COLORADO
DEPARTMENT OF NATURAL RESOURCES

ROCK TALK

DIVISION OF MINERALS & GEOLOGY
COLORADO GEOLOGICAL SURVEY

Volume 7, Number 4
Fall 2004

"…the maps are designed not so much for the specialist as for the people, who justly look to the official geologist for a classification, nomenclature, and system of convention so simple and expressive as to render his work immediately [understandable]…"

—John Wesley Powell, 1888

Hasn't Colorado Already Been Mapped?

This is a common response when Colorado Geological Survey (CGS) personnel tell someone that we have a geologic mapping program. The answer is yes. And, no. Yes, the state is completely mapped topographically at a detailed scale of 1:24,000. Yes, there is a geologic map of Colorado. No, the state has not been mapped geologically at a detailed scale. Colorado has nearly 1800 quadrangles, each covering 7.5 minutes of latitude and longitude, or about 56 square miles. However, only a fifth of the state's quadrangles are mapped in detail.

Since 1992, the CGS has mapped quadrangles in high-impact areas of the state under the STATEMAP component of the National Cooperative Geologic Mapping Program. In 2003, we completed our 50th geologic quadrangle map. CGS' approach is to select rapidly growing areas with relatively high-hazard potential and map contiguous quadrangles. In addition to mapping bedrock, CGS geologists make sure that the young (Quaternary) deposits that are so important to sound engineering practices are also adequately mapped.

CGS' mapping yields significant new scientific information on such diverse topics as the age of incision of the Colorado River; the existence of a regional, evaporite-collapse area; the chronology of late Cenozoic basaltic volcanism; the existence and nature of talus flatiron rings; the location of previously unrecognized Quaternary faults; the detailed stratigraphy of an important aquifer; and the location of a previously unrecognized, Ancestral Rockies fault.

What is a geologic map?

A geologic map portrays the distribution of rocks, deposits, or other geologic features in a specified area. Each consolidated rock type that can be distinguished by similar characteristics is categorized into a mappable unit, or *formation*. Unconsolidated deposits such as landslides and stream alluvium also are designated on our geologic maps.

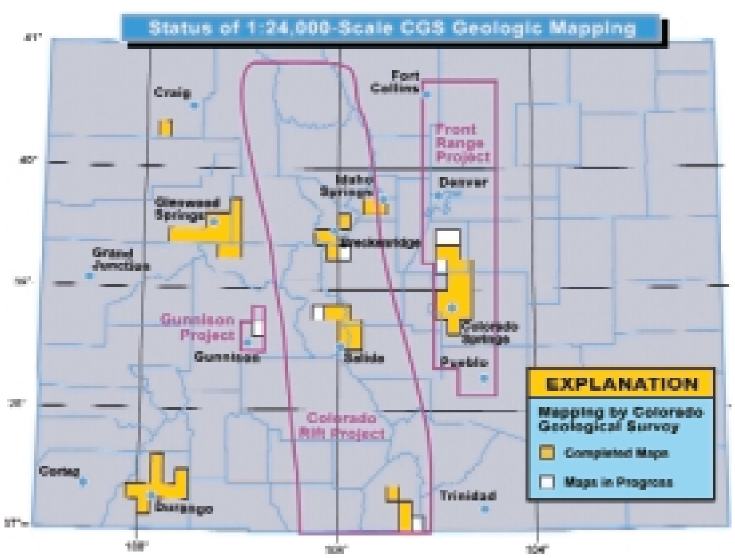
Unique colors, patterns, and labels are used to differentiate each unit on the map. Colors are chosen by the age of the rocks being described. For example, rocks from the Jurassic Period are colored in shades of green, and Quaternary deposits are colored shades of yellow. Labels designate the age and name of the formation or deposit. A geologic map is typically printed over a topographic base map.

Many different types of lines and symbols are found on geologic maps. The most prevalent are thin black lines that depict the contacts between two different mappable units. Line width and color are used to differentiate other types of features such as faults and folds.

Geologists collect structural information describing whether the rock layers are tilted or not. Most sedimentary and volcanic rocks were originally deposited horizontally. Therefore, the tilt (dip) of layered rock units may provide key information to understanding whether nonhorizontal units were deformed by faulting or folding. This type of structural information also helps geologists build interpretive cross-sections that depict how the map units may look in the subsurface.

Geologic maps provide a wealth of information to all who use them. They are important for geologic hazard detection and mitigation, mineral and groundwater resource evaluation, and provide enjoyment for the casual roadside geologist. Geologic maps help us understand the earth on which we walk, and give us a greater appreciation for the geology around us.

Matt Morgan



From the State Geologist—

The Map that Changed the World: William Smith and the Birth of Modern Geology is a recent book that emphasizes the tradition and importance of geologic mapping. the CGS believes in, and carries on, that tradition. Not for the sake of tradition, but because geologic mapping is the scientific underpinning necessary to identify geologic hazards, to explore for mineral and mineral fuel resources, and to interpret geologic history.

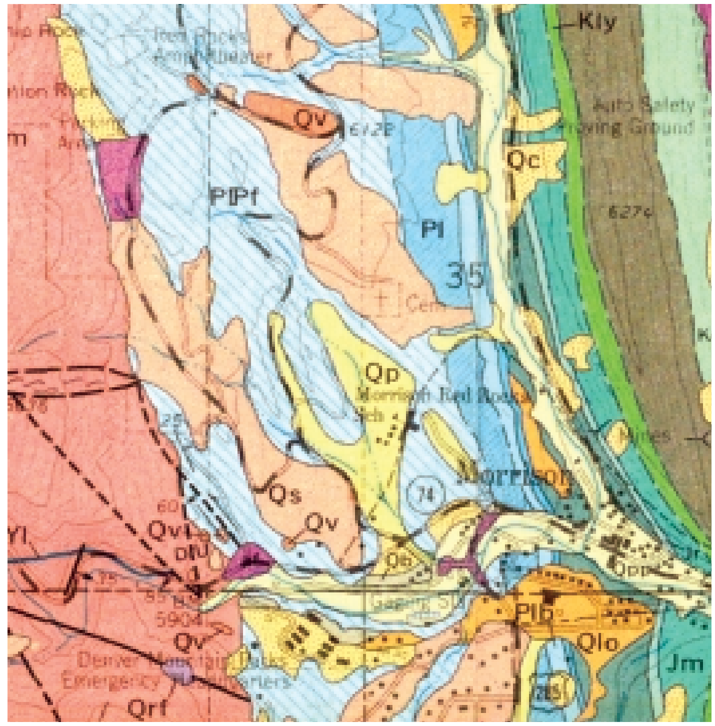
The first serious geologic studies in Colorado began in 1867 as part of the survey led by Clarence King along the 40th parallel. In 1869, F. V. Hayden and his team began the first of several surveys that resulted in many reports on the geology and paleontology of Colorado. These studies culminated in the publication of *The Geological and Geographical Atlas of Colorado* in 1877. This atlas included topographic, geologic, and mineral resource maps of the state. (the CGS has scanned these historic maps and offers reprints for sale). The geologic map of Colorado was updated and revised in 1913, 1935, and again in 1979, as more and more information became available from new geologic studies. About time for a new update, you ask?

The fundamental scale for useful geologic maps is 1:24,000. Of the nearly 1,800 quadrangles in our state, only 375 are mapped at this scale. The CGS currently maps six to seven new quadrangles per year. Historically, the federal geological survey conducted most of the detailed geological mapping in the U.S. However, in the past decade, the state geological surveys have largely taken over that responsibility.

Our team of mappers is outstanding and experienced. We also provide opportunities for students to assist and learn from our mappers. For the past five years, CGS mappers have participated in a student mentoring program funded by the National Science Foundation and administered by the Association of American State Geologists.

The CGS has led the state surveys in developing better methods of digital mapping. Our maps are highly praised by the United States Geological Survey (USGS) program administrators. Twice in the last three years, the USGS has selected CGS' mapping proposal to send to the other 49 state geological surveys as an example of an excellent proposal. The American Geological Institute recently published a booklet on the importance of geological mapping, *Meeting Challenges with Geologic Maps* (2004). A competitive panel selected 16 case histories to include in the booklet. Colorado had two examples selected. No other state had more than one. These are evidence of the success of our efforts to continually improve our mapping techniques and products.

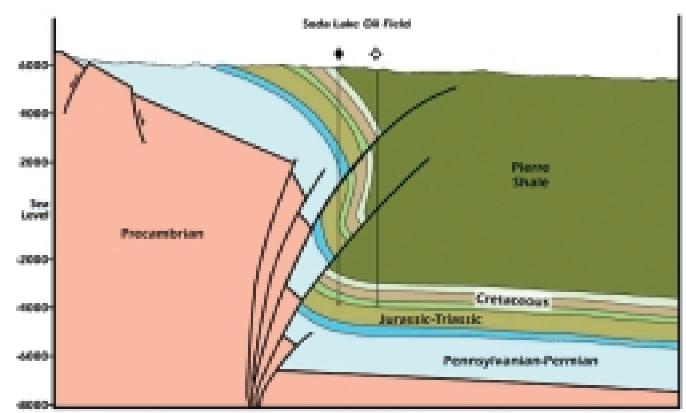
Vince Matthews



Geologic map of the area between the town of Morrison and Red Rocks Park. (from Scott,1972). Each color represents a different rock formation or unconsolidated deposit occurring at the surface.

Formation symbol. The first one or two letters of the label abbreviate the unit's age and the remaining characters abbreviate the formation name or deposit type. "J" stands for the Jurassic Period in which the rocks were deposited. The lower case "m" represents the formation name, Morrison Formation.

Symbol representing the tilt of the layered strata. The short line shows the direction of tilt (dip). The long line is at right angles to the dip (strike). The number indicates the number of degrees of tilt below the horizontal. This symbol shows that the green layer is striking northwest–southeast and is dipping 60 degrees to the northeast, thus defining a unique attitude in space.



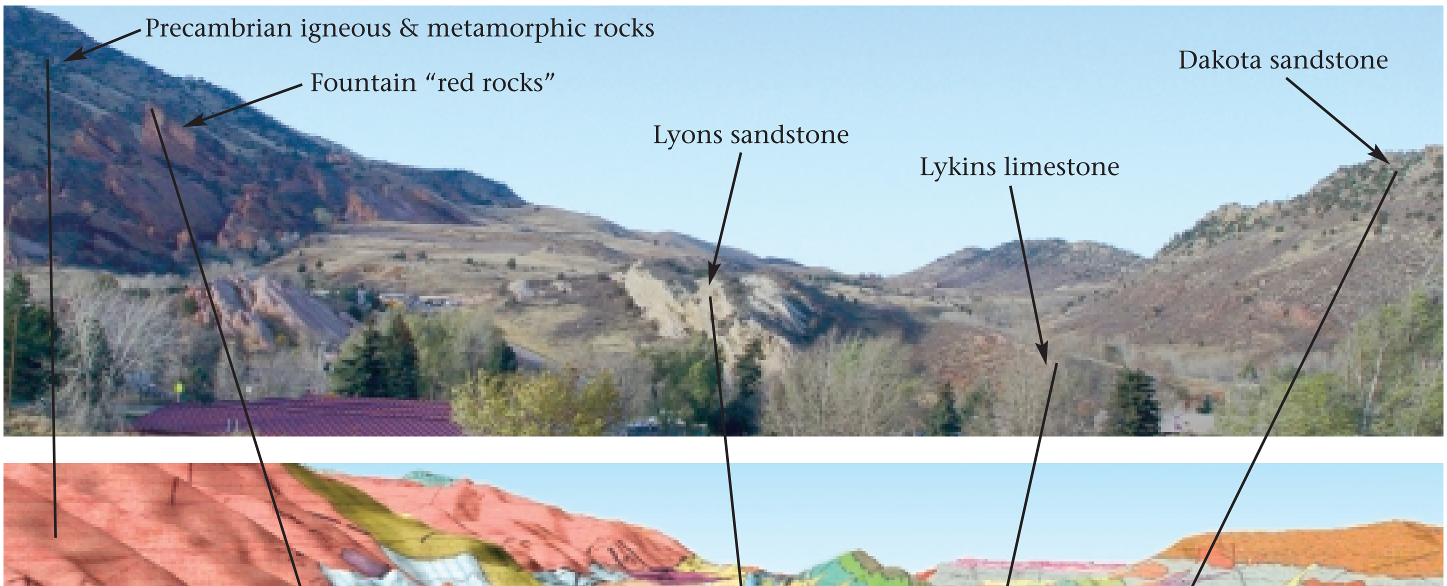
An east–west geologic cross section through the general area of the map. This is like taking a giant knife and cutting down through the earth to represent what is underground. This cross section was created using data from the rocks mapped at the surface and from data obtained in the drilling of two oil wells. Can you calculate how much the salmon colored rocks on the left have been uplifted from the same rocks on the right (vertical scale is in feet)? Cross section by Jon Vaitl (1982)

"Let us look at the map, for maps, like faces, are the signature of history."

—Will Durant

Left: A view sketched by Henry W. Elliot, artist for the 1869 Hayden Survey, of geologists working in the general area of the digital image below. The caption reads, "Near Morrison's Bear Creek." The drawing is dated July 11, 1869. USGS Open File Report 03-384.

Below: View of strata north of Morrison keyed to image below. Photo by V. Matthews



An image that was created by digitally draping the geologic map of the Morrison quadrangle over a digital elevation model (DEM) of the same area. Image by Matt Morgan

IN THE FIELD

What are we mapping? Most people are familiar with USGS topographic, or "topo" maps commonly sold at the local hiking and camping store. When people hear that geologists are mapping in the area, they often automatically think we are simply revising and updating these maps. We inform them that the USGS topo maps serve only as base maps on which we record geologic data. This inevitably leads to one of the questions most frequently asked of a geologist, "So, what do you actually do out there?"

In short, we hike through the woods and look for rocks. This, of course, turns most people green with envy; we rarely get any sympathy for our complaints. What could be better than having lunch with the birds at 13,000 feet under a Colorado blue sky and with a sweeping vista of half the state? But in fact, days in the field can be quite grueling. In Colorado, the field season is often very short, particularly in the high country. From the moment the snow finally melts to expose our sought-after rocks, the race is on to complete our mapping before the snow flies again. Ten- to twelve-hour workdays are not uncommon, and in remote areas, camping out is the only real option.

A day of hiking along Colorado's wilderness trails and an evening under the stars will sound, to most, quite pleasing. But now, take away the well-maintained trail and consider bush-whacking your way through the woods over wet, slippery downed timber, across steep slopes of broken and loose rock (talus), and through thorny scrub oak bushes (for the record, the game trails that you thought might offer a less arduous route[?], they *always* go the wrong direction). Now consider Colorado's temperamental weather. The afternoon thunderstorms invariably roll in when we have reached the top of an exposed ridge and are farthest from our field vehicle. The onset of point-blank lightning leads to a mad dash down rain-slickened talus to the relative safety of the trees—pick your poison—electrocution or broken ankle. Snow in December is great for the ski industry, but snow (and hail) in July is just plain cold and miserable. It's hard to take measurements and notes when you can't feel your fingers.

CGS field assistant in glaciated Precambrian rocks above timberline in Summit County. Photo by John Keller.

One might therefore reason that urban mappers have it easy—no rugged terrain, paved roads, and a donut shop just down the road to take shelter in when the storms hit. Though working in town has its advantages, towns are also full of people, fences, and dogs. Imagine knocking on at least a dozen doors a day to ask "May I please look at the rocks in your back yard?" And how many times have we heard "Oh, he's friendly, he won't bite" only to find ourselves clinging to the nearest tree or fence to escape snapping jaws? "I can't believe they pay me to do this!" quickly erodes into "They don't pay me enough to do this!"

Tools and techniques

So why do we battle the elements to hike every ridgeline, slog through every valley, and stumble across all the slopes in between? Our mission, and we *do* choose to accept it, is to identify and map the various rock formations (such as sandstone, granite, or shale), measure the orientation of the rocks, map and measure fractures or faults that break the rocks, delineate potential hazards such as landslide or rock fall areas, and identify mineral resources such as precious and base metals or sand and gravel. Geologists use a variety of tools to accomplish this mission. The most widely recognized is the rock hammer.

"Stuff" usually carried on a geologist's field belt includes rock hammer, notebook case, Brunton compass, and hydrochloric acid. Photo by J. Keller.

Combination GPS/ WalkieTalkie unit.

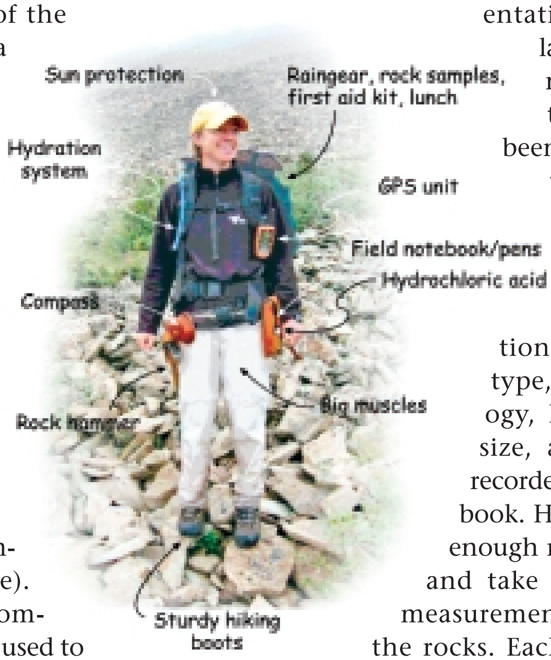
Aside from being useful in battles against everything from bears to ticks, the rock hammer is most commonly used to break open rocks, exposing a clean, fresh surface. Since rocks weather and change color with time, a fresh surface makes it easier to recognize various rock types and identify the specific minerals that make up the rock. Some mineral crystals are very small and can only be seen using a hand lens, which is essentially a very small magnifying glass. Other crystals are even smaller and cannot be identified in the field. In such cases, the geologist will collect a sample of rock and send it to a lab where a paper-thin slice of the rock is cut and glued to a small piece of glass. This *thin*

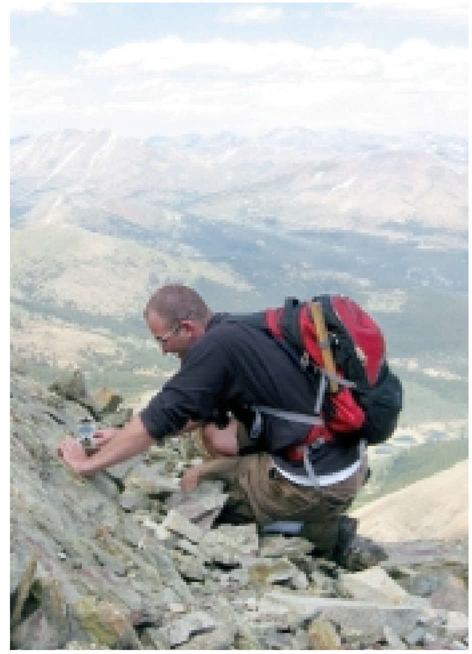
"Mapping is fundamental to the process of lending order to the world."
—Robert Rundstrom, 1990

section, as it is called, can then be viewed under a microscope. Other samples may be collected and sent to specialized labs for chemical analysis that helps the geologist further identify the rock or its age.

On the opposite side of the geologist's tool belt, and helping to balance out the weight of the rock hammer, is a heavy-duty compass, complete with two bubble levels and a mirror, and field case containing a small notebook, pens and pencils, a ruler/protractor, and a small bottle of hydrochloric acid (a few drops can help determine if a rock contains carbonate). Although the compass is frequently used to help the geologist navigate, its primary use is for measuring the orientation of rock formations and various geologic features. Anyone who has been to the Grand Canyon has been mesmerized by the beautiful layers of rock stacked atop one another like layers of a cake. The orientation of these rocks is horizontal, or flat-lying. Some rocks in Colorado are also horizontal, but many more have been deformed and are now tilted or inclined. Measuring the orientation of the rock layers helps determine how or if the rocks have been deformed over time. These measurements, along with other pertinent information such as rock type, color, mineralogy, hardness, grain size, and fossils, are recorded in a field notebook. However, it is not enough merely to go out and take a multitude of measurements and describe the rocks. Each measurement and description must be tied to its own specific geographic location. This is where two very important tools come into play—global positioning systems (GPS) and aerial photographs. A GPS allows us to record the exact location, or station, at which a measurement or sample is taken. It can also be used to pinpoint the exact location of faults, contacts between different geologic formations, and other important geologic features. It is invaluable for helping geologists navigate to various features in the field area, such as the field vehicle at the end of the day. Air photos are viewed in pairs, or *stereo-pairs*, using a *stereoboard or stereoscope*, both of which produce a three-dimensional image of the view area. The 3D capability of the air photos allows us to visually pinpoint our exact location, down to the specific tree or rock exposure in most cases. The photos also serve as another sort of notebook for recording data. Ink pens are used to draft station numbers, contact lines, faults, and other necessary information directly onto the photos. At the end of the field season, when all our data has been gathered and all the geology has been drawn on the photos, it's back to the office to begin the process of transferring everything to a computer and create a geologic map for publication.

Beth Widmann





Field Assistant, Joel Poppert, measuring the tilt of bedding with a Brunton compass. Photo by Beth Widmann.

Aerial photographs viewed in a stereoboard provide a three dimensional view of the field area and allow geologists to locate themselves with near pinpoint accuracy. Photo by Beth Widmann.

FIELD SAFETY

Mitigating Threats to our Safety

The CGS emphasizes safety in the field and takes pride in the safety record of our mappers. Geologists who are involved in geologic mapping spend many weeks in the field gathering data for each quadrangle map. This means that a lot of time is spent away from people, roads, and the relative safety of the field vehicle.

Like any wise backcountry traveler, the field geologist must take the time to learn how to conduct her/his business in a safe and responsible way, and to be prepared for accidents and emergencies along the way. Two of the most important things CGS mappers try to remember are to be aware of his/her surroundings and the inherent dangers, and to use good judgment and common sense. A course in first aid and CPR is provided for all CGS employees.

CGS geologists try to use the "buddy system" while mapping, particularly if the work is in a remote area. We hire university geology students to assist with mapping during the summer months. This gives the students some beneficial work experience and reduces the dangers of working alone in remote areas. Our combination GPS/WalkieTalkie units enable us to communicate, and we can even transmit our exact location to our co-workers in the field. If mapping alone, the mapper is required to let someone know where he/she plans to go that day; and then checks in with the same person to let them know they are safely out of the field.

The list below outlines some of the dangers involved in field geology. By being aware of these hazards, we can be prepared to prevent and/or deal with them. It is by no means a complete list.

Foot and leg injuries. We wear sturdy boots and try to watch our step.

Eye injuries. We wear safety glasses when taking rock samples with hammer.

Falls. We avoid climbing steep rock faces, particularly if working alone.

Rockfall. We watch for loose boulders and watch our step.

Lightning. We respect it, and learn safe practices and avoid unsafe practices.

Wildfires. We try to plan escape routes and don't linger if a fire is nearby.

Hypothermia. We keep extra clothes in our pack AT ALL TIMES.

Dehydration. We carry plenty of water, and drink it often.

Heat exhaustion. At first sign, we find shade, rest, and hydrate.

Giardia. We avoid drinking stream or lake water, unless it is first treated.

Snake bites. We stay up-to-date on the latest emergency procedures.

Cuts, wounds, and external bleeding. We learn first aid and carry *QuikClot™*.

Black bear encounters. We learn proper techniques and carry "Bear Spray."

Mountain lion encounters. We learn proper defensive moves.

Vehicles. We wear our seat belts, maintain our vehicles, stock them with emergency supplies, and don't take chances.

What's in my backpack?

It seems my field backpack gets heavier every year. The more backcountry experience I get, the more I realize how important it is to always keep my pack stocked with safety gear. I've been "surprised" too many times to go into the field unprepared anymore. Here's a list of safety gear that is in my field pack everyday:

Extra clothes. A warm hat is a must. I also have warm gloves, thermal underwear top, and an extra pair of warm socks.

Rain gear. A raincoat and rain pants. The breathable type is best. It's amazing how fast vicious storms can build out of a clear blue sky on summer days.

Emergency blanket. These are the shiny metallic blankets. They're lightweight and very effective for retaining body heat. They may save you from hypothermia if you get caught in a cold storm overnight.

First aid kit. These come in several sizes and are lightweight.

Flashlight. I've been caught out after dark without one and it's no fun if the moon isn't bright and there is no trail.

Waterproof matches.

Extra batteries. Mainly for my GPS which I use daily, but also for the flashlight.

Plenty of water. Never get back to the vehicle with empty water bottles.

Extra food. I like beef jerky and "energy" bars.

What's in my field vehicle when mapping?:

For most geologists, just getting to the field area often requires many miles of driving. Often, much of the driving is in remote areas on rarely-used gravel and four-wheel-drive roads. It is important to have one's vehicle supplied and ready to encounter surprises and emergencies. Besides having a good spare tire or two and a functional jack, these are few things that are good to have in the field vehicle at all times:

Camping gear. A minimal camping supply can make an unexpected overnight stay more pleasant. Your vehicle could break down miles from the nearest house or paved road. Backcountry roads can become impassable from mud in a storm, forcing an overnight stay.

Extra water.

Extra food. In case we need to camp out unexpectedly.

An axe or saw. Fallen trees can block dead-end roads in the backcountry. Without an axe or a saw, you're not going anywhere soon.

A shovel. We might get stuck or high-centered and a shovel helps to get moving again.

Toolbox. All CGS vehicles are equipped with toolboxes containing an assortment of tools, a first aid kit, emergency flares, and most importantly—duct tape.

Check the gas gauge! We try to make sure that we have enough fuel to get back to a gas station!

John Keller

CGS mapper Matt Morgan examining an alluvial fan deposit near Larkspur. Photo by V. Matthews

GETTING OUR FIELD DATA INTO A DIGITAL MAP

Providing geologic information in a digital format is critical in today's computer-based society. The CGS developed an efficient way to translate our raw field data into digital geologic data that can be used by a variety of users to make intelligent and more effective decisions.

In the field, our geologists use traditional stereo aerial photography and topographic maps along with satellite imagery, hand-held Pocket PCs and Global Positioning System (GPS) units. These high-tech devices are important tools for the modern geologist and help increase our efficiency and accuracy during valuable field time and later in transferring data to a final map.

We map geologic information directly onto stereo aerial photography using pen and ink. After completing our field work, the annotated air photos are digitally scanned. These scans are then referenced to the earth, giving the photos "real world" coordinates.

The geologist can then view the scanned photos in 3D on the computer monitor. Our software gives the ability to pan, zoom in and out, and change brightness and contrast. The images are actually clearer and sharper than if viewed with a standard stereoscope. The geologist traces each contact onscreen using the computer's mouse, enabling the geologist (the one with the most knowledge of the contacts) to fully control the digitizing process.

Once a geologic unit or feature is completed, it is given an attribute such as the formation name or type of line. The preliminary map is saved and exported as a Geographic Information System (GIS) compatible file.

The preliminary map is imported into a GIS software package where the first stage map plate is created. Point features, such as bedding information or sample locations are imported digitally from the GPS and placed on the map. Colors, line styles, and the appropriate symbols are assigned to each feature.

GIS allows the cartographer to select all similar features, for example all formations named "Jm," and color them in one step instead of individually. The GIS can also assist in building an explanation of map units which can be added to the map along with the cross-section. A very attractive and accurate map is created in just a few weeks after the geologist finishes her/his field work. After extensive internal and external reviews of the map, it is finalized and ready for distribution to the public.

Geologist Beth Widmann wearing special electronic goggles that allow her to view aerial photographs in 3D on our mapping workstation. Photo by V. Matthews.

Matt Morgan

"And out of that realization came an epiphany: that by following the fossils, one could trace layers of rock as they rose and fell—clear across England and, indeed, clear across the world."

—The Map that Changed the World

HOW IS OUR MAPPING IN COLORADO FUNDED?

Our STATEMAP program is funded 50/50 with state and federal money. Each year we must compete for funds from the national STATEMAP program. We are also required to match each dollar of federal money with a dollar of state money that comes from the Severance Tax fund derived from oil, gas, and mineral production. STATEMAP requires that the mapping be aligned with the priorities established for the National Cooperative Mapping Program. They also require each state to have a Geologic Mapping Advisory Committee representing a broad cross section of the community.

Each fall the CGS meets with our Geologic Mapping Advisory Committee to set priorities for the quadrangles we will propose in our grant application. The *Long Range Plan* approved by the committee in 2002 is posted on our Web site at http://geosurvey.state.co.us/pubs/gmapping/statemap_lrp_02.pdf. This committee provides a valuable service in helping us to determine our priorities and offering helpful advice from a wealth of backgrounds.

Vince Matthews

Retired (but not quite) CGS mapper Bob Kirkham, taking field measurements in the Sangre de Cristo Range. Photo by D. Noe.

THE MANY USES OF GEOLOGIC MAPS

"What have geologic maps done for me lately?"

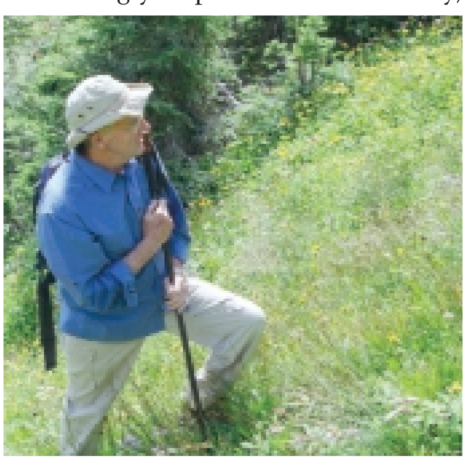
As field geologists engaged in geologic mapping, one of the most common questions we get from the public is, "do geologic maps have any practical value?" The answer is a resounding YES! Although they certainly have value for purely scientific and academic reasons as well, publicly available geologic maps have numerous applications in "the real world."

In 2000, mineral economists at the Illinois State Geological Survey (ISGS) surveyed over 500 users of Kentucky's 1:24,000-scale geologic maps. Kentucky is the only state so far to be mapped in its entirety at a scale of 1:24,000. In a rigorous economic analysis of the survey results, the Illinois economists determined that the benefits of producing geologic maps for public use are enormous. They showed that in real dollar values, benefits outweigh the costs by between 25:1 and 39:1. These benefits are only those that can be measured in real money and don't include other intangible benefits.

The main uses of geologic maps have changed over time as society has changed. In Colorado's early days, metal mining was the dominant industry. Therefore, geologic maps focused on areas such as Leadville, Breckenridge, and Idaho Springs where metal mining and exploration were important.

In the early and middle part of the 20th century, oil, gas, and coal became increasingly important economically, and the focus of geologic mapping switched from the rugged high country where most metallic ore deposits are located, to the lower sedimentary basins that contain coal and hydrocarbon resources. In recent years, population growth, real estate and land development, accelerating construction, and the dwindling water supply have created demand for geologic maps that focus on geologic hazards, ground water resources, and construction material resources such as sand and gravel deposits near high-growth areas.

Geologists of the Hayden Geological Survey set up near Table Mountain in the summer of 1869. USGS Open File Report 03-384.



CGS mapper (and USGS Emeritus) Rich Madole contemplates how beautiful a 35° slope can appear. Photo by V. Matthews

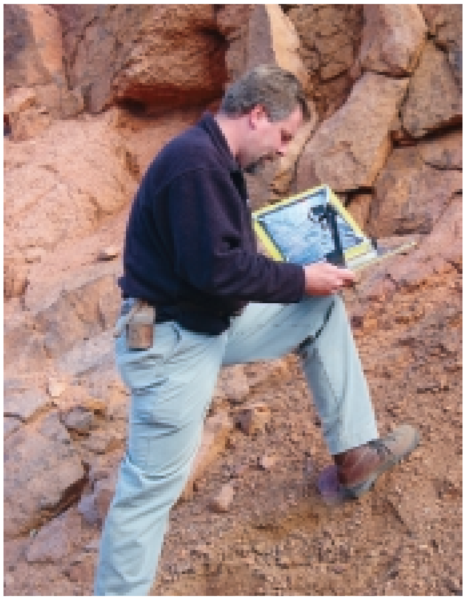
The U.S. Geological Survey developed 12 priorities for the STATEMAP component of the National Cooperative Geologic Mapping Program. The priorities were developed through review councils and forums representing a wide range of public and private stakeholders. This ensures that geologic mapping efforts funded through the STATEMAP program are directed toward issues of the greatest relevance to society. In Colorado, our Geologic Mapping Advisory Committee is composed of a diverse group of people from industry, academia, and government (state, federal, and local). In 2000, our committee took the 12 national priorities and ranked them for Colorado in order to set priorities in our *Long Range Plan*. Those priorities for our state's geological mapping program were ranked from highest to lowest as follows:

1. Land use evaluation and planning for environmental protection. Geologic maps can, and do, provide information critical to making wise land use decisions, particularly in areas undergoing rapid population growth and construction. Naturally occurring, harmful pollutants such as arsenic, selenium, acidic water, and radon are sometimes present at dangerous levels. Such pollutants occur preferentially in certain formations and geological environments that can be mapped.

2. Design and construction of infrastructure such as utility lifelines, transportation corridors, and surface water impoundments. The highly variable physical characteristics of bedrock formations and surficial deposits have an enormous influence on the design and construction of roads, dams, aqueducts, and utility lines. For example, placing an electrical transmission tower on an active landslide deposit would be grossly inappropriate and probably dangerous. Similarly, a dam should not be built over a potentially active "earthquake" fault. Accurate geologic maps provide good base level data for the design of infrastructure.

"The world's coal and oil industry, its gold mining, its highway systems, and its railroad routes were all derived entirely from the creation of Smith's first [geologic] map…"

—The Map that Changed the World



CGS Mapper John Keller viewing air photo stereo-pairs near Pikes Peak. Photo by V. Matthews

3. Identify and reduce losses from geologic hazards. Geologic hazards, such as landslides, debris flows, potentially active faults (earthquake hazards), and areas with swelling soils annually take a high toll on the economy and sometimes in lives. Costly damage to houses, commercial buildings, and roads has occurred in Colorado because geologic hazards were not recognized prior to construction. Much of our geologic mapping is focused in high-growth areas that have high geologic-hazard potential.

4. Basic earth science research. Geological research, including mapping, provides society with a better understanding of our planet and the processes that have shaped it and continue to shape it. Geologic maps are used to decipher the stratigraphy, mineralogy, structure, paleontology, and the development of the Earth's crust through time. Geologic maps are the most fundamental and important database for the geosciences. They are the foundation for all other geologic studies.

5. Exploration for and development of water resources. Understanding geology is essential to understanding and quantifying ground water resources that are a vital component of Colorado's limited water supply. Geologic maps help to define the location, size, quality, and geometry of aquifers. Water well locations are often determined on the basis of interpretations of surface geology as shown on geologic maps.

6. Exploration for and development of energy resources. Geologic maps are critical to understanding and quantifying energy resources such as natural gas, oil, coal, geothermal, and uranium. For example, geologic mapping can identify likely areas for hydrocarbon traps such as anticlines and structural domes (see *Rock Talk* v. 7 no. 2, April 2004). Geologic mapping and research can also identify mineral deposits that contain essential components of alternative energy systems. For example, the metals gallium, indium, cadmium, and tellurium are used in solar electric systems. Geologic maps usually include cross sections that show the geometric arrangement of bedrock formations and structures below the Earth's surface. Understanding subsurface geology and the three-dimensional arrangement of geological formations is critical for the discovery and assessment of energy, mineral, and water resources.

7. Exploration for and development of mineral resources. Geologic maps are still an important tool used by geologists and prospectors to direct metallic and nonmetallic mineral exploration. Geologic maps are essential for gaining an understanding of the spatial and genetic relationships between ore deposits, their host rocks, and local and regional geologic structures. Many valuable minerals in Colorado, including gypsum, clay, nahcolite, and molybdenum are restricted to specific formations or rock types. Knowing where those formations are located is the first step in finding additional mineral resources. CGS also produces *derivative maps* showing the location and quality of sand and gravel aggregate resources, which can be a valuable resource for county planning agencies and aggregate producers.

The remaining five priorities were ranked as follows: **(8th) Siting of critical facilities**, **(9th) Screening and characterizing sites for toxic and nuclear waste disposal**, **(10th) Earthquake hazard reduction**, **(11th) Mitigating effects of erosion**, and **(12th) Predicting volcanic hazards.**

Geologic maps have additional uses that are not listed above as "priorities." They are excellent educational tools for explaining local geology to children and adults alike. They can be used by travelers, hikers, and other outdoor enthusiasts who have a natural curiosity about the Earth and the environment they see around them. Colorful and informative geologic maps can even be framed and used for interior decoration! Because geologic maps are so versatile, most mapping projects that the CGS undertakes contribute valuable information toward most or even all of the 12 priorities listed above. Many of the benefits from basic geological mapping are further realized through *derivative maps*.

John Keller

CGS mapper (and Fort Lewis College professor) David Gonzales points out ash layers associated with debris flows from previous wildfires in the southern San Juan Mountains. Photo by V. Matthews

DERIVATIVE MAPS

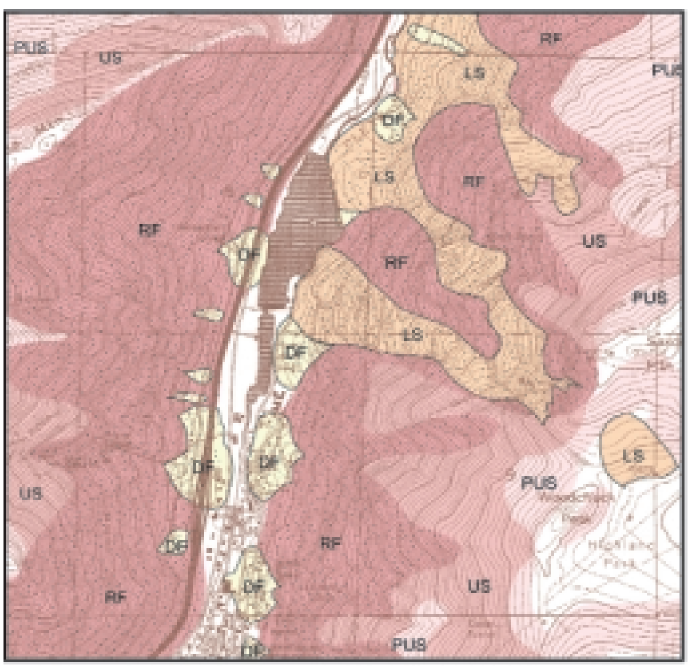
Geologic Map Rock Unit	Derivative Map Mineral Resource
Alluvium	Sand and gravel
Pierre Shale	Clay
Lyons Sandstone	Building stone
Eagle Valley Evaporite	Gypsum
Precambrian Gneiss	Crushed stone

Who uses the geologic maps that we create? Many of our geologic maps are used by county officials to develop smart growth plans for their communities. Planning can be made easier with derivative maps, which are developed by extracting selected information from a geologic map and presenting it in a manner that addresses a particular aspect of interest, such as hazard mitigation or mineral resource development.

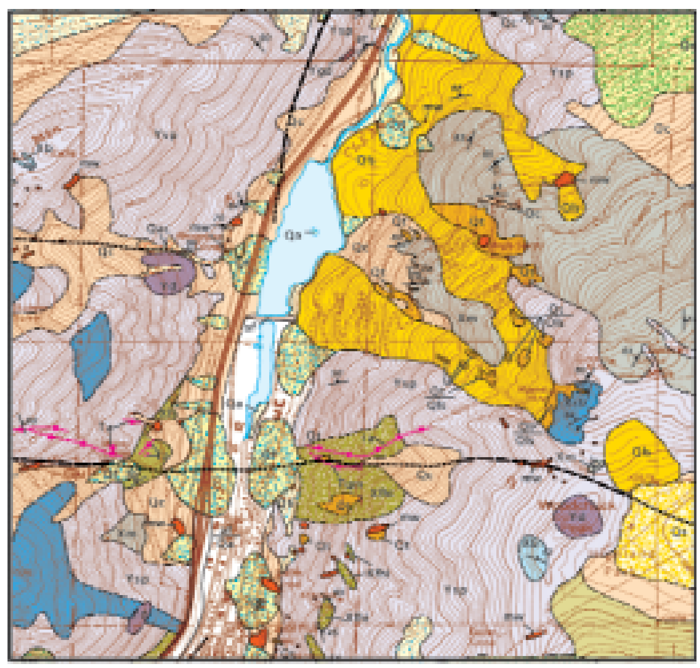
Some geologic units are in themselves hazards. For example, landslide and talus (rock-fall) deposits may be prone to future, sometimes catastrophic, movement and indicate slope instability in an area. Debris fans, commonly found at the mouth of tributary and intermittent stream channels, are made up of mud, rock fragments, and plant debris that have been rapidly transported down slope by excess rain and snow-melt water. Sudden inundation of an area by this watery debris can damage structures and may even be life threatening. A rock type such as shale may contain abundant clay minerals, which shrink and swell when water is added or removed wreaking havoc on building foundations. The hazard derivative map helps planners avoid potential hazard areas and outlines areas where appropriate building plans must be developed to accommodate or minimize the damaging effects of a given hazard.

Similarly, the location of important mineral resources can be extracted from a geologic map. The shape and extent of a unit area may be exactly the same on both maps, but on a geologic map it will be labeled according to rock type, whereas on the derivative map it will be labeled according to resource potential. Geologic units mapped as *alluvium* (transported by streams) often contain very good sand and gravel resources, which are used widely for concrete and asphalt. The same clay-rich shale that can be a building hazard may be an excellent source of clay for making bricks. Numerous types of hard rock, such as sandstone and granite, may be used for building stone or may be crushed to form aggregate for concrete, asphalt, or decorative landscaping material. Geologic units mapped as evaporite deposits contain resources such as salt, gypsum (for making wall board), and sodium bicarbonate (baking soda). Knowing where important mineral resources are located can be of great value to industries that rely on these resources and helps county officials plan wisely.

Beth Widmann



RF - rockfall, LS - landslide, DF - debris fan, US - unstable slope, PUS - potentially unstable slope



These two maps cover the same area around Georgetown. On the right is a geologic map and on the left is a geologic hazards map derived from the geologic map (derivative map). The derivative map is much more useful for planners and decision-makers. However, an accurate geologic map is required before the derivative map can be constructed. Maps by Beth Widmann.

"Determined to publish his profoundly important discovery by creating a map that would display the hidden underside of England, he[Smith] spent twenty years traveling the length and breadth of the kingdom by stagecoach and on foot, studying rock outcrops and fossils, piecing together the image of this unseen universe."

—The Map that Changed the World

WHERE CAN I GET GEOLOGIC MAPS?

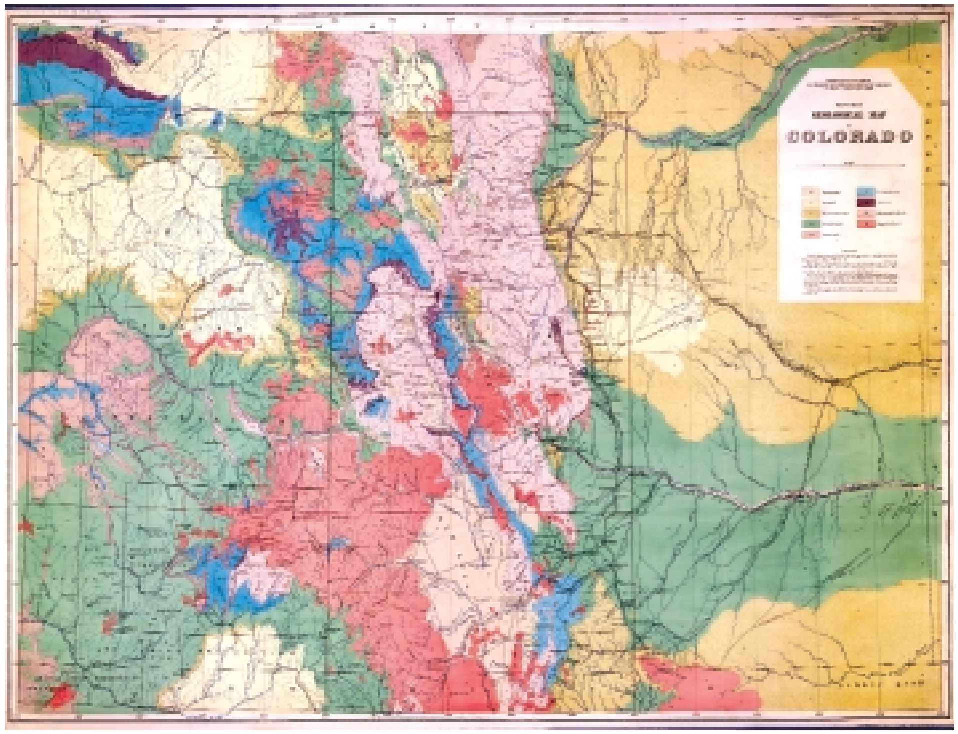
Geologic maps can be obtained from a variety of sources, such as the Internet and your state geological survey. Each distributor has a variety of services to offer. Where you look is dependant upon what you need.

State geological surveys, like the CGS, carry dozens of recent and not-so-recent geologic maps for specific areas within their state. The most common maps are 1:24,000-scale, based upon the U.S. Geological Survey's (USGS) topographic quadrangle maps. These geologic maps have excellent detail and are often accompanied by a descriptive booklet of the local geology, units, mineral resources, geologic hazards, and other pertinent information. CGS has both paper and digital versions of many geologic maps at various scales available for purchase.

The USGS publications office, located at the Denver Federal Center, sells geologic and topographic maps, as well as various earth-science related publications. A visitor's center houses thousands of thematic maps, many based on geology.

The USGS also hosts the National Geologic Map Database (NGMDB), an Internet-based catalog of geologic maps. There are over 67,000 bibliographic references for geologic maps that cover various topics such as mining, oil, gas, hydrology, and hazards. Many state surveys, universities, and colleges submit bibliographic information to the NGMDB, making this an invaluable resource.

A recent addition to the NGMDB is the Geologic Map Image Library (GMIL). Over 2,000 geologic maps are available for browsing and free download. The CGS is currently scanning all of the geologic maps in Colorado and will make them available to the public via the CGS and GMIL Web site.



Geologic Map of Colorado, from Hayden Expedition, 1877. A full-size reprint (23" x 35") is for sale in CGS' Historical Map Reprint Series

If you are searching for GIS coverages or shapefiles, the CGS and USGS have many geologic maps available for download from their respective Web sites. These "smart" files contain attributed polygon, line, and point files that can be imported and analyzed using the appropriate GIS software. You can create custom geologic maps depending upon your needs.

Recommended Internet Web sites:

Colorado Geological Survey Publications Sales: http://geosurvey.state.co.us/pubs/pub_list/publications_information.asp

Colorado Geological Survey Data Distribution (for GIS shapefiles and coverages): http://geosurvey.state.co.us/pubs/gis/data_download.asp

USGS National Geologic Map Database: http://ngmdb.usgs.gov/

USGS Geologic Map Library: http://ngmdb.usgs.gov/ImageLibrary/

USGS GIS Data Download (a lot of geologic maps here): http://pubs.usgs.gov/products/maps/

Recommended places that sell geologic maps that you can visit in person:

Colorado Geological Survey
1313 Sherman St. #715
Denver, Colorado 80203
phone 866-4762 or
E-mail at **cgspubs@state.co.us**

USGS Map Sales
Building 810
Denver Federal Center
Denver, Colorado
Phone: 1-888-275-8747

RECENTLY PUBLISHED GEOLOGIC MAPS

Geologic Map of Basin Mountain Quadrangle, La Plata County, Colorado (OF01-04)
Geologic Map of Hermosa Quadrangle, La Plata County, Colorado (OF02-01)
Geologic Map of Monument Quadrangle, El Paso County, Colorado (OF02-04)
Geologic Map of Cheyenne Mountain Quadrangle, El Paso County, Colorado (OF02-05)
Geologic Map of Fort Garland SW Quadrangle, Costilla County, Colorado (OF02-06)
Geologic Map of the Cascade Quadrangle El Paso County, Colorado (OF03-18)
Geologic Map of the Copper Mountain Quadrangle; Summit, Eagle, Lake, and Park Counties, Colorado (OF03-20)
Geologic Map of Electra Lake 7.5-Minute Quadrangle, La Plata County, Colorado (OF03-21)

ROCKTALK
is published by the
Colorado Geological Survey
1313 Sherman Street, Room 715,
Denver, CO 80203

State of Colorado
Bill Owens, Governor

Department of Natural Resources
Russell George, Director

Division of Minerals and Geology
Ronald W. Cattany, Director

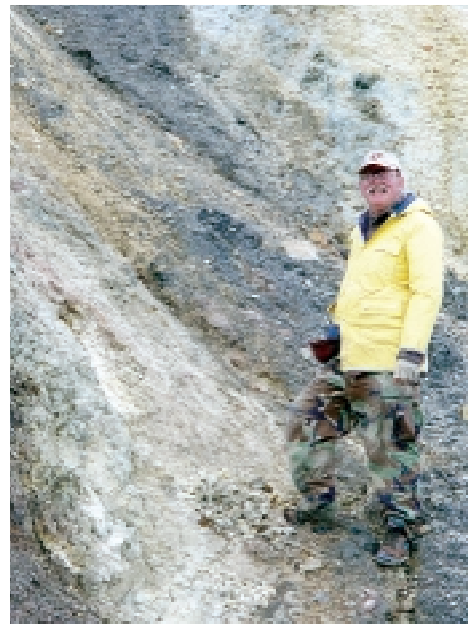
Colorado Geological Survey
Vince Matthews, State Geologist

Back issues and subscriptions
can be obtained FREE by contacting CGS by mail, fax, phone, or e-mail or download them from our Web site.

Phone: (303) 866-4762
Fax: (303) 866-2461
E-mail: cgspubs@state.co.us
Web site: http://geosurvey.state.co.us

THIS ISSUE
Editor: V. Matthews
Production: R. Ciminelli

CGS Mapper (and Colorado School of Mines Museum Director) Paul Bartos looks in disbelief as CGS mapper Beth Widmann says, after a September snow shower, "There's where we need to go." Photo by V. Matthews



CGS Mapper (and Director of the Crestone Science Center) Jim McCalpin standing in the Mosquito fault zone which has 9,000 feet of post-Laramide displacement. Photo by V. Matthews

ROCKTALK

Colorado Geological Survey
Division of Minerals and Geology
1313 Sherman Street, Room 715
Denver, CO 80203

M#341100040

PRESORTED
STANDARD
US POSTAGE
PAID
DENVER CO
PERMIT 738

DOI: https://doi.org/10.58783/cgs.rt0704.ewpc1782