COLORADO GEOLOGICAL SURVEY

ROCK TALK

VOLUME THREE, NUMBER TWO APRIL, 2000

GEOLOGY AND WATER QUALITY

In our everyday lives, few of us think about the quality of the water we use for drinking, recreation, watering plants, or sanitation. Yet, at times, water quality can become very important to us — usually when contamination is feared.

Fortunately, Colorado is blessed with large supplies of clean water, much of it in the form of snowmelt runoff from the Rocky Mountains. As the snowmelt and rain enter streams and percolate into the ground to replenish ground water aquifers, the water flows over and through various kinds of rock. This interaction changes the composition of the water. The water begins to carry suspended particles and dissolved components of the rocks. The composition, or chemistry, of the water will reflect the geology of the area with which it has been in contact. This is a natural process and generally does not change the water quality significantly enough to be a concern to humans, wildlife, aquatic organisms, or vegetation.

In some areas, though, the geology will affect water to the extent that its quality is not suitable for certain uses. Elements in the rocks may become dissolved in the water at high concentrations that, in turn, may adversely affect living organisms. This can happen in Colorado due to its geology. The following sections describe water quality issues in Colorado in which geology plays an important role.

Metals

Colorado's mountains contain large mineral deposits of various metals. Metal mining is a large part of Colorado's heritage and continues today. Some abandoned mines and waste rock piles from the state's mining heyday continue to drain water and contribute to elevated metal concentrations in streams. However, this is not the whole story. A number of streams in headwater areas of the state are affected primarily by *naturally* elevated metals concentrations caused by the area's geology. Some examples are the North Fork of the South Platte River in Park County, South Fork of Lake Creek in Lake County, and the upper Alamosa River in Conejos County. CGS is currently involved in a study to compile locations and to identify the chemistry and geologic setting of these naturally degraded streams. (See article on page 5).

Many times, both natural and mining-induced sources of metal loading to streams occur in the same area. A chemical process, called "acid rock drainage," takes place when water and oxygen interact with metal-sulfide minerals such as pyrite (below). Essentially, sulfuric acid is produced, which dissolves metals and carries them in solution to ground water

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THE CHEMISTRY OF ACID ROCK DRAINAGE

Reaction 1: $\underset{\text{pyrite}}{FeS_{2(s)}} + \underset{\text{water}}{H_2O} + \underset{\text{oxygen}}{{}^{7}/_{2}O_2} \rightarrow \underset{\text{iron}}{Fe^{2+}} + \underset{\text{sulfate}}{2SO_4} + \underset{\text{acid}}{\mathbf{2H^+}}$

Reaction 2*: $Fe^{2+} + {}^{1}/_{4}O + \mathbf{H^+} \rightarrow Fe^{3+} + {}^{1}/_{2}H_2O$

Reaction 3: $FeS_{2(s)} + 8H_2O + 14Fe^{3+} \rightarrow 15Fe^{2+} + 2SO_4 + \mathbf{16H^+}$

Reaction 4: $Fe^{3+} + 3H_2O \rightarrow Fe(OH)_{3(s)} + \mathbf{3H^+}$

*catalyzed by bacteria
(s) = solid

The chemistry of acid rock drainage. ***Reaction 1)*** *A metal sulfide (pyrite) mineral reacts with water and oxygen producing acid.* ***Reaction 2)*** *Ferrous iron released from pyrite is oxidized to ferric iron, consuming some acid.* ***Reaction 3)*** *Ferric iron reacts with pyrite and water producing large amounts of acid.* ***Reaction 4)*** *Ferric iron reacts with water to produce a red precipitate and more acid.*

INSIDE THIS ISSUE

Focus on Geology and Water Quality

Field Notes from the Director

The Environmental Geology activities of the Colorado Geological Survey help explain the connection between our water quality and our geology. CGS geologists measure and characterize the effect of acid rock drainage related to high mountain streams running across the hydrothermally altered rocks, pervasive in many of Colorado's headwaters areas. They determine the extent and pathways of contaminants in groundwater bearing formations. And they track down the occurrences of natural minerals that increase the salinity of Colorado streams and rivers. Geology is the underlying key to understanding each of these situations.

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and streams. This process occurs when sulfide minerals are naturally exposed to water and oxygen near the ground surface and in water-bearing fractures or when they are exposed during mining. Natural acid rock drainage has been active in Colorado for at least thousands, possibly millions of years.

Salinity

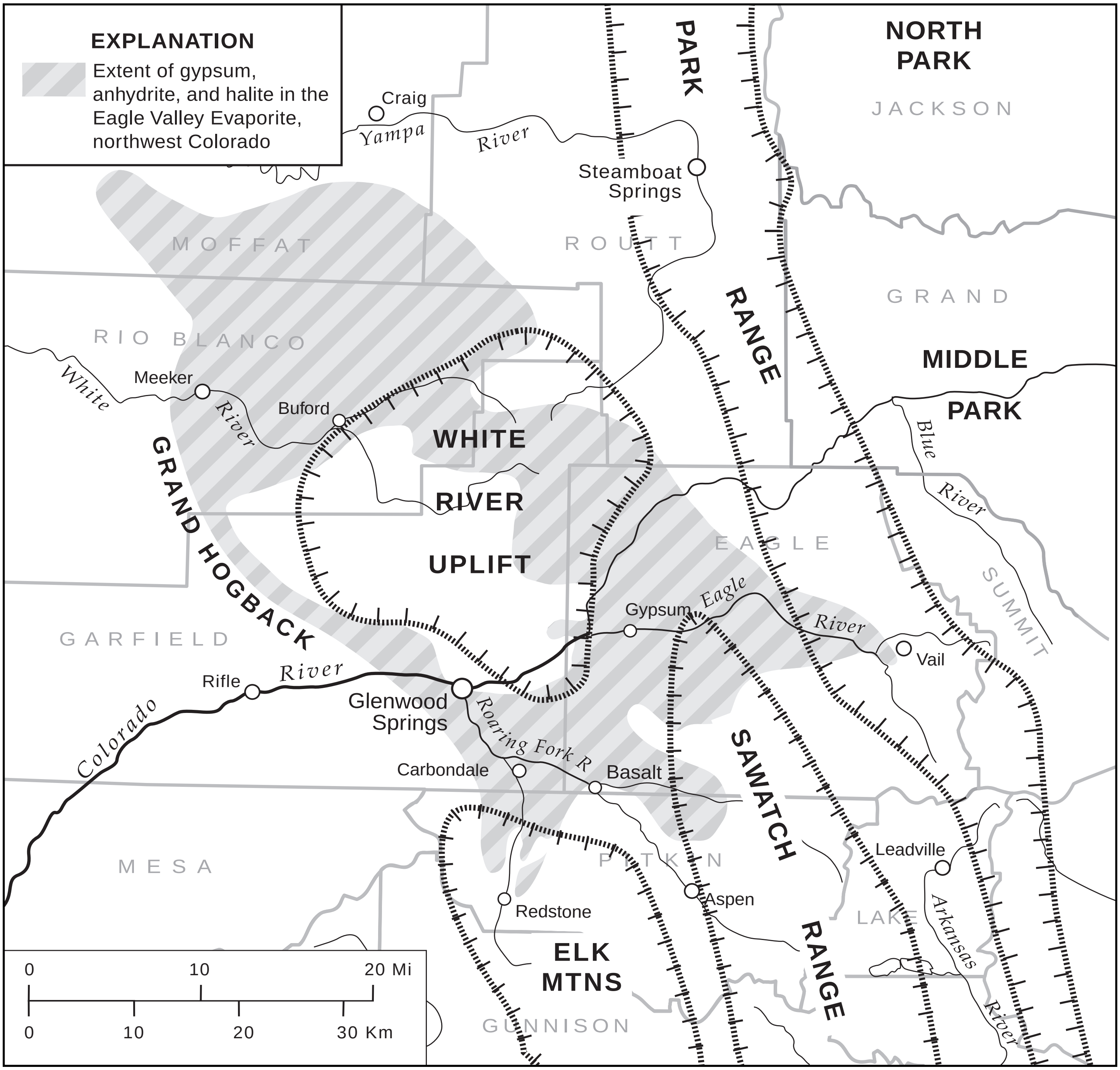
High salinity is an issue in the Colorado River basin from Colorado to California. In 1973, salinity issues even caused an important amendment to be added to an international treaty between Mexico and the U.S. This amendment requires Colorado River water to meet certain salinity (total dissolved solids) standards when it flows into Mexico. This requirement caused the federal government to fund large projects to reduce salinity in the river and its tributaries. There are several reasons for the high salinity of Colorado River water. These include geology, evaporation, dams and reservoir development, agricultural irrigation, and urban development.

Part of the salinity in the Colorado River basin of Colorado is attributable to its geologic setting. Thick deposits of ancient sea salt (halite, anhydrite, gypsum) underlie parts of this basin. One formation that contains these beds of salt is known to geologists as the Eagle Valley Evaporite. It lies beneath the Eagle River basin, lower Roaring Fork River basin, upper White River basin, and part of the Colorado River (see map on p. 3). Ground water and surface water are naturally and continually dissolving this salt layer. The saline water enters the river system and is carried downstream. Recent geologic mapping by CGS indicates that this dissolution process has been active for several million years and continues to the present. During this time as much as 540 cubic miles of salt deposits may have been dissolved and carried by streams. Natural hot springs, such as those near Glenwood Springs and Dotsero, can carry large amounts of dissolved material and play an important role in the dissolution and transport of salt to the Colorado River.

Selenium

The toxicological effects and environmental occurrence of the element selenium have been studied since the 1930s when it was discovered that high concentrations in pasture grasses caused disease and death in cattle and horses. Since that time selenium has also been found to be toxic to birds and fish, disrupting the embryo development process. Selenium occurs in higher than normal concentrations in several Colorado streams.

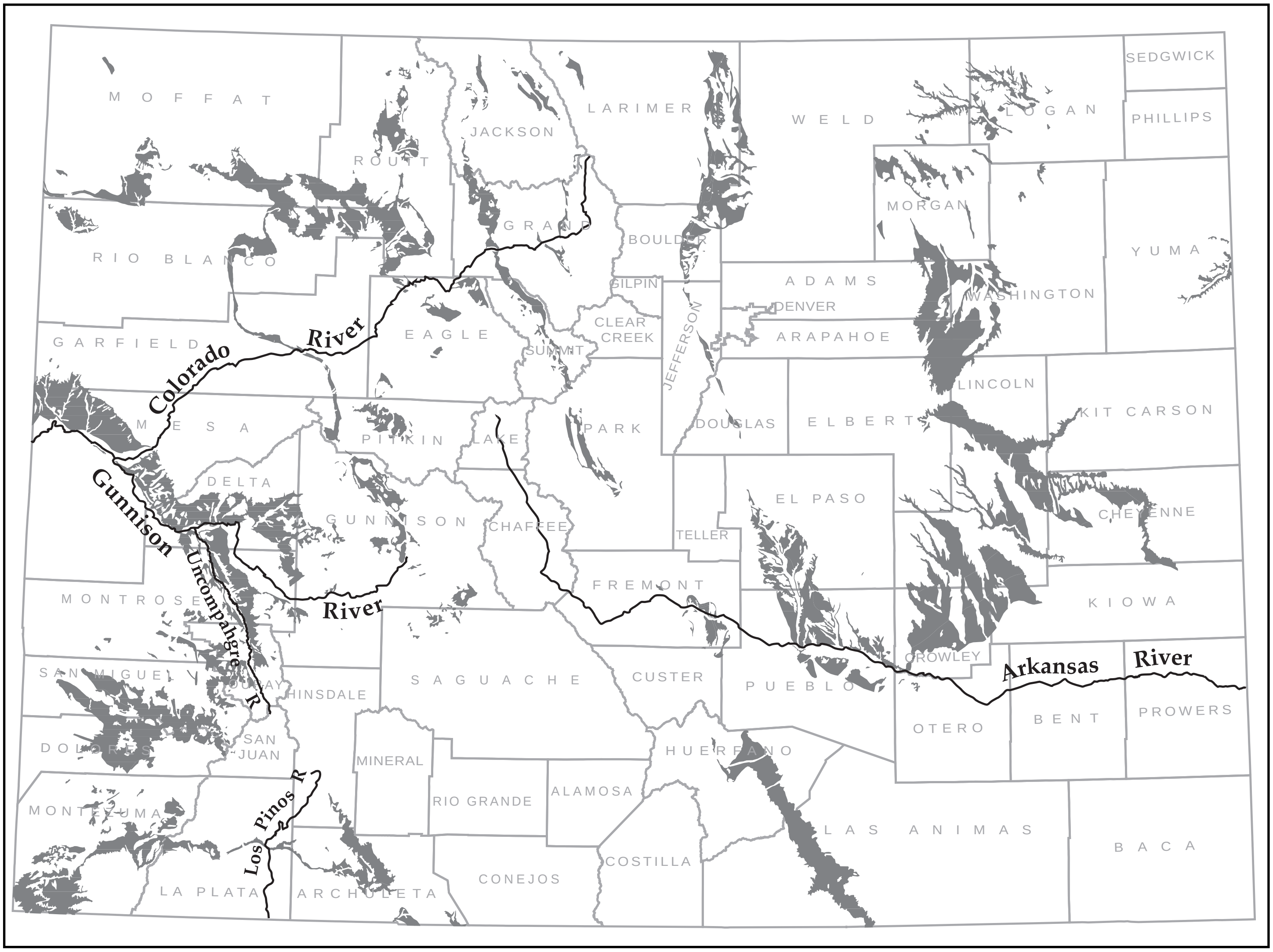
Eagle Valley Evaporite (light colored outcrop) adjacent to the Roaring Fork River near Glenwood Springs



Areal extent of salt deposits within the Eagle Valley Evaporite (modified from Mallory, 1971

Much of the selenium load in these streams can be attributed to return flows from irrigated agricultural areas.

But what is the ultimate source of this selenium? Again, the answer is found in geology. Research has revealed that Upper Cretaceous marine shales in the western U.S. generally contain higher concentrations of selenium than other rocks in the earth's crust. Abundant volcanic activity during the late Cretaceous period and bioaccumulation in the life-rich, shallow, late Cretaceous seas of the western U.S. have been suggested as possible reasons for higher-than-normal selenium concentrations in marine sediments deposited during this time. The Mancos Shale (western Colorado) and the Pierre Shale (eastern Colorado) are the major Upper Cretaceous marine shale formations in Colorado and occur at the surface in many areas of Colorado (see map on p. 4). Streams collect dissolved selenium as they traverse these areas. High evaporation rates in southern and western parts of the state can further concentrate the selenium in the streams. Areas of concern in Colorado are the Gunnison River basin / Grand Valley area, Pine River basin, and



Surface expression of selenium-bearing Mancos Shale and Pierre Shale in Colorado and streams containing selenium above aquatic life standards for part of their course

Middle Arkansas River basin. Certain reaches of these streams exhibit selenium concentrations above the national minimum contaminant level of 5 micrograms per liter. Many national, state, and local organizations are trying to address this issue in Colorado.

Ground-Water Quality

Ground water is usually of very good quality for most uses. The aquifer from which the water is drawn can serve to filter bacteria and sediment from water as it percolates into the subsurface. Chemical processes can take place that remove impurities and add desirable minerals to the water. Ground water has generally resided a significant amount of time in its aquifer and through dissolution ground water reflects the chemical characteristics of the aquifer geology.

People who rely on ground water for domestic use occasionally find their water to be too "hard" (abundant calcium and magnesium), saline (high in dissolved solids), and iron- or manganese-rich. These characteristics are a reflection of the aquifer geology, water flow path, and residence time in the aquifer. Unless extreme, these water quality problems are aesthetic in nature and do not pose health risks. Treatment systems can alleviate these problems.

Naturally occurring radioactive elements can occur in ground water in Colorado and are a health risk in high concentrations. Radon, radium, and uranium are found in small amounts in most rocks. Certain rocks can be enriched in these elements. If these rocks serve as an aquifer, the local ground water may contain higher than normal radioactivity. Recently, this happened in the town of Castle Rock, causing them to abandon a newly drilled, but unused $100,000 water-supply well.

Summary

Geology plays an important role in water quality. Some water quality issues in Colorado have their beginning and foundation in the natural interaction between water and rock. This interaction can produce poor water quality independent of other influences. Still, many of the natural conditions listed above can be exacerbated by human activities. Prior assessment of the geology and associated water quality is necessary in proposed development areas to identify pre-development, or "baseline," conditions and inform planners about potential problems. Careful planning of any development activities—*taking into account the baseline conditions*—can limit unnecessary water quality degradation.

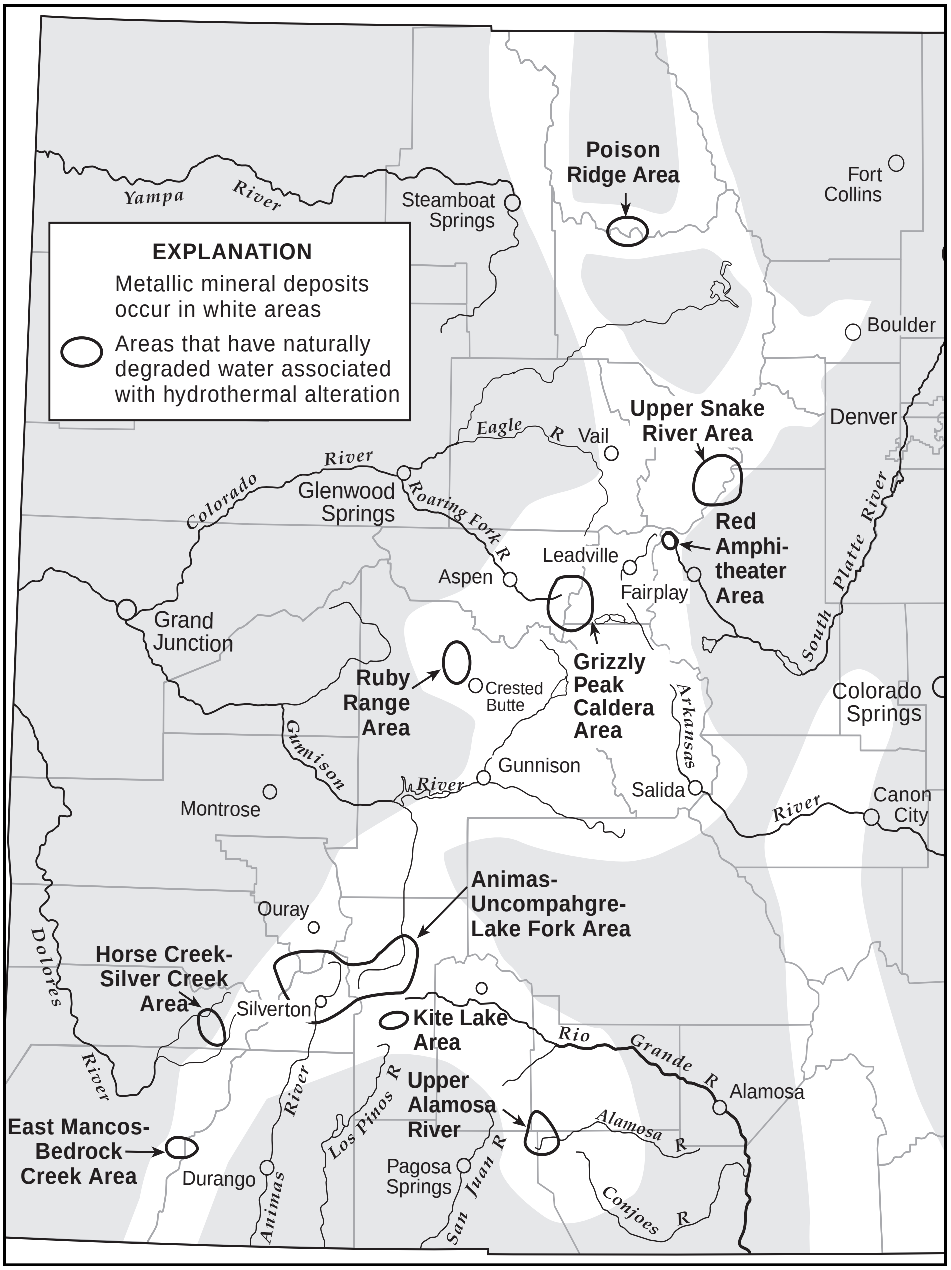
—Matt Sares

NATURALLY DEGRADED WATER IN HYDROTHERMALLY ALTERED TERRANE IN COLORADO

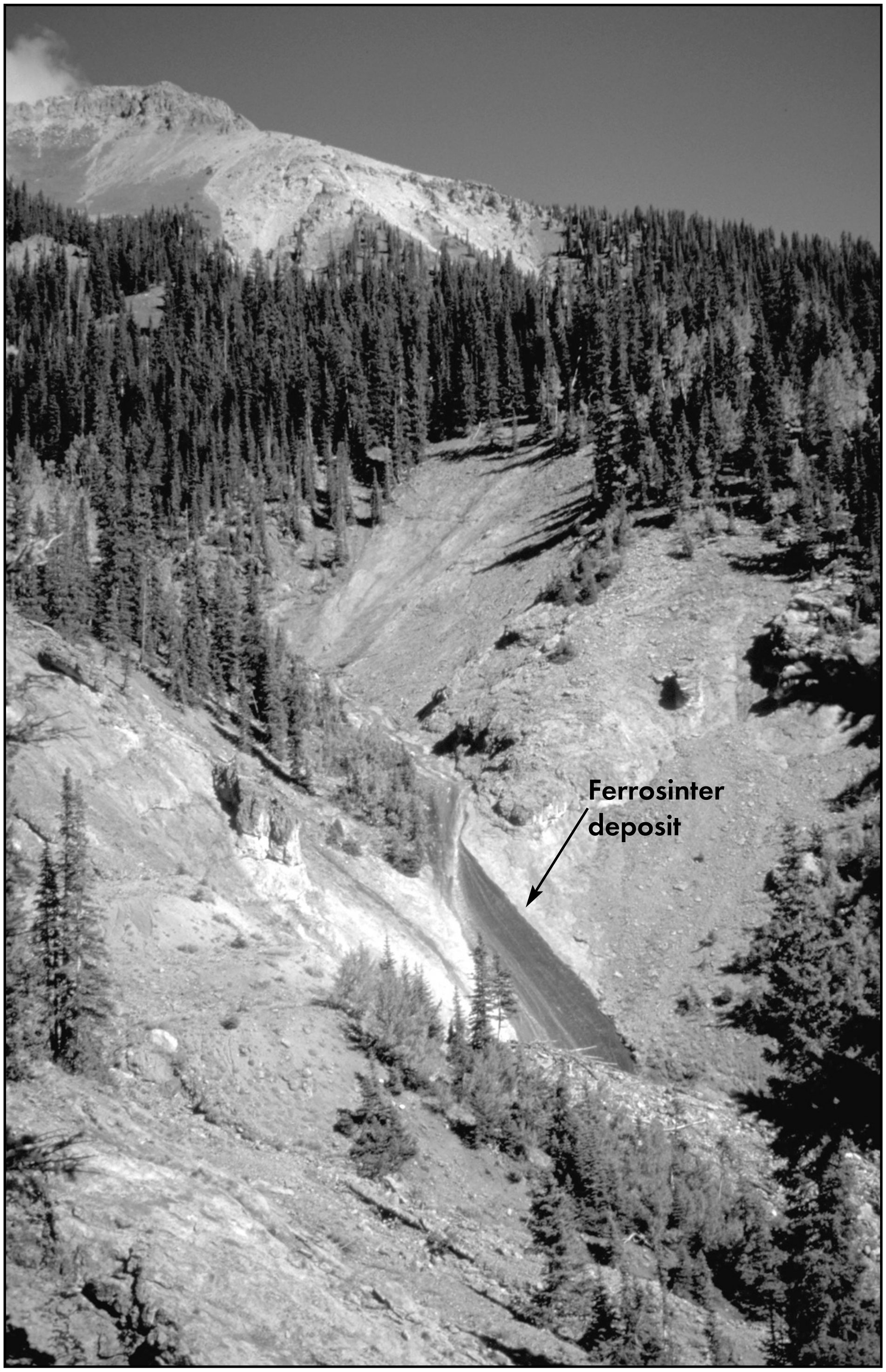
In the summer and fall of 1999 Colorado Geological Survey personnel conducted a reconnaissance-level investigation of naturally occurring, acidic and/or metal-rich surface waters in Colorado. The purpose was to identify the location, chemistry, and geologic setting of these naturally degraded streams.

Many areas of natural degradation were initially identified by water testing and sampling done in conjunction with an abandoned mine inventory conducted by the CGS for the U.S. Forest Service in the 1990s. An article in the April 1999 *RockTalk* (v. 2, no. 2) describes the mine inventory in detail. Individuals in the CGS, Colorado Division of Minerals and Geology, U.S. Geological Survey, U.S. Forest Service, and Colorado State University also provided important preliminary information regarding areas that might discharge naturally degraded waters.

A valuable source of information was U.S. Bureau of Mines Information Circular 7918 (1959) that documents iron occurrences in Colorado. Many of the iron occurrences are bog-iron deposits. Bog-iron deposits are generally formed by acidic, iron-rich water. As the acidity is neutralized by geologic materials such as limestone or other forms of calcium carbonate, or is diluted by cleaner water, iron minerals precipitate from the stream. Deposition of



Map showing some areas of naturally degraded water in comparison to mineralized areas of Colorado.



Photograph of an actively forming ferrosinter deposit in Bedrock Creek in the La Plata Mountains of southwestern Colorado. This area is underlain by mineralized igneous rocks that contain abundant pyrite and chalcopyrite.

iron minerals from solution forms the characteristic red color evident in many naturally and mining-related degraded streams. If the iron precipitate is fine-grained and has a smooth or muddy appearance, it is called ferrosinter (see photo). Sometimes the iron precipitates surround and cement stream gravel and cobbles together, forming a rough textured conglomerate called ferricrete.

Most of the areas examined for this study are related to Laramide-age and younger mineralization events that occurred about 65–15 million years ago (see map on p. 5). Naturally degraded streams frequently occur within and on the margins of Tertiary-age volcanic calderas and in highly altered and mineralized intrusive igneous rocks. These altered areas show red, brown, and yellow stains of pyrite (iron sulfide) in various stages of oxidation. Oxidation of pyrite by percolating surface water and snowmelt creates acidic conditions that lead to leaching of trace and heavy metals. Areas of naturally degraded water commonly have names such as Red Mountain, Red Cone, Iron Creek, and Cement Creek (named for the ferricrete deposits that line its banks).

The same hydrothermal processes that led to widespread alteration and pyritization in the country rocks often deposited economic grades of precious and base metals, and mining districts are usually intimately associated with naturally degraded water.

For this study, 95 water samples were collected from selected headwater areas throughout the mountains of Colorado. In general, samples were collected upstream of mine features that may adversely affect water quality. Samples exhibited a wide variety of water chemistry, although iron, aluminum, and manganese were frequently the most abundant dissolved metals. High concentrations of naturally occurring sulfate, copper, zinc, cadmium, and lead were less common. Trace metals such as arsenic, thallium, nickel, and silver rarely exceeded state water-quality standards.

Influences from natural sources should be considered when water-quality standards are set for stream segments affected by these processes. In addition, natural degradation should be considered when mining companies and regulatory agencies determine remediation goals for past and/or future mining operations.

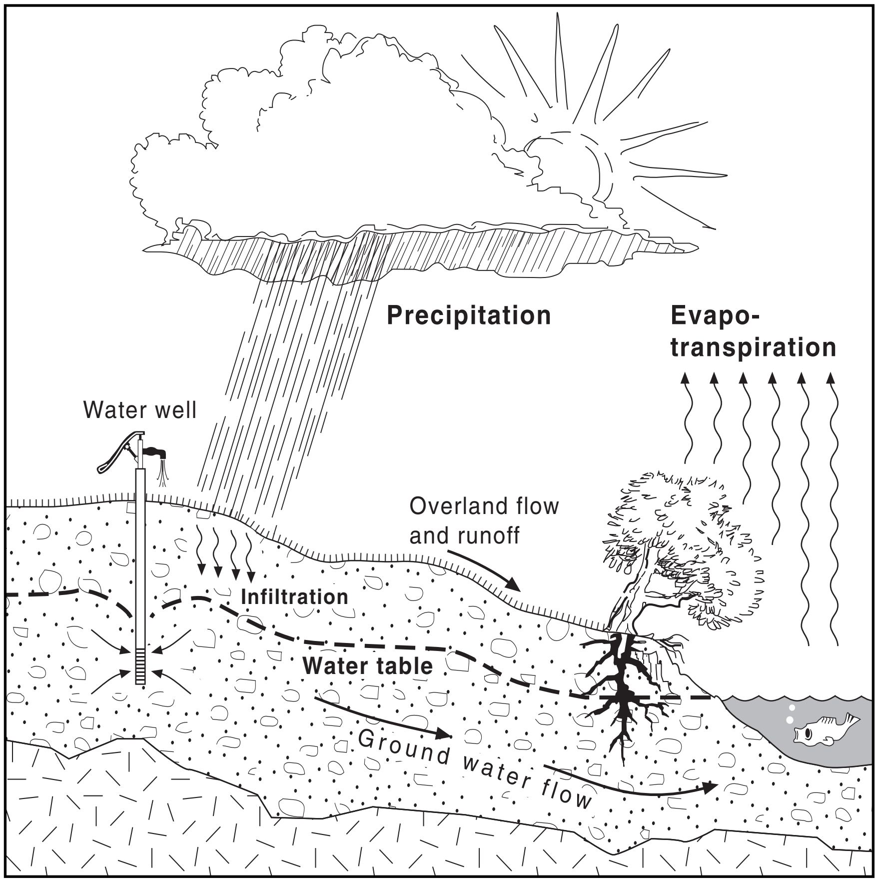
An open-file report with sample results and interpretations is scheduled for completion in June of this year. A more detailed Environmental Series publication will follow in June 2001.

—John Neubert

DRINKING WATER. . . DID YOU KNOW

Water, the elemental ingredient of life, has orchestrated the development and prosperity of civilizations throughout history. This invaluable resource exists both at the surface and in the ground. As an essential component to maintain the fluids of the body, a person requires about three quarts of fresh water per day. In Colorado, roughly 18 percent of the residents, about 900,000 people, rely mainly on groundwater for domestic use. The usefulness of water for a particular purpose is determined by its quality.

Groundwater hydrology, or hydrogeology, is an interdisciplinary science that deals with the occurrence, movement, and quality of water beneath the earth's surface. As groundwater is hidden from view, some people think it occurs as underground lakes, streams, or veins. While such features exist in areas of cavernous limestone and volcanic lava flows, groundwater most commonly is water filling spaces between rock grains or crevices, such as fractures and faults. Geologic units consist of either unconsolidated deposits or consolidated rock. Some of these materials have a greater ability to store and transmit water than others. The amount of water a material can hold depends upon its porosity—the ratio of void space to total volume.



The hydrologic cycle

The source of groundwater is precipitation (in the form of rain, snow, or hail) that does not evaporate or immediately flow to rivers, streams, or lakes but percolates into the ground. An aquifer is a groundwater reservoir composed of geologic units, which are saturated with water and sufficiently permeable to yield water in a usable quantity to wells and springs. The hydrologic cycle is an endless process of the circulation of water between the atmosphere, the oceans, and the land. As such, the quality (or chemical composition) of our groundwater is dependent upon the environmental interactions occurring along the water flow pathway, taking into account human intervention.

Water in the form of precipitation is not pure water, as it contains a wide range of dissolved substances or gases. The chemistry of rainwater undergoes change as it comes in contact with the earth's surface materials. As water percolates through the soil zone, it acquires additional chemical components from the dissolution of minerals in the soil. The water will tend to equilibrate with the materials that surround it. As water infiltrates deeper into the subsurface the concentration of organic matter decreases, while the concentrations of major ions increase as a result of the chemical interactions between the water and the host rock. Because of the longer residence times of the water in an aquifer system, its chemical composition has an opportunity to stabilize. The major dissolved inorganic constituents in groundwater are calcium, magnesium, sodium, potassium, chloride, sulfate, carbonate, and bicarbonate.

If human activity alters the natural water quality so that it is no longer fit for its intended use, the water is said to be polluted or contaminated. Pollution in the form of domestic or industrial products or wastes may upset the natural chemical balance of groundwater dramatically in a very short timeframe. Because of the many Coloradans who rely on groundwater for their domestic water supply, contamination is a very serious concern. Concerns of groundwater quality are also linked with surface water as these two waters can mix or recharge each other and consequently have the potential to contaminate each other.

The quality of our drinking water supplies is governed by the Safe Drinking Water Act (SDWA), which requires every public water supplier in the country to meet the Primary Drinking Water Regulations established by the U.S. Environmental Protection Agency (EPA). The SDWA allows states to accept the responsibility for enforcing these regulations, a condition called "Primacy." Colorado has accepted primacy and these responsibilities are under the jurisdiction of the Colorado Department of Public Health and Environment. In an effort to balance compliance costs and cost benefits, the SDWA has different requirements depending upon the type and size of the public water supply system. The requirements include the treatment and monitoring of bacteriological, chemical, and radiological contaminants; record keeping and reporting of results; and notification of noncompliance to water users.

Consumers have recently been afforded greater access and information regarding the quality of their drinking water through the new Consumer Confidence Report Rule (40 CFR 141 Subpart O). This rule requires all community public water systems to prepare and provide to their customers an annual report that summarizes the results from the previous years testing and monitoring requirements, as well as treatment techniques. If you are a customer of a community water system that supplies water to more than 25 persons, you should have received your first report in October 1999. The second and all future annual

Field Notes continued from page 2

Geology relates to many things that are important to Colorado citizens. The geologic resources, such as gas, oil, coal and gold, that are produced from the mines and wells of the state contribute to our standard of living and the healthy economies of our communities. Remediation and reclamation of those mines and wells is made better and more cost effective when geologic conditions are well understood. Our homes and highways are safer when they are built with geologic information used in the design of the infrastructure.

It seems simplistic to say, but geology underlies it all. And in the last days of 1999 the U.S. Congress reauthorized a law that helps us here at the CGS provide more useful and meaningful geologic information to all Colorado citizens, the National Cooperative Geologic Mapping Act (Public Law 106-S607).

The act calls for geologic mapping to occur across the U.S. because approximately only 20 percent of the U.S. has been geologically mapped at the useful scale of 1:24,000 which is 1 inch = 2000 feet. Mapping is to be in areas of societal relevance. The Act is implemented through the National Cooperative Geologic Mapping Program of the U.S. Geological Survey. One portion of the program, known as STATEMAP, allows for funding of geologic mapping through the offices of all state geologists. Every federal dollar that goes to a state through the STATEMAP program must be matched by a state dollar. It is a true partnership.

Colorado has been involved in the STATEMAP program from the beginning. The first year we received a $10,000 grant. In 1993, CGS received a line item from the Colorado General Assembly to provide matching funds to the STATEMAP program. Our grant, and our ability to map, has grown every year. In FY 2001, Colorado will receive $120,000 in our STATEMAP grant. As of today, Colorado has produced 15 new geological maps through the STATEMAP program that are useful to local governments and industry in Garfield, Pitkin, Eagle and La Plata Counties.

At the beginning of the program, and with the help of a statewide advisory group, the CGS identified nine critical areas of the state that had no mapping at the desired scale. In 1999, CGS began mapping in the Front Range between Colorado Springs and Denver, and along the I-70 corridor near Idaho Springs. Like the maps already made through the STATEMAP program, these maps will provide useful information for planning of infrastructure and resource development and mitigating both environmental and geological hazards.

reports must be delivered by July 1 of that year. The water utility representative listed on that report should be able to answer questions related to the water quality results or treatment techniques utilized. Further information on drinking water quality can be obtained by calling the EPA Safe Drinking Water Hotline at 800-426-4791 or contacting their website "**www.epa.gov/safewater**".

Private drinking water supplies are *not* regulated by Federal or State agencies. As such, users of private drinking water should have their water tested periodically to assure the quality is protective of human health. Recommended testing procedures and parameters can be obtained from local water quality consultants, county health departments, the Colorado Department of Public Health and Environment, or the EPA.

In summary, water quality is determined by the chemical ions and gases dissolved in the water and, in the case of surface water, the matter suspended in and floating on it. Groundwater quality is a consequence of the natural physical and chemical state of the water in equilibrium with the aquifer. Different dissolved inorganic minerals and dissolved gases will influence the water's taste, color, and odor. With the exception of radioactivity produced by naturally occurring radioactive source rocks and ambient microbiological organisms, the water quality of natural groundwater systems generally does not present a health threat. The influences of anthropogenic products and wastes, however, can adversely impact water quality rendering water unsuitable for its intended purpose. The Consumer Confidence Report provides the public a means of assessing the quality of their drinking water.

— Ralf Topper

FROM BUYER BEWARE, TO SELLER BEWARE, TO ENVIRONMENTAL SITE ASSESSMENTS

In the 1970s and into the 1980s property transactions of industrial sites often led to unknowing purchases of contaminated sites resulting in environmental nightmares for the new owner. The legacy of past operational practices at a site could be costly in terms of remediation and legal costs, not to mention upset lenders, under caveat emptor (buyer beware). The passing of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) of 1980, or Superfund, introduced the concept of joint liability. Now the tables were turned. Past operational practices could come back to haunt the seller and/or previous

Aerial photographs are used to help determine surrounding property use.

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Example of a "recognized environmental condition"

owners. There was a new saying—"seller beware." Consequently, the money allotted to remediating the nation's most contaminated sites was spent on legal fees, since responsibility could now extend as far back as the original owner.

The introduction of the Superfund Amendment and Reauthorization Act (SARA) of 1986 brought about the Environmental Site Assessment (ESA) investigation. SARA provided the "innocent landowner defense." This meant that the seller, or defendant, is not in a "contractual relationship" with a previous owner as long as there was no reason to know of the disposal or release of any hazardous substance on the property. However, in order for a defendant to have no reason to know of any disposal or release of a hazardous substance on the property, the defendant must make "all appropriate inquiry" of past ownership and operations at the site. The interpretation of "all appropriate inquiry" has led to various organizations establishing guidelines for conducting Environmental Site Assessments (ESA). Among them is the American Society for Testing and Materials (ASTM). ASTM Environmental Standard 1527 (E1527), with some minor modifications, has become the required guideline of the Colorado Department of Transportation when an ESA is conducted.

Over the past few years the Colorado Geological Survey (CGS) has conducted ESAs for state agencies involved with property transactions. These investigations have been conducted using the ASTM E1527 guideline, which is a qualitative assessment meant to identify "recognized environmental conditions" that could affect the property transaction. Assessment of contaminated soil, surface water, and ground water are the key elements of the investigation. The basic steps include

1) a search of available environmental records and historical aerial photographs,
2) a site visit,
3) interviews with current and/or past personnel and
4) a report summarizing the results of the investigation.

The CGS approach in conducting an ESA is to determine if, and where, additional investigation is necessary with respect to past operational practices at a site and to what degree additional investigation may be needed. This activity saves taxpayer dollars, in that contamination problems are identified before the state buys or sells property, minimizing time and money that would be spent in litigation.

– Ty Ortiz

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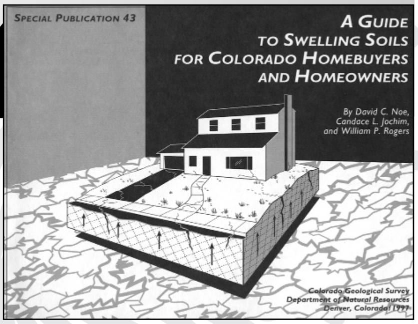

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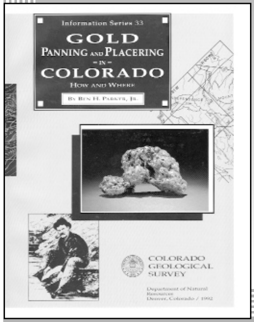
IS 33 ***Gold Panning and Placering in Colorado: How and Where***



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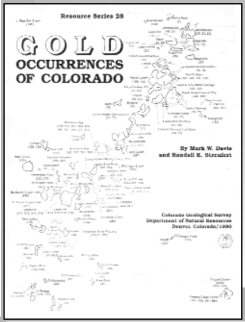

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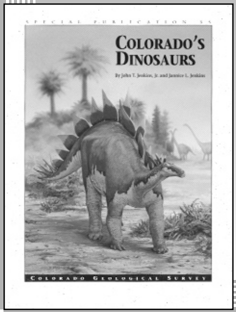

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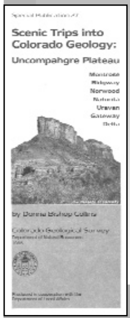

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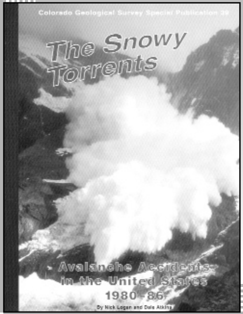

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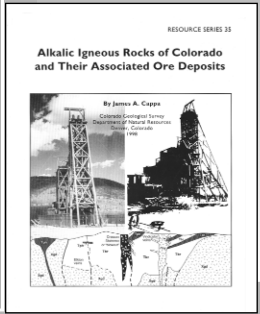
#6

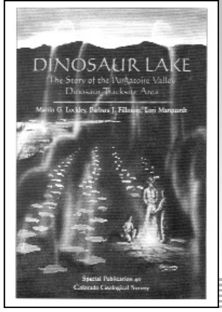
RS 35 ***Alkalic Igneous Rocks of Colorado and Their Associated Ore Deposits***



J.A. Cappa
$12.00

#7

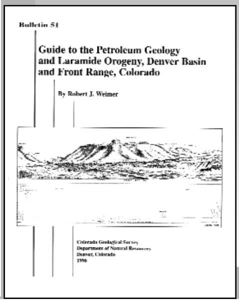
SP 40 ***Dinosaur Lake: The Story of the Purgatoire Valley Dinosaur Tracksite Area***



M.G. Lockley, B.J. Fillmore, and L. Marquardt
$12.00

#8

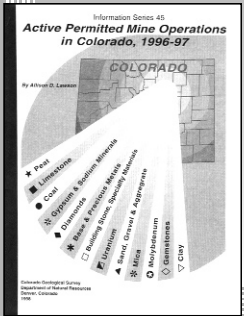
B 51 ***Guide to the Petroleum Geology and Laramide Orogeny, Denver Basin and Front Range, Colorado***



R.J. Weimer
$15.00

#9

IS 45 ***Active Permitted Mine Operations in Colorado, 1996–97***



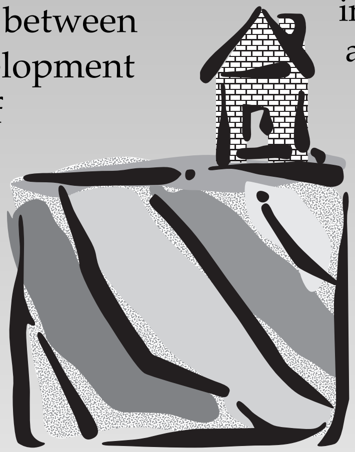
A.D. Lawson
$10.00

#10

Geohazard Conference and Field Trips in Jefferson County, April 27–29

Reducing Colorado's vulnerability to geological hazards by fostering cooperative, Smart Growth interactions between local governments and the development community will be the theme of **DIPPING BEDROCK REVISITED**, a conference sponsored by the Colorado Geological Survey and Jefferson County on April 27 at the Arvada Center, 6901 Wadsworth Boulevard. Four optional half-day field trips will follow the conference on April 28–29.

This conference focuses on geological hazards associated with dipping layers of bedrock, which have caused extensive damage to buildings and roads along Colorado's Front Range. The April 27 session will highlight policy and technical issues that are involved in mitigating the hazard. The April 28–29 field trips will visit areas that have been damaged by dipping bedrock, as well as new construction sites where innovative mitigation techniques are being used.



The conference and field trip will provide useful information for a variety of stakeholders including developers, home builders, contractors, engineers, geologists, home inspectors, landscape architects, real estate professionals, warranty insurers, water and sanitation districts, city and county planners and officials, legislators, and the general public.

The cost of the conference is $50.00 for the April 27 session and $20.00 for the optional April 28–29 field trips. Student discounts are available. To register, contact the Colorado Geological Survey, 1313 Sherman Street, Room 715, Denver, Colorado 80203, phone (303) 866-3520, fax (303) 866-4445.

ROCKTALK

Colorado Geological Survey
1313 Sherman Street, Room 715
Denver, CO 80203

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