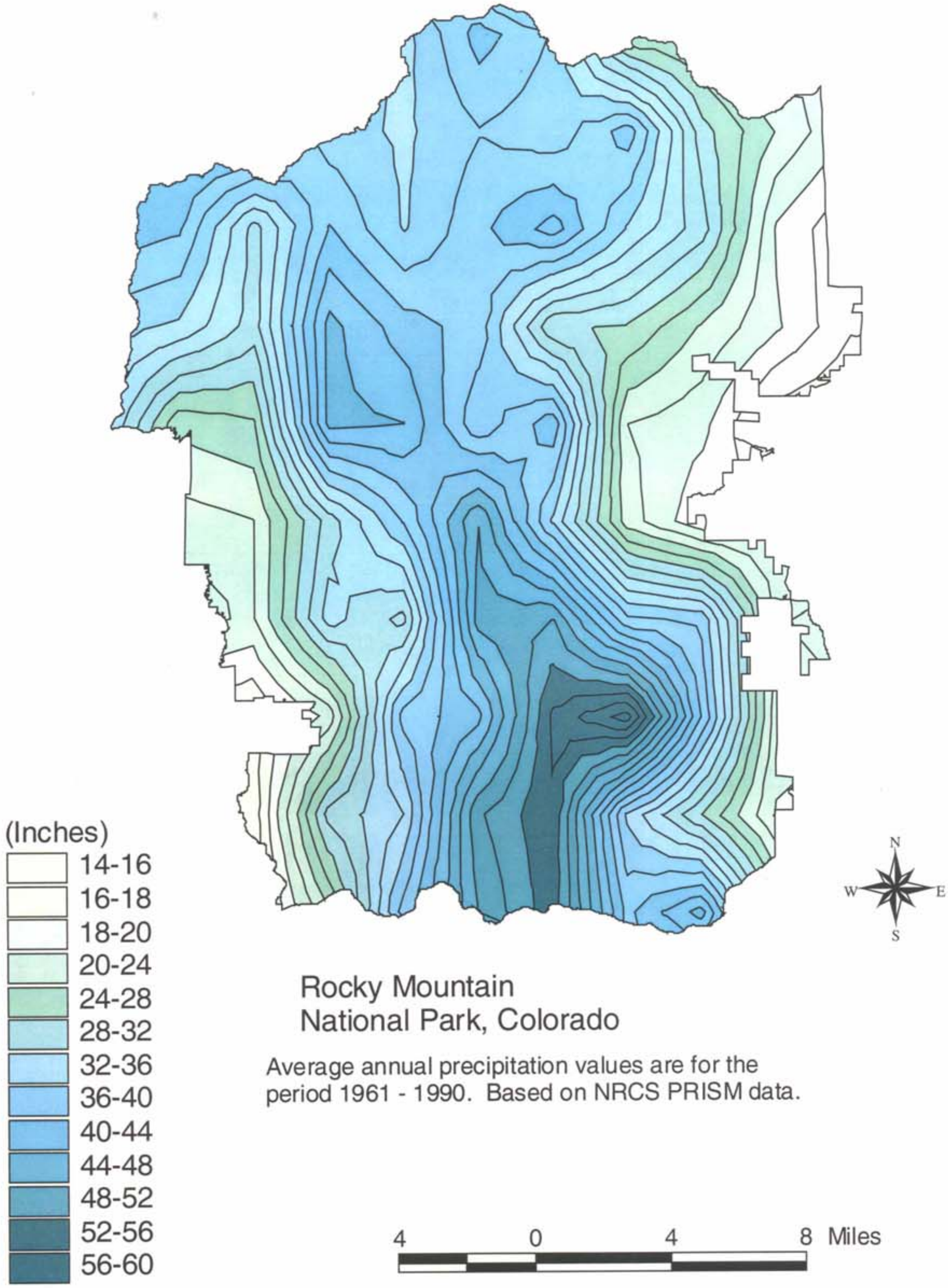
Yam — ALKALIC AND MAFIC ROCKS IN SMALL PLUTONS, AND DIABASE AND GABBRO DIKES

Xg — GRANITIC ROCKS OF 1,700–M.Y. AGE GROUP (AGE 1,650–1,730 M.Y.)—Includes Boulder Creek, Cross Creek, Denny Creek, Kroenke, Browns Pass, Powderhorn, Pitts Meadow, Bakers Bridge, and Tenmile Granites, Quartz Monzonites, or Granodiorites; also, unnamed granitic rocks

Xm — MAFIC ROCKS OF 1,700–M.Y. AGE GROUP—Gabbro and mafic diorite and monzonite

YXg — GRANITIC ROCKS OF 1,400– AND 1,700–M.Y AGE GROUPS, UNDIVIDED, OR, IN TAYLOR RIVER REGION, ROCKS WITH CHARACTERISTICS OF Xg BUT U-Th-Pb ZIRCON AGES OF Yg

Average Annual Precipitation



Rocky Mountain
National Park, Colorado

Average annual precipitation values are for the period 1961 - 1990. Based on NRCS PRISM data.

Willow Park SNOTEL Site - 10,700 feet elevation
Average Monthly Values

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Precipitation (inches)	3.5	3.4	4.1	4.5	4.1	2.4	2.7	2.0	2.2	2.7	4.0	3.6	39.1
Temperature (degrees F.)	12.5	15.5	20.9	25.9	36.4	44.3	50.0	48.7	41.3	32.3	20.1	14.7	30.2
Snow Water Content (inches)	8.8	12.2	15.4	19.7	15.7	1.9							

Bear Lake SNOTEL Site - 9,500 feet elevation
Average Monthly Values

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Precipitation (inches)	5.7	2.9	3.5	4.0	3.7	2.7	2.3	2.0	2.0	1.9	3.2	4.4	38.3
Temperature (degrees F.)													
Snow Water Content (inches)	7.8	11.0	15.0	19.6	15.8	1.1							

Phantom Valley SNOTEL Site - 9,300 feet elevation

Average Monthly Values

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Precipitation (inches)	3.3	2.0	2.2	2.5	2.3	1.3	2.2	1.7	1.6	1.5	2.7	2.5	25.8
Temperature (degrees F.)													
Snow Water Content (inches)	5.4	6.8	8.7	8.9	3.9	0							

Copeland Lake SNOTEL Site - 8,600 feet elevation

Average Monthly Values

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Precipitation (inches)	3.8	1.9	2.4	3.0	3.0	1.9	2.2	2.3	2.0	1.5	2.0	2.8	28.8
Temperature (degrees F.)													
Snow Water Content (inches)	2.8	3.7	3.2	.7									