

**Economic Development Projects  
by the Colorado Geological Survey:  
Past, Present, and Future**

A report prepared for the Colorado General Assembly by:

**The Colorado Geological Survey Advisory Committee**  
Economic Development Sub-Committee

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# Introduction

In 1992, the Colorado General Assembly directed the Colorado Geological Survey (CGS) to place primary emphasis on the recognition and mitigation of geologic risks and economic development of Colorado's natural resources. At that time, the CGS and the CGS Advisory Committee (CGSAC) were directed to report on economic development. This document is the response to that request.

## Executive Summary

Economic development of a state's natural resources, done in an environmentally responsible manner, will lead to:

- ◆ increased employment and income,
- ◆ increased tax revenues,
- ◆ an improved U.S. trade deficit.

A major responsibility of state geological surveys is to promote economic development of their state's natural resources. Given the limited capital available for exploration in the U.S., this is often a competitive process. Colorado has not effectively competed with neighboring states in economic development promotion since the imposition of cash-funding for the CGS in 1983.

The exploration and development potential of Colorado's natural resources is still significant, especially for metallic minerals, oil, natural gas and carbon-dioxide.

Limited cash-funded CGS economic development work undertaken by the CGS since 1983 has been mainly as a sub-contractor on research programs led by other state geological surveys and funded by federal agencies, research institutes or industry.

Shortcomings in current CGS economic development activities lie in an inability to tailor work designed by other state geological surveys to specific Colorado needs and ineffective distribution of the results obtained. The small- and medium-sized companies now comprising much of Colorado's resource industry cannot afford in-house research, but will buy reasonably priced CGS data, providing they know it is available and relevant to their needs. Low cost CGS/industry cooperative ventures and programs are possible, but are difficult to effectively develop under cash-funding scenarios.

Increased funding is the key requirement for increased economic development promotion work by the CGS. Necessary cash-funding to finance this work can be obtained from private-sector, state and federal sources if modest direct seed money funds necessary for design and sale of the projects is made available. Once the reputation of the

CGS for competence in economic development work is recognized, the need for seed money will diminish. Much of this work would be done by knowledgeable private-sector consultants under contract to the CGS, avoiding staff build-up. Potential sources of cash-funding and the related projects for CGS economic development projects include:

State/Local Governmental Agencies

- ❖ swelling soil and bedrock research and mapping
- ❖ rockfall and landslide research
- ❖ avalanche research and protection
- ❖ evaluation of mineral resources on State lands and other projects to encourage exploration and development of State-owned lands

Federal Agencies, including USGS, USEPA, USDOE and others

- ❖ geologic field mapping
- ❖ multi-state resource studies
- ❖ oil and gas exploration and development
- ❖ impact of and mitigation for petroleum and mineral development on the ecosystem

Private-Sector, including research institutes

- ❖ specific industrial consortia projects
- ❖ broadly-focused applied research
- ❖ natural gas related studies
- ❖ use and availability of Colorado's clean coal resources

A survey of Colorado's geological community indicates strong support for increased CGS cooperation with resource industries in economic development activities and for establishment of a CGS/Industry Joint Committee on Economic Development.

Specific Recommendations by the CGSAC:

- ❖ CGS should educate Colorado's citizens on the importance of environmentally sound, natural resource development;
- ❖ CGS should fulfill its statutory responsibility for economic development of Colorado's natural resources, emphasizing projects with immediate economic and social benefits;
- ❖ The CGSAC proposes that one additional direct-funded FTE be authorized for a five-year period by the Colorado General Assembly as seed money. Direct seed money funding would allow the CGS to conceive, design, and obtain cash-funding for economic development projects from private-sector, state and federal sources;
- ❖ The CGS, the Oil and Gas Conservation Commission and the State Land Board should design joint programs to encourage expanded natural resource exploration and development on State-owned lands with OGCC and SLB funding;

- ❖ The Colorado General Assembly, together with local government, are asked to consider whether a share of severance tax/federal royalty revenues should be allocated to the CGS for economic development and geologic hazard work. To the degree that CGS activities benefit local government areas economically, the CGS deserves financial support; and
- ❖ A CGS/Industry Joint Committee on Economic Development should be established.
- ❖ Past mistakes in resource development do not provide a rationale for prohibition of environmentally responsible economic development projects, now and in the future.

## Why Economic Development Projects?

In considering economic development of natural resources in the United States, many people ask:

- ❖ Isn't that a thing of the past?
- ❖ Doesn't it destroy the environment?
- ❖ Can't we import all this stuff?
- ❖ What are the benefits?

Answers to these questions are:

- ❖ Economic development is required for a healthy economy.
- ❖ If planned and carried-out properly, economic development of natural resources can coexist with a clean environment.
- ❖ While many resource requirements can be imported, imports worsen the U.S. trade deficit.
- ❖ Economic development of natural resources increases employment, provides higher paying jobs, increases tax revenues and improves the trade deficit, and can be done in an environmentally responsible way.

About half of the 50 states are resource-rich and each has a state geological survey, including Colorado. Promotion of economic development of their states' natural resources is a stated responsibility of all state geological surveys including Colorado's. Many state geological surveys have developed effective efforts and strategies to support private development of their state's resources. Geologic maps, cross-sections and reports, data compilations and analyses, and exploration-oriented resource "trend" and "play" studies are all used by some state geologic surveys to attract exploration dollars to their state and away from others in what has become a highly competitive process.

How do Colorado's current efforts compare in this competition for economic development spending? Not very well, in attracting exploration spending necessary for continuing, long-term, high-value success. This was not always the case. The Colorado Geological Survey, reorganized in 1967, was very active in promoting development of the state's natural resources by 1975. The CGS placed emphasis on potential for utilization of geothermal resources and on development of Colorado's coal both through mining and by producing methane (a natural gas) from wells completed in coal beds.

**Geothermal**—The CGS conducted an intensive survey of Colorado's geothermal resource base during the late 1970s-early 1980s. Identification of potential sources of inexpensive, clean energy was the objective. Numerous geothermal anomalies were described and evaluated by means of 43 publications and three maps. Although the program ended in 1983 with the imposition of cash-funding, a wealth of data of potential future value was obtained. A new inventory, funded by DOE, was completed in 1993.

**Coal**—During the 1970s and early 1980s, a major coal program was conducted in the Front Range area by the CGS. Part of this effort was aimed at subsidence problems associated with abandoned coal mines. In another coal program during this period, data were compiled and analyzed covering most of Colorado's coal basins. The results of these programs are described in the 54 publications and seven maps issued. While interest in coal mine development is dormant at present, these data will have value for future developers.

**Coalbed Methane**—Maps, reports and studies produced by the CGS provided data, information and ideas which were instrumental in development of an immense clean energy resource—coalbed methane—in the San Juan Basin of southwestern Colorado and northwestern New Mexico. A probable resource of about ten trillion cubic feet is recognized. Some of the 14 CGS publications produced are still in demand. Moderately successful coalbed methane exploration has spread north into much of the Western Slope, where additional large methane reserves may exist. Eastern Slope exploration, mainly in the Raton Basin, has not been successful to date.

Economic development promotion efforts by the CGS have been greatly reduced since cash-funding was imposed in 1983. Petroleum and mining companies, which might have funded this type of CGS activity in better times, were leaving Colorado as the energy boom became the energy bust. Geologic hazards, engineering geology, and environmental geology became the principle sources of cash-funding for the CGS in the mid-80s, and continue today. Cash-funded work by the CGS in resource areas in recent years has been largely as sub-contractor to federally-funded regional projects led by geological surveys from other states. Because of the non-Colorado management and funding, the projects are not always designed to meet specific Colorado needs.

In the remainder of this report to the Colorado General Assembly, three questions are examined, and recommendations are made on how the Colorado Geological Survey could once again become active and effective in bringing exploration and economic development of natural resources back to Colorado.

## Quo Vadis, Colorado?

There are three questions which might be asked by any concerned Colorado legislator or citizen. The first question might also be asked by resource industry explorationists.

- 1) Does potential still exist in Colorado for discovery of natural resources in deposits large enough to be developed economically on an environmentally acceptable basis?
- 2) What role could the Colorado Geological Survey play to help bring about the exploration necessary to discover these deposits?
- 3) Could this be done by the Colorado Geological Survey on a cash-funded basis? If so, how?

## Exploration Potential Of Colorado

Much of Colorado's settlement and economic development during the late 19th and early 20th centuries resulted from the discovery and exploitation of metallic minerals in the Colorado Mineral Belt. Coal mines were developed to supply local industries and consumers. Oil was discovered in 1886 and produced periodically until the early 1930s, when the giant Rangely field was discovered, providing the basis for Colorado's continuing status as an important oil-producing state. The huge natural gas field discovered during this period in the San Juan Basin of Colorado and New Mexico developed slowly because of limited markets. After the Second World War, molybdenum in the Colorado Mineral Belt and oil and gas in the Denver Basin led a revival of Colorado resource activity which boomed in the 1950s and 1970s and then crashed in the early 1980s. Today, carbon-dioxide and coalbed methane operations have real long-term economic significance for Colorado, and natural gas has great potential.

Large mining and petroleum companies which once led resource exploration and development in Colorado have drastically reduced or terminated their activities in the state. Many gold-oriented mining companies have their headquarters in Colorado, but do not explore or operate mines in the state—they "just live here." Only the coal

miners are still active on a large scale, on the Western Slope, but underground operations have become increasingly uneconomic. Whatever future exists for metal-mining and petroleum in Colorado lies with the independent companies, which may range in size and economic heft from sometimes-profitable organizations with several hundred employees down to one-person shops. Some of these are very profitable while others barely get by. Most small Colorado resource companies currently emphasize either gold or natural gas. Coalbed methane specialists are active and there is interest in diamonds. With both gold and natural gas prices strengthening, does potential remain in Colorado for additional exploration and development?

Exploration potential of Colorado's principal natural resources is still great, although some minerals will receive little attention or activity for many years. Others may attract increased exploration spending in the near term. Their potentials, near term or long term, are discussed below by specific mineral resource class. Since most natural resource prices follow cyclical patterns, the true economic potential of any Colorado natural resource will vary cyclically as well. Environmental considerations also affect the economic potential of mineral resources, regardless of market conditions. Deferred resource development and the trade deficit may eventually combine to drive up the price of increasingly scarce commodities to levels which justify economically sound development. All will be exploited in time—but the time for some is now.

## Non-Fuel Minerals

Non-fuel mineral production in Colorado continues the dramatic decline that began in the 1980s. Colorado now ranks 29th in the nation, well behind such states as Utah, Nevada and South Carolina. The value of Colorado minerals produced in 1991 was only \$310 million, down 20 percent from the \$386 million produced in 1990. Exploration and new development activity are also extremely low; for example, the number of new lode and placer claims staked in Colorado was 2,243 in 1991 versus 17,726 in 1981. Colorado's metallic mining industry employed only 3000 people in 1993 versus 5500 people in 1983, a drop of 45 percent in 10 years.\* The decline of production has resulted in a loss of wages and taxes that is compounded by losses in secondary businesses that support the mining industry.

Geologically, Colorado is one of the most mineral-rich states in the nation. Its early development was based in large part upon the production of several metallic commodities along the Colorado Mineral Belt, which cuts diagonally across the Rocky Mountains from Boulder to the San Juan Mountains. Between 1799 and 1965, Colorado pro-

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\*Reference: Business/Economic Outlook Forum, 1993, produced by College of Business at University of Colorado at Boulder.

duced 41 million ounces of gold, second in the nation only to California. Yet in 1991, the value of gold production was only \$26 million (versus \$2.2 billion in Nevada!). In the 1960s, Colorado produced over 60 percent of the molybdenum consumed in the non-communist economies. Yet Colorado's molybdenum industry continues to decline despite the presence of two significant discoveries in recent years.

Some mining companies based in Colorado will not operate here because they believe the reasons for the decline of non-fuel mineral production are not strictly geological, but rather are due to a downturn in the prices of metals, taxation, complex State regulatory environment, pressures from land developers, land withdrawals in some prospective areas, and the dislike of mining by many of the people in Colorado. The State is recognized by the mining industry as a place in which it is difficult to do business.

The non-fuel minerals industry believes that the Colorado Geological Survey needs to take a more proactive role in developing the State's mineral resources.

## Oil, Natural Gas and Carbon-dioxide (CO<sub>2</sub>)

The resource potential of oil, natural gas and CO<sub>2</sub> in Colorado is very large, especially for natural gas. As the United States continues to increase its reliance on natural gas, the exploration and development potential in Colorado is immediate. CO<sub>2</sub> is a naturally occurring gas that is used for pressure maintenance in oil fields, primarily in west Texas. With an increased emphasis on enhanced recovery, CO<sub>2</sub> has become a new focus for exploration. It occurs in the subsurface in the same types of situations as oil or natural gas, and is produced in both southeastern and southwestern Colorado.

A subcommittee of the CGSAC's predecessor committee reviewed the potential for undiscovered oil, gas and CO<sub>2</sub> in Colorado in 1991. Based on the experience of the subcommittee members (five experienced Colorado petroleum geologists), their review and analysis of the petroleum geology, and the exploration and development history of Colorado oil and gas plays, the group determined a most-likely undiscovered resource base of:

OIL	1,427,000,000 Barrels
GAS	20,548,000,000 MCF (MCF = thousand cubic feet)
CO <sub>2</sub>	4,560,000,000 MCF

with a value of approximately \$60 billion. These figures are comparable to reserve estimates generated by the US Geological Survey and the American Association of Petroleum Geologists. This is a significant potential Colorado resource.

For comparison, Colorado produced over 31 million barrels of oil and over 251 million MCF of gas during 1991. The activity associated with

development of coalbed methane on the Western Slope has had a major impact on Colorado gas production (Rio Blanco and LaPlata Counties were the second and third highest gas producing counties in the State, following Weld County). At these production rates, the undiscovered oil resource represents 46 years of production, while the undiscovered gas resource would be produced over a period of 82 years.

## Coal

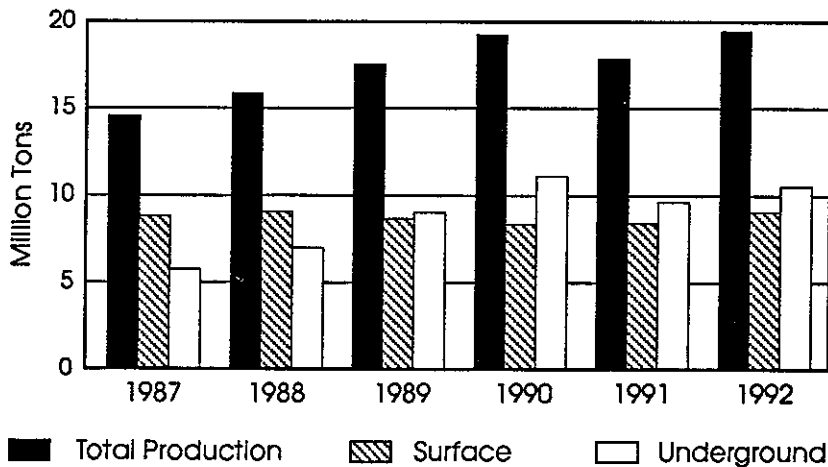
The market for Colorado coal remains competitive, with surplus production capacity—particularly in Wyoming's Powder River Basin—and depressed spot sales making it challenging for coal producers to earn profits. Growth has been slow. Nationwide, some coal companies are acquiring or consolidating with other mining companies, positioning themselves for business in the years ahead. Coal companies in the State experienced limited relief from depressed market conditions in the second half of 1993, due to the UMWA strike and flooding in the Midwest.

On May 25, 1993, Amax Inc. of New York and Cyprus Minerals Co. of Englewood, Colorado, announced plans to merge their operations. This merger will make Cyprus-Amax the second largest coal concern in the United States. Smaller coal companies are being bought by larger mining companies. In the future, there will be fewer independent coal operations and larger mining conglomerates.

Coal consumers impacted by the strike of eastern coal mines were driven west to find alternative coal supplies. The strike has created spot sale opportunities for Colorado coal producers, and these opportunities may continue as long as the UMWA strike persists. Colorado coal companies made other spot sales when flooding became a major problem this spring and summer in the Midwest. High waters cut some coal consumers off from their main suppliers, as railroads and waterways were blocked or submerged.

Coal production in Colorado has increased from 14 million tons in 1987 to 19 million tons in 1992. However, the number of coal mines in the State has dropped from 29 to 21 in the past seven years. The number of people employed in production and maintenance jobs at Colorado coal mines has dropped from 2,128 to 1,756 since 1987. The main area of growth is in underground mining. Underground mines surpassed production of surface coal mines in Colorado in 1989. In 1992, underground mines in Colorado produced 10.4 million tons of coal, compared to 8.9 million tons produced by surface coal mines. This growth in underground mining is attributed to the use of new longwall technology, combined with a 4.5 percent lower royalty rate on federal coal reserves mined using underground methods versus surface techniques.

## Colorado Coal Production 1987-1992



### Colorado Coal Industry—Tons Produced

	1987	1988	1989	1990	1991	1992
Total production	14,387,860	15,714,155	17,427,889	19,130,905	17,744,424	19,291,735
Surface	8,650,720	8,878,550	8,552,040	8,176,011	8,253,924	8,932,528
Underground	5,737,140	6,835,605	8,875,849	10,952,894	9,490,500	10,539,207

### Colorado

	1987	1988	1989	1990	1991	1992
Miners	2,128	2,186	2,027	2,141	1,571	1,758
Coal mines	29	28	24	24	24	21

## Non-Metallic Minerals

Gypsum production in 1992 at the Eagle Gypsum Mine in Eagle County was 280,000 tons and, according to a mine representative, is expected to grow by approximately 20 percent in 1993. Much of the gypsum produced goes to Colorado construction activities which have been enjoying substantial growth.

Changes in product marketing have resulted in plans for increased production from 20,000 tons to 60,000 tons of sodium bicarbonate at the White River Nahcolite Minerals company solution mine in Rio Blanco County. Commodities like gypsum and sodium bicarbonate are widespread in Colorado and, generally, do not require a significant exploration effort. Their potential is driven by the development of, and proximity to, active markets.

Exploration and development activities for diamonds in the State Line Kimberlite district in Larimer County have been increasing, primarily due to recent discoveries made in the Northwest Territories of Canada. The reevaluation of the known deposits and future discoveries will probably lead to the establishment of an economic diamond mine in northern Colorado.

## Sand, Gravel and Aggregate

Sand, gravel and aggregate industries in Colorado enjoyed a record year in 1992, producing 38 million tons. Supplies of known sand and gravel deposits close to markets in the Front Range are dwindling. The increased production demands caused by the new Denver International Airport and a housing construction boom is being met more often by aggregate quarries in the foothills of the Front Range. Most quarry operators believe that aggregate production will settle back to 22 to 26 million tons per year after the new airport is completed. This production level can be adequately met by existing quarries for the next five to ten years. Public opposition to new quarries in the foothills near major Front Range markets will continue and, if not modified, will eventually lead to supply shortages in growing Front Range communities, longer material hauls and increased costs to the consumer.

## Current Economic Development Promotion

Despite its dependence on cash-funding projects, the Colorado Geological Survey (CGS) has maintained limited efforts in economic development of mineral and mineral fuel resources. Funding for these projects has been obtained by a variety of methods, but the dominant funding mechanism is through cooperative programs with other state geological surveys, usually with federal funding.

The CGS is currently involved with the following economic development activities:

## Oil and Gas

The Mineral Fuels staff has recently completed the Colorado portion of the *Atlas of Major Rocky Mountain Gas Reservoirs*. The atlas provides vital geological information to the natural gas exploration and development industry about existing fields in Colorado. Such information will likely be used to develop models and analogs to guide additional exploration or to improve production practices. The project was funded by the private sector Gas Research Institute and is a joint pro-

ject with the state surveys of New Mexico, Utah and Wyoming. The New Mexico Bureau of Mines and Mineral Resources will publish the atlas; the CGS will handle sales in Colorado.

The CGS joined a similar cooperative venture with the Kansas Geological Survey (KGS) and other adjoining states. The KGS submitted a proposal to the U.S. Department of Energy (DOE) to produce an atlas of mid-continent oil fields. The atlas would inventory and analyze existing oil fields and identify geological factors that can optimize economic recovery from existing oil fields. However, the DOE declined to fund the project at this time.

The CGS pioneered and continues research on coalbed methane in the San Juan, Piceance and Sand Wash Basins, Western Slope. Current activity is funded by the Gas Research Institute through a grant administered by the Texas Bureau of Economic Geology.

## Coal

The U.S. Geological Survey underwrites the CGS effort of compiling geochemical data on coal beds throughout the State. As part of the National Coal Resource Data Systems (NCRDS) Program, the CGS inventories and analyzes geochemical data on Colorado's coal. At present, the CGS is evaluating the best way to make such data available to coal buyers from the eastern U.S. because of the clean-burning nature of Colorado coals. Whether provided as a database to coal utilities or as a marketing tool to Colorado coal producers, the coal analysis database will be a useful tool in making coal buyers aware of the positive attributes of Colorado coal.

## Minerals

The CGS Minerals staff is involved with several projects for the Colorado State Land Board to provide assessments of potential for mineral resource occurrences on State Lands. Continuation of this work could result in a Map Series showing the distribution of metallic elements throughout the State, which would be useful to both land managers and explorationists.

In keeping with the desire to promote environmentally responsible development of mineral resources, the CGS has done some preliminary work on the topic of acid metal drainage in pre-mining settings. The CGS has begun work on baseline studies of pre-mining water quality. The project is funded by the EPA and is being done in cooperation with several other agencies in the Department of Natural Resources.

In 1991, the Minerals staff contacted several mining companies about joining a consortium to provide studies of ore deposits associated

with igneous alkalic rocks in Colorado. Although there was only limited participation, work was completed on two chapters of a proposed publication. The second year of the Minerals Consortium has begun, and two more chapters will be written and made available. A survey was included with this year's membership letter and communication with mining companies has begun in an attempt to make the research efforts meaningful, pertinent and useful to the Colorado mining industry.

## Geothermal

Work continues on a review and inventory of the physical and chemical properties and usage of geothermal resources in Colorado. The project is funded by the U.S. Department of Energy through the University of Utah Research Institute. A database will be created and made available to encourage development of geothermal resources.

## Geological Field Mapping

The fundamental cornerstone to economic development of mineral or natural resources is geological mapping. Mapping is also essential to make reasonable land use decisions and evaluate environmental concerns related to development. It also is a critical tool for public safety in the sound development of land subject to geological hazards such as landslides, swelling soils, avalanches, earthquakes, etc. The CGS has done little mapping in the recent past, due to a lack of funding. In September 1993, field mapping commenced in the Glenwood Springs area as a result of winning a U.S. Geological Survey grant. With passage of the National Geological Mapping Act, the CGS has an opportunity to begin providing this essential service to local government, state agency planners and industry. The STATEMAP portion of the National Geological Mapping Act provides federal funds to match state funds put into the mapping projects. The CGS can effectively match the small federal grant in 1993, but continuation of the project will require the investment of new or reallocated dollars in 1994 and beyond.

## How The CGS Can Improve Its Economic Development Efforts

Economic development work being done by the CGS is sound and generally useful. Its shortcomings are in distribution of results and in the Survey's inability to tailor the work specifically to Colorado's needs. These problems are related in that they result from insufficient resources.

Since much of the economic development of natural resources being undertaken in Colorado is done by small companies, projects must be built with the small company's needs in mind. These companies don't have research departments or big budgets for data purchases. Public documents or reasonably priced data are essential to these small companies. Widespread distribution of CGS information is important to help these small companies be aware of and effectively use the results of CGS studies. Distribution of CGS results costs money and is not always possible under the current cash-funding scenario.

Lack of research budgets means that small companies may be interested in reasonably priced cooperative ventures. Development of such projects takes the time and effort of CGS scientists. Cash-funding, which forces the CGS scientist to always be working on a specific project or contract, does not allow for the development of new concepts that can be sold to industry on a cooperative basis.

Finally, since CGS scientists have little in the way of project development resources, even when federal projects include Colorado, the CGS is in a sub-contractor position. Work is farmed out to the CGS by Texas, New Mexico, Utah and other state geological surveys and may have a focus that is not pertinent to Colorado problems or interests. In recent times, the CGS has not had the resources to develop its own Colorado-focused research. It is our belief that significant amounts of economic development work can be cash-funded, but it is essential that seed money be available to develop the projects and proposals that will then generate cash-funding. Regardless whether that cash-funding comes from private industrial consortia or from federal programs, the time and money to develop proposals, ensure that the work relates to Colorado problems and needs, and then tailor the proposal to the appropriate funding entity are required. There are ample data to suggest that state seed money investments are more than returned to state coffers through severance taxes, corporate and personal taxes and other revenues.

## Potential for an Expanded Future Economic Development Promotion Program

Increased funding for the CGS is the key to expansion of economic development work by the CGS. In view of Colorado's financial status and the resulting limitations on direct appropriation monies, ways of largely cash-funding these projects must be found. As noted previously, this will be possible if relatively small amounts of seed money are provided by direct appropriation to finance the design and promotion (i.e., "selling") of economic development project proposals. The size and nature of eventual economic payoffs resulting from

successful projects should be kept in mind when requests for seed money are considered, as the CGS is one of the few State agencies where a large return can be obtained on a relatively small investment of State funds.

The CGSAC believes that with proper planning and effective promotion to prospective funding resources, the CGS will be able to gradually expand an effective economic development program on an almost entirely cash-funded basis. Some programs may be multi-year requiring seed money only at the beginning. And, as the CGS regains a reputation for competency in this area, the potential for obtaining greater amounts of future cash-funding will gradually develop, with the need for seed money appropriations diminishing.

All economic development promotion work will probably not be done by CGS staff. Rather, the CGS might function mainly as a managerial agency for economic development project activities, with responsibilities for design, promotion, and fund-raising for specifically designed and targeted projects. Frequently, the actual project work might be done on contract by geologists expert in the program subject area who could be private-sector consultants and/or geology department staff members at Colorado universities. Joint CGS/university projects may sometimes be inhibited by the high overhead factors used by universities in determination of research project costs in comparison to the lower CGS overhead. However, universities are often effective in obtaining cash-funding. Thus, some CGS projects might be conceived, designed and sold on a collaborative basis with geology department staff members, or with consultants.

Sources of cash-funding, whether state, federal or private-sector, vary with the type of project to be undertaken.

## State-Funded Economic Development Promotion Projects (EDPPs)

The CGS has on-going programs in three areas which affect the health, safety and economic well-being of Colorado's citizens. They are largely State-funded, with some local government, federal and private sector funding sporadically available. Potential for increased funding from the latter three sources may exist, with proper planning and presentation.

- 1) Swelling and unstable soils research and remediation is currently funded internally by the CGS with limited outside funding. High-priority needs exist because it is a problem which affects the economic welfare of many Coloradans. Current and future problems in the Pierre/Mancos shale outcrop areas affecting both new and existing construction constitute one of Colorado's "dirty little secrets." Although millions of dollars of uninsured damages affecting individual citizens have occurred and still occur, only

limited funds are available to the CGS to study the problem and recommend means of avoidance and remediation. Affected local governments and the construction industry could offer more support, and, as these problems are not limited to Colorado, federal co-funding should be sought.

- 2) Rockfall, landslide and mudflow study recognition and remediation work by the CGS is largely funded by the Colorado Department of Transportation. Some federal funding is obtained via the US Forest Service. As these problems are not unique to Colorado, expanded federal support is justifiable. Ways of maintaining or expanding cash-funding for these projects must be explored.
- 3) The Colorado Avalanche Information Center (CAIC), a unique program among state governments in the United States, provides forecasting, monitoring and educational programs for mitigating avalanche hazards, which are defined by Colorado statutes as geologic hazards. The CAIC operates entirely on cash-funding obtained from some 30 sponsors in government and industry. Sponsors include the ski industry, local governments, federal agencies, citizens' groups, and other state agencies, such as the Colorado Department of Transportation and the Division of Parks. Significant in-kind contributions come from federal agencies, industry and individual volunteers across Colorado.

There is potential for growth and new sources of support as CAIC becomes involved with the Colorado Transportation Institute and its university consortia on avalanche detection work. Because of the international interest in the work done by CAIC, there is potential for some cooperative work with similar agencies in countries like Canada, France and Switzerland.

Promotion of expanded natural resource exploration and exploitation on State Lands has received only sporadic attention and effort in recent years, even though this is a statutory responsibility of the CGS, the Oil and Gas Conservation Commission (OGCC), and the State Land Board (SLB). The State owns 4,038,600 mineral acres, of which about 25 percent are currently under lease. About 5 percent are productive of oil, gas, minerals, coal, sand or gravel. Potential for both near-term and long-term projects designed to increase leasing, exploration and eventually production of oil and gas from State Lands has been discussed with OGCC and SLB representatives. SLB has funds available for projects which would encourage exploration activity and potentially generate additional cash flow. OGCC theoretically has funds for these purposes as well. Some State Lands in the mountains still have metallic mineral potential.

State Lands have oil and gas potential of three types:

- 1) Horizontal drilling prospects, mainly for oil, in and along the flanks of the Denver and North Park basins. Oil has been pro-

duced from stratigraphic traps in the 'D' and 'J' sandstones of the Denver basin since the late 1940s. Some of the old fields might be rejuvenated by horizontally- drilled wells. State Lands are scattered throughout the Denver basin. State Lands in large tracts also lie along the southeastern Denver basin flank, formed by the Las Animas Arch. Oil-bearing strata there may benefit from horizontal drilling as well. The Niobrara formation along the western Denver basin flank and in North Park may also have horizontal drilling potential. However, oil industry interest and activity are at a sufficiently high level in the areas with Niobrara potential that State promotional activity is probably not necessary at present.

- 2) Frontier exploration for natural gas could involve large amounts of unleased, unproductive State Lands in northwestern and west-central Colorado and, especially, the southern Denver basin. Western Slope gas exploration and production activities are currently at satisfactory levels. State-funded promotional efforts would probably increase activities here, but the time and effort might better be spent on the southern Denver basin. Potential for oil production is not great in this area, but possibly extensive natural gas prospects may exist in this lightly-explored area, where State-owned mineral rights are extensive. Natural gas oriented projects proposed and partially funded by these State agencies might attract federal or private sector cash-funding as well.
- 3) Enhanced recovery is a term used to describe the concept or activity of obtaining additional oil and gas production from depleted or declining oil fields. These older fields may still be marginally productive or abandoned. Most Colorado oil and gas reservoirs are "tight," which means that it is difficult for the oil and gas to migrate through the reservoir to the well. This results in most of the oil and gas being left in the reservoir unproduced and *available for enhanced recovery*. Most of the oil and gas produced in both Colorado and the U.S. in the future will be obtained by enhanced recovery methods. Some methods are not new, going back to the 1940s. But new methods and concepts, often based upon detailed study of "reservoir architecture" continue to appear. The Department of Energy and some private sector industrial consortiums and research institutes fund both basic and applied research involving tight reservoirs. State geological surveys are increasingly involved in cash-funded enhanced recovery reservoir studies.

Additional potential for State-funded joint ventures involving the CGS together with the State Parks and tourism agencies may emerge as Amendment 8 funds become available for state park development. Interest in dinosaurs shows no evidence of diminishment. Exploitation of Colorado's "dinosaur resources," including establishment of new State Parks, might involve CGS personnel.

## Federal-funded EDPPs

Two major sources of federal funding for CGS economic development projects are the U.S. Geological Survey (USGS) and the US Department of Energy (DOE). The U.S. Forest Service, the Bureau of Land Management, the Minerals Management Service and the Environmental Protection Agency also occasionally fund geologic research by state geological surveys. Federal funds made-up 18.5 percent of CGS revenues in 1989-90 and 17.5 percent in 1990-91.

**USGS**—CGS-USGS activities within Colorado are typically jointly funded, often on a 50-50 basis. This is the case with the current surface mapping project. The USGS has supplied \$10,000 to the CGS in 1993 for this project, which the CGS, lacking a State appropriation, must match with internal funds. Beyond surface mapping, some CGS-USGS joint projects have been partly to completely funded by the USGS. Recent examples are a CO<sub>2</sub> program, a Lower Paleozoic stratigraphy study, the multi-year National Coal Resource Data program, and a COGEOMAP landslide study of the Douglas Pass-Baxter Pass area. Multi-state USGS programs involving several state surveys are theoretically 100 percent USGS-funded, but sometimes require State funding "for completion."

**DOE**—The U.S. Department of Energy provides funding for oil and gas resource studies, and has become a major funding source for state geological surveys in recent years. Typically, multi-state projects are jointly undertaken by several state geological surveys. Ordinarily, one state takes the lead, designs a project that involves other state surveys as sub-contractors, and applies to the DOE for funding. The DOE usually funds 100 percent of a multi-state project, but commonly less for a single-state project. The CGS joined a multi-state project proposal led by the Kansas Geological Survey to produce an atlas of mid-continent oil fields. However, the DOE has declined to fund the proposal at this time.

Due to a lack of appropriated seed money, the CGS has not been able to take a leadership role in proposals to DOE, and has been limited to sub-contractual work. Additional regional multi-state projects and similar in-state natural gas projects could provide opportunities for substantial DOE funding of CGS-led economic development projects in the future. The DOE also supplies funds for a continuing geothermal program, led by the Utah Research Institute, for which the CGS is a sub-contractor.

**U.S. Forest Service**—The CGS started a multi-year, abandoned-mine inventory program in 1992 funded by the Forest Service.

## Private-Sector-Funded EDPPs

Economic development project work by state geological surveys dealing with any natural resource—metals, petroleum, coal, etc.—can be

funded by private sector sources. Oil and gas projects are the most common at present among state geological surveys. The CGS has a small but active minerals industry consortium funding basic research on alkalic rocks. Planning is in progress to build a petroleum industry consortium.

Extensive reorganization and reorientation of the international petroleum industry has taken place during the past decade. Crude oil prices remain at levels too low to justify exploration in most of the U.S. Surplus U.S. natural gas production capacity depressed prices, and hence drilling, until recently. Gas drilling has started to increase, but a "boom" is neither expected nor possible. Smaller and less profitable than in the past, the petroleum industry has reduced in-house research by individual companies on exploration and development problems. Private and public sector research organizations, including universities and state geological surveys, now perform increasing amounts of petroleum industry research. This offers new opportunities for state geological surveys, including the CGS.

Funding for petroleum industry studies and research comes from two types of sources. Individual companies may directly fund specific research objectives, and consortia of major and independent companies sometimes subsidize more generalized basic or applied research. Research institutes funded directly or indirectly by the petroleum industry also finance both research and data compilation projects, mainly in the natural gas area. Gas Research Institute (GRI), Institute for Gas Technology (IGT) and the American Petroleum Institute (API) are the most prominent.

Research project proposals may be originated by industry or research institutes and contracted to researchers, or may be originated by research organizations and sold to industry or a research institute. Subjects of current private-sector-funded studies by state geological surveys include:

#### GRI/IGT/API

- ❖ abandoned well characterization study
- ❖ gas reservoir and field studies \*
- ❖ fluvial deltaic reservoir studies
- ❖ tight carbonate reservoir studies
- ❖ gas reserve growth potential
- ❖ critical production criteria for coalbed methane \*
- ❖ gas well testing programs

#### Industry/Industrial Consortia

- ❖ basic geodynamic research
- ❖ depositional system/ structural development relationships
- ❖ Ferron sandstone depositional study, Utah
- ❖ light oil recovery studies
- ❖ hydrogeologic characterization
- ❖ aerial photograph utilization

- ❖ petroleum reservoir classification
- ❖ completion techniques, Green River and Wasatch Formations, Utah

\* CGS involved as sub-contractor

(Two of the projects listed above are in Utah because the Utah survey has a very aggressive program to obtain cash-funding for their petroleum-oriented projects, as does Texas.)

Subjects and problems investigated are often located in states other than the state of the lead investigator state geological survey. In the past, the CGS has been a sub-contractor for programs managed by other state surveys but involving Colorado geology. Lack of available funds preclude the design of proposals for CGS-led projects. The availability of relatively small amounts of seed money for project design and promotion would allow the CGS to compete for private sector and Federal contracts, on either a sole-source basis or as lead investigator for multi-state projects.

## Survey of Colorado's Geological Community

A questionnaire was widely distributed to Colorado geologists by the CGSAC and the CGS in connection with this report. The purpose of the survey was to determine whether members of the resource industries in Colorado, primarily geologists, would support a greater effort by the CGS in economic development promotion, how this support might be obtained, and to obtain suggestions of specific projects for CGS consideration. A copy of the questionnaire is included as Appendix A. Questionnaire recipients were asked:

- 1) to specify and suggest types of economic development projects which might be undertaken by the CGS if funding was available,
- 2) whether they or their company would provide funds, data and/or time/effort to such projects and
- 3) whether they would support and join a joint CGS/resource industry committee to aid and support economic development projects by the CGS.

At the time this report was written, 174 questionnaires had been returned, with about three per week still coming in. Among the respondents, 46 percent are in oil and gas, 24 percent in mining, 18 percent in government (mainly USGS) and 12 percent in other specialties—hydrogeology, engineering geology, environmental geology or computer-application specialties. Strong support is indicated for expanded CGS activities in the resource development area, although a number are concerned that such activities should not directly compete with private-sector consultants. Numerous specific projects were

proposed for CGS consideration, ranging from simple compilations of geologic data or production statistics through regional resource studies, maps and cross-sections to a few esoteric, "off-the-wall" projects. In addition, an unexpected suggestion made by many respondents is that the CGS should make an effort to educate Colorado's citizens on the economic and social value of resource production industries (especially natural gas), on how these resources can be developed in an environmentally-sound basis, and the ultimate costs of non-development. Many more worthwhile projects have been suggested than the CGS will be able to undertake. Compilations of basic production, geologic and statistical data were most commonly requested; as the cost of data compilations is relatively low, they are potentially very worth while. Geologic field mapping also received strong support. Projects in applied research for resource exploration are also popular, but tend to be more expensive and must ordinarily be cash-funded. Many respondents were willing to volunteer considerable time, effort and data to CGS projects, to lobby for their financial support, and in a few cases, to supply funding.

## CGS/Industry Joint Committee On Economic Development

Many survey respondents stated a willingness to provide active support for CGS economic development projects, including participation in a CGS/Industry Joint Committee on Economic Development. Working closely with the CGS and the CGSAC, the Joint Committee would help identify, discuss, plan and implement economic development projects to be undertaken by the CGS. The large number of projects suggested in the questionnaire provide a beginning. Serious consideration should be given to organization of such a committee.

## Funding—The Key Issue

Resource data compilations and analyses, surface geologic mapping and applied research in resource exploration and development subjects are the project types favored by many questionnaire respondents. A number are willing to contribute time, effort and data to CGS projects in these areas. Many specific projects were suggested. But only a handful were willing to supply funding to these projects, although many would purchase copies of maps, studies and reports produced. This lack of financial support "up-front" is not surprising, as most respondents are consultants, independent geologists or employees of small resource companies or the USGS. So, while local private sector funding for specifically-proposed projects may some-

times be obtained from large petroleum and mining companies and from industrial consortia, additional sources of seed money necessary to conceive, design and sell projects depending upon federal or research institute funding will be necessary if the CGS is to meet its responsibilities.

If the Colorado General Assembly wishes to promote responsible economic development projects in areas welcoming exploration and development activities, the CGS can play an important role. Annual seed money cost would not be great—one additional fully funded FTE in the first four or five years of an expanded EDP program. Consideration should be given to allocation of a portion of annual severance tax and/or federal royalty revenues to the CGS, as CGS economic development activities indirectly support and enhance these revenues. Alternatively, many economic development projects could be targeted at specific areas of one, two or several counties. One source of seed money funding might be an agreed portion of the severance tax and/or federal royalties revenues received by the counties involved. The State Land Board and OGCC might sometimes supply additional funds. With more than one project in the design and promotion stage by the CGS, the annual revenues supplied per county for seed money purposes could be low and subject to a cap in terms of total amount or years. The Colorado General Assembly might wish to consider direct appropriation matching of funds supplied by counties. Industrial consortia, if organized for multiple-year project funding, might be an additional source of seed money supplemental to State and county funding.

The CGSAC and CGS are confident that multi-year funding for natural gas-oriented economic development projects could be obtained from federal and research institute sources, with the CGS acting as lead-contractor. But, before this can be done, the projects must be conceived, designed and sold to the funding agencies. One FTE, however funded, should be enough to do the job. Eventual return, in increased employment and tax revenues, and lower cost, in-state sources of clean energy, could easily supply modest but absolutely necessary seed money.

## CGSAC Recommendations

In order to obtain more effective and efficient development of Colorado's lands and natural resources for the benefit of the State and its citizens, it is recommended that CGS, DNR and the Colorado General Assembly consider the following:

- 1) The CGS should educate Colorado's citizens on the importance, economically and socially, of environmentally-sound natural resource development.

- 2) The CGS should increase activities designed to fulfill its statutory responsibility for economic development promotion of Colorado's natural resources. Projects undertaken should serve broad industrial constituencies and not be competitive with private-sector consultants.
- 3) Emphasis should be placed on projects with immediate economic impact, whether in land use, natural gas development or promotion of increased exploration and production from the State Lands.
- 4) Strategic application of seed money funding would allow the CGS to create, design and obtain cash-funding for economic development projects from industrial consortia, research institutes and federal sources. Seed money funding would permit the CGS to act as a lead-contractor on such projects, rather than the sub-contractor. Consistent seed money funding could be most easily obtained by the addition of one direct-funded FTE for a four or five year period, specifically to set-up and operate ultimately cash-funded economic development projects and to establish CGS credibility in this area.
- 5) The CGS should help design and cooperate in joint programs with the Oil and Gas Conservation and State Land Board, funded by the latter two, to encourage expanded natural resource exploration and development on State-owned lands.
- 6) The Colorado General Assembly is encouraged to consider a) whether a portion of severance tax and/or federal royalty revenues should be permanently allocated to the CGS, or b) together with local governments, whether a share of county/group of counties severance tax and/or federal royalty revenues should sometimes be allocated and used to cash-fund specific CGS activities in the economic development and related geologic hazard areas in that county. Such funds would be allocated and used for specific projects, and not for long-term continued funding. Further such funds might be allocated on a matching fund basis, to be matched from federal, State, industrial, foundation and other third-party sources.
- 7) The CGS and DNR should undertake the formation of the CGS/Industry Joint Committee on Economic Development, and select members for this Committee from Resource Industry Survey volunteers.
- 8) Unconscious, unthinking actions of the past often caused problems that we must deal with in the present. An example is the manner in which the Colorado Mineral Belt was exploited during the nineteenth century. Economic benefits were obtained then, but now Colorado must solve problems that resulted from the development methods used in that era. Care must be taken to ensure

that the resulting current attitudes critical to resource development are not allowed to adversely affect future generations of Coloradoans. Development of the States's resources in an *environmentally responsible manner* must continue if a balanced economy beneficial to ALL Colorado citizens, urban and especially rural, is to be maintained and improved.

