Geology, Water Quality, and Avalanche Hazards of the Ouray – Silverton Area, Southwest Colorado

Earth Science Week Field Trip
October 9, 2000

by
Matthew A. Sares and J. Andrew Gleason

Colorado Geological Survey
Division of Minerals and Geology
Department of Natural Resources
1313 Sherman Street, Room 715
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FIELD TRIP GUIDE

Miles from start	Miles from last point

STOP 1. Ouray Hot Springs Parking Lot

0.0 0.0

The cliffs around Ouray are composed of Paleozoic and lower Cretaceous sedimentary rocks overlain by Tertiary San Juan Formation volcanic rocks. The Ouray hot springs are heated by geothermal waters emanating from faults beneath the alluvium of the valley bottom and are a faint reminder of past volcanic activity.

Look up at Mt. Abrams, the starting zone for the East Riverside avalanche path, the most deadly snowslide on Red Mt Pass. Avalanche control used to be conducted from this parking lot. The 105 mm Howitzer was shot from here until it blew out windows on this side of town.

Head south on State Highway 550.

1.2 1.2

As you drive out of Ouray and up towards Red Mt Pass, notice the large bowl-shaped valley to the east, known as the Amphitheater. The gray rocks on your right (south) in the Amphitheater are from the San Juan Formation (30-35 million years). The reddish rocks on your left (north) are the Hermosa Formation (Pennsylvanian). The debris in the amphitheater is from an ancient landslide.

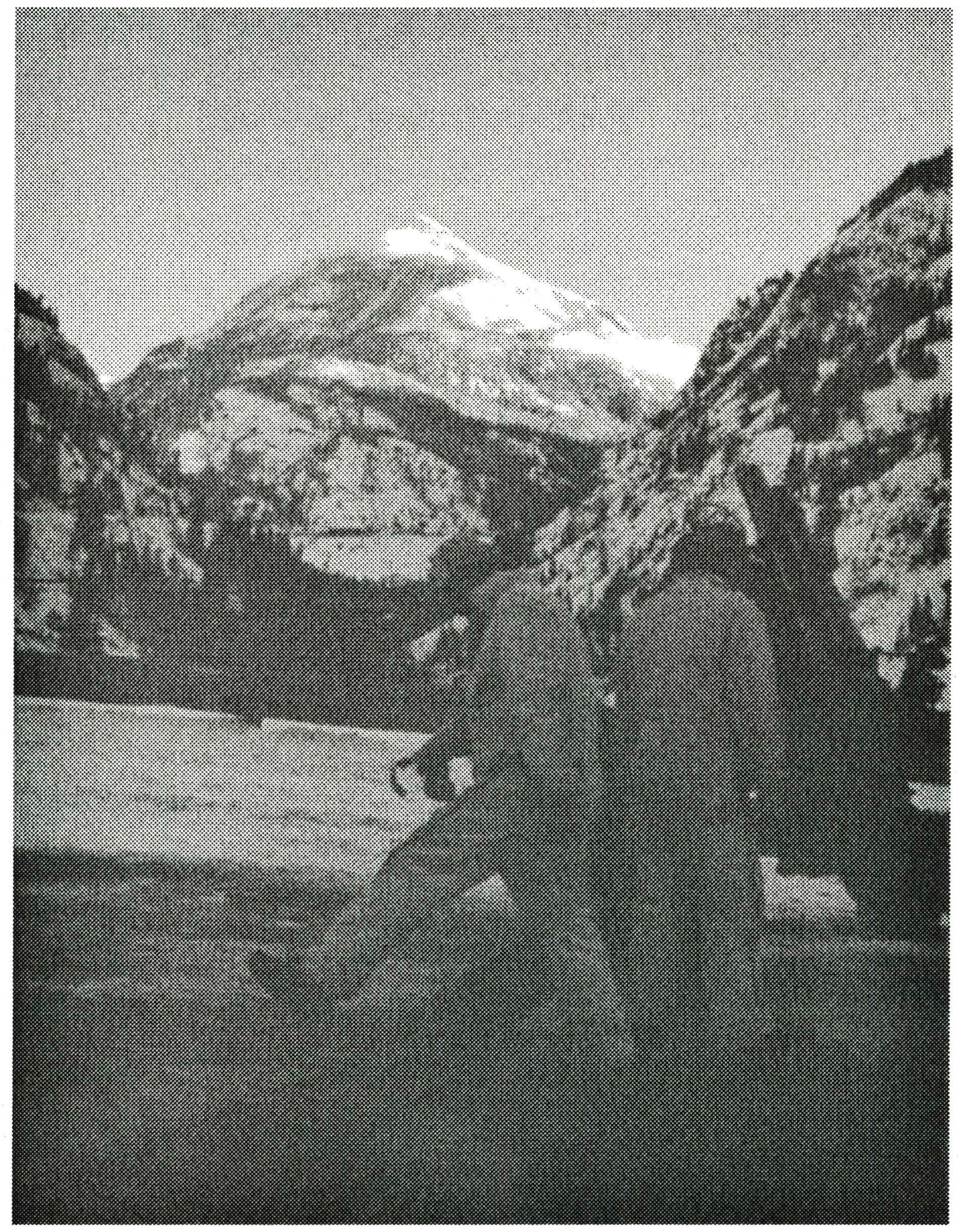
2.3 1.1

Unconformity: Steeply dipping Precambrian Uncompahgre Formation below horizontal Devonian Elbert Formation.

STOP 2. Bear Creek Falls (Milepost 90.6)

3.3 1.0

Bear Creek is a hanging valley carved by glaciers. The ice was estimated to be over 3000 feet thick here where Otto Mears had his toll station for the Million Dollar Highway. Across the Uncompahgre River you can see ripple marks in Precambrian Uncompahgre Formation quartzite that is about 1.5 billion years old. Avalanche control is done from this location with a 105 mm Howitzer. The East Riverside and Mother Cline avalanche paths are mitigated by launching explosives into the starting zones to release the avalanches while the road is closed.



Avalanche control on Mount Abrams using the Howitzer from the Bear Creek launching area.

Miles from start	Miles from last point

3.7 0.4

On the west side the unconformity on top of the Uncompahgre Formation has changed and is overlain by San Juan Formation volcanic rocks.

4.4 0.7

Road to Alpine Loop and Engineer Pass on east side.

4.6 0.2

The cliffs just ahead (0.2 miles) to your left are the site of numerous avalanches on the Mother Cline slide path. The avalanche path was named after Mother Cline who ran a boarding house for miners in the area.

5.3 0.7

Open adit (tunnel) on east side of road.

STOP 3. East Riverside Avalanche Shed (Milepost 88.1)

5.8 0.5

The avalanche shed was designed to protect the traveling public from the East Riverside avalanche path, the most deadly slide path on US 550. Since 1960, six people have been killed here. The shed was built in 1985, but is only one quarter of the designed size. It mitigates about 90% of the avalanches from Mt Abrams. The East Riverside slide path has a vertical fall of 3280 ft with a starting zone of about 75 acres. The West Riverside path, across the river and south of the snowshed, also terminates in the gorge and can put up to 35 ft of snow on the road.

East Riverside Slide on the northwest side of Mount Abrams.
Note snow-covered shed over State Highway 550 at bottom.


The avalanche shed saves lives and keeps the highway open.

Miles from start	Miles from last point
6.1	0.3

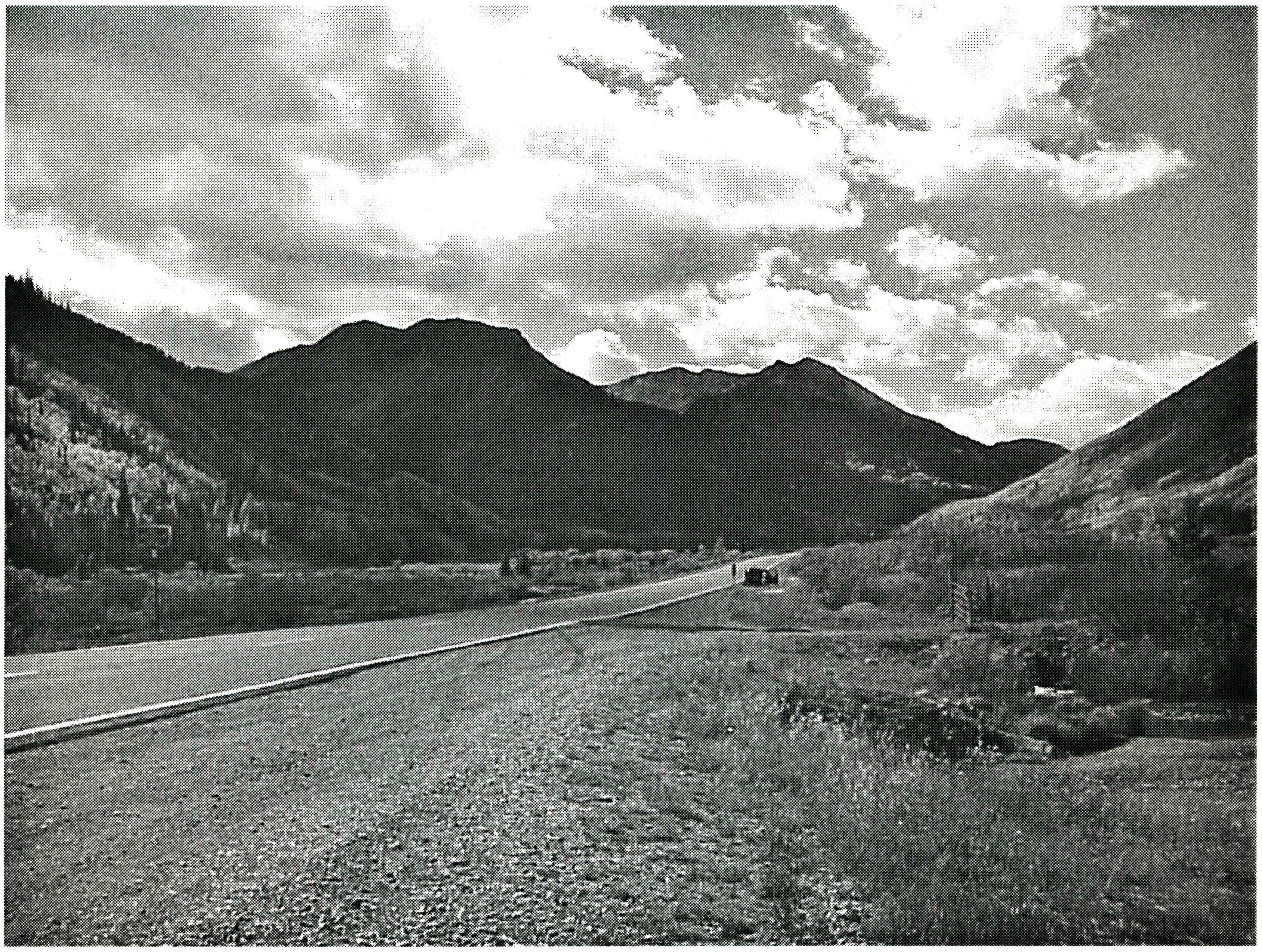
Memorials to avalanche victims are on east side.

6.7 0.6

On your left is an alluvial fan in the runout zone of the East Guadalupe avalanche path. To the right the West Guadalupe path runs over the cliffs to hit the road. Just past the stone building on the left, notice the color of the Uncompahgre River. Is the discoloration natural or from mining activities?

7.0 0.3

You are now entering Ironton Park. Ironton Park is a glacial valley that has been partially filled with gravels and sands (alluvium) from Red Mountain Creek. A glacial lake may have covered most of this valley after the glaciers retreated and before it was filled with lakebed mud, alluvium, and colluvium. Crystal Lake still remains at the northern end of the park. Much of the park exhibits riparian vegetation with extensive wetlands as ground water moving through the mountains comes to the surface in the park. The mining communities of Ironton and Red Mountain were located between here and Red Mountain Pass. Population in Ironton Park was over 1,000 in the late 1880's and 1890's.



Ironton Park with Red Mountains No. 1 and 2 in the background.

Miles from start	Miles from last point	
8.5	1.5	The tailings, or waste-rock pile, you see here is the lowermost of the tailings piles (Tailings Pond 4) remediated by the Idarado Mining Co.
8.7	0.2	Adit on west side of road with nearby abandoned bunk house.
10.1	1.4	American Girl shaft house on east side.

Miles from start	Miles from last point

STOP 4. Geologic Overview and Idarado Tailings Reclamation Site (Milepost 82.9)

10.9 0.8

Geologic Overview

Volcanic activity, related faulting, and subsequent erosion formed the landscape and geology of this area. This stop is located on the northwestern side of the roughly circular Silverton caldera. To the southeast Red Mountains No.2 and 3 can be seen. They are within the subsided or down-dropped central portion of the caldera. The upper part of these mountains consists of the Henson Formation. The lower part consists of the older Burns Formation. Both units are Tertiary Oligocene in age (~27-28 million years), a time when intense volcanic activity in the San Juan Mountains area caused deposition of thick beds of volcanic rock. Looking west to the outside of the Silverton caldera, the Burns formation is at the surface and the Henson Formation is not present due to erosion.

The stunning red, maroon, orange, and yellow colors of the Red Mountains are primarily due to past hydrothermal alteration of these rocks. Hydrothermal alteration is literally the process of "hot water" circulation through the strata that changes the mineral composition of the original rocks. Hydrothermal fluids commonly contain significant concentrations of metals and sulfur. Hydrothermally altered rocks can contain significant amounts of disseminated sulfide minerals, primarily pyrite (iron sulfide). This process happened within and surrounding the Silverton caldera. Subsequent erosion of the strata exposes the pyrite to oxidation, and as the iron combines with oxygen it turns the rock various colors evident in the Red Mountains.

The oxidation of pyrite does more than provide beautiful colors. The oxidation commonly occurs when pyrite is in contact with water. Unfortunately, this chemical process causes the production of sulfuric acid. The water becomes acidic (commonly pH <6.0) as it moves over the surface or through hydrothermally altered rocks containing pyrite. The acidic water then dissolves metallic elements in the rocks and carries them downstream where they may occur in concentrations that are toxic to aquatic life. This process, called *acid rock drainage* (ARD), happens both naturally and at mine sites. Significant volumes of acidic runoff may occur at mine sites where an abundance of sulfide minerals are exposed to water and air, and the surface area of exposed rock has been greatly increased. ARD associated with mine sites is often called "acid mine drainage."

Idarado is trying to stem the tide of the ARD that occurs in and around the tailings piles by limiting water infiltration. It appears that their work is paying off, evidenced by declining zinc levels downstream in Red Mountain Creek.

Idarado Tailings

The Red Mountain mining district is well known in Colorado and was an important district in the San Juan Mountains between 1881 and 1896. During this time period it was second only to Leadville in importance in Colorado. The important mines in this district, in terms of ore production, include the Yankee Girl, Guston, Genessee-Vanderbilt, National Belle, and Congress mines. The district produced silver, copper, lead, and zinc ores. Many of the mines in the area produce from rich chimney-like ore deposits called "breccia pipes." Mining waned in most of the district after the turn of the century, but continued at modest levels until World War II. During the war effort and with government subsidies the Treasury Tunnel was expanded to intersect many mines on the west side of the district, continuing into the Telluride mining district.

After World War II, the Idarado Mining Company took over the mines interconnected with the Treasury Tunnel and other properties in the mining district. The Idarado mines and mill operated until 1978, producing silver, lead, zinc, copper, and gold.

In 1992 negotiations between Idarado and the State resulted in a Remedial Action Plan to reclaim mine tailings and surface disturbances in the Red Mountain and Telluride mining districts. In addition to their own properties, Idarado is reclaiming 12 mine sites that are not owned by them. Aquatic habitat degradation is the major problem related to mine drainage and mine tailings in the Red Mountain district, with zinc being important as one of the elements toxic to fish. Even though human contact with tailings is minimal, a potential human health issue is exposure to heavy metals in the tailings, specifically lead and cadmium. The tailings piles contain elevated lead levels of 1,300 to 10,000 ppm. The goal of remediation in the Red Mountain Creek drainage basin is to reduce zinc concentrations in the creek by 50% to a concentration of 1.25 parts per million (ppm) below Tailings Pile No. 4. This concentration in Red Mountain Creek should, result in a 0.23 ppm concentration in the Uncompahgre River below Ouray.

Actions taken by Idarado include combining many tailings piles into "cells," revegetation of the tailings cells, and constructing run-on/run-off controls to prevent surface water from moving through the pile and to eliminate erosion of the piles.

Since reclamation efforts began to take effect, zinc concentrations in Red Mountain Creek have been declining. The summer of 1997 saw the 52-week average of zinc concentrations drop below 1.5 ppm below Tailings Pile No. 4, which is the compliance level, but is slightly above Idarado's performance objective of 1.25 ppm. In 1999, levels continued to be close to the 1.5 ppm level.

11.9 1.0

Idarado Mill and Treasury Tunnel on east side.

12.2 0.3

Yankee Girl Mine on east side.

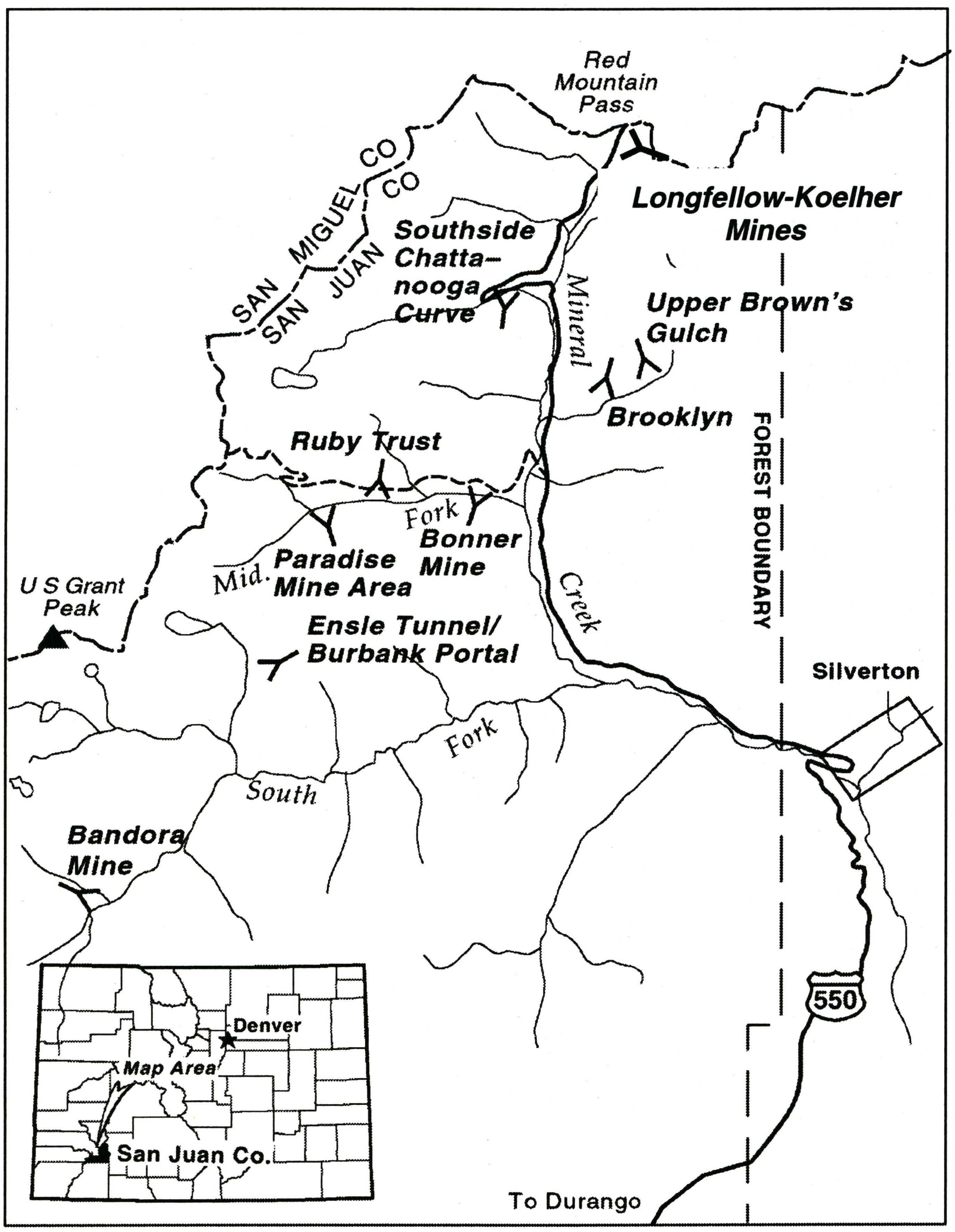
Miles from start	Miles from last point

12.7 0.4

On your right past the switchbacks is the Blue Point slide path, the most frequent path on the highway. While not the largest avalanche on the road, it is the most problematic. It slides the most because of its steepness and its fetch area. The fetch of an avalanche path is the area adjacent to the starting zone, where snow is picked up by the wind and deposited into the starting zone. There is a snow fence near the top of the path that helps keep some of the snow out of the starting zone.

13.6 0.9

Red Mountain Pass, elevation 11,018 feet.



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

Miles from start	Miles from last point

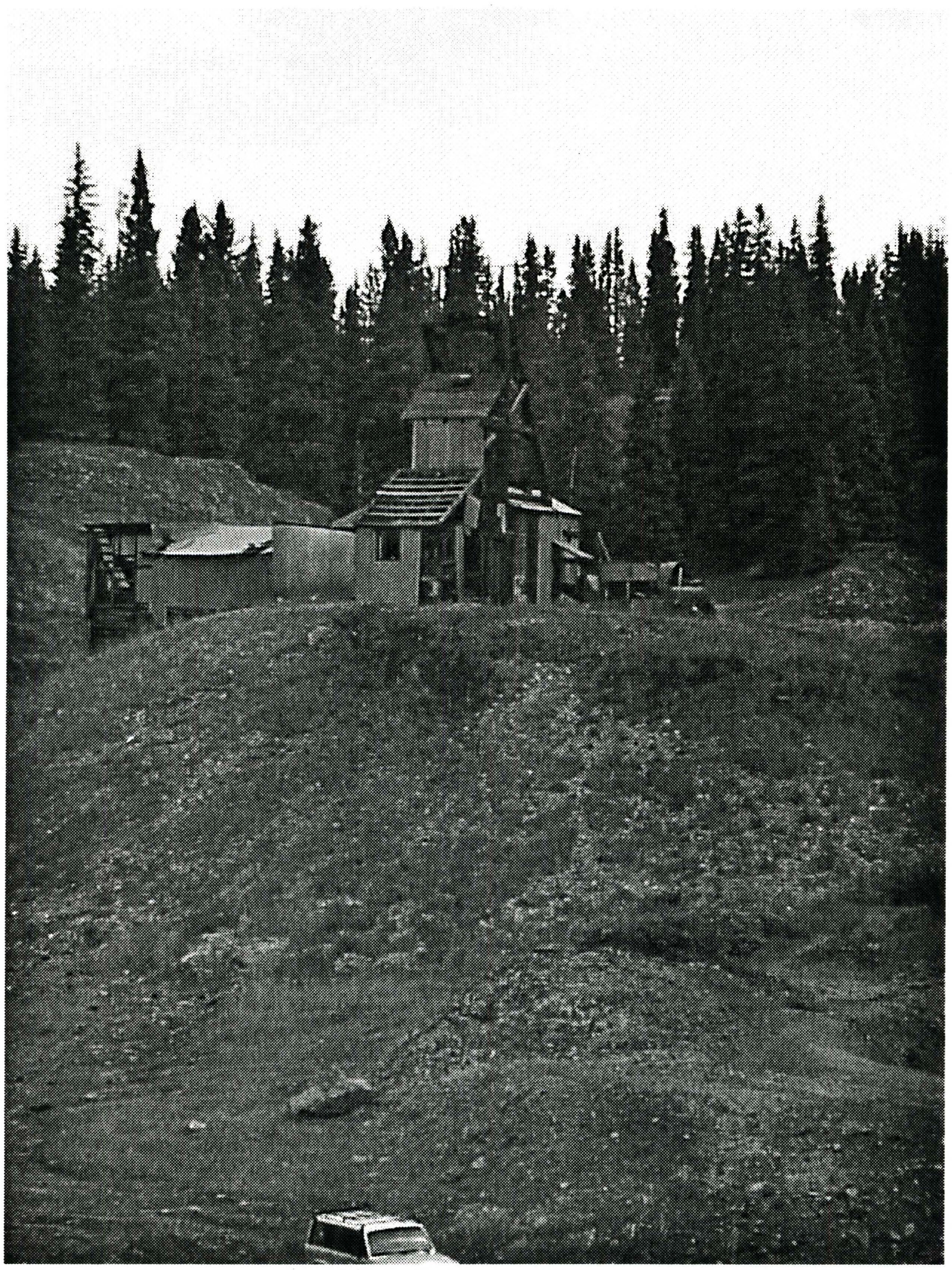
STOP 5. Longfellow - Koehler Mine Site (Milepost 80.0).

13.8 0.2

This stop is just south of Red Mountain Pass, in the upper reaches of the Mineral Creek drainage basin, a tributary of the Animas River. 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 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 also inventoried and investigated AML sites within 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 standing on the northwest structural boundary or rim of the Silverton caldera. The caldera center is to the east-southeast. Mineral Creek, which State Highway 550 follows to the south, traces the western rim of the caldera. 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 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.



Longfellow Mine shaft house. The waste-rock dump around this mine has undergone reclamation. (Stop 5)

This is the top priority abandoned mine site for remediation in the Mineral Creek basin. The site has historically contributed extremely high metals loading to the headwaters of Mineral Creek. It is 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.

EARTH SCIENCE WEEK

Earth Science week began in 1997 when the Association of American State Geologists (AASG) passed a resolution declaring the second week of October as "Earth Science Week." The American Geological Institute (AGI) is the national sponsor of Earth Science Week and is the lead organization coordinating national events. Many earth science-related organizations and government agencies, including the Colorado Geological Survey, celebrate Earth Science Week because it offers a tremendous opportunity for increasing earth science outreach and for improving science literacy.

The AGI objective in establishing an annual national Earth Science Week is to raise public understanding and awareness of the contributions the earth sciences make to our daily lives. This objective mirrors the mission of the Colorado Geological Survey- "to serve and inform the people of Colorado by providing sound geologic information and evaluation and to educate the public about the important role of the earth sciences in everyday life in Colorado."

To learn more about Earth Science Week or to request an Earth Science Week information kit, visit the Earth Science Week web site, http://www.earthsciweek.org , or send your request to Earth Science Week, AGI, 4220 King St., Alexandria, VA, 22302.

EARTH SCIENCE WEEK FIELD TRIPS

During Earth Science Week 2000, geologists and avalanche forecasters from the Colorado Geological Survey will lead a free public trip along State Highway 550 from Ouray to Silverton over Red Mountain Pass in the San Juan Mountains. This trip is designed to acquaint participants with the avalanche terrain and water quality issues as well as some background geology and mining history of the Red Mountain Pass area 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. People of all ages are welcome. The trips are especially helpful to earth science teachers.

Logistics:
You must travel in the caravan during the October 9, 2000 field trip. We will meet in Ouray in the morning at the parking lot of the Ouray Hot Springs 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.

Miles from start	Miles from last point

14.8 1.0

On your left you will see the shaft house of the Silver Ledge Mine. Mineral Creek in the valley below the road, follows the direction of the caldera rim faults.

Silver Ledge Mine shaft house adjacent to Mineral Creek near Chattanooga. (Roll-by 5a)

15.7 0.9

The Eagle avalanche path on the right side of the road has deposited up to 30 feet of snow on the highway.

16.0 0.3

Silver Crown Mine and avalanche path on west side of the "Chattanooga curve" in Mill Creek drainage.

Miles from start	Miles from last point

STOP 6. Chattanooga (Milepost 77.1)

16.7 0.7

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 the 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, these debris flows put up to 20 feet of mud and rocks on the highway.

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

17.1 0.4

Beaver ponds and wetlands west of the road naturally filter metals from Mineral Creek.

17.4 0.3

Debris flow fan deposits on east side.

STOP 7. Ophir Road Avalanche Path (Milepost 75.1).

18.7 1.3
This avalanche path extends east of State Highway 550, east of 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 10-15 feet of snow on State Highway 550 at Ophir Road.

18.7 0.0
Middle Fork of Mineral Creek

Turn right on San Juan County Road 8 toward Ophir Pass. The next three stops will be along the Middle Fork of Mineral Creek. Even though this watershed has unique features, it also provides typical examples of the influences on water quality in historically mined, high headwaters areas of Colorado. There is a water quality puzzle that unfolds with each stop in this drainage. Geological knowledge provides the foundation for solving the puzzle.

For comparison sake, water sample analytical results from August 1995 are compared to standards for the adjacent downstream segment, which includes Mineral Creek from just above the confluence of South Mineral Creek to the Animas River.

Miles from start	Miles from last point

STOP 8. Bonner Mine.

19.7 1.0

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 reveal very high concentrations of several metals such as aluminum (184x), cadmium (40x), copper (7.7x), iron (2.2x), manganese (10x), and zinc (24x). The concentrations exceed state standards for the adjoining downstream segment of Mineral Creek by the factors shown in parentheses!

This mine is currently being reclaimed. Water will be collected in a culvert sump and then re-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.

20.1 0.4

An unnamed avalanche path on the right.

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

20.6 0.5

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 the tributary's confluence with the Middle Fork, it is very acidic (pH=3.8) with elevated concentrations of aluminum and iron. Aluminum is 115 times, and iron is 5 times the standard for the adjoining downstream segment of Mineral Creek. The Red Trib flows at about 500 gpm and, therefore, has a significant effect on the Middle Fork.

Miles from start	Miles from last point

The pH of Middle Fork drops from 6.26 upstream of the Red Trib to 4.75 downstream. Near the mouth of the Red Trib, 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 gravels that have been cemented by iron precipitates deposited on the streambed.

The "Red Trib," an unnamed tributary stream of the Middle Fork Mineral Creek. (Stop 9)

<u>STOP 10. Paradise Portal.</u>

21.3 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 indicate that aluminum (82x), iron (11x), and manganese (4.6x) exceed state standards for the adjacent downstream segment of Mineral Creek by the factors shown in parentheses. The white precipitate is aluminum 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.

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 propylitically 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.

21.7 0.4

Turn around location. Head back down the hill.

24.7 3.0

Turn right on State Highway 550.

25.5 0.8

The Battleship slide path is to the west. It has to flow uphill over 250 feet from South Mineral Creek to hit the highway.

Miles from start	Miles from last point

29.1 3.6

Turn left on the Miner's Shrine road at Point of Interest sign.

STOP 11. Christ of the Mines Shrine.

29.6 0.5

Several avalanche paths affect the town of Silverton. We will discuss avalanche zoning issues that affect building in Silverton and San Juan County.

Following this stop, drive to Cement Creek road. Follow Shrine road NE into Silverton (don't turn around). Drive to paved road (Greene Street) and take a left. Drive out of town on Colorado State Highway 110 towards Cement Creek. Pass Memorial Park and turn left at fire hydrant (30.8). When the road turns to gravel, you are on Cement Creek road.

Along Cement Creek you will cross the runout zones of 45 avalanche paths. Numerous mines are located along Cement Creek and its tributaries. Both mining and natural acid rock drainage contribute to water quality degradation in this stream. Analysis of data collected for more than five years indicates a predominately natural component controls the water quality here.

31.2 6.0

Ferricrete deposits line both sides of Cement Creek and crop out adjacent to the road on the east side. Ferricretes are stream gravels that have been cemented by iron precipitates deposited on the streambed. The position of these ferricretes up to 60 feet above the current stream level indicates these deposits correspond to a higher stream level at some time in the past. They are likely Holocene in age were deposited since the last glacial period.

35.2 5.6

The Fairview avalanche path to the left put 20 ft of snow on the road in the spring of 1996.

STOP 12. Gladstone and the Sunnnyside Mine

37.2 2.0

Gladstone was the most recent location of the main haulage tunnel from the Sunnyside Mine. The mine enjoyed a long history in an area where most mining ended around the turn of the century. Several owners and operators have been involved with the mine, the more notable ones being U.S. Smelting/Washington Mining Co., Standard Uranium/ Standard Metals Corp., Echo Bay Ltd., and finally, Sunnyside Gold Corp. The mine was first located in 1873 in the Sunnyside Basin at an elevation of 12,300 feet. The mine has produced both precious metals (gold, silver) and base metals (lead, zinc, and copper). Between 1930 and 1958 Sunnyside was mostly idle because of low base metal prices, decreasing ore grade, and increased operating costs for hoisting ore. Mine rehabilitation started in 1958, which resulted in completion of the American Tunnel as a new haulage level. This is the access tunnel at Gladstone. The revitalized mine again became productive and profitable. High-grade veins were discovered in 1969 and became the mine's principal source for gold until the mine ended production in 1991. Sunnyside Gold Corp. started final reclamation of the mine at that time and is continuing that work today.

Various mills served the mine. Initially (1890), a stamp mill was built about 1½ miles below the mine and was served by an aerial tramway. In 1899 a larger mill was built at the Eureka townsite. In 1917 the Mayflower flotation mill was built northeast of Silverton and continued as Sunnyside Mine's mill until production ceased. The Mayflower mill tailings were reclaimed in the early 1990's.

The mine is located in the Eureka Graben, a down-dropped northeast trending block within the San Juan Caldera.

A frightening moment in the history of the Sunnyside Mine occurred on June 4, 1978 when the bottom of Lake Emma collapsed and flooded the mine workings, just 70 feet below, with millions of tons of mud and water. No miners were hurt or injured because it was a Sunday. The "Christ of the Mines" shrine (Stop 11) commemorates the miner's protection from this disaster.

End of the field trip. Head back to Silverton.

Selected References

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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 your 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.

This free guidebook explaining the geology, water quality issues, and avalanche terrain along the route will be given to each participant.

INTRODUCTION

The purpose of this one-day field trip is to look at the geology, water quality issues, and the avalanche hazards along Highway 550 from Ouray to Silverton. 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 that they contribute to the watershed. We will view remediation that has been accomplished to help clean up 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 23 "roll bys" or things to look at while we drive by.

GENERAL GEOLOGY OF THE OURAY-SILVERTON AREA

The mountains that you see while driving along Red Mountain Pass were shaped over billions of years through multiple episodes of mountain building and uplift, ancient seas, volcanic upheavals, and icy glaciers.

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.

Underlying the volcanic rocks, the older geologic sequence is visible in the Ouray area and south along the Uncompahgre River Canyon. Small outcrops are present in Ironton Park.

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.

In Ouray and south to the vicinity of Bear Creek, sedimentary rocks from the Paleozoic era outcrop on the canyon walls. The rocks unconformably overlie the Uncompahgre Formation. 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.

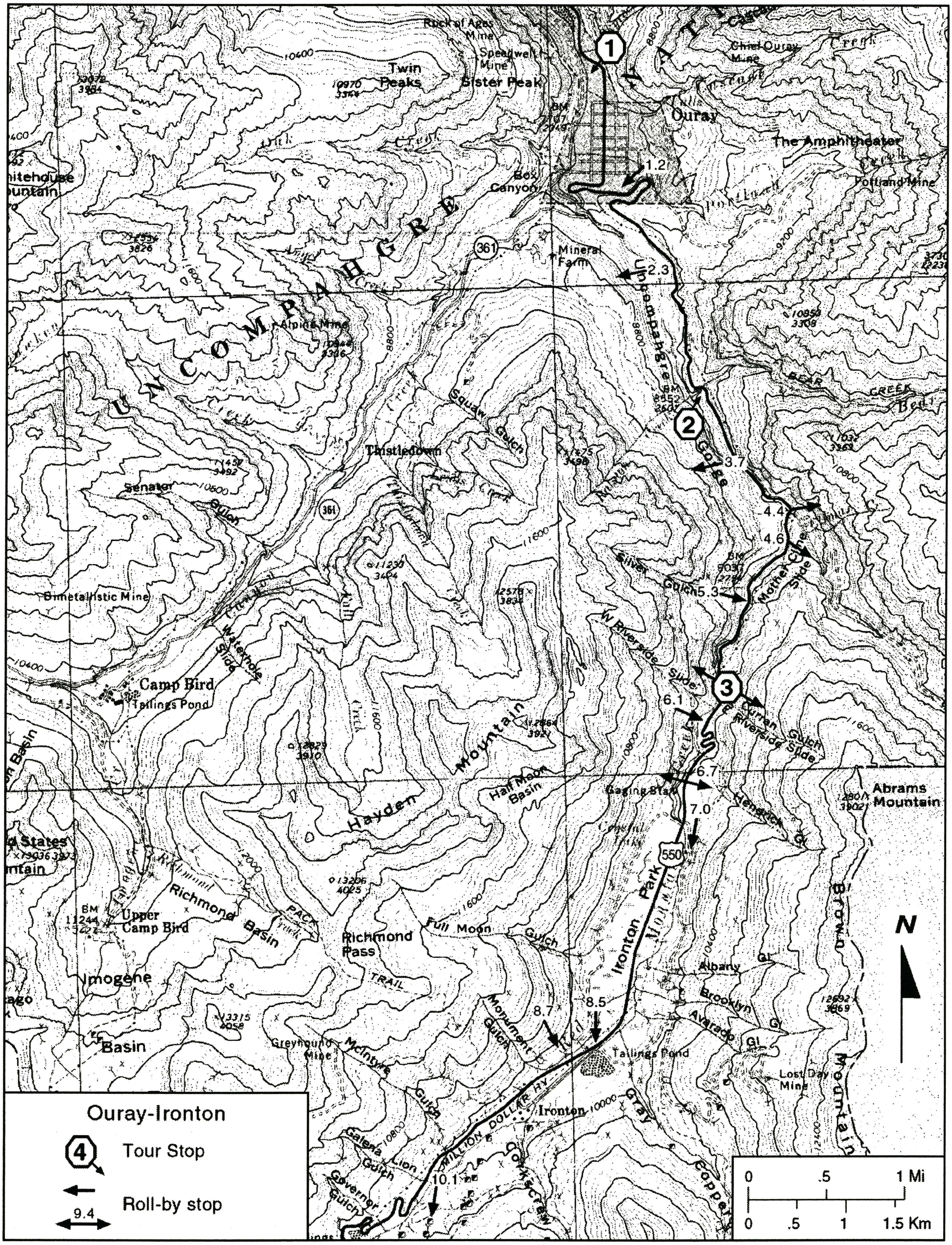
Unconformably overlying the Paleozoic sequence are the Mesozoic rocks of the Triassic Dolores Formation, Jurassic Wanakah and Morrison Formations, and the Cretaceous Dakota Formation. These rocks are exposed north and west of Ouray, but are not visible south along the Uncompahgre River Canyon.

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 Ouray-Silverton area. Younger volcanic deposits are not encountered during this field trip.

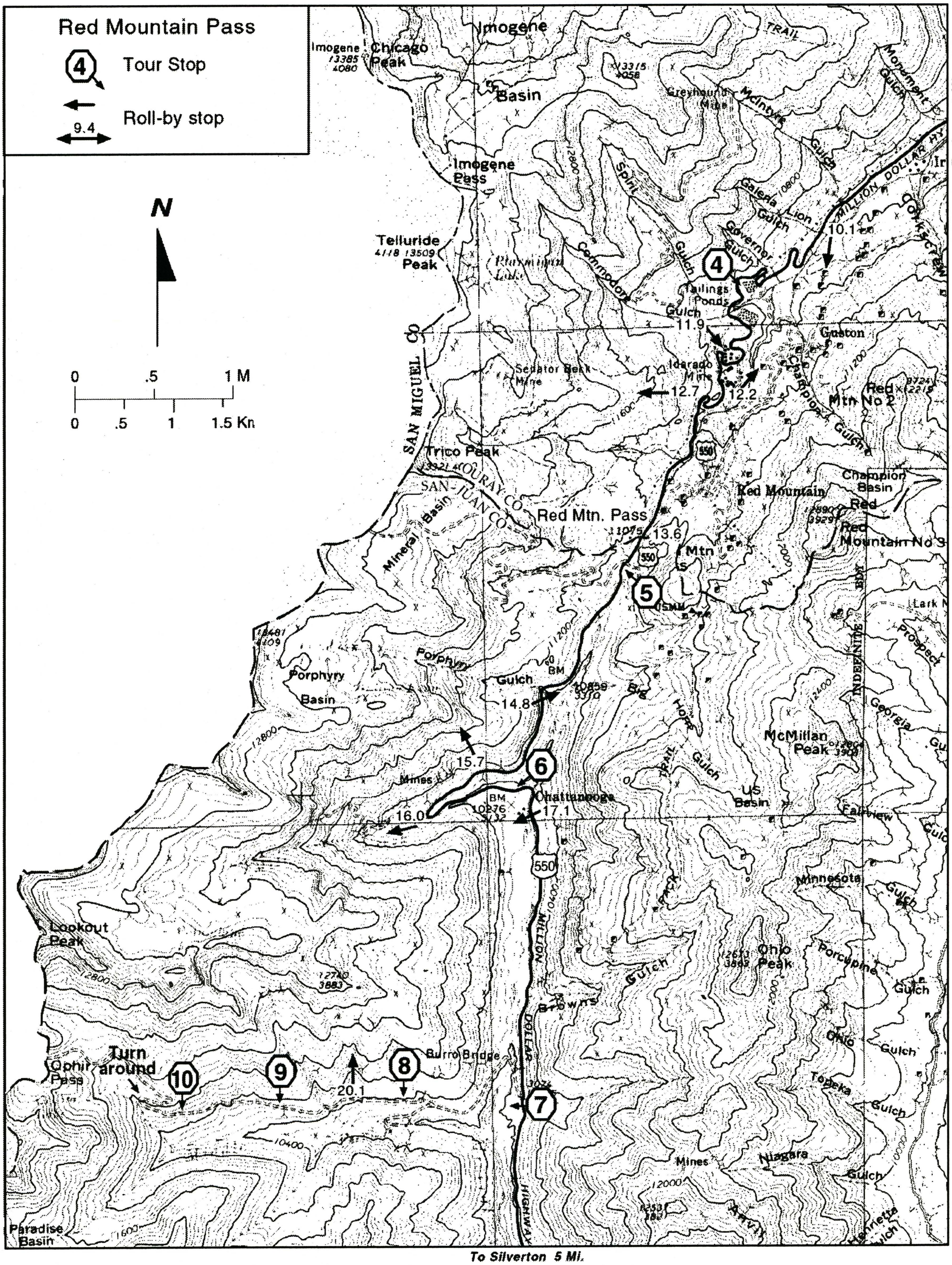
GEOLOGIC TIME SCALE

ERA	PERIOD	EPOCH (Age in Millions of years)	SELECTED ROCK UNITS (Western San Juans)
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)	Mesa Verde Group, Mancos Shale
	Jurassic	(208)	Morrison Formation, Entrada sansdtone
	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

Field Trip Index Map 1



Field Trip Index Map 2



Field Trip Index Map 3