
# The San Juan Mountains of Southwest Colorado: Geology, Water Quality, Mine Remediation, and Avalanche Hazards

## FIELD TRIP GUIDEBOOK
## OCTOBER 17, 2001

**J. Andrew Gleason, Matthew A. Sares**
**Rob Blair**

1313 Sherman Street, Room 715
Denver, CO 80203


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# CGS GEO-CONFERENCE FIELD TRIP

## The San Juan Mountains of Southwest Colorado: Geology, Water Quality, Mine Remediation, and Avalanche Hazards

This trip is designed to acquaint participants with the geology, glaciology, avalanche terrain and water quality issues as well as some mining history of the western San Juan Mountains. Geologists and avalanche forecasters from the Colorado Geological Survey as well as local specialists in glaciology and water quality issues will lead a trip along State Highway 550 from Durango to Silverton over Red Mountain Pass in the San Juan Mountains. Along the route, participants will stop frequently to explore a special area, talk with geologists and avalanche forecasters, see historic mining areas, and learn about avalanche paths. This guidebook explaining the geology, water quality issues, mine remediation, and avalanche terrain along the route will be given to each participant.

**Logistics**

If you wish to drive your own vehicle and are not in one of the conference vans, you must travel in the caravan during the October 17, 2001 field trip. We will meet Durango in the morning at the parking lot of the Doubletree Hotel at 8:00 am and carpool as best we can. There is not a lot of parking space on Red Mountain Pass, so the fewer vehicles we have the better. Please drive with your lights on while in the caravan. Drive safely but stay as close as you can to the car in front of you. Please obey all traffic signs. When we stop, park as close a possible to the car in front of you and turn off your lights.

**Private property**

Some stops on the field trip are on private property and private mining claims. The owners have given us permission to visit on the day of the field trip only. Please conduct yourselves as guests and obey all instructions from the trip leaders, so that we may be welcome to return on future field trips.

Please follow these simple rules of courtesy at the field trip stops:

- Do not litter the area. (This includes cigarette butts.)
- Do not climb on fences or mine buildings.
- Be careful on Highway 550, there will be traffic.
- Treat public property as if you were the owner—which you are!

When using this booklet for another field trip with students, a youth group, friends, or family, remember that you must get permission from property owners or their agents before entering private property and mining claims.

The Colorado Geological Survey would like to acknowledge the contributions of Bill Simon and Steve Fearn to stops in the Silverton area, and Mary Gillam for information on the Trimble Hot Springs.

# INTRODUCTION

The purpose of this one-day field trip is to look at the geology, glaciology, water quality issues, and the avalanche hazards along Highway 550 from Durango to the top of Red Mountain Pass. We will focus on the water quality issues that affect the upper Animas watershed. The local geology will be discussed in order to understand the context of heavy metal loading in streams. We will look at some historic mines in the area and discuss the metal loads they contribute to the watershed. We will view remediation that has been accomplished to help improve the watershed.

We will also focus on the avalanche problem near Red Mountain Pass, which is one of the most hazardous stretches of highways for avalanches in the country. We will discuss past avalanche accidents, current avalanche forecasting, avalanche dynamics, and avalanche mitigation.

The Colorado Geological Survey (CGS) plays an active role in both the water quality and the avalanche hazard issues in the San Juan Mountains. CGS provides technical support for the Animas River Stakeholders Group (ARSG). The ARSG is a collaborative effort involving a wide range of public and private interests whose mission is improving water quality and aquatic habitats in the Animas watershed in southwestern Colorado. The group is committed to an interactive, open forum where all interested parties are involved in the design and implementation of a watershed plan. Activities include collecting and consolidating river monitoring data, assessing the impact of contaminants and channel modifications on aquatic life, evaluating the feasibility of cleanup actions, formulating plans of improvement, and if necessary, implementing and assisting with remediation activities. The CGS helps with water quality sampling and technical expertise on various water-related issues.

CGS is the supervisory agency of the Colorado Avalanche Information Center (CAIC). The Colorado Avalanche Information Center is the snow avalanche forecasting and education center for the state of Colorado. The mission of the CAIC is to promote safety by reducing the impact of avalanches on recreation, industry and transportation in the State of Colorado through a program of forecasting and education.

This field trip guide may be used for self-guided parties. The trip guide contains 12 stops and 12 "roll-bys" or things to look at while we drive by.

## GENERAL GEOLOGY OF THE SAN JUAN MOUNTAINS

The mountains that you see while driving along Highway 550 were shaped over billions of years through multiple episodes of mountain building and uplift, ancient seas, volcanic upheavals, and icy glaciers. As you drive from Durango to Silverton the rocks by the highway generally get older, the further you drive north. Close to Durango are rocks of Mesozoic age. First you see Mancos Shales, then Dakota Sandstones. Near Hermosa are the Paleozoic redbeds of Permian and Pennsylvanian time. The cliffs near Purgatory are Hermosa Formation (Pennsylvanian) marine sequences with sandstones and limestones. The horizontal slopes above Molas Lake are older Pennsylvanian limestone beds that have abundant marine fossils (Chronic 1980). As you drive north of Molas pass, you begin to see the Tertiary volcanics as you enter in to the San Juan caldera.

In the San Juan Mountains we see evidence of rock formations that span a vast amount of geologic time. From recent landslide features and relatively young volcanic events to billion-year-old basement rocks, we see a large part of the geologic time scale represented in these rocks.

The San Juan Mountains are mostly composed of rocks that erupted from Tertiary volcanoes beginning about 40 million years ago. The volcanic activity continued sporadically for another 30 million years. Lava flows covered vast areas and mixed with older rocks to form conglomerates and breccias.

Precambrian rocks (> 600 million years before present) in much of Colorado are igneous or extensively metamorphosed rocks, but the Precambrian Uncompahgre Formation near Ouray comprises former sedimentary rocks that have been only moderately metamorphosed, and retain much of their original character. Sandstones have become quartzites; shales and mudstones have become slate.

Paleozoic rocks include the Ouray Limestone of Devonian age, the Leadville Limestone of Mississippian age, the Pennsylvanian Molas and Hermosa Formations, and the Permian Cutler Formation. The horizontally bedded, tan rocks to the east of the hot springs are part of the Ouray Limestone.

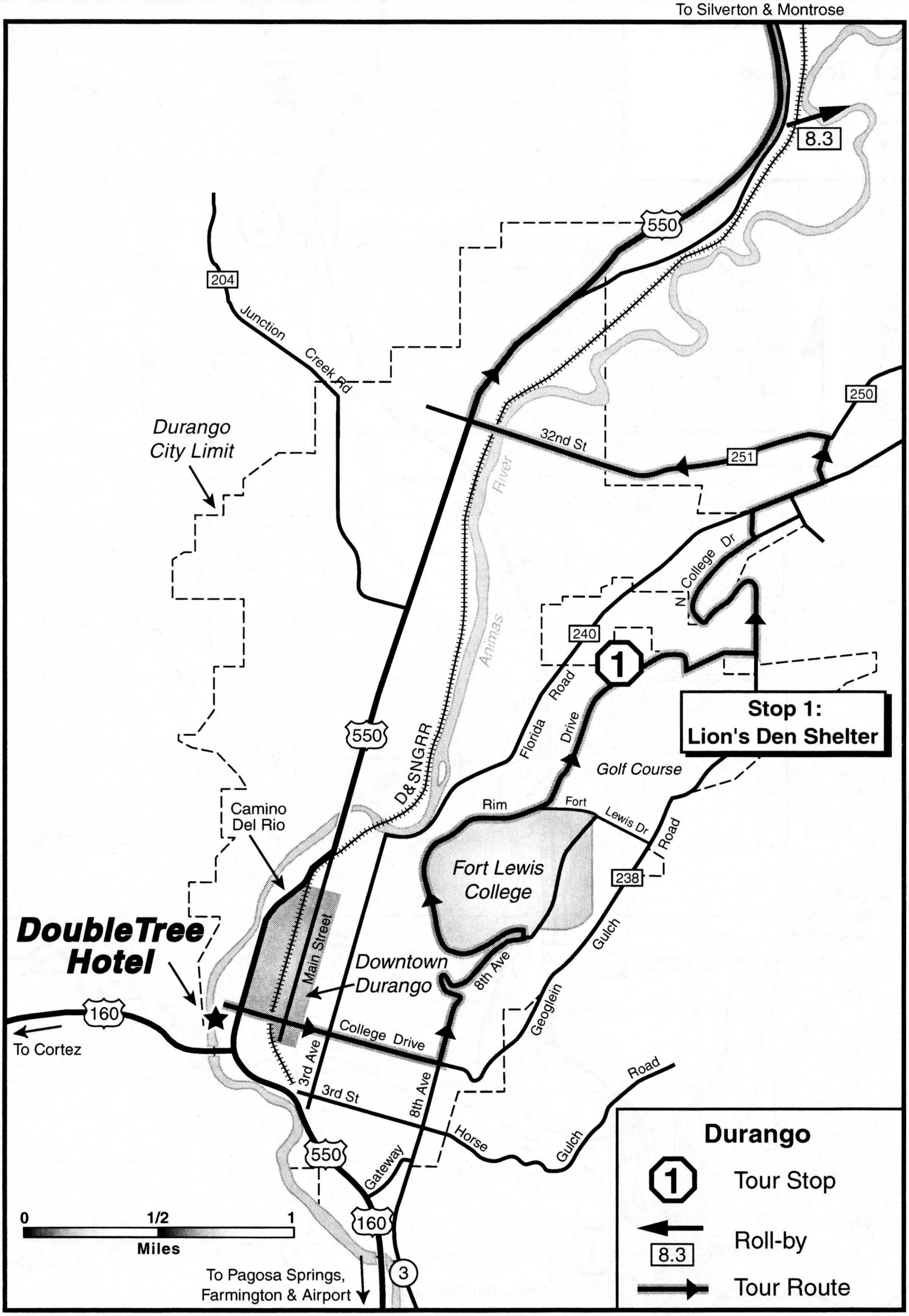
Unconformably overlying the Paleozoic sequence are the Mesozoic rocks of the Triassic Dolores Formation, Jurassic Wanakah and Morrison Formations, and the Cretaceous Dakota Formation. After the Mesozoic sediments were deposited, a time of uplift and erosion ensued and the Tertiary Eocene Telluride Conglomerate was deposited. Another period of erosion removed most of the Telluride Conglomerate in this area. Subsequent volcanic activity began in the area of the San Juan Mountains. The San Juan Formation volcanic material was erupted from stratovolcanoes (like Mount St. Helens) and was deposited unconformably above the older formations exposed at the surface. The San Juan Formation volcanics are predominately andesites. Subsequent to deposition of the

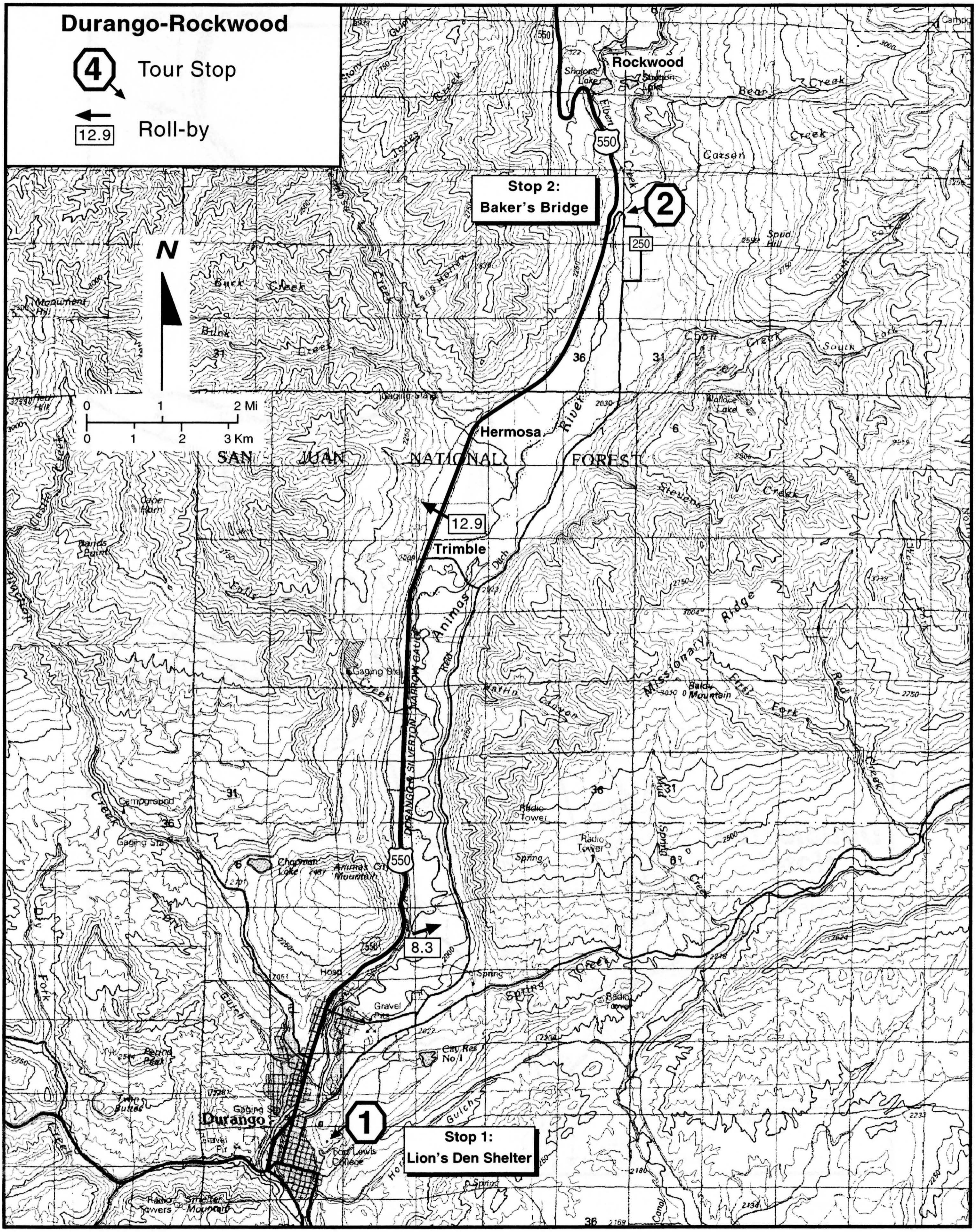
San Juan Formation, the Silverton Volcanic Group was deposited. The early members of this volcanic sequence are contemporaneous with caldera development in this area. Its members, from oldest to youngest, are the Eureka Member (rhyolite), Burns Member (andesite, rhyodacite), Henson Formation (andesite), and a pyroxene andesite member. The San Juan, Uncompahgre, Silverton, and Lake City Calderas and their associated volcanic deposits record a 15-20 million-year history of volcanism in the San Juans.

Browns Gulch area, Mineral Creek basin. View of west-central part of the Silverton Caldera.

# GEOLOGIC TIME SCALE

| ERA | PERIOD | EPOCH (Age in Millions of years) | SELECTED ROCK UNITS (Western San Juan Mountains) |
|---|---|---|---|
| CENOZOIC Age of Mammals | Quaternary | Holocene (0.01) | Recent, stream deposits, ferricrete deposits |
| | | Pleistocene (1.6) | Ice Age, alluvial, colluvial, glacial deposits |
| | Tertiary | Pliocene (5) | Missing in geologic record |
| | | Miocene (24) | Andesites and rhyolites |
| | | Oligocene (37) | Ash flow tuffs, San Juan Formation |
| | | Eocene (58) | Telluride Conglomerate |
| | | Paleocene (66) | Animas Formation |
| MESOZOIC Age of Reptiles | Cretaceous | (144) | Kirtland Shale, Fruitland Formation, Pictured Cliffs Sandstone, Lewis Shale, Mesa Verde Group, Mancos Shale, Dakota Sandstone |
| | Jurassic | (208) | Morrison Formation, Entrada Sandstone |
| | Triassic | (245) | Dolores Formation |
| PALEOZOIC Age of Fishes | Permian | (286) | Wingate Sandstone, Cutler Formation |
| | Pennsylvanian | (320) | Hermosa Formation, Molas Formation |
| | Mississippian | (360) | Leadville Formation |
| | Devonian | (408) | Ouray Limestone, Elbert Formation |
| | Silurian | (438) | Missing in geologic record |
| | Ordovician | (505) | Missing in geologic record |
| | Cambrian | (570) | Ignacio Quartzite |
| PRECAMBRIAN | Proterozoic | (2500) | Uncompahgre Formation |
| | Archean | (> 2500) | Missing in geologic record |


To Silverton & Montrose
8.3
550
204
Junction Creek Rd
250
32nd St
251
Durango City Limit
River
Animas
N College Dr
240
1
Florida Road
Drive
Stop 1:
Lion's Den Shelter
550
D&SNGRR
Golf Course
Rim
Fort
Lewis Dr
Road
Camino Del Rio
Fort Lewis College
238
Gulch
DoubleTree Hotel
Main Street
Downtown Durango
8th Ave
Geoglein
160
To Cortez
College Drive
3rd Ave
3rd St
8th Ave
Road
Horse
Gulch
550
Gateway
160
3
0
1/2
1
Miles
To Pagosa Springs, Farmington & Airport
Durango
Tour Stop
Roll-by
Tour Route


Durango-Rockwood
4
Tour Stop
12.9
Roll-by
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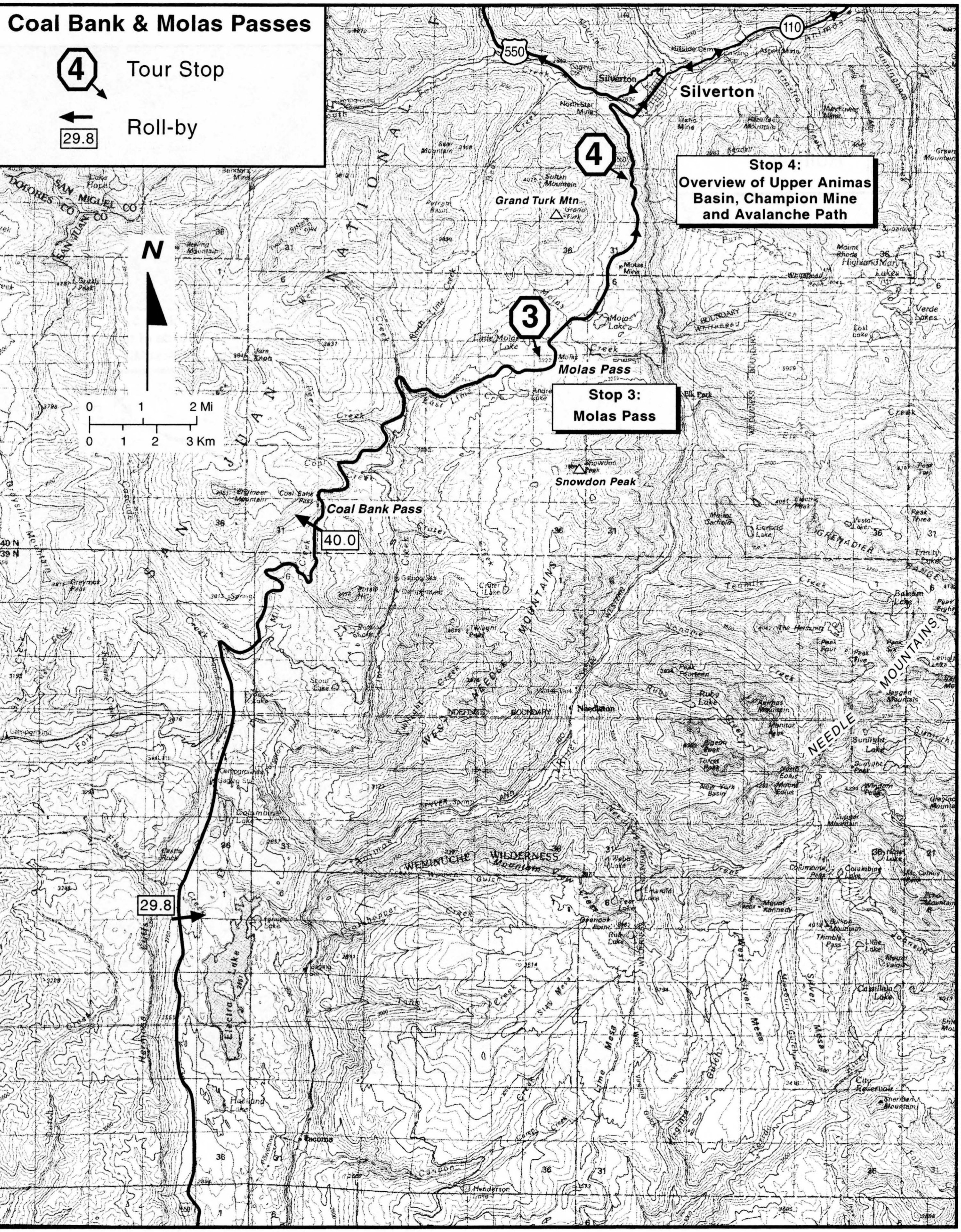
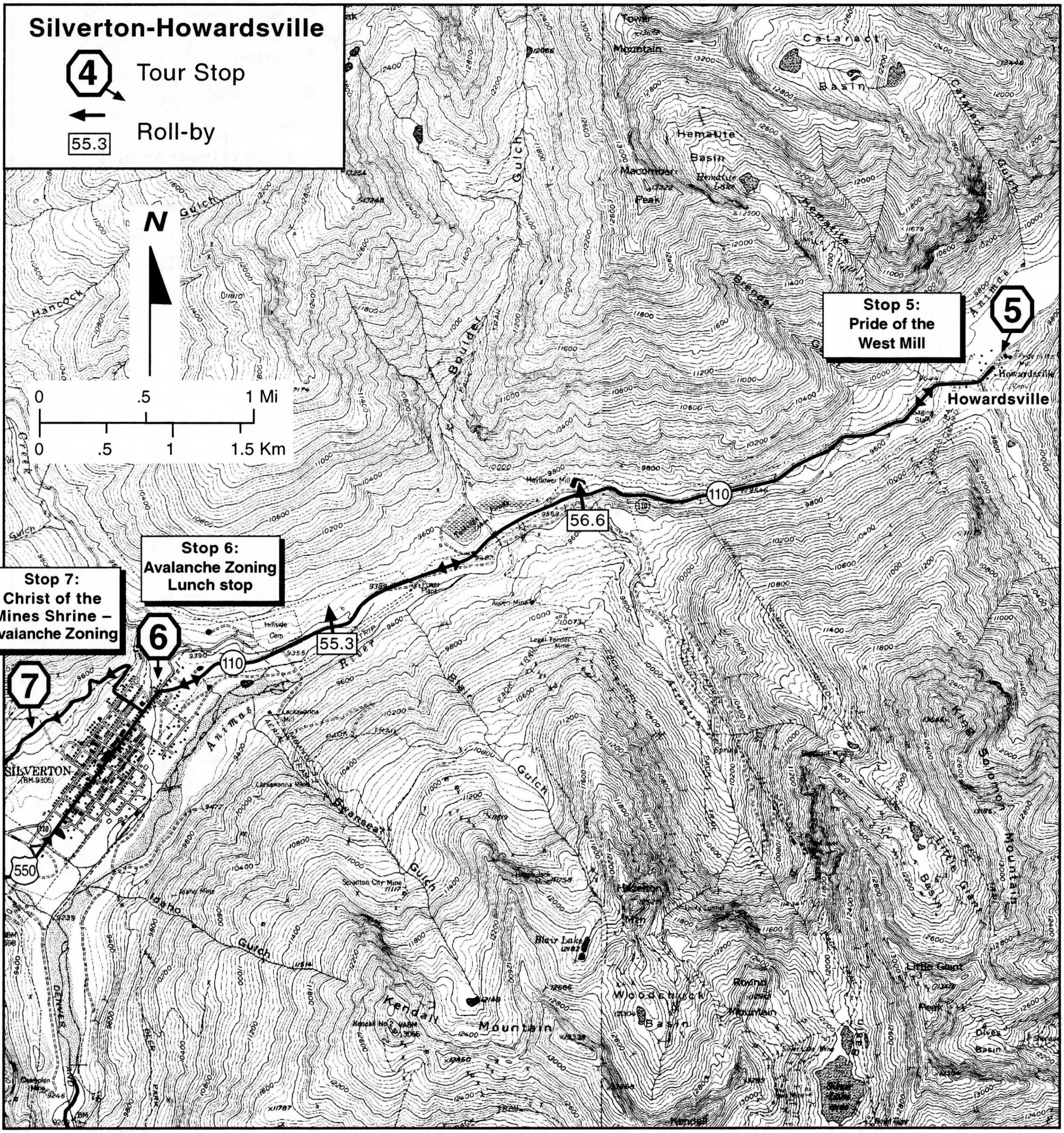
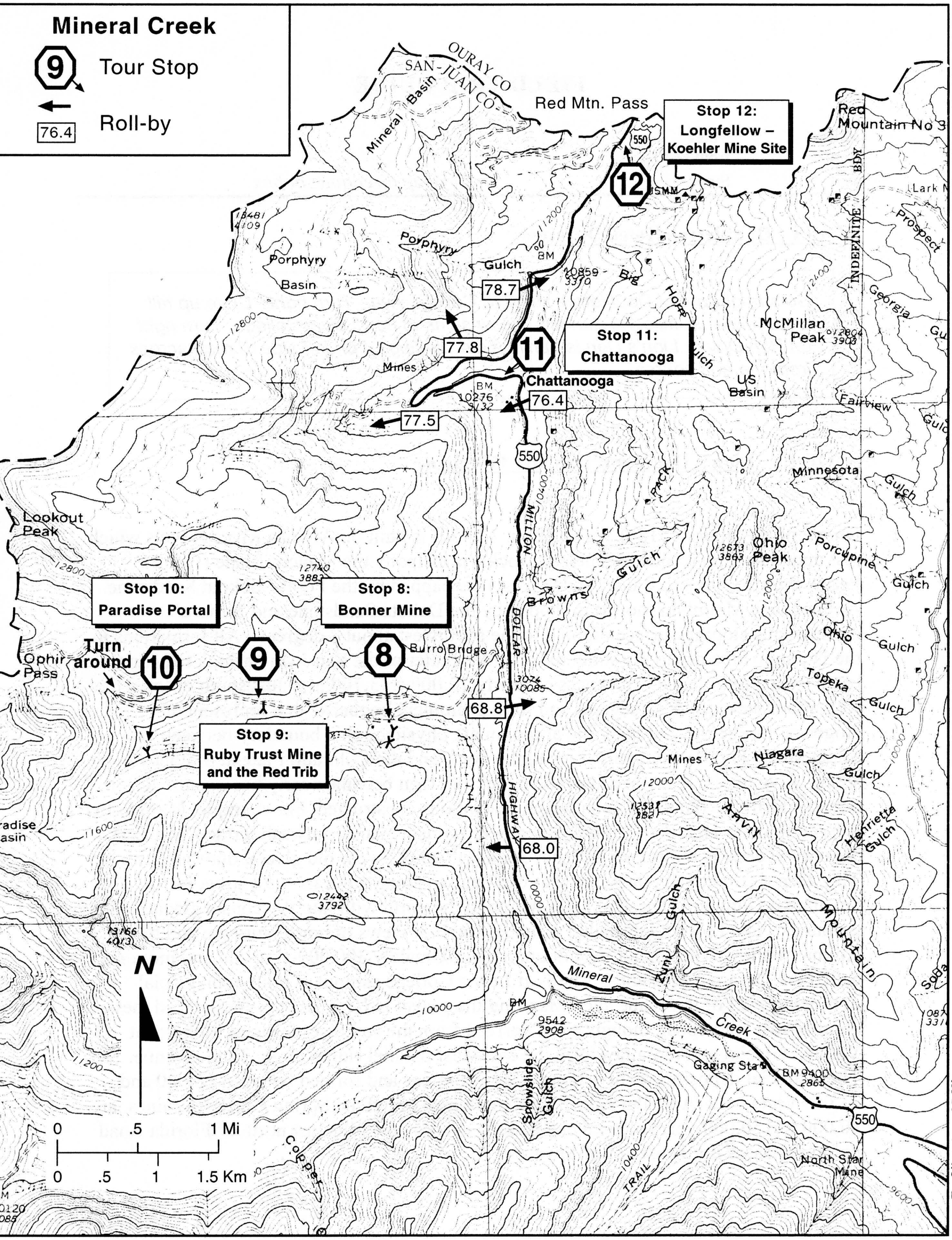
2 Mi
0
1
2
3 Km
Rockwood
Stop 2:
Baker's Bridge
2
250
550
Hermosa
SAN JUAN NATIONAL FOREST
12.9
Trimble
Animas
River
8.3
Durango
1
Stop 1:
Lion's Den Shelter
Fort Lewis College
Missionary Ridge
Baldy Mountain
Chapman Lake
Animas City Mountain
Perins Peak
Twin Buttes
Smelter Mountain
Gravel Pits
City Res No 1
DURANGO & SILVERTON NARROW GAUGE


Coal Bank & Molas Passes
4
Tour Stop
29.8
Roll-by
N
0 1 2 Mi
0 1 2 3 Km
Silverton
550
110
4
Stop 4:
Overview of Upper Animas
Basin, Champion Mine
and Avalanche Path
Grand Turk Mtn
3
Molas Pass
Stop 3:
Molas Pass
Snowdon Peak
Coal Bank Pass
40.0
29.8
NEEDLE MOUNTAINS
WEMINUCHE WILDERNESS
Electra Lake



Silverton-Howardsville
4
Tour Stop
Roll-by
55.3
N
0 .5 1 Mi
0 .5 1 1.5 Km
Stop 5:
Pride of the
West Mill
5
Howardsville
56.6
110
Stop 6:
Avalanche Zoning
Lunch stop
6
55.3
Stop 7:
Christ of the
Mines Shrine –
Avalanche Zoning
7
SILVERTON
550
Cataract
Basin
Hematite
Basin
Macomber
Peak
Boulder
Gulch
Hancock
Animas
River
Kendall
Mountain
Blair Lake
Woodchuck
Basin
Round
Mountain
Little Giant
Peak
Swansea
Gulch
Idaho
Gulch
Hazelton
Mtn


Mineral Creek
9
Tour Stop
76.4
Roll-by
OURAY CO
SAN JUAN CO
Red Mtn. Pass
Stop 12:
Longfellow – Koehler Mine Site
12
550
Red Mountain No 3
Mineral Basin
Porphyry Basin
Porphyry Gulch
Big Horn Gulch
78.7
77.8
Mines
11
Stop 11:
Chattanooga
Chattanooga
76.4
77.5
McMillan Peak
US Basin
Fairview Gulch
Prospect
Georgia Gulch
INDEFINITE BDY
Minnesota Gulch
PACK
MILLION DOLLAR HIGHWAY
Browns Gulch
Ohio Peak
Porcupine Gulch
Ohio Gulch
Topeka Gulch
Niagara Gulch
Anvil Mountain
Henrietta Gulch
Lookout Peak
Ophir Pass
Turn around
Stop 10:
Paradise Portal
10
9
Stop 8:
Bonner Mine
8
Burro Bridge
68.8
Stop 9:
Ruby Trust Mine and the Red Trib
68.0
Zuni Gulch
Mineral Creek
Gaging Sta
Snowslide Gulch
Copper
TRAIL
North Star Mine
550
To Silverton .25 Mi.
N
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0 .5 1 1.5 Km

## FIELD TRIP GUIDE

| Miles from start | Miles from last Stop | *Driving directions in box* |
|---|---|---|

**<u>START Doubletree Hotel, Durango</u>**

0 0

> *Go straight out of Doubletree Hotel to College Ave. Turn right. Drive up hill on to mesa, at mile 1.8 turn left, follow signs to Fort Lewis College. Turn right on Rim Drive. Lion's Den is uphill of dirt parking lot on left side of road across from the golf course.*

**<u>STOP 1. Lion's Den, Lion's Shelter Overlook</u>**

2.7 2.7

Durango (elevation: 6512 ft., population: 12,430) is built on Animas River gravels which rest upon late Cretaceous sedimentary rocks, principally the Mancos Shale (Fig. 2). Perins Peak (west) and Raider Ridge (east) are capped by the Point Lookout Sandstone. Animas City Mountain (north) is capped by the Dakota Sandstone and forms a conspicuous sloping surface dipping to the southwest about 7 degrees. All formations in the Durango area dip to the south towards the center of the San Juan basin, a structural basin with a sedimentary thickness of nearly 12,000 ft (3,700 m). Just south of town the formations steepen to 35 degrees and form prominent hogbacks that represent the Hogback monocline and mark the approximate physiographic boundary between the Southern Rocky Mountain province to the north and the Colorado Plateau province to the south. Five miles (8 km) south of town the beds then become nearly horizontal. River terraces form the flat areas upon which Durango is constructed. For example, Main Street is built upon an 18,000 to 25,000 year old Wisconsin glacial outwash terrace, and East Second Avenue is built upon a higher 36,000 to 40,000 year old glacial outwash terrace. The steep riser between these terraces can be seen along any east-west street in downtown Durango. These terraces merge to the north with late Wisconsin glacial end moraines. The Lions Club shelter provides the best views of north Durango and the Animas Valley. The shelter is built upon approximately 300,000-year-old end moraines called the Durango Moraines. The Fort Lewis College campus is built upon glacial outwash gravel of this same age. Mantling the gravel is 10 to 30 ft (3-9 m) of red loess, a wind-blown silt deposit thought to be derived from the southwest around Monument Valley. Glacial end moraines form the east-west parallel ridges along 32nd Avenue. These glacial deposits are the Animas City Moraines and formed between 18,000 and 25,000 years ago. An older suite of end moraines, called the Spring Creek Moraines, are 80,000 to 150,000 years old and can be seen capping the hills just north of Florida Road before it passes northeast out-of-town.

| Miles from start | Miles from last Stop | *Driving directions in box* |
|---|---|---|

> *Head north on Rim Drive. Turn left at stop sign onto Goeglein Gulch Rd. Follow this road down the hill (Goeglein Gulch becomes N. College Drive). Turn right at stop sign at Florida Road. After 0.2 miles turn left on CR 250. After 0.1 mile, turn left on 32nd St. Follow to light, turn right on Highway 550(north).*

8.3 **Roll By – Missionary Ridge Rockfall** to the right as you pass the Iron Horse Inn.

12.9 **Roll By – Trimble Hot Springs** on left. The hot springs occur within the developed Trimble Hot Springs Resort complex. Trimble Hot Springs is one of several warm springs that exist near the sides of the alluvial Animas Valley, north of Durango. Inactive tufas of former springs are also common, indicating that discharge points have shifted during postglacial time. Most warm springs are located near bedrock faults that serve as conduits for upward flow. Meteoric water, recharging aquifers at higher elevations, has been heated by deep circulation at depths of many thousand feet (McCarthy and others, 1982). High heat flows have persisted in the San Juan region after intrusive and volcanic activity from latest Cretaceous to Miocene time.

Flow at the spring is now just a few gallons per minute, and the resort is served by a 150-ft well that pumps about 260 gpm. Reported temperatures at the spring and well range from 90 to 124° F, but subsurface temperatures are estimated as 113 to 158° F (Cappa and Hemborg, 1995). Total dissolved solids have ranged from about 1,600 to 3,300 mg/l.

Long-term human use of the springs is evident from prehistoric artifacts at some sites. The first resort at Trimble opened in 1884, and it is now the only spring in the area with commercial development. Guests like Clark Gable and Marilyn Monroe must have hobnobbed here with famous Durango geologists.

> *At mile 18.2 turn right on CR 250. After 0.2 miles turn right onto 250 south. Park at dirt lot on right before bridge.*

**STOP 2. Baker's Bridge**
18.8 16.1

The 1,720 million year old Baker's Bridge Granite is exposed here and to the north for several miles along the Animas River. From here south, the granite is buried under alluvium and Paleozoic rocks. The contact between the granite and overlying Upper

Devonian Elbert Formation is a nonconformity and represents a missing time gap of 1,200 to 1,300 million years. The unconformity is clearly displayed just west of the west bridge. This 400+ million year old erosion surface is noted for its weathered granite hillocks lying beneath the 70 ft (21 m) thick McCracken Sandstone Member of the Elbert Formation. The overlying 40 ft (12 m) of the Elbert consists of shales containing scales and plates of primitive fish. At the bridge site, glacial and fluvial erosion have stripped off the sedimentary cover to expose the Precambrian granite. Glaciation, in particular, has produced prominent rock steps seen east from the main highway and north of the bridge. Lateral moraines found high on the west and east sides of the valley indicate the Animas glacier maintained a thickness of 2000 ft (600 m) or so in this part of the valley. North of Baker's Bridge, the Animas River is entrenched into granite to form a narrow gorge. As can be seen from the bridge, the path of this channel is largely controlled by jointing. Previously, the river split into two channels just above Baker's Bridge; thus, it once flowed in the abandoned channel just west of the main bridge. South of the bridge where the granite disappears below the surface, the river takes on the characteristics of a gravel bedded channel and is braided for much of the next 5 mi (8 km).

> *Go back to Highway 550 and turn right (north).*

29.8 **Roll By – Weminuche Wilderness**. Near the Needles store, look right at the high peaks of the Weminuche Wilderness. The two highest are Pidgeon Peak and Turret Peak. These are composed of Eolus granite, which is 1.4 billion years old.

40.0 **Roll By – Engineer Mtn. Avalanche Paths.** The avalanche paths to the left are the site of a backcountry skier avalanche fatality in 1994. Avalanche control is conducted by CDOT/CAIC in this vicinity.

> *At mile 47.2 turn right into the Molas Pass parking lot at the top of Molas Pass.*

**STOP 3. Molas Pass**
47.2 28.4

Eighteen thousand years ago this region was buried beneath a 500 to 1000 ft (115-330 m) ice field. The ice surface was at a level close to that of the present tree line, about 12,500 ft (3830 m). The high peaks in the area were islands of rock projecting above the ice surface. This ice field fed the Animas Glacier, one of the longest valley glaciers documented in the Rocky Mountains of Colorado. Glacial features abound. Look for cirques, horns and U-shaped glacial valleys. Many outcrops display scratches and grooves from the ice dragging stones across the bedrock. Which direction was the ice moving locally? The sloping benches at and above road level are the Honaker Trail Formation consisting of carbonate-clastic sequences representing cyclic sedimentation. The benches are the resistant limestones or arkosic sandstones and the slopes are siltstones. The limestones are fossiliferous and contain phylloid algae, pelecypods, crinoids, fusulinids, gastropods, and brachiopods. Many of these 300 million-year-old fossils can be found in the local outcrops scattered about the area. From the pass one can see structural elements of the Grenadier Horst, a Paleozoic highland. The horst is expressed as high peaks making up the Grenadier Range to the southeast. The Molas Creek valley, seen south of Molas Lake, is the topographic expression of the Molas graben. This is a local down-faulted block bounded on the north by the northeast trending Molas-Andrews Lake fault and to the south by the Snowdon fault, which passes just north of Snowdon Peak seen due south. To the north is Grand Turk Mountain. This peak is capped by the San Juan Formation. This 30-35 million year old volcanic unit overlies a thin prominent cliff of the Telluride Conglomerate, a late Eocene pediment-fan gravel, which rests upon a late Eocene erosion surface, locally called the Telluride peneplain. This surface is an angular unconformity and indicates the uplifting and erosion of the San Juan dome during the Laramide Orogeny in late Cretaceous and early Tertiary time. Note the red Permian Cutler Formation dipping slightly southwest beneath the Telluride cliff below Grand Turk. Can you pick out any faults that offset these formations?

To the east of the highway at the north end of Molas Lake, a paleokarst tower is partially exposed in an old quarry east of the road. This quarry exposes the contact between the light gray Mississippian Leadville Limestone and the overlying dark red shales of the Pennsylvanian Molas Formation. The quarry was excavated into the west side of a buried 330 million year old karst tower and karst breccia. The Leadville Limestone is partly recrystallized and contains bryozoa, coral, brachiopods and crinoids. These fossils indicate this area was once a shallow-water carbonate platform. After the sea withdrew, the region became humid subtropical to tropical. This led to aggressive solution weathering of the exposed limestone and to the eventual development of numerous karst towers, sinkholes and caves. Around the lake at least three buried karst towers have been located, one with a height 65 ft (20 m). The Molas siltstones and shales are thought to represent a paleo-oxisol soil similar to the type of soils now forming in Java and North Vietnam.

| |
| --- |
| *Head north on Highway 550 for 4.4 miles. Park in the dirt pullout on the right just past a large rock on the right side of the road.* |

| Miles from start | Miles from last Stop | *Driving directions in box* |
|---|---|---|

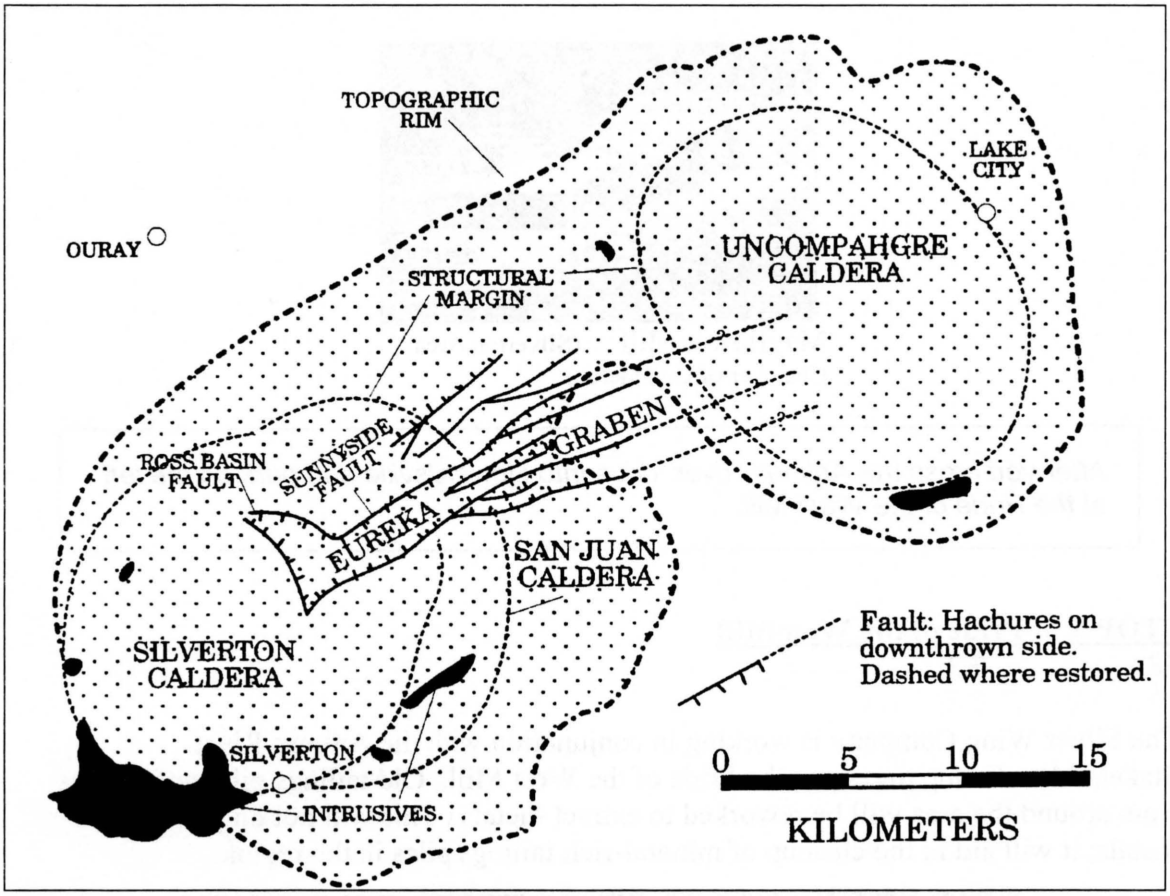
**STOP 4. Overview of Upper Animas Basin, Champion Mine and Avalanche Path**
51.6 4.4

The Animas River basin has been an area of intense research into water quality degradation related to mining and natural causes. Historically, poor water quality in the Animas River has extended a significant distance south of Silverton. The Animas River Stakeholders Group, a grassroots watershed group, was organized to help address water quality issues in the basin with local stakeholder input. It has coordinated the different studies, organizations, and volunteers involved in water quality data collection and research. The U.S. Geological Survey has completed a multi-disciplinary study of the upper Animas basin, helping to identify and quantify sources of metal loading to streams. The Colorado Geological Survey completed an abandoned mine land (AML) inventory for the U.S. Forest Service in this area in 1996. This inventory encompassed the Mineral Creek watershed. The Bureau of Land Management and the Colorado Division of Minerals and Geology have inventoried and investigated AML sites in other areas the Animas River basin. AML inventories have been done throughout the state by these organizations with the purpose of identifying environmental degradation and physical hazards associated with abandoned mines.

We are now just south of the Silverton caldera. The caldera center is to the north-northeast. Mineral Creek, which State Highway 550 follows to the north, traces the western rim of the caldera and the upper Animas River generally traces the southern and eastern rim. The Silverton caldera formed after the last major eruption cycle of the older San Juan caldera in the middle Tertiary period (~ 27 million years ago). As the caldera collapsed on itself, vertical faults and fractures formed pathways for the upward movement of gases, ore bearing fluids, and igneous intrusive plugs. The rim faults also became pathways for circulating hydrothermal fluids, which caused extensive alteration and emplacement of sulfide minerals.

The Champion Mine is fairly typical of many abandoned mines in the upper Animas basin. The mine is developed by two adits. The upper adit is located immediately below Highway 550. It is locally known as "Malachite Falls" because of the blue-green precipitate in its drainage. The lower adit drains up to 120 gpm and is source of zinc loading to the River.

Miles from start | Miles from last Stop | *Driving directions in box*



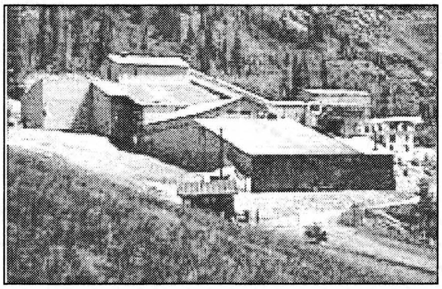

Location and Features of the San Juan, Silverton, and Uncompahgre Calderas (Blair, 1996)

> *Continue north on HWY 550 and turn right into Silverton on CO 110. Drive through town about 1 mile. At the end of town, past the county courthouse, turn right on CO 110.*

55.3 **Roll By – Sunnyside Tailings**. To your left is the tailings pile from the Sunnyside Mine in Gladstone. Most of the waste is from the workings of the Mayflower Mill.

56.6 **Roll By – Mayflower Mill**. This historic mill processed ore from the Sunnyside Mine and other mines in the Silverton area. Sunnyside Gold Corporation donated the mill to the San Juan County Historical Society, preserving nearly seven decades of mining history. The mill, built in 1929, contains all of the original equipment and every tool that would be necessary to make it run. (Echo Bay Mines, 2001)

| Miles from start | Miles from last Stop | *Driving directions in box* |
|---|---|---|



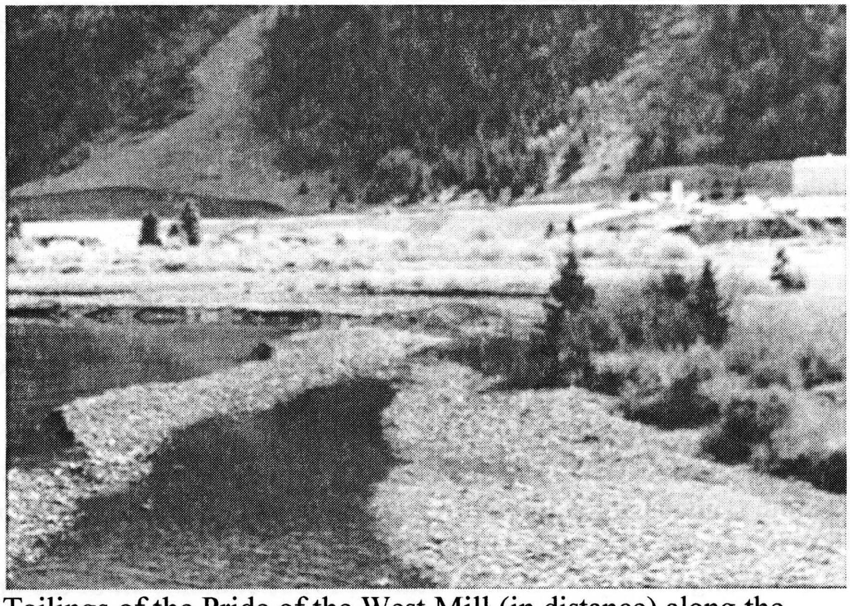
Mayflower Mill (Silverton Area Chamber of Commerce)

> *After you cross the Animas River, drive into Howardsville and park on the left at the Pride of the West Mill.*

**STOP 5. Pride of the West Mill**

58 7.2

The Silver Wing Company is working in conjunction with the Animas River Stakeholders Group to reopen the Pride of the West Mill. Old tailings piles and dumps from around the area will be reworked to extract metals. This will not only provide metals; it will aid in the cleanup of mineral-rich tailings piles in the region.



Tailings of the Pride of the West Mill (in distance) along the Animas River northwest of Silverton. Mill buildings are to left. (photo by William Simon)

| Miles from start | Miles from last Stop | *Driving directions in box* |
|---|---|---|

> *Head back to Silverton on CO 110. At the stop sign, turn right, park at Memorial Park for lunch and a bathroom break.*

**STOP 6. Avalanche Zoning in Silverton and Lunch Stop**

62.8 4.0

> *Head back into Silverton, just past the County Courthouse, turn right on 15th St. Head up the hill towards the Christ of the Mines Shrine.*

**STOP 7. Christ of the Mines Shrine – Avalanche Zoning (continued)**

63.9 1.1

Here we will discuss the importance of avalanche zoning in general and, in particular, in the town of Silverton (elevation: 9,318 ft or 2840 m; population: 450). Silverton lies along the southern margin of the Silverton caldera, the collapsed interior of an ancient volcano complex, which last erupted about 27 million years ago. Christ of the Mines Shrine, located immediately northwest of town, is built on a glacial moraine. The shrine was constructed in 1959 as a monument to the local miners. The alcove is constructed from local stone and the 12-ton statue carved from Carrara marble from Italy.

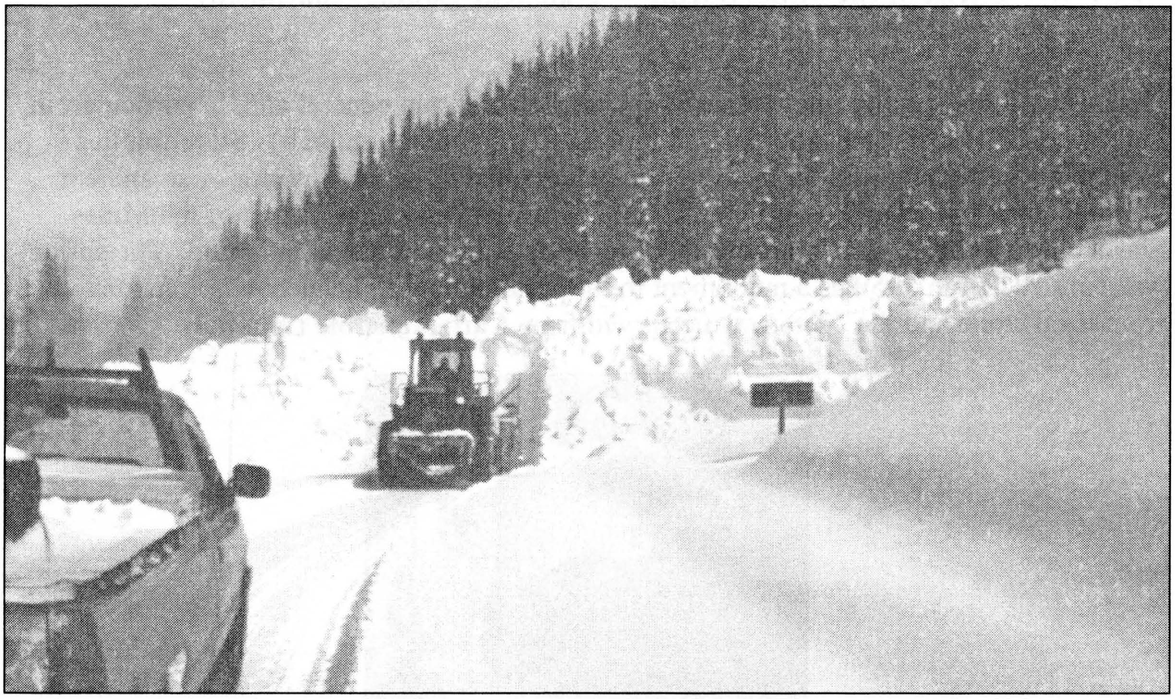
Photo by Dileo

| Miles from start | Miles from last Stop | *Driving directions in box* |
|---|---|---|

*Drive southwest 0.5 miles to HWY 550 and turn right.*

68.0 **Roll By – Battleship Slide** avalanche path is to the west. When it runs, it must flow uphill over 250 feet from South Mineral Creek to hit the highway.

68.8 **Roll By** – The **Ophir Pass Road Avalanche Path** extends east of State Highway 550, at the intersection with the Ophir Pass road (County Road 8). In the spring of 1998, this avalanche put 18 ft of snow on the highway. Historically, snow had just barely reached the road. That spring brought at least a hundred-year slide to this avalanche path. Ten acres of trees were flattened by the slide as it ran down the track. Most of the trees dated to about 130 years old. The crown height of the avalanche was 20 ft in the upper part of the starting zone.



A 1998 avalanche deposits 18 feet of snow on State Highway 550 at Ophir Road.

*Turn left on Ophir Pass Road*

| Miles from start | Miles from last Stop | *Driving directions in box* |
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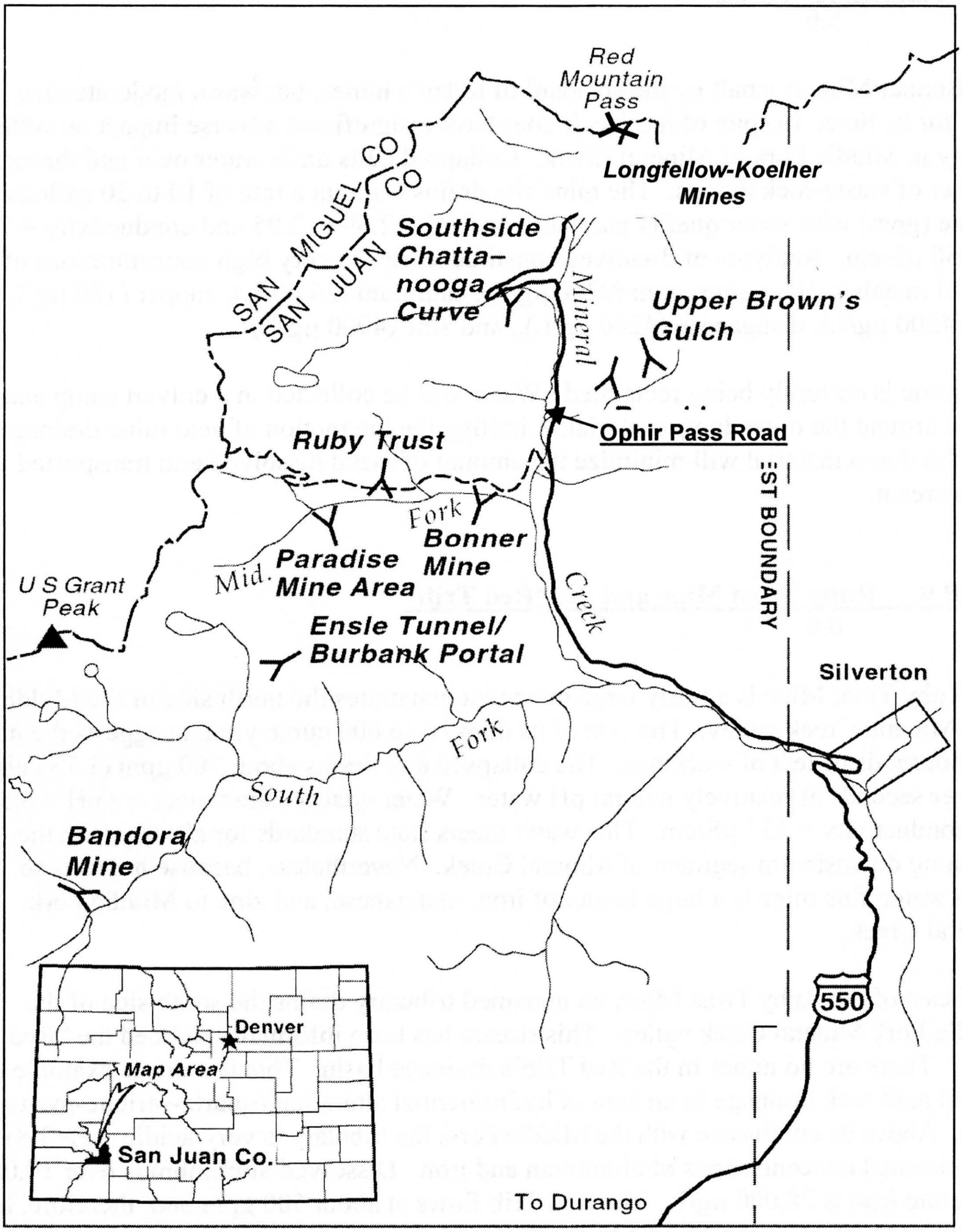



Priority Mines loading metals to streams in the Mineral Creek drainage basin.

**STOP 8. Bonner Mine**

69.8 5.9

The Bonner Mine is small by the standard of today's mines, but was a moderate-size mine for its time. In spite of its size, it does have a significant adverse impact on water quality in Middle Fork of Mineral Creek. Collapsed adits drain water over and through a number of waste-rock dumps. The mine site drains water at a rate of 10 to 20 gallons per minute (gpm) with water quality parameters of pH = 2.69 to 2.95 and conductivity = 750 to 1050 μS/cm. Analyses of dissolved constituents reveal very high concentrations of several metals such as aluminum (9200 μg/L), cadmium (26 μg/L), copper (180 μg/L), iron (4500 μg/L), manganese (4200 μg/L),, and zinc (4900 μg/L).

This mine is currently being reclaimed. Water will be collected in a culvert sump and routed around the mine dump material. Limiting the interaction of acid mine drainage with the dump material will minimize the amount of metal dissolved and transported downstream.

**STOP 9. Ruby Trust Mine and the "Red Trib"**

70.5 0.9

The Ruby Trust Mine is a fairly large mine that penetrates the north side of the Middle Fork Mineral Creek valley. The size of its dump (~ 6,000 cubic yards) suggests the mine has thousands of feet of workings. The collapsed adit drains about 780 gpm (1.73 cubic feet per second) of relatively neutral pH water. Water quality parameters are pH = 6.5 to 7.0, conductivity = 437 μS/cm. This water meets state standards for all metals in the adjoining downstream segment of Mineral Creek. Nevertheless, because it drains so much water, this mine is a large loader of iron, manganese, and zinc to Middle Fork Mineral Creek.

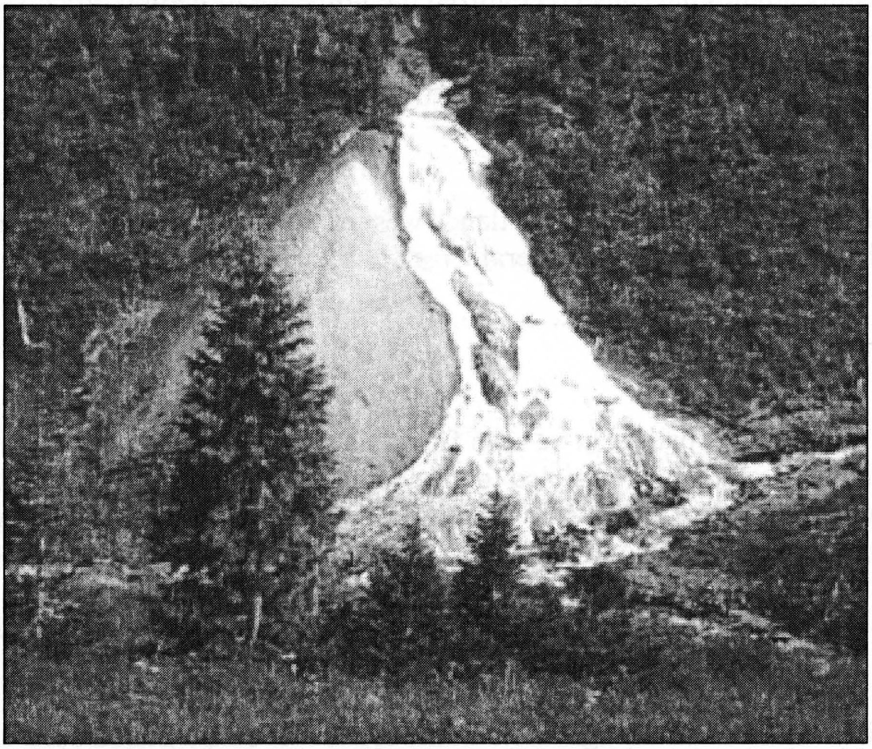
Southeast of the Ruby Trust Mine, an unnamed tributary drains the south side of the Middle Fork Mineral Creek valley. This stream has been informally dubbed the "Red Trib." There are no mines in the Red Trib's drainage basin. This is a prime example of natural acid rock drainage in an area of hydrothermal alteration (quartz-sericite-pyrite type). Above its confluence with the Middle Fork, the tributary is very acidic (pH=3.8) with elevated concentrations of aluminum and iron. Dissolved aluminum is over 10,000 μg/L, and iron is 28,000 μg/L. The Red Trib flows at about 500 gpm and, therefore, has a significant effect on the Middle Fork.

The pH of Middle Fork drops from 6.26 upstream of the Red Trib to 4.75 downstream. Near the Red Trib's mouth, its streambed is heavily caked with orange-colored iron and aluminum precipitate (iron and aluminum oxides and hydroxides). Deposits of ferricrete occur along the south side of Middle Fork Mineral Creek from this confluence to the Bonner

Mine. Ferricretes are stream sediments and gravels that have been cemented by iron precipitates deposited on the streambed, giving a concrete-type appearance.

**<u>STOP 10. Paradise Portal</u>**
71.4 0.7

This stop provides one of the most spectacular views of acid mine drainage in Colorado. The mine effluent flows at 340 gpm, has a "milky" color, and leaves a white precipitate on the dump that is visible from the Ophir Pass road (County Road 8). In August 1995, the mine effluent had pH = 5.43 and had a very high conductivity = 1815 μS/cm. Effluent from the portal area was sampled and lab analyses for dissolved constituents indicate that aluminum (7,200 μg/L), iron (61,000 μg/L), and manganese (4,600 μg/L) exceed state standards for the adjacent downstream segment of Mineral Creek. The white precipitate is aluminum hydroxide that has dropped out of solution (dissolved phase). This sample was also high in calcium, magnesium, and sodium, which account for some of the high conductivity. The pH in Middle Fork drops from 7.34 above the Paradise Portal to 6.00 below the mine site. The mine appears to have been fairly small, so perhaps a natural subsurface watercourse was intercepted by the workings to obtain such a large effluent flow. If so, then the metal-laden water could be partially natural in occurrence.



The Paradise Mine. Mine effluent precipitates aluminum hydroxide on the dump and in Middle Fork Mineral Creek (it's not snow!).

Discussion

There certainly are mines that drain poor quality water along the Middle Fork Mineral Creek, but questions remain: Why does the much larger Ruby Trust Mine drain cleaner water than the smaller Bonner Mine and Paradise Portal? Why does the Red Trib, a natural drainage, produce poorer quality water than the Ruby Trust Mine?

The geology of this area significantly controls water quality, whether from natural drainages or from mines. A fault with at least 400 feet displacement trends east-west through the center of this valley. The north side of the fault is dropped down relative to the south side. On the south side, hydrothermally altered San Juan Formation occurs at the surface along with an altered granite intrusive body further to the south. Water moving over and through these rocks quickly becomes acidic through acid rock drainage processes. The acidic water readily dissolves the surrounding minerals, including pyrite, carrying the constituents to the stream. On the north side of the fault, the top of the hydrothermally altered San Juan Formation occurs at about the level of the Ruby Trust Mine. The relatively unaltered to propyliticaly altered Eureka and Burns Formations are still present above. These formations contain alkaline minerals. As water percolates down through these units the water becomes buffered and remains relatively neutral with low metal concentrations, even when draining through a large mine such as the Ruby Trust. Although mines influence water quality in the Middle Fork, intensive geological and water-quality studies have also recognized the influence of natural processes.

71.8 *Turn around location. Head back down the hill.*

74.8 *Turn Left on State Highway 550.*

76.4 **Roll By** – Beaver ponds and wetlands west of the road naturally filter metals and settle metal colloids from Mineral Creek.

**STOP 11 . Chattanooga**

76.8 2.0

Two groups of avalanche paths can be seen from this stop. The Eagle group is to the northwest and the Brooklyns are located to the southeast. Both groups receive frequent avalanche mitigation with a Howitzer and the "Avalauncher." In the Brooklyn group, deep incised channels are found in the gullies of some of the paths. These are debris flow channels that form during intense rain events in the summer. The water creates a milkshake-like fluid that transports mud and rocks down the mountainside. In the summer of 1999, debris flows put up to 20 feet of mud and rocks on the highway here.

A mine can be seen amidst the vegetation on the south side of the Chatanooga curve. This mine drains effluent at about 60 gpm and loads significant amounts of aluminum, iron and manganese into Mineral Creek.

| Miles from start | Miles from last Stop | *Driving directions in box* |
|---|---|---|

77.5 **Roll By – Silver Crown Mine** and avalanche path on west side of the "Chattanooga curve" in Mill Creek drainage.

77.8 **Roll By – Silver Ledge Mine.** On your right you will see the shaft house of the Silver Ledge Mine.

Silver Ledge Mine shaft house adjacent to Mineral Creek near Chattanooga.

78.7 **Roll By** – The Eagle avalanche path on the right side of the road has deposited up to 30 feet of snow on the highway.

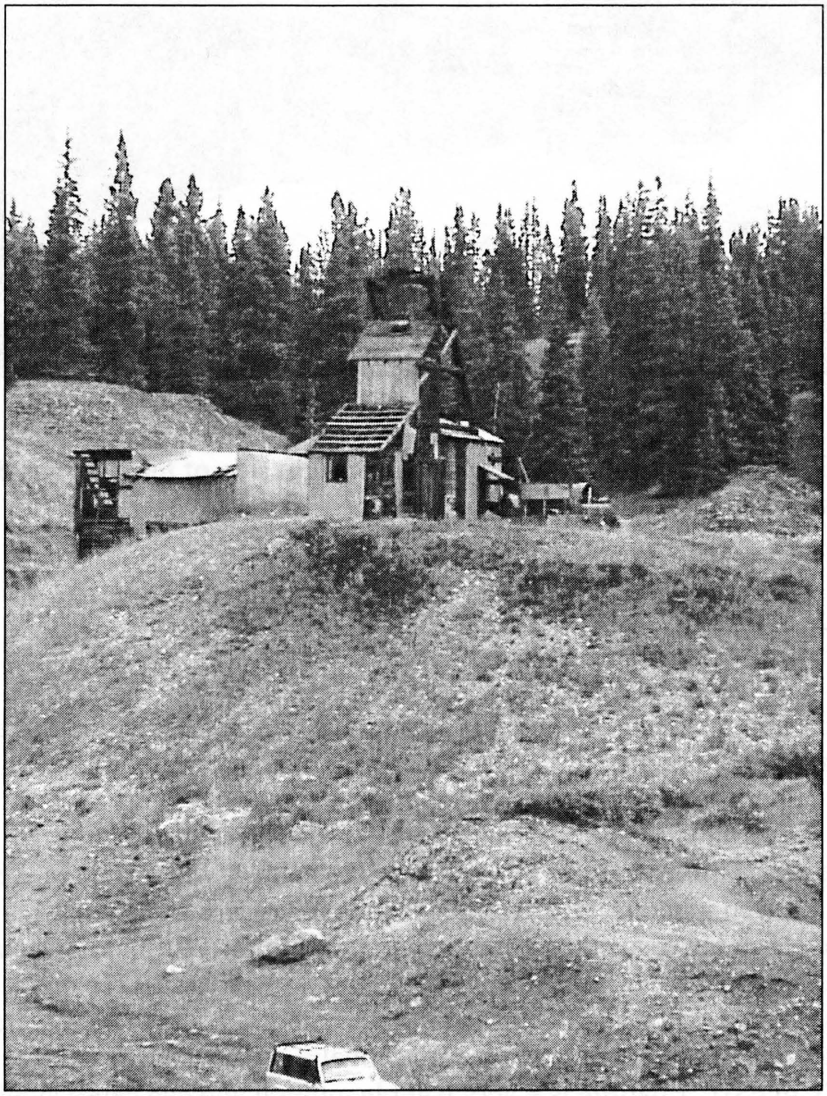
**<u>STOP 12. Longfellow - Koehler Mine Site</u>**

79.7 2.9

This stop is just south of Red Mountain Pass, in the upper reaches of the Mineral Creek drainage basin. We are on the northwest structural boundary or rim of the Silverton caldera. The caldera center is to the east-southeast.

After collapse of the Silveron caldera, the rim of the caldera was a zone of weakness in the crust that allowed igneous intrusive plugs to move upward. The intrusive plugs commonly have rich ore associated with them in the form of veins and breccia pipes. The Longfellow and Koehler mine openings (a shaft and two adits) are on the west side of one of these igneous plugs and access associated breccia pipes. Ore minerals at these mines consisted mainly of enargite ($Cu_3AsS_4$), covellite ($CuS$), pyrite ($FeS_2$), and chalcopyrite ($CuFeS_2$). Enargite is a very soluble mineral and can cause significant water quality degradation.

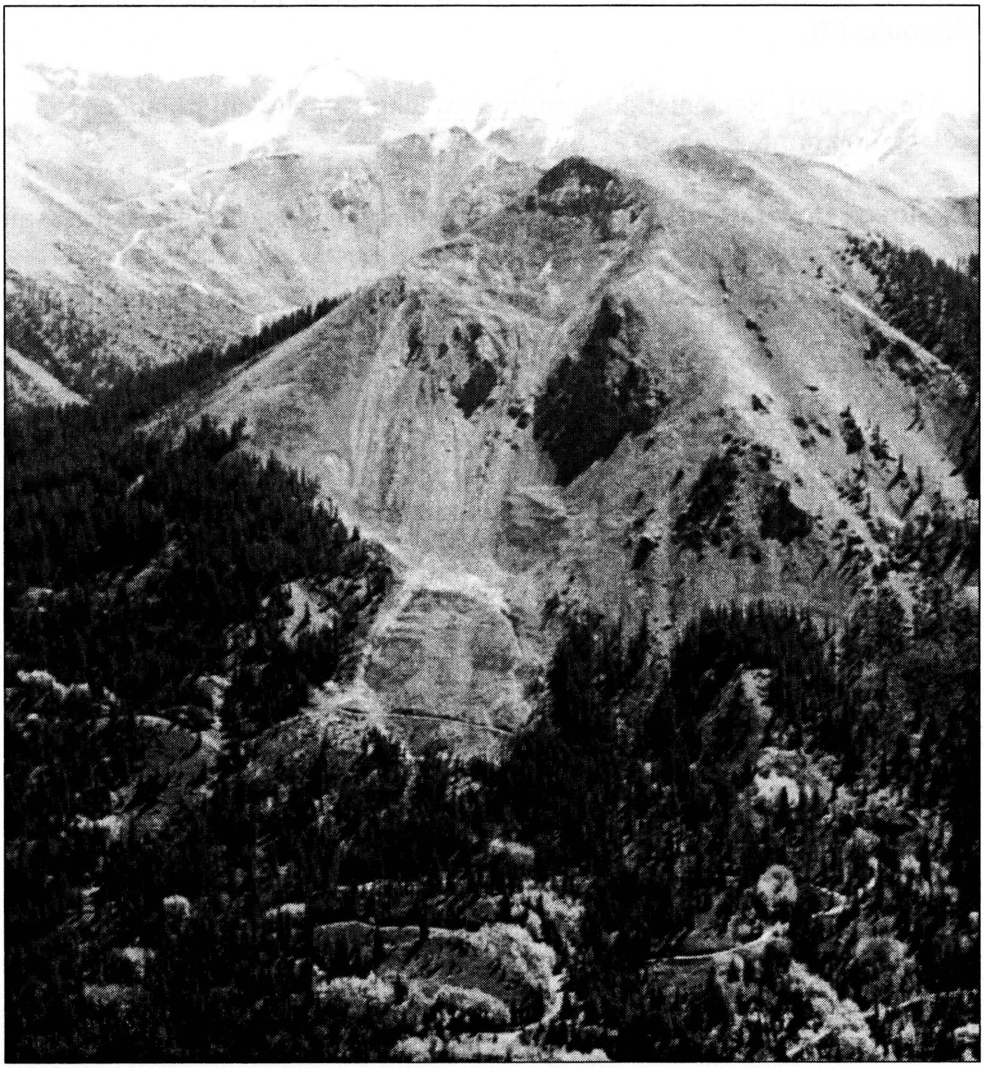
This is the top priority abandoned mine site for remediation in the Mineral Creek basin. The site has historically contributed extremely high metal loads to the headwaters of Mineral Creek. Prior to reclamation, it was responsible for about 70% of the zinc load and much of the iron load in Mineral Creek. In 1997-98, Sunnyside Mine personnel performed remedial work designed to reduce metal loading to Mineral Creek. The Koehler Mine waste-rock dump was removed, the waste rock around the Longfellow Shaft was mantled with alkaline fly ash, and surface water run-on/run-off controls were constructed.



Longfellow Mine shaft house. The waste-rock dump around this mine has undergone reclamation.

**For Those Continuing Over Red Mountain Pass toward Ouray:**

North of Red Mountain Pass, the Red Mountain Peaks rise east of the highway. They occur within the subsided or down-dropped central portion of the Silverton caldera. They consist of a complex system of flows, flow breccias, and pyroclastics of rhyolite and latite making up the Burns Formation (Tertiary Oligocene). These units, in turn, have been penetrated by fingers of rhyolite and quartz-latite-porphyry intrusives. Most of the rocks have been highly altered by late Tertiary hydrothermal activity and have subsequently weathered to a variety of iron oxides with shades of red, orange and yellow-brown. Fresh exposures of the altered rock are commonly white, greenish white or gray, and represent an assortment of clay minerals mixed with primary alteration minerals such as pyrite, chlorite, alunite and quartz. Throughout there are patches of silicified breccias derived from replacement of shattered parent rock. Landsliding is common on the slopes of these highly altered and fractured rocks, especially on the west slope of Red Mountain No. 2.



Red Mountain #2 showing landslide on its west-facing slope

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