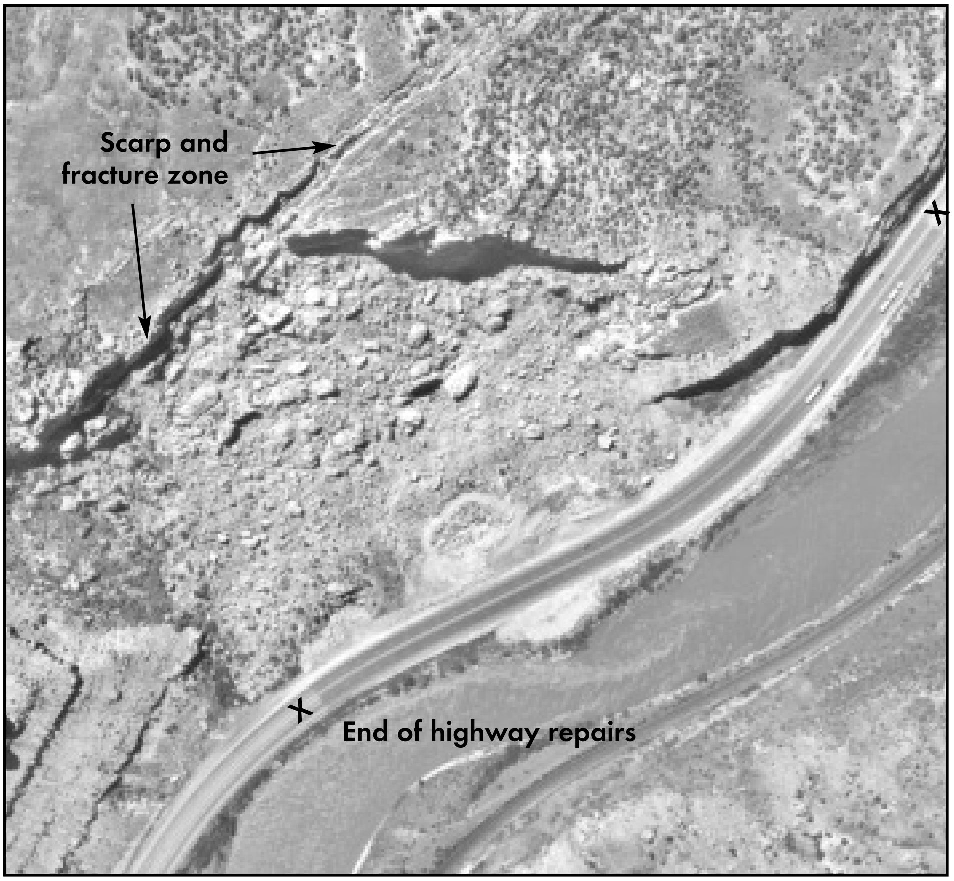
COLORADO GEOLOGICAL SURVEY

ROCK TALK

VOLUME TWO, NUMBER FOUR — OCTOBER, 1999



June, 1999 aerial photography of the DeBeque Canyon Landslide and vicinity. The mass of coarse rubble in the center of the photo that extends into the Colorado River and the large tension cracks in the cliffs above define the major slide mass (compare size of blocks and ground cracks with semi-trailer trucks on I-70).

This rock mass failed catastrophically in 1924 when it temporarily blocked and permanently diverted the Colorado River channel, destroying the existing road and washing away a peach orchard, several buildings, and a thousand feet of railroad track on the other side of the river. Old Highway 6 was relocated to the present approximate alignment, but was disrupted again in February 1958. Interstate 70 was eventually constructed in 1986 across the toe of the old slide, but was seriously disrupted in April 1998. In each slide occurrence, the roadbed was pushed up vertically 15 to 23 ft. The darker segment of pavement shows where damage/repair occurred from the most recent 1998 reactivation.

This last event triggered concerns for much more serious sliding that might involve all of the larger old slide and/or the massive sandstone and shale cliffs that are semi-detached and poised in front of the major shear zone that defines the upslope limits of the old slide mass. A major study and evaluation is currently underway involving a partnership of Colorado Department of Transportation, Colorado Geological Survey, Colorado School of Mines, and Golder Associates, Inc. Jon White is the CGS senior staff geologist on the team.

FLOODS, LANDSLIDES, AND DEBRIS FLOWS HIT HARD

Storm Events and Their Results

Spring and summer 1999 saw considerable action in Colorado for floods, landslides, and debris flows. Spring flooding was extensive along the Front Range piedmont and in river valleys on the eastern plains.

1) Overbank flooding caused considerable property damage and loss in La Junta, Otero County.

2) Several homes were severely damaged and abandoned in Colorado Springs because of landslides.

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FOCUS: ENGINEERING GEOLOGY AND GEOLOGIC HAZARDS

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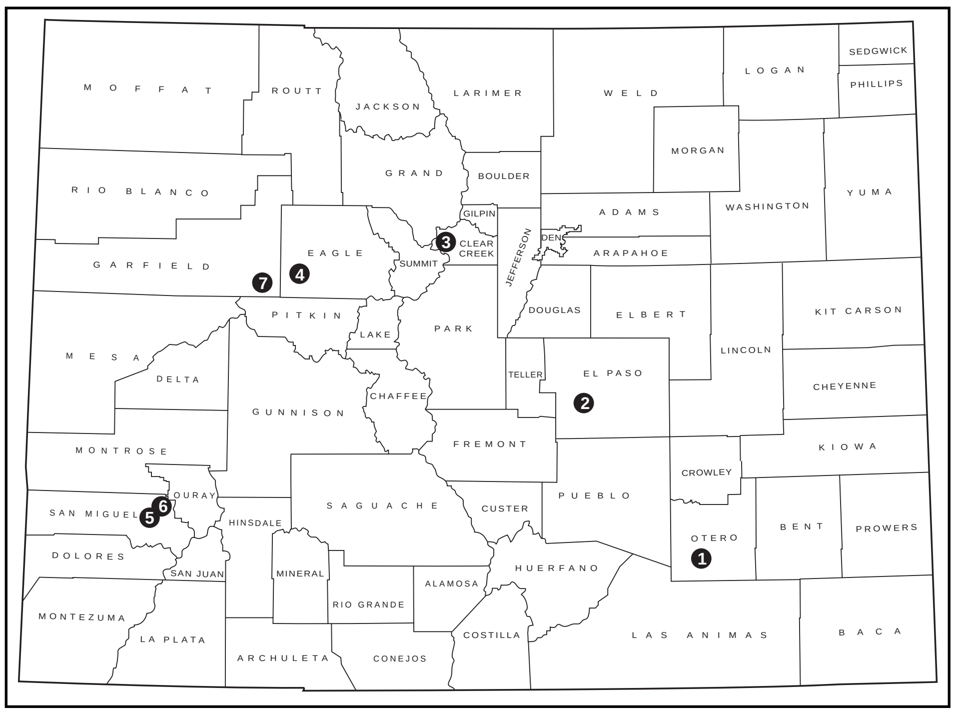
3) High in the Front Range a large-scale debris flow originated on the slopes of Mt. Parnassus near Bakerville, Clear Creek County. The debris came down Watrous Gulch and closed Interstate 70 for more than a day. In this general vicinity, eighty or more other debris flows occurred including one in the Arapahoe Basin Ski Area, immediately west of Georgetown, and in other nearby remote places.

4) Debris flows from the barren Eagle Valley Evaporite cliffs near Dotsero, Eagle County, closed Interstate 70 for a time.

5) Numerous small debris flows, rockfalls, and sediment-charged water floods originated in the steep cliffs between Placerville and Ilium along S.H. 145, near Telluride, San Miguel County; these occurred approximately simultaneously with . . .

6) A large water flood on Leopard Creek which is tributary to the San Miguel River a short distance downstream from Placerville.

7) The S.H. 82 and S.H. 133 corridor in Garfield and Pitkin Counties and the Main Elk Creek drainage north of New Castle also had several debris flows.



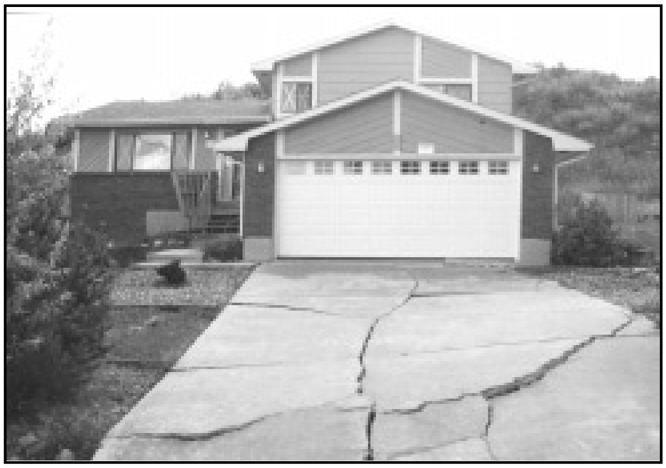
Localities indicated in text

Numerous other cases of events throughout the state involving flooding and movements of mud and rocks were reported. Governor Owens declared the following seven mountain-area counties to be disaster areas after the mid-summer storms: Clear Creek, Eagle, Ouray, Pitkin, San Juan, San Miguel, and Summit.

The late spring and summer months are usually the most active ones in Colorado for floods, landslides, and debris flows. This fact can be attributed to several factors. The peak snowmelt usually occurs in May to mid-June and spring snows tend to carry more moisture than those that occur early to mid-winter. Along the Front Range piedmont, May to mid-June are also the heaviest rainfall months.

In 1999, extensive flooding occurred during late April to mid-May. This was sufficient to warrant a Presidential Disaster Declaration (1276-DR-CO) for several counties in the drainages of the Arkansas and South Platte Rivers. Among the hardest hit were El Paso, Pueblo, and Otero.

Summer thunderstorms tend to be concentrated and heavy throughout Colorado and a prolonged flow of monsoonal moisture across the Colorado Mountains occurred during the last few days of July and early August. It was during this time that most of the indicated mountain-area debris flows and flooding occurred. The piedmont saw an increase in heavy, long-duration rainstorms then, as well. In and near Colorado Springs, these storms and their resulting stormwater infiltration aggravated several problem landslide areas which had been troublesome earlier.



The Colorado Springs area has numerous places with landslide-prone ground and ancient and modern landslides. One of these is in the Holland Park neighborhood in the north-central part of the City. Several homes were damaged or destroyed in this area this past summer.

Smaller debris flows frequently cause loss of service on Colorado roads. Two examples this past summer were multiple events on I-70 near Dotsero and several debris flows on the frontage road west of Interstate 70 at Georgetown (shown above). PHOTO BY JIM SOULE

CGS Assistance

As a fundamental part of its statutory charge, CGS must provide assistance to local governments, other state agencies, and the public with geologic hazards. During and after these events, CGS personnel participated in the Interagency Hazard Mitigation Team appointed after the Governor's Declaration, examined the debris-flow areas to estimate the possibility of sudden recurrence and possible continued loss of highway service, and continued its observation of landslide areas to assess immediate threats to property.

Jim Soule

Field Notes from the Director

As another lovely Colorado summer ends, those of us fortunate enough to live in Colorado get ready to enjoy the fall season, which many of us consider to be the most spectacular. Still others of us look forward to winter, with its opportunities for outdoor recreation. And then there's the Colorado spring —always full of promise and surprise. It doesn't matter which season we're in, most of us feel lucky to live in Colorado.

In many ways, Colorado's geologic character contributes to this sense of good living and not just because of the spectacular scenery. We are free from worries about many of the worst natural hazards such as hurricanes or tsunami. Even our exposure to earthquake and tornado hazard, although present, is relatively small compared to other locations.

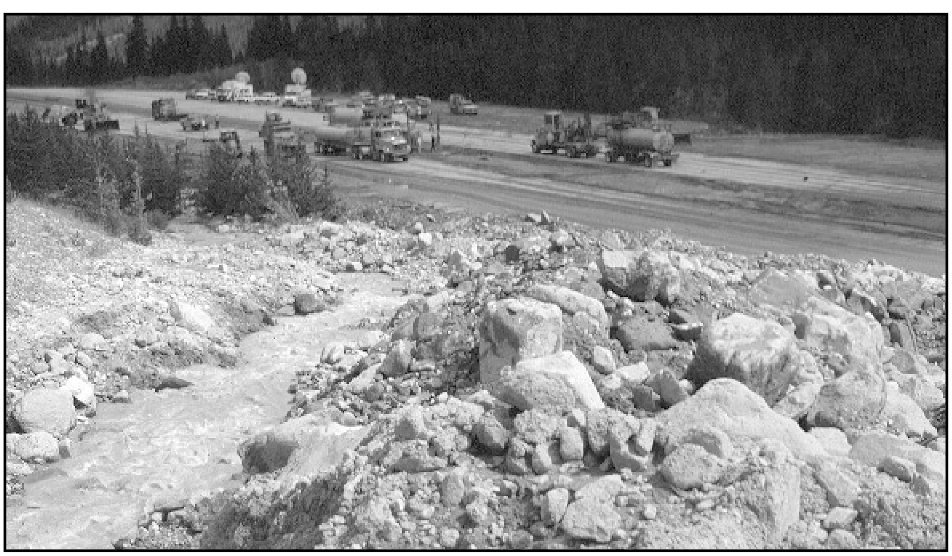
But there are geologic hazards in Colorado, and many of our citizens experienced them this year. Serious and damaging debris flows closed I-70 this summer, enough to warrant a Governor's declaration of emergency. Rockfall claimed two lives this year. Several communities continue to struggle with the destruction of homes due to landslides.

Field Notes continued on page 13

Debris flow source area, scoured channel and natural levees, vicinity of Arapahoe Basin PHOTO BY JEFF COE, USGS

Oblique aerial view of Watrous Gulch PHOTO BY USGS, AUG. 1999

The Watrous Gulch debris flow occurred on July 28 and was triggered by a heavy afternoon rainstorm. Its intercept distance across the freeway was about 600 ft and Colorado Department of Transportation officials estimated that the maximum depth of material on the highway was about 25 ft. The U.S. Geological Survey estimated that the volume of debris deposited on the debris fan was about 100,000 cubic meters. Probably due to low traffic volume and fortunate timing, no one was injured during or after the debris flow event.



View of cleanup effort at Watrous Gulch from debris fan PHOTO BY JEFF COE, USGS

JIM SOULE RETIRES AND REMINISCES

After 25 years of working land use reviews and geologic hazards for the Colorado Geological Survey, Jim Soule retired effective August 31, 1999. Colorado Geological Survey interviewed Jim about some highlights of his long and productive career.

CGS: Jim, what were things like when you joined the Survey in 1974?

JS: Well, basically, CGS consisted of about five employees. I was hired in response to House Bill 1041, which stated that "certain matters of state interest" were to be investigated by CGS. These included preparation of a manual to address geologic hazards and mineral resources (CGS publication SP 6, *Guidelines and Criteria for Identification and Land-Use Controls of Geologic Hazard and Mineral Resource Areas*). CGS was asked to develop the technology for mapping geologic hazards in the state, which the counties could use as a model. In implementing the mapping program, I prepared geohazard maps for Gunnison and Douglas counties, choosing one mountain and one Front Range county.

A younger Jim on national TV expounding on the Castle Rock rockfall

CGS: What projects occupied most of your time during the early part of your CGS career?

JS: The geologic hazards business was alive and well in the 1980s. Early on, I worked on the Northwest Energy Lands Project, which was funded by the USGS. The purpose of the project was to develop a geologic hazards database for areas that might mushroom because of the energy boom. This was the first land-use oriented study on the Western Slope. Of course, our funding dried up when the boom went bust. In the mid 1980s, CGS began a structured study of critical landslides in the state. The ones I was particularly involved with were those at Dowds Junction, Clear Creek Canyon, and eastern Mesa County, where the Vega Reservoir area was at risk.

CGS: Jim, you've been head of the land use department for the past 9 years, and have always worked in this field. What changes have you seen in the process?

JS: Earlier sites were not as difficult and the reports were not as sophisticated as what we receive now. Really, there was no guide to how land should be managed from a geologic standpoint until CGS published SP 6. Also, at the beginning funding was from the legislature. Starting in 1984, the legislature required and authorized CGS to charge the applicants for reviews.

CGS: We know there is not a part of the state, either geologically or geographically, that you're not familiar with. What are some of the most interesting projects you've worked on?

JS: One would certainly have been the Big Thompson Flood, which is Colorado's worst disaster. The flood occurred July 31, 1976, 2 years after I joined CGS. Within a few days of the flood, Pat Rogers, Dave Shelton and I were in the

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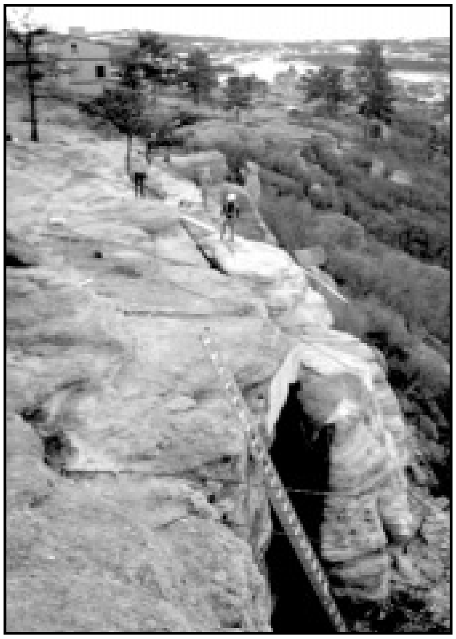


Castle Rock: remedial work at top of rock

canyon studying the storm impact on hillslopes and the drainage basins to document what occurred geologically and why. We worked for 2 months commuting to Drake because motel rooms were either destroyed or occupied by relief workers. The work was presented to the legislators in the fall and was ultimately published as CGS Environmental Geology No. 10.

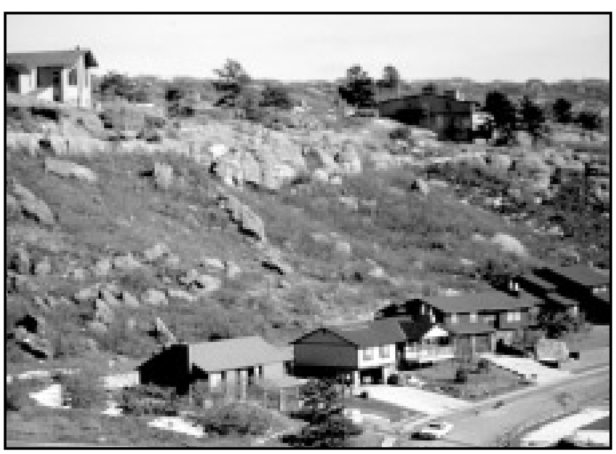
Then, there was the Crested Butte bank explosion, which killed and injured people. CGS was asked to investigate whether biogenic gas from swampy areas and coal beds might have caused the explosion. After one-half day of poking around, I began to smell a rat. When CDOT crews drilled to vent the remaining gas, I collected soil gas samples for analyses. These revealed that the gas was propane, a refined gas, which we determined had leaked from a utility line. The gas had collected in the crawl space beneath the bank after being trapped by the surrounding frozen soil (this was winter). Something, perhaps an electrical spark, ignited the gas.

Oh, and in 1981, there was the fuss over the Castle Rock rockfall. Residents of Castle Rock awoke to earthquake-like rumbles cause by a large block from a sandstone outcrop that had broken loose from its ledge and was slowly slipping downslope, where it endangered homes below. The mitigation efforts were complicated by the ownership of the property. The homes below the cliff were within city limits, the cliff ledge was county-owned, and the land above the ledge, where runoff from the parking lot may have contributed to the rock slippage, belonged to the Archdiocese of Denver. The geologic hazards map I prepared of Douglas County had warned about this potential danger.

This drama of removing the unstable rock with highly vulnerable homes below received front page coverage in the local papers, and the NBC Today Show had shots of Bruce Stover and me on national TV.

The state of Colorado is not short of geologic hazards to investigate. Fortunately, CGS will retain the benefit of Jim Soule's expertise, as he follows Pat Rogers' example of emeritus status and continues to act as geo-inspector for misbehaving rocks in Colorado's dynamic environment.

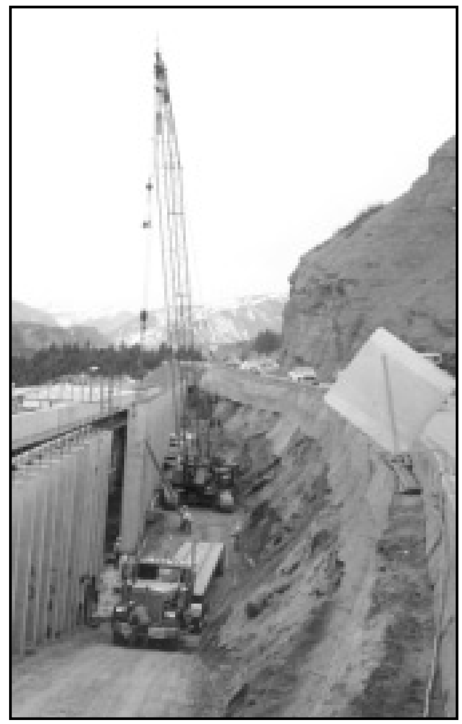
Celia Greenman



Castle Rock rockfall site

ENGINEERING GEOLOGY ON CDOT PROJECTS

The Colorado Department of Transportation began utilizing the Colorado Geological Survey in 1984 for the construction of Interstate 70 through Glenwood Canyon Colorado. The steep terrain and complex geology of the canyon environment created numerous geological and geotechnical challenges. Realizing this in the early stages of the process, the Project Manager, Mr. Ralph Trapani, sought to establish a multidisciplinary design and construction team to meet the upcoming challenges. The Engineering Geology section of the CGS was able to provide two engineering geologists for full time work on the project. Timothy Bowen and Roger



Retaining walls at Highway 82 Shale Bluffs project PHOTO BY R. PIHL

Pihl supervised a staff of between 10 and 20 geologists, engineers and drilling personnel.

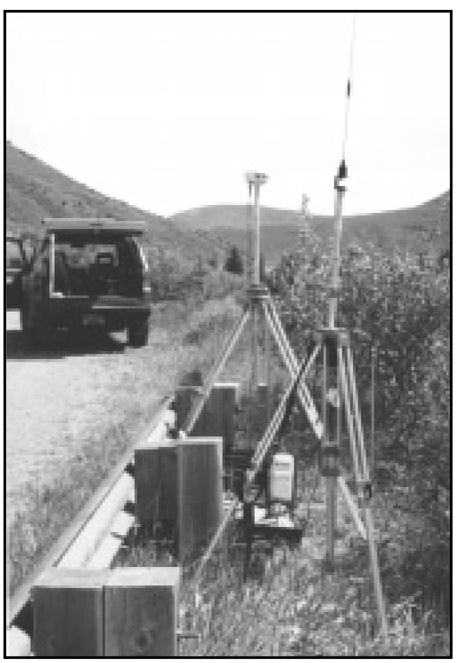
The geotechnical office provided design and construction assistance to consultants and CDOT staff from 1984 through the completion of the project in 1994. The continuity between design and construction proved essential for the completion of this complex $486 million project. This successful arrangement led to CGS involvement in several other highway projects such as State Highway 285 and 74 re-alignments on the Front Range, tunnel repairs on Highway 6 above Golden, and various landslide and rockfall mitigation projects.

The CGS is currently providing a staff of three geologists and engineers for the design and construction of State Highway 82 from Basalt to Aspen. The CGS' responsibilities include oversight of the drilling and exploration programs, in addition to coordination and oversight of consultant efforts for the design and construction of the $200 million

Blasting Highway 82 re-alignment at Shale Bluffs PHOTO BY R. PIHL

Rock anchor installation to support Mancos shale at CDOT Highway82 Shale Bluffs project PHOTO BY R. PIHL

corridor project. Debris flows, rockfall areas, avalanches and potentially troublesome soils characterize the project where the alignment traverses the steep, geologically complex slopes through the scenic Roaring Fork River valley. Parsons Transportation Group and MK Centennial are designing the project in their Denver office. Mr. Shan-Tai Yeh of Yeh and Associates and Dr. Hsing-Cheng Liu of CDOT have been working with Roger Pihl, Monica Pavlik, Ty Ortiz, and Ben Arndt of the CGS



GPS technology is used extensively on Western Colorado projects for specialty survey and mapping work (This is a base station setup.)
PHOTO BY TY ORTIZ

CGS engineering geologist Monica Pavlik makes observations from a helicopter PHOTO BY R. PIHL

Cluster of wick drains and outfall at a State Highway 13 location PHOTO BY TY ORTIZ

Close-up of a completed wick drain installation (State Highway 13)
PHOTO BY TY ORTIZ

to provide the geotechnical engineering and geology for this challenging project. CGS is also a partner with CDOT, Colorado School of Mines and Golder Associates, Inc. in a major investigation and evaluation of the De Beque Canyon landslide, which is threatening Interstate 70 in Mesa County. Jon White is the CGS senior geologist on that project team.

The CGS also provides emergency assistance to CDOT maintenance forces for rockfalls, avalanches, landslides and other geologic hazards. The CGS is currently involved in a slope stabilization project on State Highway 13 where two persistent embankment failures have threatened the serviceability of the highway. This work was possible because of substantial Federal Emergency Response funds received by CDOT. The problems are caused by a combination of poor quality local soils and adverse groundwater conditions. The CGS has provided GPS mapping, drill hole logging, and in coordination with the CDOT Geotechnical staff, has provided remedial recommendations, cost estimates and construction support.

Some of the newer techniques to dewater slopes are horizontal wick drains. These drains are geocomposites of plastic and non-woven fabrics that are driven into soft slopes by backhoes and provide an avenue of water movement out of the slope. The reduction in groundwater and pore pressure stabilizes these slopes. The advantage of wick drains over conventional pipe is flexibility and lower cost.

The CGS will begin work on several other slope stability projects in Eagle County along State Highway 24 and Interstate 70 in the near future. The slopes in question have required periodic maintenance for many years and future improvement projects will warrant more permanent fixes for these slopes.

The CGS mandate to provide geological services to state and local governments has allowed CDOT to attain cost-effective, creative solutions to a wide range of geological and geotechnical problems.

Roger Pihl and Pat Rogers

Helicopter delivered modular drills are used for access for exploratory drilling in difficult and sensitive areas PHOTO BY TY ORTIZ

COLORADO EARTHQUAKE INFORMATION UPDATE

Earthquakes and their possible hazards to life and property in Colorado have been of concern in Colorado, especially since the sizeable and widely felt earthquakes in the Northeast Denver Metropolitan area in the mid-1960s. These were almost certainly triggered by deep injection of liquid waste at the Rocky Mountain arsenal, but most geoscientists believe that tectonic strain energy stored at depth was the source for much of the seismic energy released.

Seismicity was listed as a Geologic Hazard in HB 1041 of 1974, and CGS produced several publications summarizing and interpreting available data. Although widely used, this information badly needed updating. Funding to update and publish this 15-yr catchup became available from Severance Tax funding to the CGS for a Critical Geologic Hazards program in 1996. Many of the resulting reports are newly published or in press at this time. These are listed in another section of this edition of *RockTalk*, and actual availability can be obtained on the CGS publication website or a call to the CGS publications desk.

Another product that CGS and Colorado Office of Emergency Management (OEM) observed a need for was a "Fact Sheet" for distribution to citizens and others interested in an understandable overview of Colorado Seismicity. This task was given to the Earthquakes Subcommittee of the Colorado Natural Hazards Mitigation Council and we are presenting below their final draft version. When finalized, it will be available on the CGS website and as a handout for CGS and OEM outreach and education efforts. This fact sheet was considered necessary to minimize conflicting information to the public and decision makers that often appeared in the media concerning this important but complex and evolving subject.

Pat Rogers

FINAL DRAFT FACT SHEET

COLORADO EARTHQUAKE INFORMATION

Prepared by the Earthquake Subcommittee
Colorado Natural Hazards Mitigation Council

Introduction

Colorado is composed of areas with low to moderate potential for damaging earthquakes, based on research by geologists and geophysicists who specialize in seismology. There are about 90 potentially active faults that have been identified in Colorado, with documented movement within the last 1.6 million years. However, there are several thousand other faults that have been mapped in Colorado that are believed to have little or no potential for producing future earthquakes. Because the occurrence of earthquakes is relatively infrequent in Colorado and the historical earthquake record is short (only about 130 years), it is not possible to accurately estimate the timing or location of future dangerous earthquakes in Colorado. Nevertheless, the available seismic hazard information can provide a basis for a reasoned and prudent approach to seismic safety.

Faulting

Sudden movement on faults is responsible for large earthquakes. By studying the geologic characteristics of faults, geoscientists can often determine when the fault last moved and estimate the magnitude of the earthquake that produced the last movement. In some cases, it is possible to evaluate how frequently large earthquakes occurred on a specific fault during the recent geological past.

Geological studies in Colorado indicate that there are about 90 faults that moved during the Quaternary Period (the last 1.6 million years) and should be considered potentially active. The Sangre de Cristo Fault, which lies at the base of the Sangre de Cristo Mountains along the eastern edge of the San Luis Valley, and the Sawatch Fault, which runs along the eastern margin of the Sawatch Range, are two of the most prominent potentially active faults in Colorado. Not all of Colorado's potentially active faults are in the mountains, and some can not be seen at the earth's surface. For example, the Cheraw Fault, which is in the Great Plains in southeast Colorado, appears to have had movement during the recent geologic past. The Derby Fault near Commerce City lies thousands of feet below the earth's surface but has not been recognized at ground level.

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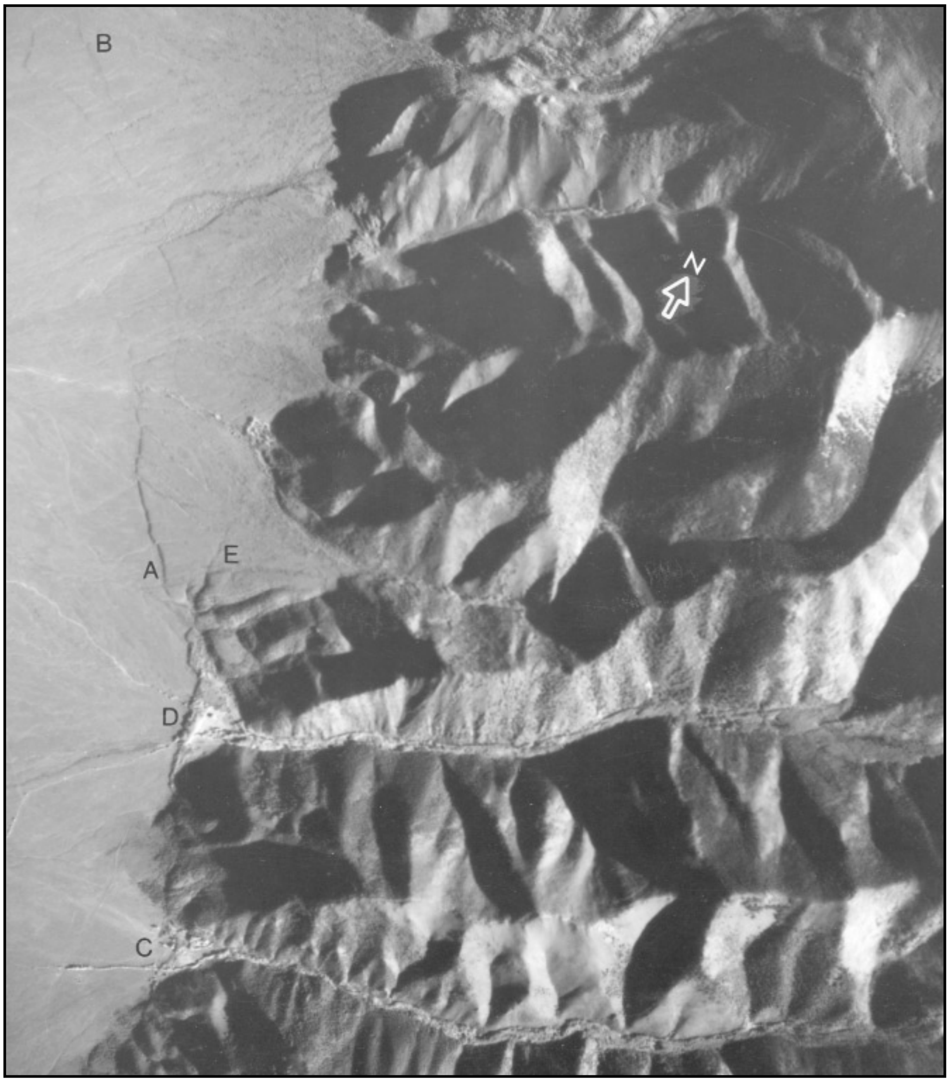

Vertical low-sun-angle aerial photograph of parts of the Villa Grove and Sangre de Cristo fault zones. Note decrease in scarp height from "A" to "B" along the Villa Grove fault zone. Prominent scarps are present along the Sangre de Cristo fault at the mouths of Major Creek(C), Garner Creek (D), and Hot Springs Canyon (E). NASA PHOTO COURTESY OF KEENAN LEE, COLORADO SCHOOL OF MINES, FROM CGS BULLETIN 43

Several potentially active faults in Colorado are thought to be capable of causing earthquakes as large as magnitude 6.5 to 7.25. In comparison, California has hundreds of hazardous faults, some of which can cause earthquakes of magnitude 8 or larger. The time interval between large earthquakes on faults in Colorado is generally much longer than on faults in California.

Past and Possible Future Earthquakes

More than 400 earthquake tremors of magnitude 2.5 or higher have been recorded in Colorado since 1867. More earthquakes of magnitude 2.5 to 3 probably occurred during that time, but were not recorded because of the sparse distribution of population and limited instrumental coverage in much of the state. For comparison, more than 20,500 similar-sized events have been recorded in California during the same time period. The largest known earthquake in Colorado occurred on November 7, 1882 and had an estimated magnitude of 6.5. The location of this earthquake, which has been the subject of much debate and controversy over the years, appears to be in the northern Front Range west of Fort Collins.

Although many of Colorado's earthquakes occurred in moun-

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Trench excavation exposing Quaternary fault displacement on a branch of the Rampart Range Fault. Location is on the Air Force Academy grounds, vicinity of Colorado Springs. The contact between the 600,000 year old Douglass Mesa Gravel and underlying Cretaceous bedrock is strongly offset but younger surface soils estimated to be 30,000 to 50,000 years old are not displaced across the fault line. PHOTO BY BRUCE STOVER

COLORADO'S LARGEST HISTORIC EARTHQUAKES

(Records date back to 1867)

Date	Location	Magnitude	Intensity
1870, Dec. 4	Pueblo-Ft. Reynolds	--	VI
1871, Oct.	Lily Park, Moffat Co.	--	VI
1880, Sep. 17	Aspen	--	VI
1882, Nov. 7	North-Central Colo.	6.5*	VII
1891, Dec.	Maybell	--	VI
1901, Nov. 15	Buena Vista	--	VI
1913, Nov. 11	Ridgway area	--	VI
1944, Sep. 9	Montrose/Basalt	--	VI
1955, Aug. 3	Lake City	--	VI
1960, Oct. 11	Montrose/Ridgway	5.5	VI
1966, Jan. 5	N.E. of Denver	5.0	V
1966, Jan. 23	CO-N. Mex. border near Dulce, N. Mex.	5.5	VII
1967, Aug. 9	N.E. of Denver	5.3	VII
1967, Nov. 27	N.E. of Denver	5.2	VI

*magnitude estimated for older earthquake; based on historical felt reports

tainous regions of the state, some have been located in the western valley and plateau region or east of the mountains. The most economically damaging earthquake in Colorado's history occurred on August 9, 1967 in the northeast Denver metropolitan area. This magnitude 5.3 earthquake, which was centered near Commerce City, caused more than a million dollars damage in Denver and the northern suburbs. This earthquake is believed to have been induced by the deep injection of liquid waste into a borehole at Rocky Mountain Arsenal. It was followed by an earthquake of magnitude 5.2 three months later in November of 1967. Although these events cannot be classified as major earthquakes, they should not be discounted as insignificant. They occurred within Colorado's Front Range Urban Corridor, an area where nearly 75 percent of Colorado residents and many critical facilities are located. Since March of 1971, well after the initial flurry of seismic activity, 15 earthquakes of approximate magnitude 2.5 or larger have occurred in the vicinity of the northern Denver suburbs.

Relative to other western states, Colorado's earthquake hazard is higher than Kansas or Oklahoma, but lower than Utah, and certainly much lower than Nevada and California. Even though the seismic hazard in Colorado is low to moderate, it is likely that future damaging earthquakes will occur. It is prudent to expect future earthquakes as large as magnitude 6.5, the largest event of record. Calculations based on the historical earthquake record and geological evidence of recent fault activity suggest that an earthquake of magnitude 6 or greater may be expected somewhere in Colorado every several centuries.

Summary and Conclusions

Based on the historical earthquake record and geologic studies in Colorado, an event of magnitude 6.5 to 7.25 could occur somewhere in the state. Scientists are unable to accurately predict when the next major earthquake will occur in Colorado; only that one will occur. The major factor preventing the precise identification of the time or location of the next damaging earthquake is the limited knowledge of potentially active faults. Given Colorado's continuing active economic growth and the accompanying expansion of population and infrastructure, it is prudent to continue the study and analysis of earthquake hazards. Existing knowledge should be used to incorporate appropriate levels of seismic safety in building codes and practices. The continued and expanded use of seismic safety provisions in critical and vulnerable structures and in emergency planning statewide is also recommended. Concurrently, we should expand earthquake monitoring, geological and geophysical research, and mitigation planning.

The information contained herein is intended to provide general information to the public and should not be used for site specific engineering purposes. Seismic hazard assessment for a particular location should incorporate an appropriate engineering evaluation.

Further Published Information

The Colorado Geological Survey has several publications on Colorado earthquakes and potentially active faults, and maintains a reference collection on Colorado seismicity that includes reports by consultants or agencies. A listing of the reports can be viewed at the CGS web site, www.dnr.state.co.us/geosurvey, under "programs".

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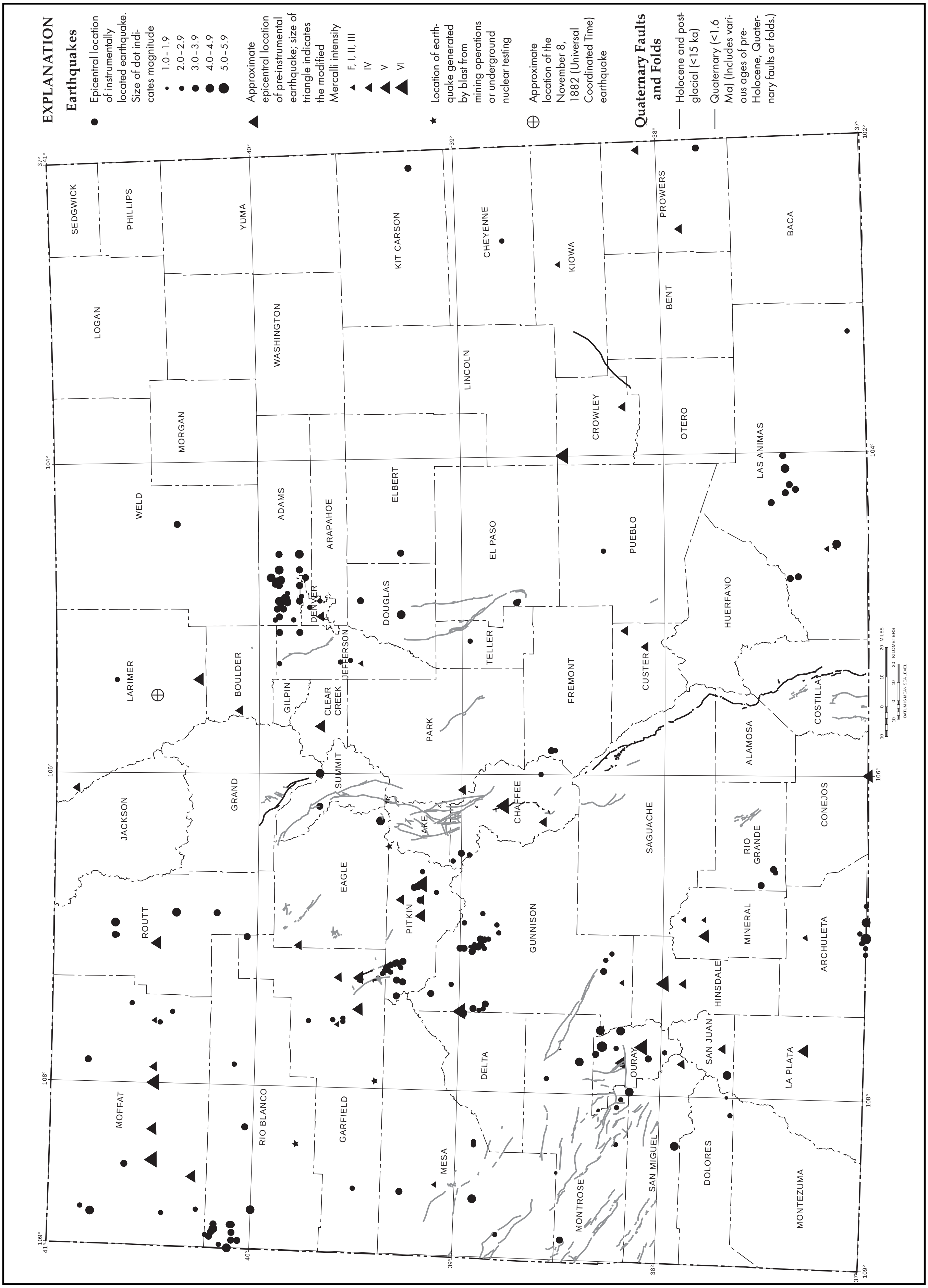


Generalized map showing location of earthquake epicenters, Quaternary faults and folds

ADAPTED FROM CGS BULLETIN 52 AND OPEN-FILE REPORT 98-8

GeoDenver 2000

The American Society of Civil Engineers will hold **GeoDenver** August 3–8, 2000 at the Marriott in the Denver Tech Center. Topics for talks will be:

♦geophysical exploration; ♦construction practices; ♦geoarcheology; ♦unsaturated soils; ♦environmental geotechnics; ♦geosynthetics; deep foundations; ♦slope stability; ♦rock mechanics; ♦risk assessment; ♦earthquake engineering; ♦pavements and pavement subgrades; ♦instrumentation and monitoring; ♦computer applications and numerical methods; ♦soil/rock property determination and site characterization

Interested parties should call ASCE at 800-548-2723 or 703-295-6300 outside the U.S. The e-mail address is conf@asce.org.

Thumbnail Sketch of the CGS Engineering Geology Section

The Engineering Geology Section has been an integral part of the Colorado Geological Survey since the agency's inception in the latest 1960s. The Section has flourished and taken its present form under the able leadership of William "Pat" Rogers (1971–1998). There has been one preceding and one subsequent leader at each end of Pat's 27-year tenure: Bob Sennett (1970-1971) and David Noe (1999). The following is a short history of the section.

Section History and Highlights

The CGS Engineering Geology Section was created to fulfill the following purposes, as mandated by the CGS Enabling Act (amended by HB-1282, 1973): 1) Assist and advise local governments; 2) determine areas of geologic hazards; 3) conduct geologic studies; 4) collect geologic information; 5) publish maps, reports, and bulletins. The Section has accomplished these mandates through a number of different programs and activities over a three-decade period.

1970s

CGS investigated geologic problems associated with the Marble ski area in Gunnison County. The proposed development was geologically unsuitable, occupying large tracts of a narrow, glacial valley that was plagued with debris flows, landslides and potentially unstable slopes, flooding, and avalanches. The results were published in MI-8, *Engineering Geologic Factors of the Marble Area, Gunnison County*. As a direct

Field Notes continued from page 3

Chances are, you live in, work in or regularly drive through an area of geologic hazards. You may choose to accept the risk of that hazard because of other benefits that are important to you. But even if your property is not directly damaged by a geologic hazard, you still bear a cost. The costs of geologic hazards are borne collectively by all of us, through taxes for road maintenance, replacement of infrastructure or even disrupted communities as neighbors have to leave their damaged homes.

When geologic hazards cause extreme destruction, such as that which we've just seen in Turkey, it seems obvious that we should seek to avoid or mitigate the hazard. Generally speaking, however, the expected cost of dealing with the aftermath of a hazard event must be very high before we as a community will require regulation to avoid or mitigate those expected effects.

So what can you do, as a private citizen to protect yourself from geologic hazards? Be informed about your own risk. Find out if you live on or near a hazard and understand what you can do to retrofit your home or business to lessen your risk for damage. Avoid or plan for the hazard as you build or purchase property.

What do we do, here at the CGS, to help? We provide effective and useful information to citizens, the building community, and local governments through our maps, reports and geologic hazard reviews. The best time for our input is before building takes place on or near a hazard. This ensures that the geologic information can be used as a part of the local decision and planning process.

The old saying "Pay me now or pay me later" is true for geologic hazards. Up front proactive planning, which includes using geologic information, is a good investment in keeping Colorado a great place to live.

result, the State of Colorado passed key land-use legislation that required reviews of geologic suitability to protect prospective homeowners and their property:

1972 SB-35, "The Subdivision Law", was passed, which requires CGS review of subdivision applications for geologic suitability. CGS gave critical input.

1974—HB-1041, "The Areas and Activities of State Interest Law", was passed, which defines geologic hazards, in a legal sense, and advocates counties to map areas of potential geologic hazards for planning purposes. CGS gave critical input and helped to compile "1041" geologic-hazard maps for several counties.

1976—The Section was called into action in August 1976, following the Big Thompson flood in north central Colorado. There, CGS geologists helped to document geologic-hazard effects related to the flooding as part of the emergency response and recovery team.

1980s

1984—The Section's activities were significantly impacted in 1984, when the CGS lost most of its general funding. To maintain staffing and assistance levels, the Legislature required the CGS to adopt fees for its review activities, and the ability to perform cash- and grant-funded projects for state-, federal-, and local-government agencies. The Section responded to this funding crisis by securing and completing a large number of research projects during the 1980s, including earthquake and seismicity studies, a statewide radon survey, and the Superconducting Supercollider study. A popular booklet on swelling soils was written as a disclosure document for the general public.

1984—CGS land-use review activities were augmented by new legislation, including "The School Site Law" (HB-1045) and "The Soil and Hazards Analysis Law" (SB-13). In partnership with the Colorado Department of Transportation (CDOT), CGS provided investigation and construction support for the I-70 Glenwood Canyon project and assisted in developing the Statewide Rockfall Rating and Inventory Program and the Colorado Rockfall Simulation Program (CRSP), which has been adopted worldwide as a rockfall modeling tool.

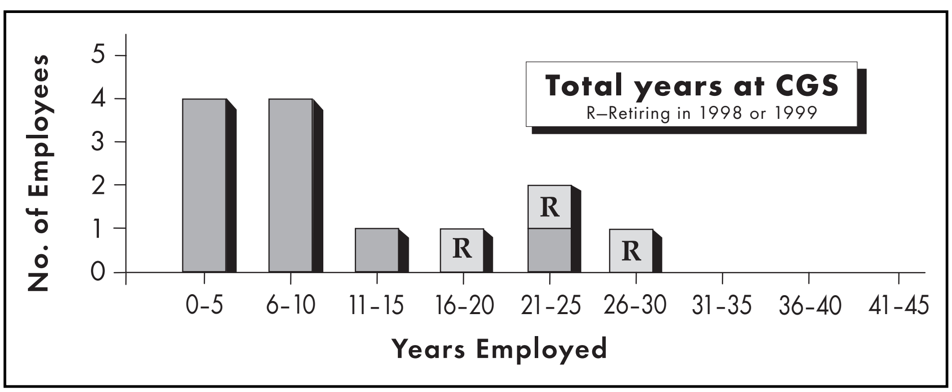
1990s

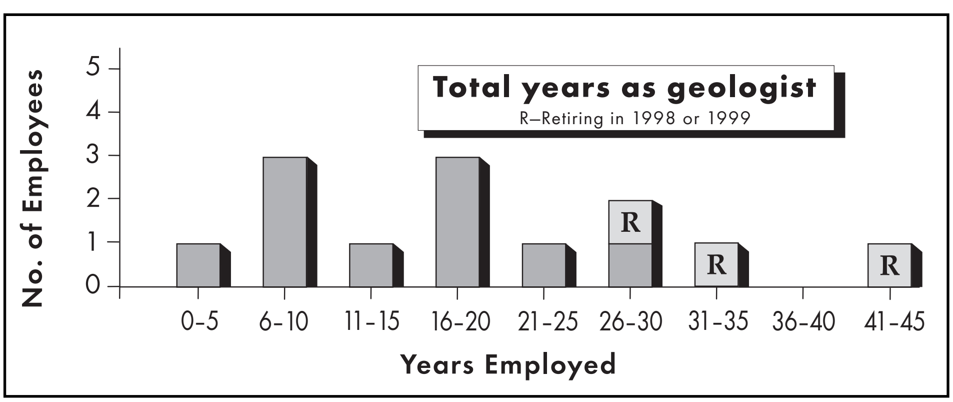
In the 1990s, the Section renewed its efforts to provide geologic hazard technology transfer and outreach to technical practitioners, local-government decision-makers, and the general public.

1996—Legislation was passed (SB-190) to allow the CGS to use Severance Tax monies from hydrocarbon and mineral production to fund critical research projects, based upon the success of and demand for these types of activities. The Severance-Tax funded Geologic Hazards program has produced a plethora of products since 1996 (see related article in this issue of *RockTalk*) which include digital re-issues and updates of existing publications, new publications, and annual geologic-hazard conferences.

1997—CGS efforts resulted in a new swelling-soil disclosure booklet for homebuyer and homeowners (SP-43) and new heaving-bedrock regulations in Jefferson and Douglas Counties.

The pace of land-use reviews has increased in response to the State's decade-long building boom, and the section continue to provide technical-assistance services for CDOT at numerous locations across Colorado.





Statistics of the CGS Engineering Geology Section

Section Personnel Profile

The CGS Engineering Geology Section is composed of seven permanent employees. In addition, we have two "emeritus" retirees and four employees who share duties with other CGS sections. The charts at left show the distribution, in years, of our group's history of employment as geologists. Notice the difference between employment with CGS and total employment. Our group has, on average, 11.3 years of experience with the CGS and 17.7 years of total experience as geologists. This shows that most of our staff comes to CGS equipped with a wealth of experience from other geological work. The graph also shows that we will be losing valuable agency experience through the retirement of the Section's three most senior geologists.

A composite resume of our thirteen engineering geologists shows that we have held positions in "former" lives in other geologic specialties that include oil-and-gas (6 employees), mining and industrial minerals (10 employees), geotechnical engineering and engineer-in training (5 employees), geophysics (3 employees), and glacial geology and avalanche specialist (3 employees). In addition, our staff members have served as forensic engineers, environmental planners, erosion and sediment-control specialists, construction-claims consultants, professors, mudloggers, surveyors, underwater demolition team members, park rangers, coaches, and youth leaders at various times in our lives. Five of us are technical climbers, which is of great on-the-job value given Colorado's rugged terrain.

We have one staff member with a PhD degree (and one in progress). Ten have a master's degree (including two awarded in 1999). Three of us were born and raised in Colorado. The rest of us hail from the Northeast (five employees), the Midwest (three employees), the Southwest (one employee), and Texas, a region in itself (one employee).

Programs and Challenges

At this writing, the CGS Engineering Geology Section has three main programs, each with its own particular challenges for the future. The Land-Use Review Program faces a major loss of institutional knowledge with the current and impending retirements of Pat Rogers, Jim Soule, and Jeff Hynes. This program is currently undergoing a formal re-evaluation so that we may improve our overall customer service. The Severance Tax Critical Geologic Hazards Program needs to reach new audiences, provide accessible materials for a wide variety of technical and non-technical users, and find means of improving technology transfer for our technical-practitioner and decision-maker customers. The CDOT Technical Assistance Program is focused on responding to the needs of CDOT projects as the State proceeds with a massive upgrade of its transportation infrastructure. The CGS is working closely with several private consulting companies to provide a healthy and harmonious mix of private and public involvement on these transportation projects. The CGS sees outreach and communication as critical keys for success in all of these programs.

That summarizes the Section's history, personnel profile, programs, and challenges. We encourage you, as our customers, to contact us if you have any questions or comments. It is my pleasure to be the new leader of this dedicated and talented group of engineering geologists.

David Noe

Publications continued from page 5

Special Publication 6
Guidelines and Criteria for Identification and Land-Use Controls of Geologic Hazard and Mineral Resource Areas $6.00

Special Publication 42
Heaving Bedrock Hazards Associated with Expansive, Steeply Dipping Bedrock, Douglas County, Colorado $25.00

SELECTED GEOLOGIC HAZARD RELATED PUBLICATIONS

Bulletin 37
Bibliography and Index of Colorado Geology, 1875 to 1975
Special offer thru 12/31/99 (Mention RockTalk) $5.00

Bulletin 48
Colorado Landslide Hazard Mitigation Plan $15.00

Environmental Geology 9
Coal Mine Subsidence and Land Use in the Boulder-Weld Coalfield: Boulder and Weld Counties, Colorado $25.00

Information Series 47
Geologic Hazards Avoidance or Mitigation: A Comprehensive Guide to State Statutes, Land Use Issues and Professional Practice in Colorado $25.00

Miscellaneous Information 57
The Citizen's Guide to Geologic Hazards: An AIPG Issues and Answers Publication $20.00

Special Publication 12
Nature's Building Codes—Geology and Construction in Colorado $4.00

Special Publication 28
Contributions to Colorado Seismicity and Tectonics—A 1986 Update $15.00

Special Publication 30
Debris-Flow Hazard in the Immediate Vicinity of Ouray, Colorado $6.00

Special Publication 37
Highway Rockfall Research Report $5.00

Special Publication 38
Proceedings: Summitville Forum '95 $95.00

SEVERANCE TAX FUNDING GETS NEW PUBLICATIONS IN PRINT

Nearly all CGS publications are the result of multiple funding sources. Very often, at the end of a research project, the funding needed for final review and manuscript preparation for a published document is not available. This has in the past delayed or completely sidetracked timely publication in numerous cases. Thanks to the Critical Geologic Hazards budget that began in 1996, this small amount of discretionary income funding has helped immensely in getting important publications in print or digital files that can be distributed to the end users.

The table at left lists the status, title, and description of publications that have been recently brought to completion thanks to funding from Colorado severance taxes, which are derived from the production of oil, gas, coal, and minerals.

Publication Title, Number, and Content	Status	Completion Date
Surficial Geologic Map of Storm King Mtn., ***SP 46*** geomorphic analysis of Sept 1, 1994 debris flows	Final review	Dec. 1999
Colo. Earthquake Information, 1867–1996, **B 52** CD-ROM linking map, text and tables	Final review	Dec. 1999
Bibliography and Index of Colorado Geology, 1875–1999, ***IS 51***, CD-Rom listing 26,000 entries, INMAGIC search engine adapted by AGI	In review	Feb. 2000
Map of Areas Susceptible to Differential Heave in Expansive, Steeply Dipping Bedrock, City of Colorado Springs, ***MS 32***	Completed, available	
Preliminary Quaternary Fault and Fold Map and Database of Colorado, ***OF 98-8***	Completed, available	
Heaving Bedrock Hazards Associated with Expansive, Steeply Dipping Bedrock, Douglas County, ***SP 42***	Completed, available	
Active Surficial Geologic Processes and Related Geologic Hazards in Georgetown, Clear Creek County, ***OF 99-13***	Completed, available	
Geologic Hazards and Mineral Resource Potential of Southwestern Costilla County, **OF 99-14**, CD in ArcView and hard copy prints on order	Final review	Jan. 2000
Colorado Rockfall Simulation Manual, Version 4.0 for Windows, ***MI 65***	In press	Dec. 1999

Upcoming Events Involving CGS

November 1–5
National Avalanche School, Incline Village, Nevada, presentations, Knox Williams, (303) 499-9650

November 29
Colorado Counties, Inc. Winter Conference, exhibit, contact Kristin Dunn, (303) 861-4076

ROCKTALK

BULK RATE
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Denver, Colorado
Permit No. 738

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

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