UNITED STATES DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

The National Mineral Resource Surveys Program

A Plan for
Mineral-Resource and Mineral-Environmental Research
for National Land-Use, Environmental, and
Mineral-Supply Decision Making

by

U.S. Geological Survey
National Plan Committee*

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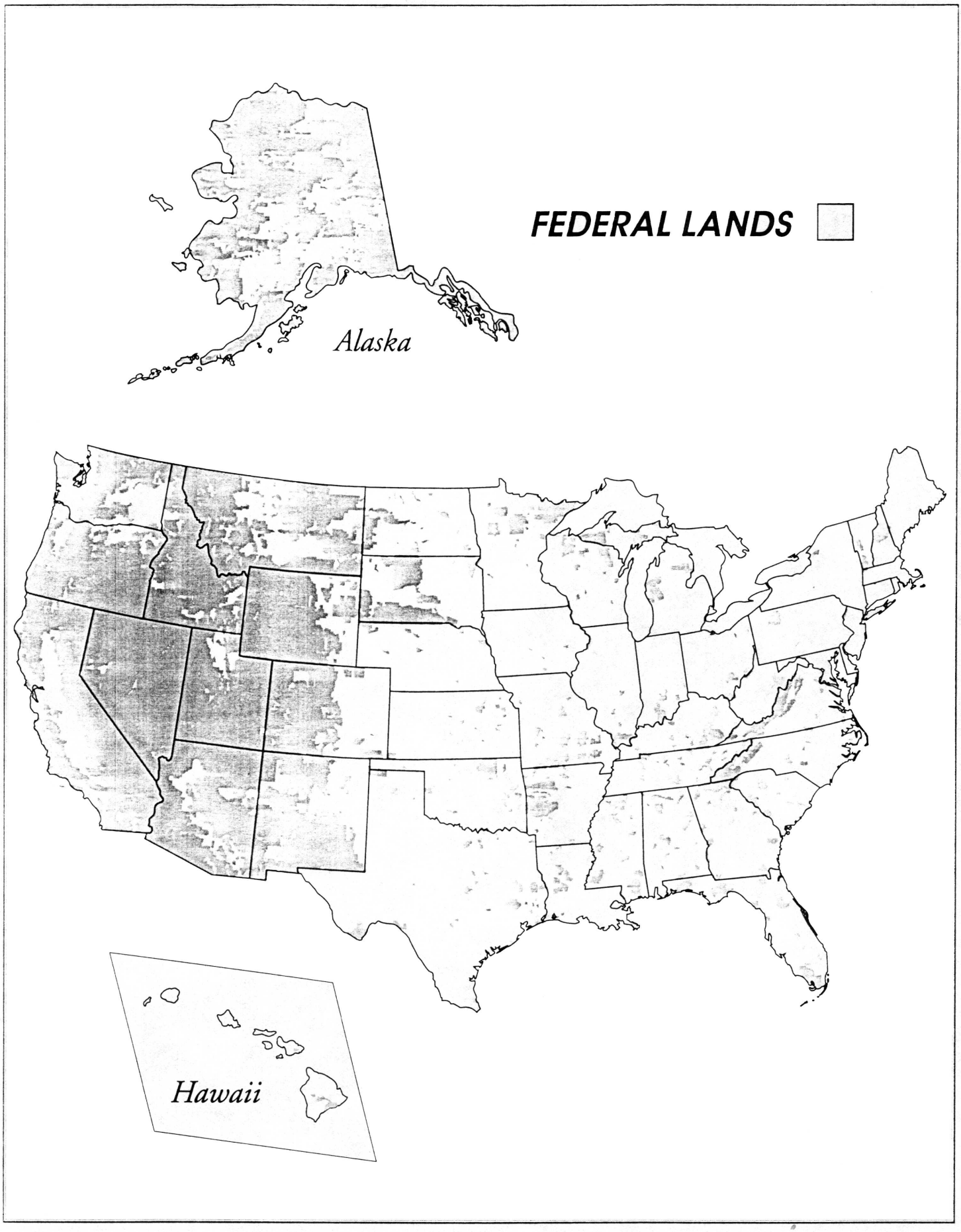

FEDERAL LANDS
Alaska
Hawaii

EXECUTIVE SUMMARY

The United States is continually faced with important decisions regarding the use of Federal lands, environmental protection, and supply of mineral raw materials. The Nation's 740 million acres of public lands have been, and are likely to continue to be, a source for a large share of U.S. mineral production. Land-managing agencies must develop land-use plans that reconcile competing demands for mining and other human activities, while recognizing environmental values and ensuring the sustainability of resources and natural environments. Thus, the Nation's need for minerals must be balanced with environmentally sound methods for extraction.

Although mineral supplies are currently abundant, new resource development will be necessary as deposits are depleted. Also, future shortages may occur as demand for resources increases, local or regional political instability curtails supplies, and environmental concerns further restrict mining. The United States must continue to monitor global sources of minerals so that possible shortages are anticipated sufficiently in advance to allow alternative sources or materials to be identified and secured. Our ability to make informed decisions concerning land stewardship, mitigation, and mineral supply ultimately depends on having current, accurate, unbiased information on the location, quality, and quantity of mineral resources, and on the environmental consequences of their development.

These national issues are addressed by the U.S. Geological Survey's (USGS) Mineral Resource Surveys Program (MRSP), which provides objective scientific information to Congress, Federal and State agencies, industry, and the general public on all aspects of mineral resources. In the committee report accompanying the FY 1995 Department of the Interior appropriations bill, the U.S. Congress directed the USGS to develop a program plan for mineral-resource activities. This document presents a comprehensive, balanced, and integrated 5-year plan to address key mineral-resource issues, increase our understanding of the processes that form and destroy mineral deposits, and improve our predictive capabilities to help guide the sustainable development of the Nation's mineral resources and maintain its natural environments. The plan has been reviewed by the USGS, the Department of the Interior, other Federal agencies, and State institutions.

Research activities of the Mineral Resource Surveys Program are conducted under four complementary, issue-related subprograms (fig. A): Assessments, Mitigation Studies, Resource Investigations, and Information and Technology Transfer. These subprograms, although responding to different issues, are interrelated and mutually supporting (fig. B). The program structure is designed to eliminate duplication so that information and knowledge acquired by activities conducted under each subprogram are available to all other subprograms. The subprograms are prioritized into a 5-year plan on the basis of national needs (fig. C), redirecting appropriated funds within the MRSP to better address the major minerals-related issues facing the Nation.

- **Assessments** will remain the core focus of the MRSP (fig. C), reflecting the continued commitment to meeting the priority needs and requests for mineral-resource and mineral-environmental information by Federal land-managing agencies. The USGS works in partnership with the U.S. Bureau of Mines (USBM), Bureau of Land Management (BLM), U.S. Forest Service (FS), and other Federal agencies, to conduct and coordinate assessment and related earth-science studies on Federal lands, primarily in response to priorities set by the land-managing agencies. Integrated mineral-resource and mineral-environmental assessments provide the agencies with information on known mineral deposits, predict the probable location and quantity of undiscovered mineral resources, and anticipate the kinds of environmental effects that could result from minerals development.

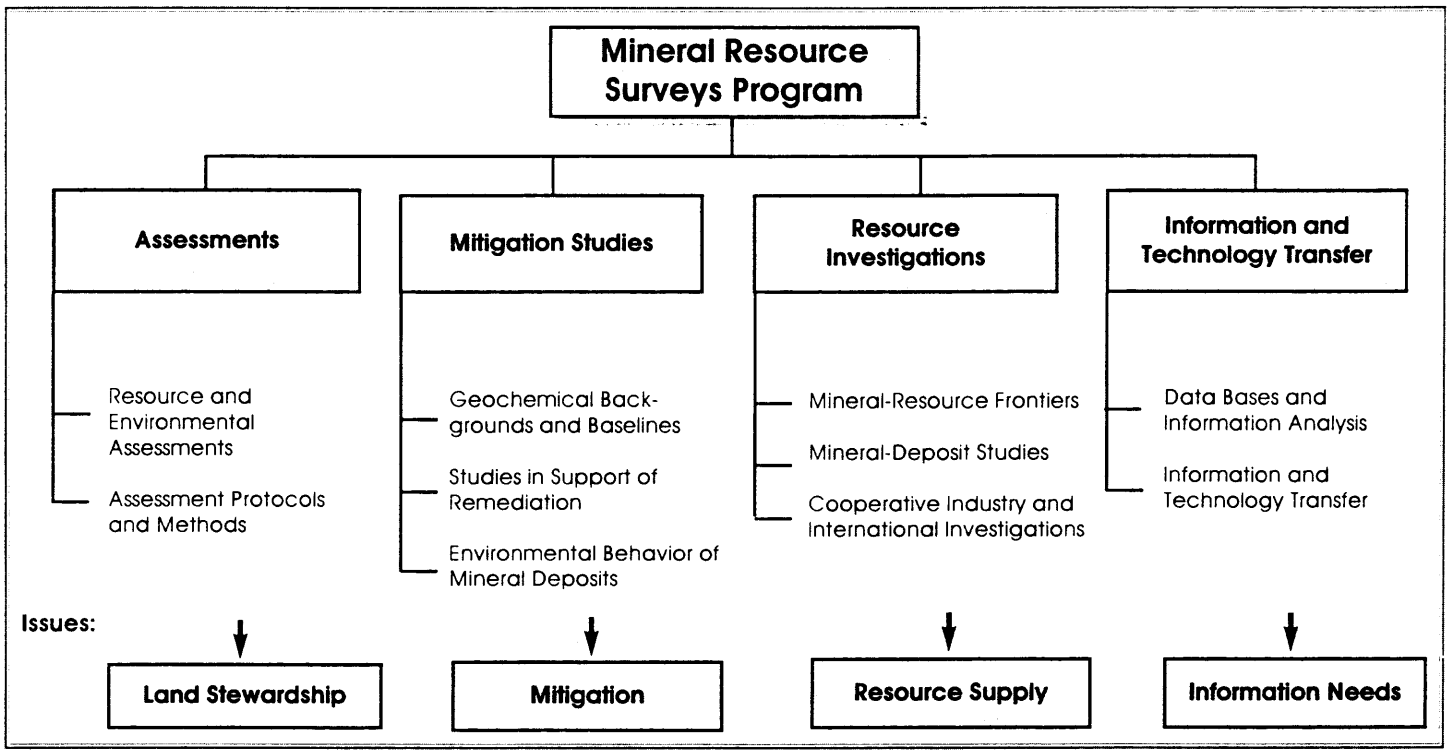


Figure A. Organization of the Mineral Resource Surveys Program

The USGS conducts recurring regional and national assessments to (1) increase knowledge of known and undiscovered mineral resources and their environmental characteristics at regional scales nationwide, (2) develop and improve national digital data bases, and (3) provide quick response to requests from Congress, Federal and State land-managing agencies, industry, and the public for minerals-related information. Mineral-environmental assessments are a new component of the MRSP and were developed in response to requests by Federal land managers. A priority of this 5-year plan is to fully develop the capabilities necessary to meet these priority requests.

- **Mitigation Studies** will increase during this 5-year plan (fig. C). This increasing emphasis is in response to: (1) requests from Federal land-managing and regulatory agencies for information to assist them in the mitigation and remediation of environmental impacts of minerals development; (2) Congressional concerns regarding possible environmental hazards associated with inactive and abandoned mine lands, many of which are located on Federal lands; and (3) the need to improve predictive capabilities regarding the environmental impacts of mineral resources and their development. Mitigation Studies provide information to assist governmental efforts to identify hazards on inactive and abandoned mine lands on public lands, to determine their impact on humans and the environment, and to formulate solutions to mitigate their impact. The studies reduce costs by scientifically determining the extent and character of environmental impacts as a basis for developing effective controls. Priority activities include:

  - Development of regional baseline geochemical maps for major areas of inactive and abandoned mines in the United States to assist Federal and State agencies in establishing priorities for reclamation;
  - Development of improved methods to compare and distinguish between natural and human-induced chemical distributions;

- Investigations into geologic constraints on remediation plans for priority Federal clean-up sites;
- Development of geoenvironmental deposit models that characterize the environmental behavior of particular mineral-deposit types to improve predictive capabilities.

The scientific information resulting from these investigations assists Federal and State regulatory and land-managing agencies, as well as industry, to more effectively manage the Nation's lands and resources, develop resources in environmentally responsible ways, maintain cleaner water supplies, and design more cost-effective remediation plans.

- **Resource Investigations** will decrease during this 5-year plan (fig. C). This decreasing emphasis reflects: (1) the changing priorities of government and industry for increased information on mineral-environmental issues; (2) an immediate need to build mineral-environmental capabilities in other areas of the program to meet client requests; (3) the availability of a large base of mineral-resource information and knowledge gained through 116 years of USGS research; and (4) a current supply of metals generally adequate for short-term needs. The USGS continues to be at the forefront in development of new mineral-deposit concepts and in identifying new regions of mineral-resource potential. This frontier research provides theoretical and conceptual models to improve capabilities to predict where future mineral resources may be found and the kinds of deposits likely to host those resources. Such research is not generally undertaken by the private sector, which focuses its efforts on well-known deposit types in more traditional mineral-producing regions that have more immediate prospect for financial return. Priority mineral-resource investigations include:

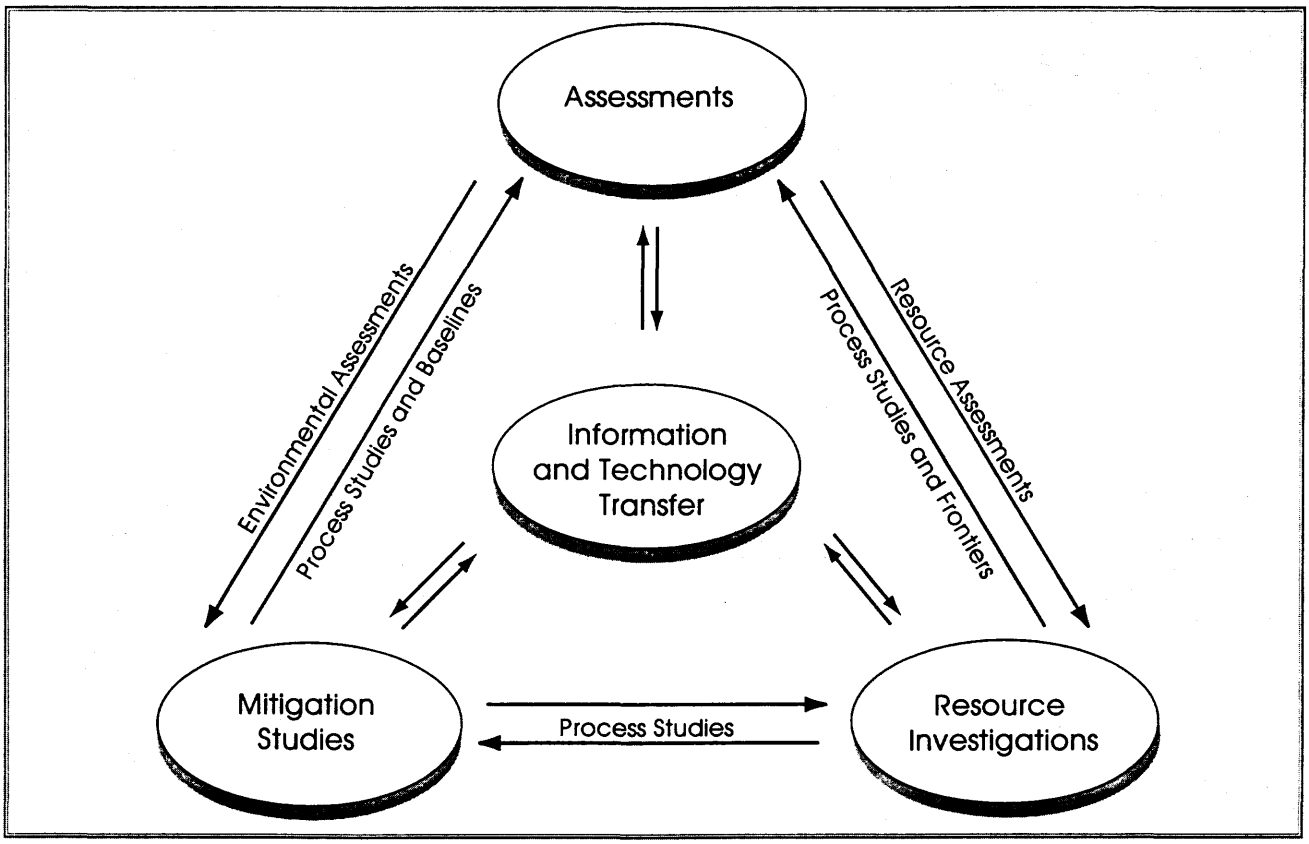


Figure B. Interrelationships between subprograms of the Mineral Resource Surveys Program

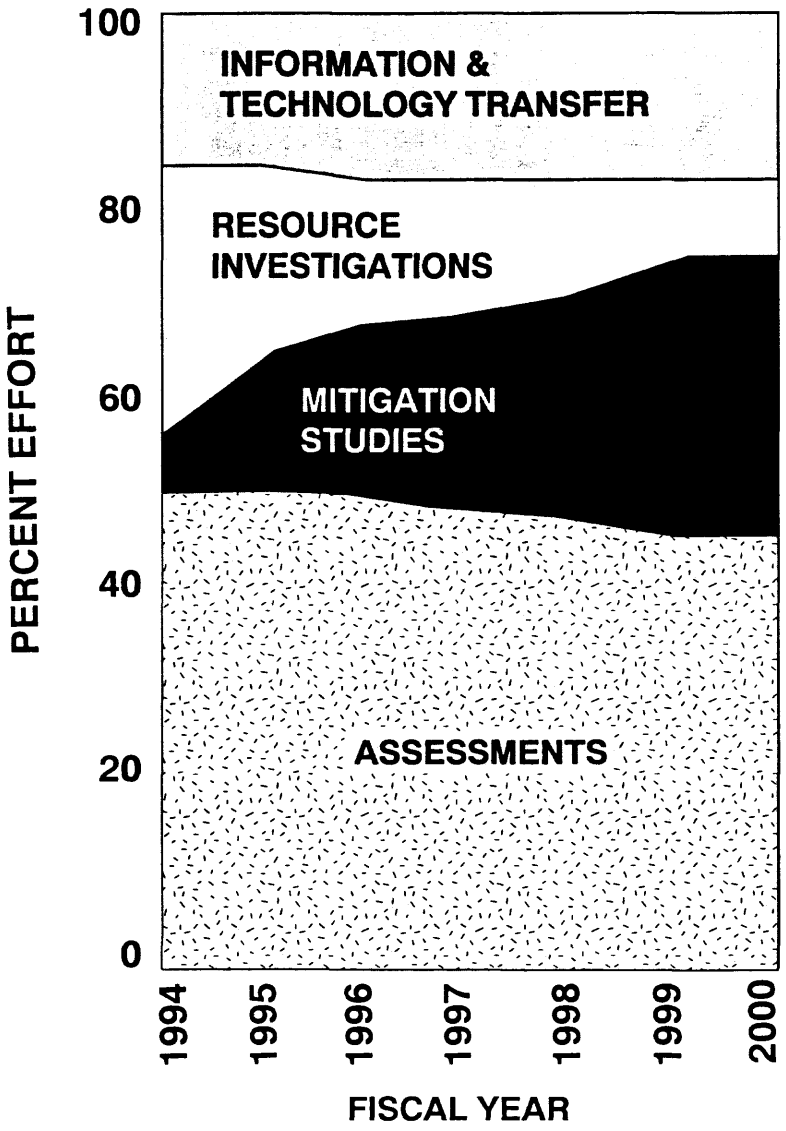


Figure C. Approximate percentage of effort in each of the four subprograms of the MRSP

- Development of new theories of mineral-deposit formation to define new and unconventional deposit types;
- Studies of selected mineral districts and regions to test new theories of mineral deposit formation and define new areas with potential for undiscovered mineral resources;
- Development of new mineral-deposit models and revision of existing models, including tonnage and grade information for well-sampled deposits to improve predictive capabilities;
- Selective cooperative industry and international mineral-resource investigations to help maintain accurate and current global minerals information.

The information provided by USGS resource investigations aids the Federal Government in development of resource policies that maintain secure, reliable, and cost-effective supplies of mineral raw materials. The information also benefits the minerals industry by identifying new deposit types and regions for future exploration.

- **Information and Technology Transfer** will remain an important component of the program during this 5-year plan (fig. C). The development and efficient distribution of mineral-resource data bases in digital formats is a major priority of the program. It is also important to improve capabilities to interpret data through scientific visualization techniques such as Geographic Information Systems (GIS). The MRSP communicates with the users of minerals information to identify their information needs. USGS researchers work to anticipate national needs, identify emerging trends and minerals issues, and ensure that products are relevant and presented in formats appropriate for the user's needs. Important training and outreach activities include: (1) increasing understanding of the significance and limitations of mineral-resource data and information and (2) increasing awareness of local, regional, national, and global minerals-related issues.

INTRODUCTION

Human societies face momentous decisions concerning their control of many future activities that require understanding the Earth. Currently, the expanding world population requires more resources; faces increasing losses from natural hazards; and contributes to growing pollution of the air, water, and land.

National Research Council, "Solid-Earth Sciences and Society" (1993)

Purpose

This document presents a 5-year plan for research activities to be conducted by the Mineral Resource Surveys Program* of the U.S. Geological Survey (USGS). The program is designed to describe the occurrence, quality, and quantity of mineral resources, to understand the fundamental processes that create and modify them, and to develop predictive models that provide understanding of the Nation's mineral-resource endowment and the potential environmental consequences of their development. The program addresses issues of national importance, providing comprehensive information on national and global mineral resources for public benefit.

Issues—Stewardship, Mitigation, Supply, and Information

The USGS has been addressing mineral-related national issues since its inception in 1879. However, as society and the economy have evolved, these issues have expanded from the need to create wealth, jobs, and infrastructure to include the sustainable development of resources and protection of the environment. As the issues have expanded and priorities have changed, mineral-resource programs in the USGS have increased efforts to assist those who manage public lands and resources, set public health and safety standards, formulate economic policy, and minimize the environmental effects of minerals development, while continuing to provide information to maintain secure and reliable supplies of mineral raw materials. The present Mineral Resource Surveys Program addresses four interrelated issues:

- Stewardship of public lands and resources;
- Mitigation of environmental effects resulting from mineral development;
- Maintaining stable, long-term supply of mineral raw materials;
- Availability of timely, objective mineral information and analysis.

Each of these issues forms a theme around which the activities for the next 5 years will be organized.

Minerals and Land Stewardship

Effective stewardship of our lands and resources is a primary responsibility of the Department of the Interior and of vital concern to the Nation. Of the Nation's 2.3 billion acres of land, one-third (740 million acres) is under Federal management. These Federal lands have been, and are likely to continue to be, a source for a large share of U.S. mineral production. Land-managing agencies must develop land-use plans that reconcile competing demands for mining and other human activities, while recognizing environmental values and ensuring the sustainability of resources and natural environments.

Accurate, objective information that can be used to compare mineral resources with other natural, economic, and cultural resources is essential to the development of sound land-management plans. Mineral-resource information is further enhanced as a land-planning tool when expanded to include predictions of the location and types of environmental impacts that could result from mineral-resource development. With information on mineral resources and their possible environmental effects, land managers can judge both the economic benefits that result from mining and the environmental consequences of past, present, and future mineral production.

Congress has legislated that mineral-resource assessments be made on most Federal lands.

*Mineral Resource Surveys Subactivity of the Geological and Mineral Resource Surveys and Mapping Activity, U.S. Geological Survey

At the present time, an oversupply of many nonfuel commodities exists despite the fact that minerals are being consumed globally at an unprecedented rate. This disparity is partially due to demands that fluctuate more rapidly than supplies produced by the mining industry. ***Inevitably, the rate of discovery will decline, and shortfalls will emerge once more.*** *While each new technique or concept revives portions of the Earth as prospecting targets, the remaining virgin territories are disappearing.*

National Research Council, "Solid-Earth Sciences and Society" (1993)

However, of the almost three quarters of a billion acres of Federal land, only 248 million acres have been assessed in any detail (1:250,000 scale or larger). These assessments are critical because public lands in the United States are being proposed for wilderness classification or other restricted land uses without adequate information on the potential for the occurrence of mineral resources and on the environmental effects of active and abandoned mine sites. As a consequence, plans for sustainable resource development may be inaccurate or incomplete.

Mitigation of Environmental Effects of Minerals Development

The Nation's economic development and the environmental consequences of that development are ultimately reflected in the health of natural environments and the well-being and quality of life of its people. It is vital that future mining minimize environmental impacts while providing the mineral raw materials required to maintain the Nation's economy and security. Our national needs for mineral raw materials are met through a mixture of domestic and foreign mine production. As a result, there will continue to be mining and associated environmental consequences both in the United States and other countries. Further, there are several hundred thousand inactive and abandoned mine sites in the United States alone, many on Federal lands in the West. About half of the current 1,200 sites on the Superfund National Priority List are mine sites. The huge task of remediation of these sites could cost taxpayers many tens of billions of dollars.

Our ability to reduce the environmental impacts of minerals development and the costs of mitigation and remediation ultimately depends on scientific research into the geologic factors and processes that result in contamination and environmental degradation. Research on environmental aspects of mineral deposits and their geologic settings provides information needed to avoid potential post-development problems and to assess the environmental impacts of inactive and abandoned mine lands. The information is necessary for such groups as the U.S. Bureau of Mines to develop techniques that lessen the environmental impacts of mining or correct problems caused by previous development activity. Mineral-environmental information is also needed for private industry, as well as Federal and State regulatory and land-management agencies, to provide the resources required by the Nation while maintaining and restoring environmental quality in a fiscally efficient manner.

Mineral Supply and the Economic Prosperity of the Nation

The long-term economic health of the United States, its national security, and the competitiveness of its industries depend on a secure and reliable supply of mineral materials. Historically, U.S. mineral supply has come from a strong domestic mining industry supplemented by imports of mineral materials. Current trends show, however, greater diversification of sources for minerals with many U.S. mining companies directing greater percentages of their exploration and mining activities overseas. Nevertheless, much exploration by domestic companies is still conducted in the United States, and many foreign companies have large U.S. exploration programs. Continued discoveries and new mineral production in the United States are a certainty, but the overall balance of future domestic production versus imports is unclear.

Although production of metals appears adequate for short-term needs, increasing global demands and consumption of mineral resources are concerns for the future. Sharply increased mineral consumption is expected as the 4.5 billion people living in developing countries strive to increase their standard of living through industrialization. That large and growing population, which currently represents 85 percent of the world's population, but presently consumes only 20 percent of global mineral production, is helping to drive mineral consumption up faster than the rise in population. Further, although the end of the Cold War has led to a relatively free global market, political instability in some mineral-producing regions of the world could significantly affect future mineral supply. Supply restrictions are also likely as a result of globalization of environmental concerns, which may result in prohibiting of mining in sensitive environments both in the United States and in other countries. Overall, the long-term mineral

An integrated national effort is required to provide a coherent and continuing framework for obtaining information about natural resources and geologic hazards. This information is used by the private sector and by governments at all levels as the basis for exploration, planning, environmental policy, and land-use decisions.

"The Social Imperative for Earth Resources, AGI Congressional Action Workshop Participants" (1995)

As the BLM moves more aggressively to implement ecosystem management concepts into its planning and environmental compliance efforts, there is an increased need for high quality data on our resources so that decisions can be based on sound and unbiased scientific information.

Bureau of Land Management (1993)

supply outlook indicates a need for continued development of new mineral deposits and for continued monitoring of global mineral-resource availability to ensure a secure and reliable domestic mineral supply base.

Meeting the Mineral Information Needs of the Nation

Accurate, timely, and objective information on national and global mineral resources and expert analysis of these data are needed to address the issues of land stewardship, mitigation, and mineral supply. Minerals information is available in many forms including maps, text, physical samples, and aerial and space-based imagery, as well as data bases and related tabular and graphical presentations of geologic, geochemical, geophysical, and mineral-resource data. The acquisition, analysis, dissemination, and use of these data have changed dramatically in concert with the rapid development of computer technology that provides direct access to large data bases via information networks.

Modern capabilities for digital analysis of data, such as Geographic Information Systems (GIS), require development of standard data formats that permit the rapid transfer and integration of information. To satisfy user needs, data bases must be developed, updated, and made available through easily accessible outlets. Using minerals information in land-use plans, environmental mitigation, and policy decisions also requires prompt access to such information. Outreach activities are essential to maintaining the relevance and utility of the information provided and to identifying the changing needs for minerals information by government, industry, commerce, and the public.

All of the issues above relate to fundamental choices that the United States faces regarding use of Federal lands, environmental protection, and supply of mineral raw materials. The United States will always need a secure, economical supply of minerals. Our national needs are likely to be met by a mixture of domestic and foreign production. Thus, there will be mining and associated environmental consequences somewhere in the world. Even in times of relative resource abundance, important decisions must be made regarding the most appropriate sources of mineral supply considering all aspects of economy, environment, and technology. Our ability to make informed decisions will be improved by continued research on mineral resources and the environmental consequences of mineral occurrences and mining and by improving distribution of this information.

Authorizations

The role of the U.S. Geological Survey in addressing mineral-resource issues was originally defined by the Organic Act of 1879, which established the USGS and directed it to conduct the systematic and scientific "classification of the public lands, and examination of the geological structure, mineral resources, and products of the public domain." The basic authority has been amended to authorize mineral-resource studies outside the national domain. The role of the USGS has been delineated further by several subsequent authorizations, including legislation that requires Federal departments and bureaus to provide and consider mineral-resource information in managing the Nation's lands and resources. The USGS works in partnership with the U.S. Bureau of Mines (USBM), Bureau of Land Management (BLM), U.S. Department of Agriculture, Forest Service (FS), and other Federal agencies to provide comprehensive and required mineral-resource and related environmental information.

Programs designed to improve the human condition, whether related to resources, hazards, or environmental change, depend on the results of basic research aimed at expanding our understanding of the Earth's processes.

National Research Council, "Solid-Earth Sciences and Society" (1993)

U.S. Mineral-Resource and Land-Use Policy, Since 1964, Affecting USGS Mineral-Resource Program Activities

- **Wilderness Act of 1964** directed that wilderness study areas "shall be surveyed on a planned, recurring basis by the Geological Survey (USGS) and the Bureau of Mines (USBM) to determine the mineral values, if any, that may be present."
- **Forest and Rangeland Renewable Resources Planning Act of 1974, as amended by the National Forest Management Act of 1976** (NFMA) led to an interagency agreement between the USGS, the USBM, and the FS to assess the mineral resources of National Forests.
- **Federal Land Policy and Management Act of 1976** (FLMPA) specifically requires that the USGS and USBM conduct a mineral survey of each area recommended by BLM for wilderness suitability.
- **Alaska National Interest Lands Conservation Act of 1980** requires that the Secretary of the Interior assess the oil, gas, and other mineral potential, and expand the minerals base, *for all public lands* in Alaska.
- **Mining and Minerals Policy Act of 1970 and the Materials and Minerals Policy, Research and Development Act of 1980**, along with Congressional requests to the Executive Branch, and a Presidential policy statement called for increased government attention to secure future mineral supplies from domestic and foreign sources.

References

AGI Congressional Action Workshop Participants, 1995, The Social Imperative for Earth Resources: Geotimes, March 1995, p. 11.

National Research Council, 1993, Solid-Earth Sciences and Society: Washington, D.C., National Academy Press.

PROFILE OF THE USGS MINERAL RE OURCE SURVEYS PROGRAM

As the Nation's earth-science information agency, the USGS has the scientific expertise, data, technology, and research programs needed: (1) to provide extensive, objective estimates of the probable locations, types, amounts, and qualities of undiscovered mineral resources, (2) to predict and help prevent the possible environmental consequences of development of mineral resources, and (3) to disseminate this information in both technical and nontechnical formats.

The USGS has no financial, regulatory, or political interest in minerals development and, therefore, can be objective in its evaluations. Further, USGS expertise, data bases, and mandate transcend traditional Federal and State land-management boundaries and philosophies and are more readily applicable to regional mineral-resource issues and multi-issue management approaches than information based on data collection that stops at, for example, a National Forest boundary. The expertise and capabilities of the USGS, which are outlined in this 5-year plan, uniquely qualifies this agency to respond to the changing national needs for minerals-related information and to develop and maintain information and knowledge of mineral resources from both a national and international perspective.

Capabilities

The USGS Mineral Resource Surveys Program (MRSP) is carried out by highly skilled personnel with comprehensive knowledge of geology, mineral resources, geochemistry, geophysics, statistics, and information management. Program activities are conducted at the three primary USGS centers: Reston, Virginia; Denver, Colorado; and Menlo Park, California; at the USGS field center in Anchorage, Alaska; and at field offices in Reno, Nevada; Spokane, Washington; and Tucson and Flagstaff, Arizona. Facilities maintained at these locations include laboratories to support a full range of mineral-resource investigations and a computing infrastructure that includes GIS and national and international networking capabilities.

The MRSP is served by a number of organizational units that provide minerals information to its many users including Congress, State agencies, industry, environmental groups, the general public, and other Federal agencies. The Center for Inter-American Mineral Resource Investigations (CIMRI) in Tucson and the Center for Russian and Central Asian Mineral Studies (CERCAMS) in Denver are focal points for the exchange of minerals information, technology transfer and training, and cooperative mineral-resource investigations and research with Latin America and the Caribbean, and Russia, respectively. The Center for Environmental Geochemistry and Geophysics (CEGG) in Denver coordinates and supports research on the natural and human-induced environmental effects associated with geologic sources, especially those related to mineral resources and their development. Minerals information specialists in the Minerals Information Offices (MIO's) in Denver, Reno, Spokane, Tucson, and Washington, D.C., facilitate access to minerals-related information of the USGS by Congress, government agencies, industry, and the public.

Activities

The research activities conducted by the Mineral Resource Surveys Program are designed to determine the origin, occurrence, quality, quantity, and environmental significance of mineral resources. Studies address issues in:

- **Land and resource stewardship**, to identify areas with potential for undiscovered mineral deposits, predict the probable sizes of those deposits, identify environmental impacts resulting from inactive and abandoned mine sites, and anticipate potential problems related to future mineral-resource development.
- **Mitigation**, to characterize the natural variations of minerals and chemical elements and compare them with human-induced

effects, identify the geologic, geochemical, and geophysical factors that effect remediation plans and technologies, and better understand and help mitigate minerals-related environmental impacts.

- **Resource supply**, to identify and evaluate potential for new types of mineral deposits and areas where those deposits may occur, improve predictive capabilities by increasing the understanding of the processes that form mineral deposits, and promote information and technology transfer through cooperative industry and international investigations.

- **Information and technology transfer**, to develop, maintain, and improve minerals-related data bases and information analysis technologies and to improve the access to and distribution of minerals-related information and technology to government, industry, academia, and the public.

Mineral Resource Surveys Program activities directed toward these issues are conducted through two complementary and interdependent avenues of research:

- **Studies and investigations** improve understanding of fundamental geologic processes critical to better predictive capabilities. These critical processes, including those that form and destroy mineral deposits and those that lead to minerals-related environmental contamination, are relevant to a variety of problems in the U.S. and abroad.

- **Assessments** integrate and build on results from studies and investigations to provide a systematic appraisal of where, how much, what kind, and possible environmental consequences of mineral resources and their development. Typically, assessments are undertaken for specified regions (for example, a BLM management area, a national forest, or even a multi-state area). These regional studies are eventually compiled to provide national assessments.

Products

The timely, useful, and efficient transfer of minerals-related information tailored to meet the needs of diverse users is fundamental and paramount to MRSP activities. Results of program research are provided to the public directly through USGS and non-USGS publications (maps, digital data bases, and technical and nontechnical reports, articles and books) and by several organizational units (MIO's, CIMRI, CERCAMS, CEGG). Program personnel also share information with the public through public workshops and forums, invited lectures and talks presented at professional societies, colleges, universities, and secondary schools, and through other outreach activities. Increasing emphasis is being placed on the dissemination of information through a variety of digital media, including CD-ROM's and interactive computer networks, to provide users on the information highway with up-to-date information.

USGS scientists and technical staff are members of numerous regional, national, and international scientific and technical advisory boards and provide specialized expertise and insight to Federal, State, and local agencies. Program staff also participate in collaborative international investigations through requests for assistance by international development agencies, foreign governments, and geoscience organizations.

Relations with Other Government Agencies

Federal Agencies

The USGS provides mineral-resource and related environmental information necessary for the efficient and responsible management of the public lands by the BLM, FS, Fish and Wildlife Service (FWS), National Park Service (NPS), Bureau of Indian Affairs (BIA), Department of Energy (DOE), and Department of Defense (DOD). The USGS cooperates in formal and informal agreements with these agencies and with the USBM to coordinate and conduct mineral-resource assessments and assists the agencies with their planning functions as required by existing legislation (see box on page 4). Priorities for Federal land studies are set by the agencies charged with the management of those lands. At the request of the land-management agencies, interagency Memoranda of Understanding (MOU's) are being revised and expanded to include mineral-environmental assessments and related studies.

Personnel of the MRSP also conduct cooperative investigations with other Federal agencies and bureaus, including the Bureau of Reclamation (BOR), National Institute of Standards and Technology (NIST), National Aeronautics and Space Administration (NASA), Department of Commerce (DOC), Environmental Protection Agency (EPA), Department of State (DOS), and National Science Foundation (NSF). The USGS role in these cooperative investigations is to provide objective scientific information on a variety of earth science issues related to mineral resources and the environment. In particular, the range of expertise and capabilities in geophysics and geochemistry maintained by the program is increasingly relied on by other agencies, including EPA, DOE, and DOD, to assist them with site-specific environmental investigations and technology applications.

State Agencies

The MRSP routinely forms partnerships with State geological surveys, State departments of natural resources, and other State agencies to accomplish specific program objectives. State scientists have assisted in mineral-resource assessments, mineral district studies, data base development, geochemical and geophysical surveys, and other minerals-related investigations. The State researchers bring important local expertise and historical perspective to these activities. The USGS provides a national and regional perspective and works to incorporate local information into national data bases.

International Relations

The MRSP provides assistance to Federal agencies to accomplish foreign policy objectives. For example, the U.S. Agency for International Development (USAID) has commissioned the USGS to conduct mineral-resource assessments in countries where demonstrated mineral resources could lead to investment by international minerals corporations. Other agencies, such as the Department of State, use the USGS as a vehicle for foreign policy outreach. Foreign governments and geoscience organizations have requested assistance for training and technology transfer, mineral-resource and mineral-environmental assessments, and basic research on mineral deposits. In most cases, international projects are fully funded by the agency requesting assistance, by a development bank (such as the Inter-American Development Bank), or the foreign country itself; however, the MRSP shares the costs of certain projects that are consistent with its mission and that achieve specific program goals.

Relations with Other USGS Programs

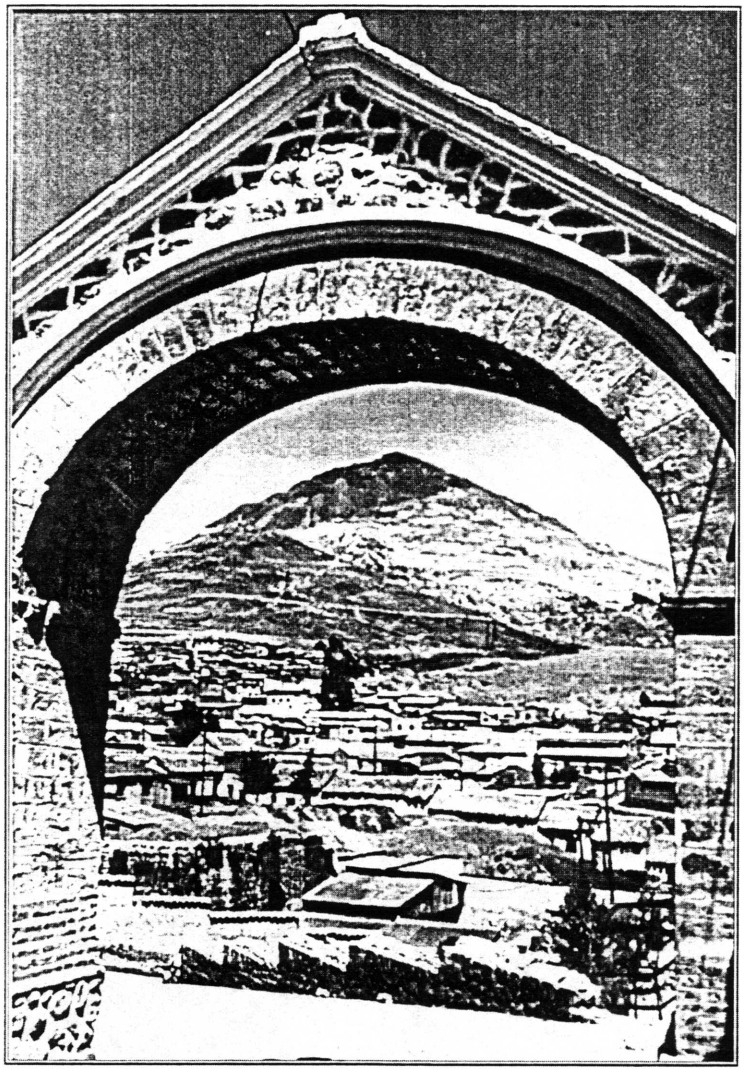
The MRSP supports cooperative activities with other program personnel within the USGS such as scientists of the National Geologic Mapping Program, National Energy Program, National Marine and Coastal Geology Program, the Geothermal Program, and the National Water Quality Assessment Program. MRSP assessments and investigations are often conducted in coordination with activities supported by these other USGS programs. MRSP research activities provide understanding of processes and develop techniques useful to other earth-science investigations conducted by the USGS as well as by other Federal agencies, industry, and academia.

Relations with Private Sector

The USGS cooperates and works in partnership with industry to achieve specific program objectives. Industry relies on the USGS to provide a national and regional geologic framework and evaluation of mineral-resource potential and an information base for environmental assessment, mitigation, and remediation. The USGS undertakes cooperative investigations with industry under formal agreements that permit research on mineral deposits in areas of active development and mining.

The MRSP also promotes the transfer of technology to industry through formal agreements under Federal Cooperative Research and Development Agreements (CRADA's). These agreements promote the distribution of technological information and help to maintain jobs, ensure a strong domestic mineral supply, and enhance the competitiveness of U.S. industry in international markets.

The U.S. Geological Survey assists Bolivia to revitalize its mining industry and economy



Cerro Rico de Potosi, the conical hill shown here from the city of Potosi, Bolivia, is the world's largest silver deposit. The light-colored mine dumps in the middle distance are the result of centuries of mining silver and tin. Mining of rich veins containing as much as 40 percent silver began before 1545 and has resulted in production of an estimated 30,000 to 60,000 metric tons (33,000 to 66,000 short tons) of fine silver. In the 20th century, tin production became dominant when the high-grade silver ores were largely mined out. The deposit is currently being evaluated as a bulk mineable source of low-grade silver and tin ores. It is estimated that the amount of silver remaining in low-grade ore is equal to all the silver produced to date.

With the breakup of the Soviet Union, the threat to U.S. access to strategic and critical minerals has diminished. However, because we now live in an increasingly interdependent global economy in which economic changes in one part of the world can have large and unforeseen consequences in other places, global supply and demand of minerals continues to be a concern to the United States. For example, the collapse of the tin mining industry in Bolivia in the mid-1980's, which was an important component of their economy, ultimately led to efforts by the United States and international agencies to revitalize the Bolivian mining industry and economy.

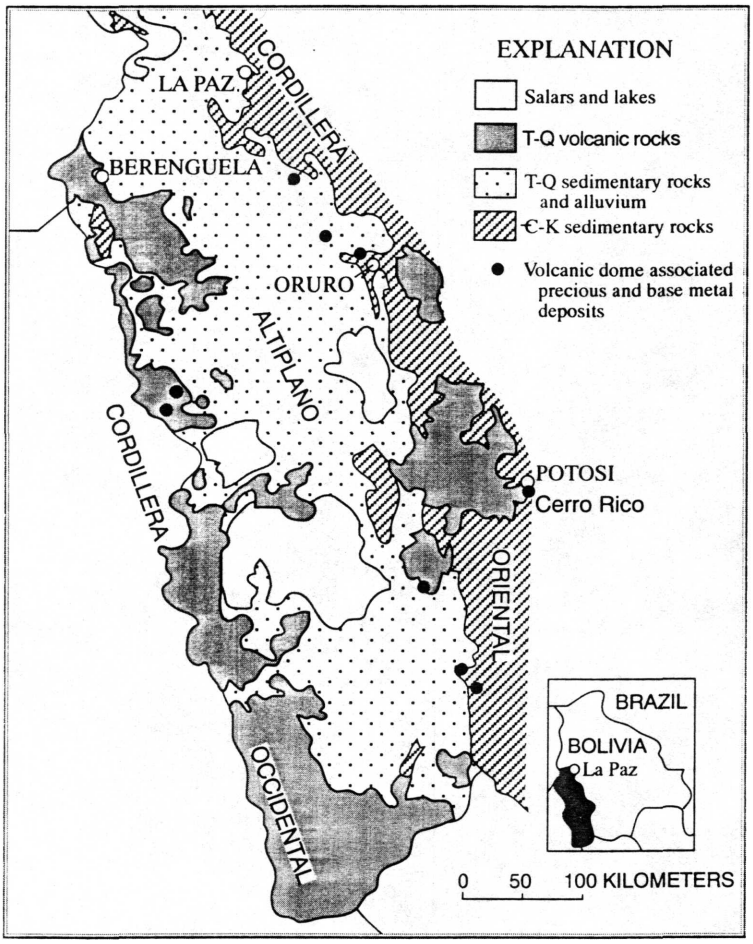
During the early 1980's, three factors converged to produce a crisis in the international tin market and in tin-producing countries. The first factor was the discovery of very large tin deposits in Brazil. The second factor was the development of Chinese tin deposits that had been discovered during the 1970's. These two new sources of supply fell outside the control of the existing tin cartel. The third factor was the International Tin Council (ITC) policy of maintaining high prices for tin. The ITC's policy had stimulated production from marginally economic tin deposits in Bolivia, Canada, Malaysia, and the United Kingdom. In October of 1985, the ITC announced that it would cease supporting the price of tin. In the ensuing months, the price of tin fell by 65 percent.

This precipitous decrease in price caused serious problems in many of the countries with marginally economic deposits. In the United Kingdom, the government had to re-examine its policy with regard to subsidies for the mines of southwest England. In Malaysia, unemployment among the ethnic Chinese tin miners reached high levels. In Bolivia, COMIBOL, the state-owned mining company, was forced to close many mines which employed a significant fraction of the Bolivian work force.

The ability of these countries to deal with the resulting dislocations differed considerably. In the United Kingdom, which has a large, diverse, and developed economy, the problem was manageable through existing government programs. In Malaysia, a rapidly developing economy lessened the impact of the problem. However, in Bolivia with its state-run, under-developed economy, the collapse of the price of tin caused major unemployment.

In the late 1980's, the U.S. Department of State and organizations such as the International Monetary Fund and the World Bank were examining ways to revitalize the Bolivian economy. Because Bolivia had a tradition of minerals production, the mining industry seemed a likely starting point for these efforts. However, mining had been in the hands of a state-run mining company for more than 30 years. Government institutions, such as the Geological Survey of Bolivia, which provided the regional geoscience information that would attract investment from private mining companies, had been severely weakened. In an effort to revitalize the mining sector of the Bolivian economy, international and U.S. government agencies provided loans and technical assistance to help Bolivia privatize its mining investment. As part of this effort, the Department of State requested and the U.S. Trade and Development Program funded a joint project by the U.S. Geological Survey and the Geological Survey of Bolivia to develop and disseminate information about mineral resources of the Bolivian Altiplano. The information included a data base of mineral deposits, a new geologic map, a geochemical orientation study of an important new mineral district, new geophysical data, and an analysis of the economic feasibility of producing three kinds of mineral deposits. The results of the project were disseminated at public meetings, as a published monograph, and as digital data. The project has resulted in increased interest and investment in Bolivia's mineral sector by U.S. and international mineral companies.

At the request of the U.S. Department of State, and with funding from the U.S. Trade and Development Program, the U.S. Geological Survey undertook a joint project with the Geological Survey of Bolivia to develop and disseminate information about the mineral resources of the Bolivian Altiplano.



Simplified geologic map of southwestern Bolivia, including the Cordillera Occidental and Altiplano. T-Q (Tertiary and Quaternary) rocks were deposited in the last 65 million years: Є-K (Cambrian to Cretaceous) rocks were deposited between 570 and 65 million years ago.

The USGS works in close cooperation with Federal and State agencies on mineral-resource and related environmental studies

- Numerous mercury-rich deposits are scattered over several thousand square miles in southwestern Alaska. Several of these mercury deposits have been mined in the past, but none are currently operating. Mercury can be toxic to living organisms and constitutes a potential hazard for residents and wildlife populations in southwestern Alaska because streams drain the areas containing the mercury deposits. The USGS, in cooperation with the U.S. Fish and Wildlife Service, U.S. Bureau of Mines (USBM), State agencies, the Calista native corporation, and private citizens, is measuring mercury concentrations in sediment, water, and fish. Although the stream sediments and fish collected near the mines contain elevated concentrations of mercury, the mercury in fish is below the level recommended safe by the Food and Drug Administration. To date, mercury concentrations measured in stream waters are also within safe water quality standards.

- The USGS, in cooperation with the State of Colorado's Geological Survey and the U.S. Bureau of Land Management (BLM), has developed a geology-based regional screening process that was used to identify and rank Colorado mining districts according to their likely mine drainage hazards. This screening process allows land management agencies to rapidly prioritize and focus their remedial activities on mining districts with the greatest potential for environmental problems, thereby avoiding costly field assessments of all mining districts.

- In response to requests from the BLM, the USGS is conducting geologic investigations and mineral-resource assessments for two large tracts in New Mexico—the seven-county Roswell Resource Area in east-central New Mexico and the four-county Mimbres Resource Area in the southwestern part of the State. These studies, done with assistance from the New Mexico Bureau of Mines and Resources, U.S. Bureau of Mines, and outside organizations and individuals, provide mineral-resource and related environmental information used by the BLM for land-use and ecosystem planning.

- To assist the BLM in developing land management plans for the extensive Federal lands in southeastern Oregon, the USGS is working cooperatively with scientists from the Oregon Department of Geology and Mineral Industries, the Idaho Geological Survey, BLM, FS, and USBM, to conduct mineral-resource assessments of about 10 million acres. In addition to predicting mineral-resource potential, the scientific results will be used to assess environmental hazards related to mineral occurrences and development, to assess the availability of groundwater, and to identify seismic, landslide, and volcanic hazards.

- The USGS has coordinated a major cooperative effort involving scientists from the USGS and 16 State geological surveys to estimate the undiscovered mineral-resources of a 433,000-square-mile area of the Midcontinent region of the United States. The project has (1) provided an inventory of geologic and mineral-resource data for the region; (2) improved understanding of the origin and extent of known mineralization such as the major lead-zinc deposits of southern Missouri; and (3) evaluated the potential for major new deposit types in the region, including major deposits of iron, copper, uranium, gold, rare earth elements, and silver.

- As part of its mineral-resource assessment activities, the USGS, in cooperation with State resource agencies, the USBM, and university scientists, is assessing the potential for deposits containing titanium-, zirconium-, hafnium-, rare earth-, and yttrium-bearing minerals in onshore and offshore areas along the Atlantic coast of the United States. These studies have resulted in the definition of large areas with potential for such deposits, particularly in offshore areas, as well as new types of deposits in areas previously thought to have low or no potential. The studies have prompted considerable industry interest and have led to increased exploration activity.

DESCRIPTION OF THE USGS MINERAL RESOURCE SURVEYS PROGRAM

Developing the National Plan for the USGS Mineral Resource Surveys Program

The U.S. Congress in the committee report accompanying the FY 1995 Department of the Interior appropriations bill directed the USGS to develop a program plan for mineral-resource activities. Over the last year the USGS has held a series of meetings to formulate a Mineral Resource Surveys Program consistent with national needs for minerals information. The plan is responsive to the needs of Federal, State and local land- and resource-managing agencies, the minerals industry, and the public. It has been reviewed by the USGS, the Department of the Interior, other Federal agencies such as the U.S. Bureau of Mines, Bureau of Land Management, and the Forest Service, and by State institutions.

The USGS will continually review and update this National Plan. It will work to ensure that the program: (1) continues to efficiently meet the needs of the users of mineral-resource data and information; (2) increases fundamental understanding of mineral deposits and their environmental effects; and (3) meets the Nation's long-term needs for mineral resources. Comments on the plan are welcome and should be addressed to the USGS, Chief, Office of Mineral Resources, 12201 Sunrise Valley Drive, Reston, VA 22092.

The Changing Nature of the Mineral Resource Surveys Program

Traditionally, USGS mineral-resource activities have advanced understanding of the origin of mineral deposits, provided the basic geologic information needed for identifying new areas of mineral potential, and facilitated land-use planning by Federal and State agencies. Today, the USGS is also conducting scientific research on the environmental consequences of mineral development because the Nation's need for minerals must be balanced with environmentally sound methods for extraction. This 5-year plan outlines changes in direction of the USGS mineral-resource activities necessary to accommodate the diverse types of minerals information and research required by the Nation.

- Development and implementation of mineral-environmental assessments that provide predictions of the environmental consequences of minerals development, to accompany current USGS mineral-resource assessment products;
- Greater emphasis on research that supports mitigation of environmental impacts related to extraction and use of mineral resources;
- Greater emphasis on assessments of nonmetallic resources (such as sand, gravel, and construction aggregate) needed for urban development and infrastructure renewal;
- Greater emphasis on the timely, useful, and efficient transfer of minerals-related information in a wide variety of formats tailored to meet the needs of diverse users.

The objectives of the Mineral Resource Surveys Program are accomplished by research in four complementary subprograms (fig. 1):

- **Assessments**, to provide the minerals-related resource and environmental information necessary for the management of our Nation's mineral resources and Federal lands;
- **Mitigation Studies**, to identify processes that contribute to minerals-related environmental impacts and provide information to assist in mitigation and remediation;
- **Resource Investigations**, to provide information that aids the Nation in the development of policies and new mineral resources required to maintain a secure, reliable supply of mineral raw materials; and

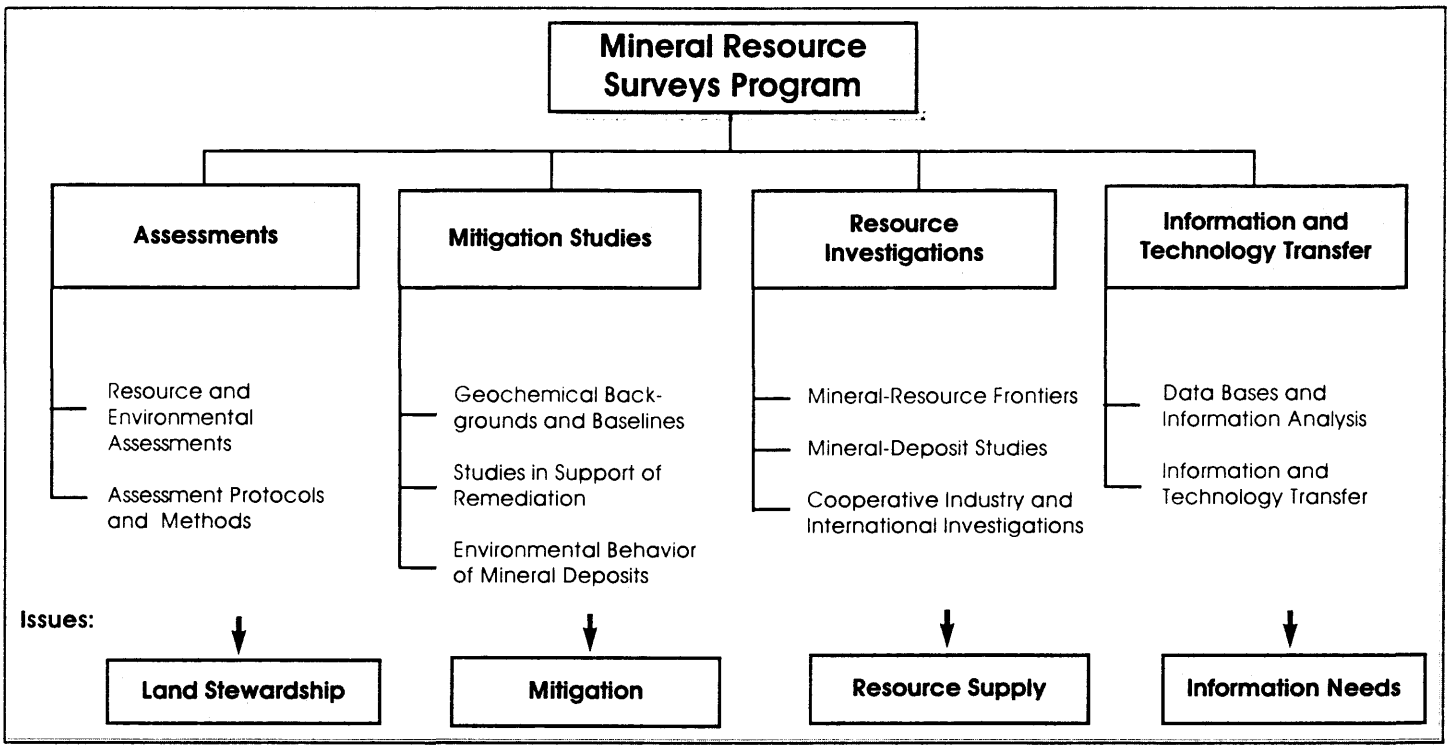


Figure 1. Organization of the Mineral Resource Surveys Program

- **Information and Technology Transfer**, to provide timely, useful, and efficient transfer of minerals-related information and technology in various formats tailored to meet the needs of a variety of users at all levels of Federal, State, and local government, industry, and the public.

The Mineral Resource Surveys subprograms and the projects they support, although having distinct goals and objectives, are closely interrelated. Research activities under one subprogram, although directed at distinct issues and customers, also support activities of other subprograms (fig. 2). For example, studies of environmental processes and baselines conducted as part of Mitigation Studies provide information required for improving mineral-environmental assessments. Similarly, studies carried out as part of Resource Investigations help improve mineral-resource assessment. The Information and Technology Transfer subprogram assists all MRSP activities by providing methods and technology required for GIS development and analysis and for management, analysis, and transfer of digital data bases.

Subprogram Prioritization

The relative emphasis of the four subprograms of the MRSP is projected to change during the next 5 years as shown in figure 3.

- **Assessments** will remain as the core focus of the program but will decline slightly from 50 percent of total appropriated funds in FY 1994 to 45 percent by FY 2000 as activities related to mitigation studies increase. This level of effort for Assessments reflects a continued commitment to meeting the priority needs and requests for mineral-resource and mineral-environmental information by Federal land-managing agencies.

- **Mitigation Studies** will increase from 5 percent in FY 1994 to 27 percent by FY 2000. This increasing emphasis is in response to: (1) requests from Federal land-managing and regulatory agencies for information to assist them in the mitigation and remediation of environmental impacts of minerals development; (2) Congressional concerns regarding possible

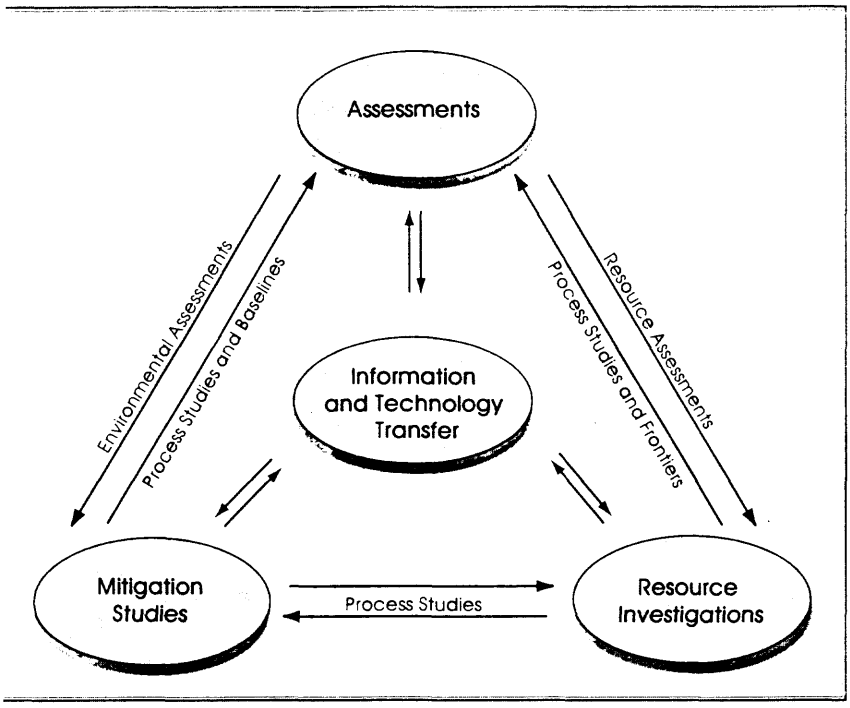


Figure 2. Interrelationships between subprograms of the Mineral Resource Surveys Program

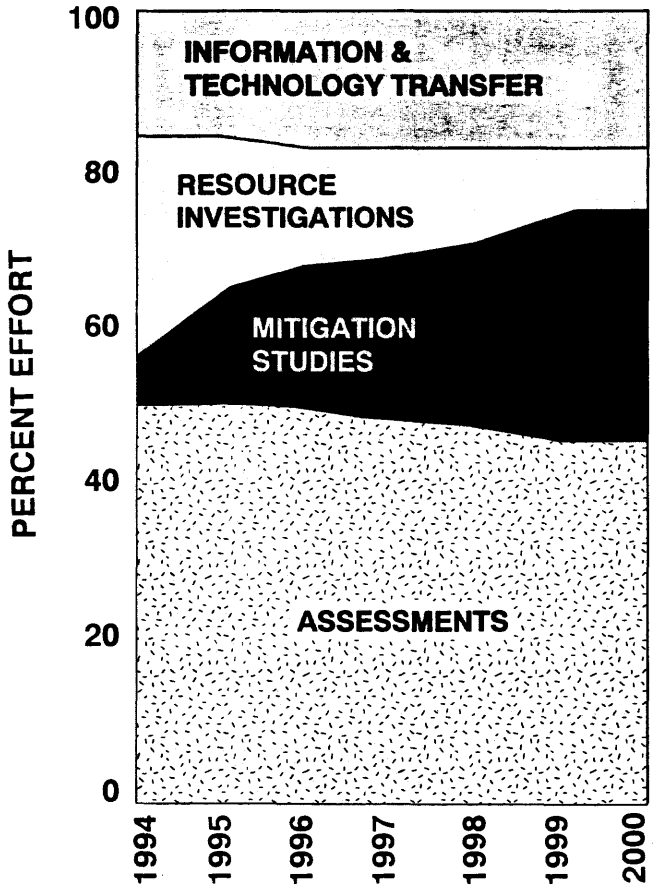


Figure 3. Approximate percentage of effort in each of the four subprograms of the MRSP

environmental hazards associated with inactive and abandoned mine lands, many of which are located on Federal lands; and (3) the need to improve predictive capabilities regarding the environmental impacts of mineral resources and their development.

- **Resource Investigations** will decline from 30 percent in FY 1994 to 12 percent by FY 2000. This decreasing emphasis reflects: (1) the changing priorities of Government and industry for increased information on mineral-environmental issues; (2) an immediate need to build mineral-environmental capabilities in other areas of the program to meet client requests; (3) the availability of a large base of mineral-resource information and knowledge gained through 116 years of USGS research; and (4) a current supply of metals generally adequate for short-term needs.
- **Information and Technology Transfer** will remain an important component of the program staying at about 16 percent during this 5-year plan. This level of effort reflects program commitment to providing timely, useful, and efficient transfer of minerals-related information and technology to Government, industry, and the public.

Assessments

Assessments provide the minerals- and environmental-related information necessary for effectively managing the Nation's mineral resources and Federal lands.

Public lands managed by the Federal government constitute more than 30 percent of the United States and more than 50 percent of 11 Western States and Alaska. These public lands are managed by agencies in both the Department of the Interior and the Department of Agriculture. During the past 30 years, the USGS has had increasing responsibility for providing the minerals-related information required by Federal agencies for developing land-use plans and monitoring the results of land-management programs. As national needs and priorities regarding use of our public lands and resources change, Federal agencies must periodically update and revise these land-use plans. This requires that the USGS and other research agencies constantly re-evaluate and refine the information that they provide to Federal land managers. These USGS studies also benefit the public by making mineral-resource assessment information available to them. Industry uses the maps and mineral assessments as aids in planning their exploration and development strategies.

Land-management agencies, such as the BLM and FS, are adopting a multi-issue approach to land-management planning in which decisions concerning timber harvesting, grazing, mining, motor vehicles, and other land uses, as well as the management of habitat for endangered and threatened species, are evaluated on the basis of the general well-being of the natural system as a whole. In this approach, artificial boundaries, such as land ownership, power-line right-of-ways, and roads, are replaced in the management decision process with landscape units such as watersheds, drainage basins, and ecoregions. The mineral-resource and related environmental assessments of the MRSP provide much of the basic geologic and geochemical information used in the land-management decision process and multi-issue approach to land management. The USGS undertakes both regional and more detailed assessments, tailoring assessment products to encompass the management areas defined by the land-managing agencies.

The USGS works in partnership with Federal agencies including USBM, BLM, FS, and BIA, and on a special-request basis with FWS, EPA, NPS, and DOD, to conduct and coordinate assessment and related earth-science studies, primarily in response to priorities set by the Federal agencies. The information provided assists these agencies in meeting inventory and evaluation, resource-management planning, and other management requirements as directed by Federal legislation. Assessment products are designed to meet the needs of the user and include maps, briefing books, customized reports, digital data, and nontechnical presentations.

Assessment activities are carried out under two interrelated components (fig. 4):

- **Resource and Environmental Assessments**, to provide national, regional, and requested or special-purpose mineral-

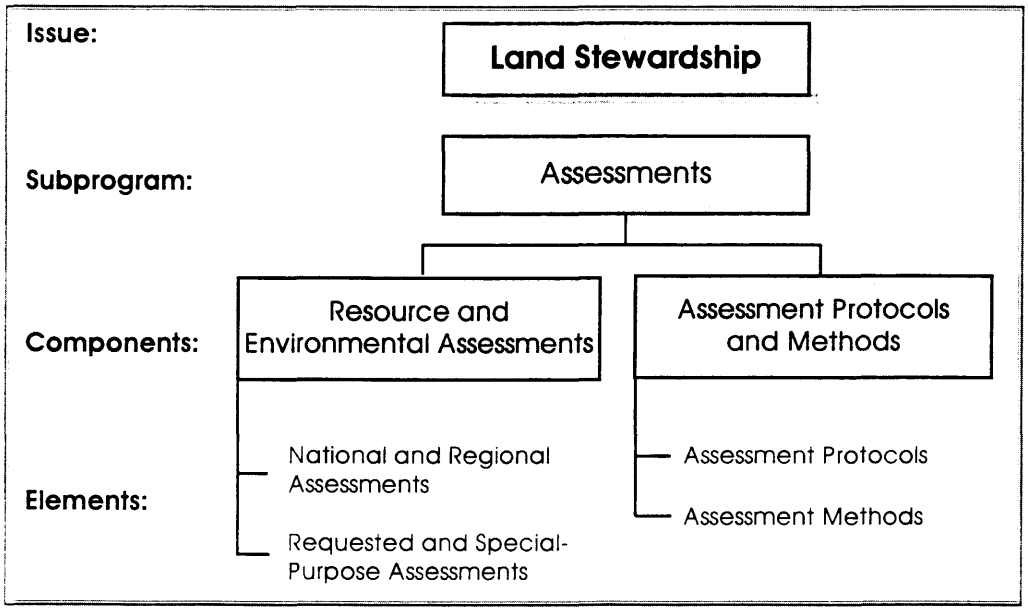


Figure 4. Organization of the Assessments subprogram

resource and mineral-environmental assessments to government, industry, and the public; and

- **Assessment Protocols and Methods**, to allow assessments to be completed better, faster, and at lower cost.

Resource and Environmental Assessments

Information that addresses economic, environmental, and other societal issues considered in developing land-management plans is provided by the USGS in the form of mineral-resource and mineral-environmental assessments. Mineral-resource assessments provide inventories of the past production and remaining resources of known mineral deposits, indicate areas where the geology permits various deposit types, and give estimates (at various confidence intervals) of the numbers of undiscovered deposits of each type. The estimates of undiscovered deposits, in conjunction with the appropriate grade and tonnage information, provide the basis for forecasts of metal endowments of the areas under consideration. These quantitative estimates can be directly incorporated into economic assessment modeling done by the USBM and land-management agencies to evaluate various management scenarios. Mineral-resource assessments depend on the integrated results of multidisciplinary studies done under the Resource Investigations subprogram for an understanding of the complex geologic histories that control different mineralizing processes and that result in the formation of mineral deposits in different geologic settings.

Mineral-environmental assessments complement the mineral-resource assessments by providing analysis of environmental effects of undisturbed mineral deposits and of environmental consequences resulting from past or current mining and minerals processing (fig. 5). The assessments offer predictive capability for determining and mitigating probable environmental effects of development, on the basis of the kinds of deposits likely to be present and their probable locations. In areas where large amounts of earth materials have been disrupted and redistributed by mining and minerals processing, the assessments provide information to assist in selecting remediation techniques for environmental restoration. Mineral-environmental assessments use the results from research conducted under both the Mitigation Studies and Resource Investigations subprograms to improve predictive capabilities.

Mineral-environmental assessments are a new component of the MRSP. A goal of the program during this 5-year plan is to develop the capabilities necessary to meet the priority requests by Federal and State land-managing agencies for such mineral-environmental information.

Objectives

- Conduct recurring national and regional assessments, especially to identify the likelihood of undiscovered mineral deposits on Federal lands and throughout the Nation;
- Work in partnership with Federal and State land-management agencies to provide information on where mineral deposits, and thus future development, may be located;
- Assist land-management agencies and business decision makers to plan for the environmental effects of future mineral-resource extraction;
- Provide geologically-based assessments of environmental effects related to inactive and abandoned mine sites.

Elements

These objectives are addressed by two elements (fig. 4):

1. National and Regional Assessments: The USGS conducts recurring national and regional mineral-resource and related environmental assessments to:

- Accumulate a working knowledge of known and undiscovered mineral resources and their environmental characteristics at regional scales nationwide;
- Develop and improve national digital mineral-resource data bases; and
- Respond quickly to requests for minerals-related information for land areas throughout the country from Congress, Federal and State land-managing agencies, industry, and the public.

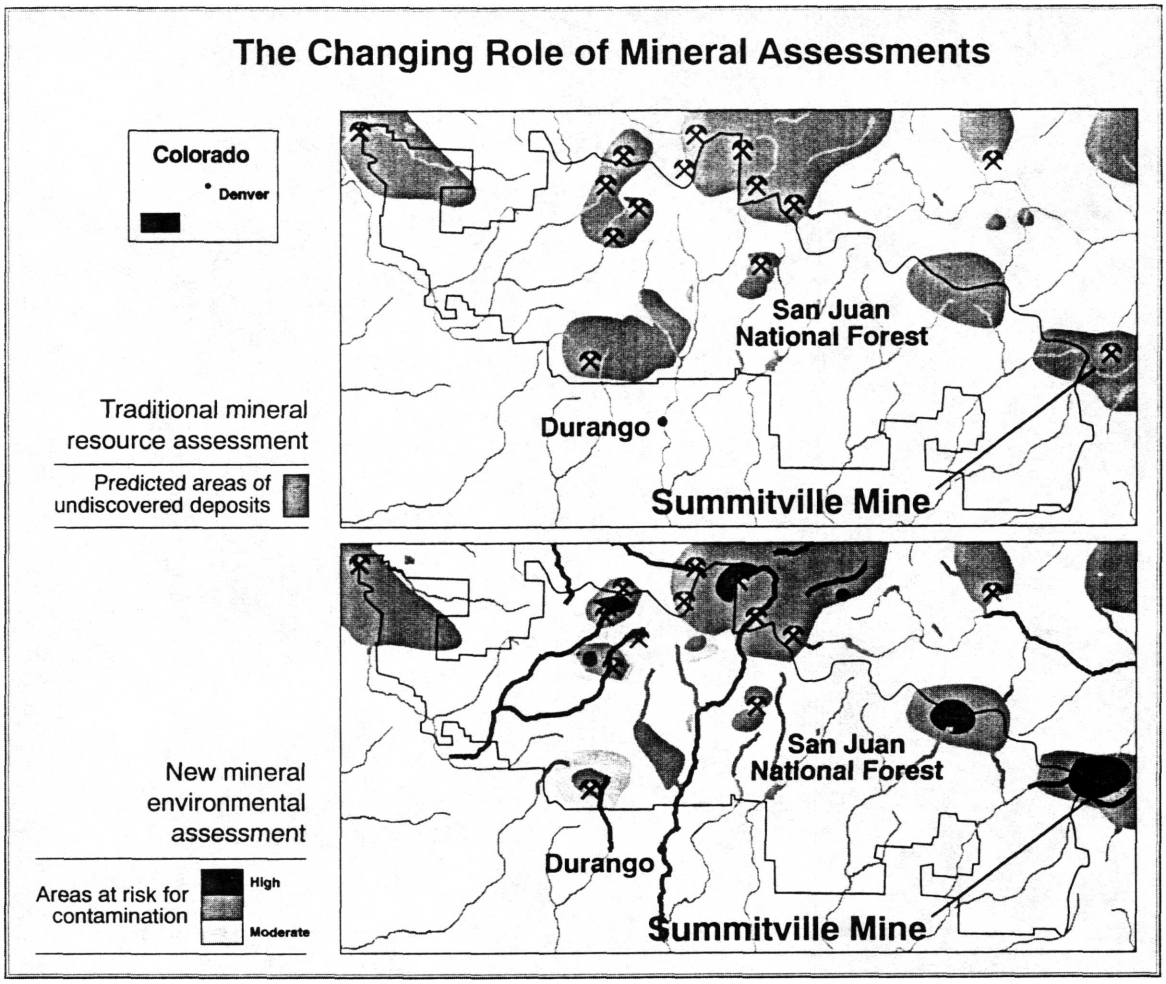


Figure 5. Mineral-resource and mineral-environmental assessments for San Juan National Forest

National assessments are built in two ways:

(1) through compilation of information on selected mineral commodities at a national scale, and

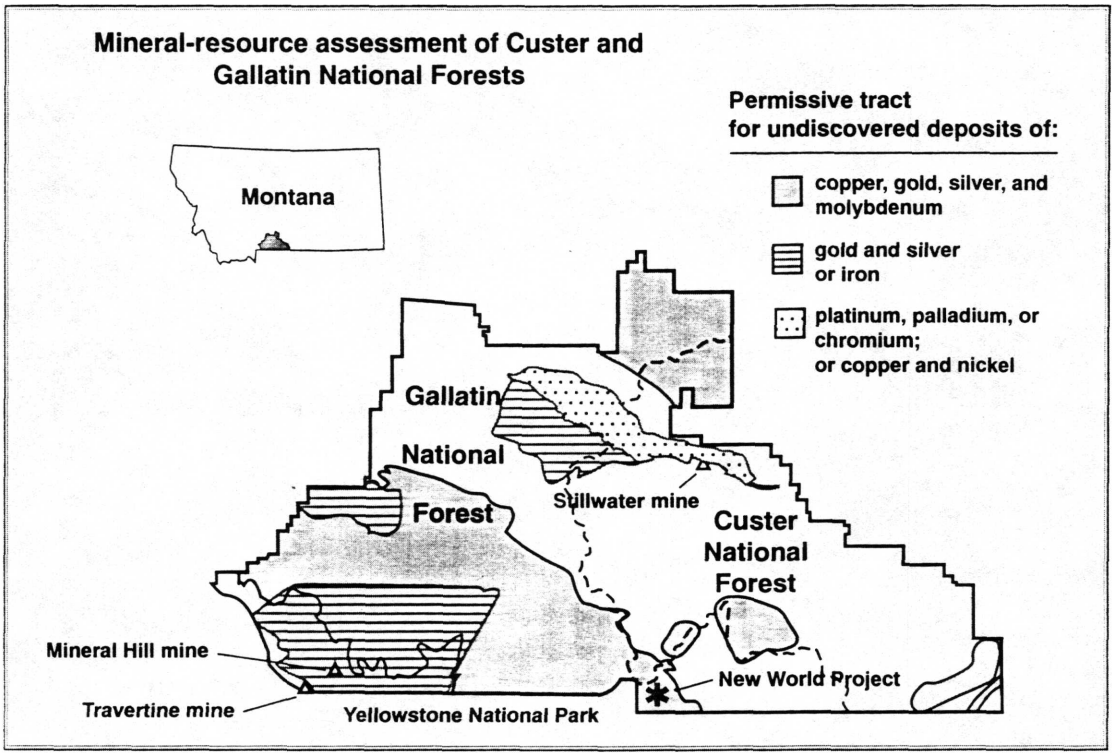
(2) by aggregating more detailed regional-scale assessments.

In FY 1992, the USGS began a prototype National Mineral-Resource Assessment to provide a quantitative prediction of the Nation's potential for undiscovered deposits of copper, zinc, lead, silver, and gold. This assessment project is scheduled for completion in FY 1995. Future national assessments will be upgraded based on the combined results derived from more comprehensive and detailed mineral-resource assessments conducted for 22 regions of the United States (fig. 6). To prepare for a new national assessment, a 5-year program of regional assessments was begun in FY 1994 (table 1). This regional assessment effort will be followed with a new national mineral-resource assessment of selected commodities in FY 1999 and 2000. To assist in developing the capabilities necessary to provide comprehensive mineral-environmental assessment information, a prototype National Mineral-Environmental Assessment for selected deposit types will also be undertaken in FY 1999 and 2000. Thereafter, mineral-environmental assessments will be an integral component of the regional assessment studies.

2. Requested and Special-Purpose Assessments: The USGS works closely with Federal land-management agencies to conduct and coordinate mineral-resource and mineral-environmental assessments for designated management areas. Current and requested assessment studies from the FS and BLM include 11 National Forest areas and 20 Resource Areas (tables 2, 3; figs. 7, 8). These assessments support Federal agencies by fulfilling their high-priority needs for revising, amending, or writing new land- and resource-management plans. It is expected that new and larger areas will be designated for priority assessments as these Federal

U.S. Geological Survey Mineral-Resource Assessment of the Absaroka-Beartooth Study Area, Custer and Gallatin National Forests, Montana

In response to a high-priority request of the U.S. Forest Service (FS), the USGS prepared a report on the undiscovered mineral resources of contiguous parts of the Custer and Gallatin National Forests in southwestern Montana. The FS is using this information to develop comprehensive land- and resource-management plans for the Absaroka-Beartooth area, which lies within the Greater Yellowstone ecosystem.



The USGS provided quantitative estimates of the undiscovered mineral resources to enable the FS to evaluate the significance of the mineral-resource potential. Most of the identified and estimated resources of platinum, palladium, and chromium in the United States occur in the Absaroka-Beartooth study area. The USGS estimates that an additional 3,000 metric tons of platinum and palladium resources and 4 million metric tons of chromium resources are present in extensions of known deposits. Mean probabilistic estimates (in metric tons) for gross-in-place undiscovered mineral resources include 200 tons of gold, 2,000 tons of silver, 130,000 tons of molybdenum, 230,000 tons of nickel, 6.5 million tons of copper, and more than 6.5 million tons of chromium.

In this assessment, the USGS delineated a favorable tract for the occurrence of gold deposits on the basis of historical mining and exploration in the southwestern part of the study area near Jardine, Mont. The USGS estimated a 50-percent probability that the tract contains at least 8.1 metric tons of gold in undiscovered deposits. Commercial exploration that started before the USGS study resulted in an announcement of a new discovery within the tract at Crevice Mountain that contains preliminary drill-indicated reserves of 12.4 metric tons of gold. Industry exploration in the area continues and focuses primarily on gold, platinum-palladium, chromium, and oil and gas.

Among the results of the Absaroka-Beartooth study are new maps showing the geology, aeromagnetic and gravity data, and stream-sediment geochemical anomalies. Locations of mines, prospects, mineral occurrences, and tracts favorable for various types of mineral deposits are also included. Because these data are provided at a map scale used by the FS (1:126,720), they can be easily incorporated into the FS planning process as base maps for ecosystem management. The results of the USGS study are published in "Mineral-Resource Assessment of the Absaroka-Beartooth Study Area, Custer-Gallatin National Forests, Montana" (USGS Open-File Report 93-207).

National Mineral-Resource Assessment for Copper, Lead, Zinc, Silver, and Gold

The first national assessment for selected commodities, scheduled for completion in FY 1995, will (1) identify regional tracts of land permissible for the occurrence of undiscovered copper, lead, zinc, silver, and gold resources, in selected mineral-deposit types, throughout the United States, and (2) estimate the quantities of these undiscovered mineral resources in the tracts. This project will provide analog and (or) digital (1) maps showing tracts for undiscovered mineral resources, (2) tables of estimates of undiscovered mineral resources in the tracts, and (3) tables listing mineral resources in major known deposits by type.

agencies move toward a multi-issue-based strategy for land management. The USGS is currently providing assessment information or planning assessments for several regional multi-issue management areas in the western United States (table 4; fig. 9). The USGS coordinates on an annual basis with the USBM, BLM, and FS to determine their priorities for mineral-resource assessments. USGS assessment studies for priority areas are undertaken each year to the extent permitted by program staffing and budget.

In addition to providing assessments for areas requested by Federal agencies, the USGS also conducts special-purpose assessments to help deal with specific land-planning issues and more long-range planning. For example, the USGS is conducting assessments of industrial minerals (such as sand, gravel, and construction aggregate) within and outside public lands. Aggregate materials are not distributed uniformly, and many communities have built on lands containing resources of sand and gravel and other construction materials. Because these lands are now permanently dedicated to housing and other uses, the industrial minerals needed for development and infrastructure rebuilding must be found elsewhere. The added transport of such materials can significantly increase the cost of large construction projects such as housing developments, industrial plants, airports, highways, and bridges. This will be an increasingly important problem as the Nation works to restore and rehabilitate its aging infrastructure. Priority industrial mineral assessment areas include urban corridors along the Atlantic and Gulf coast and the U.S.-Mexico border region affected by the NAFTA agreement.

Assessment Protocols and Methods

Timely, reliable, mineral-resource and mineral-environmental assessments depend on sound procedural guidelines and on continued improvements in the predictive capabilities and accuracy of assessments.

Objectives

- Test, revise, and improve assessment protocols; and
- Develop and improve assessment methods and techniques so that assessments can be completed better, faster, and at less cost.

Elements

These objectives are addressed by two elements (fig. 4):

1. Assessment Protocols: Assessment protocols are continually tested, revised, and improved as new information becomes available on mineral-resource and mineral-environmental assessments. These guidelines help ensure systematic coverage of all pertinent aspects of an assessment area and consistency of methods and coverage from place to place and among different assessment teams. They also address the integration of mineral-environmental information with mineral-resource assessments. A priority of this 5-year plan is to develop and maintain the capabilities required to provide comprehensive mineral-environmental assessment information. Specific priorities include:

- Development of guidelines for mineral-resource and mineral-environmental assessments;
- Design and implementation of workshops in mineral-environmental assessment methods; and
- Advancing the use of GIS methods in assessments to manipulate, interpret, present, and archive assessment data.

2. Assessment Methods: The USGS is the leader in the development and application of quantitative, probabilistic methods to mineral-resource assessments. In addition, studies are being initiated to develop methods to screen existing environmental hazards and assess potential environmental risk of mineral-resource development. Specific research priorities during this 5-year plan include:

- Improvement of methods used to estimate the numbers of undiscovered mineral deposits in a tract of land;
- Development and testing of methods to rank potential environmental risk of abandoned mine sites and mineral-resource development;
- Improvement of methods for presentation of the results of the probabilistic numerical mineral-resource estimates; and
- Continued improvements in the software used to calculate quantitative resource estimates.

Table 1. Schedule for regional and national mineral-resource assessments (see figure 6)

Region	Program Year						
	FY 1994	FY 1995	1	2	3	4	5
1							
2							
3							
4							
5							
6							
7							
8							
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22							
National Assessment	(Prototype)						

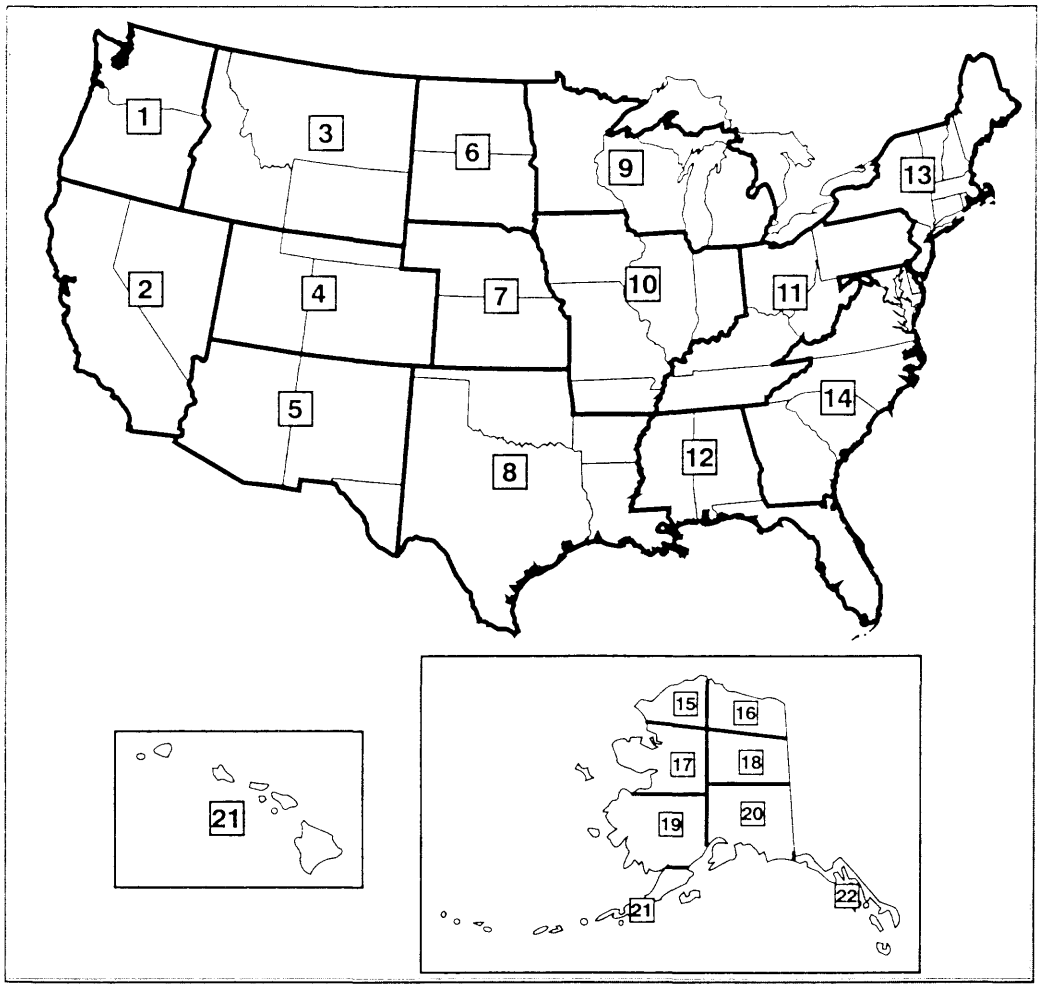


Figure 6. Regional assessment areas for National Mineral-Resource Assessments

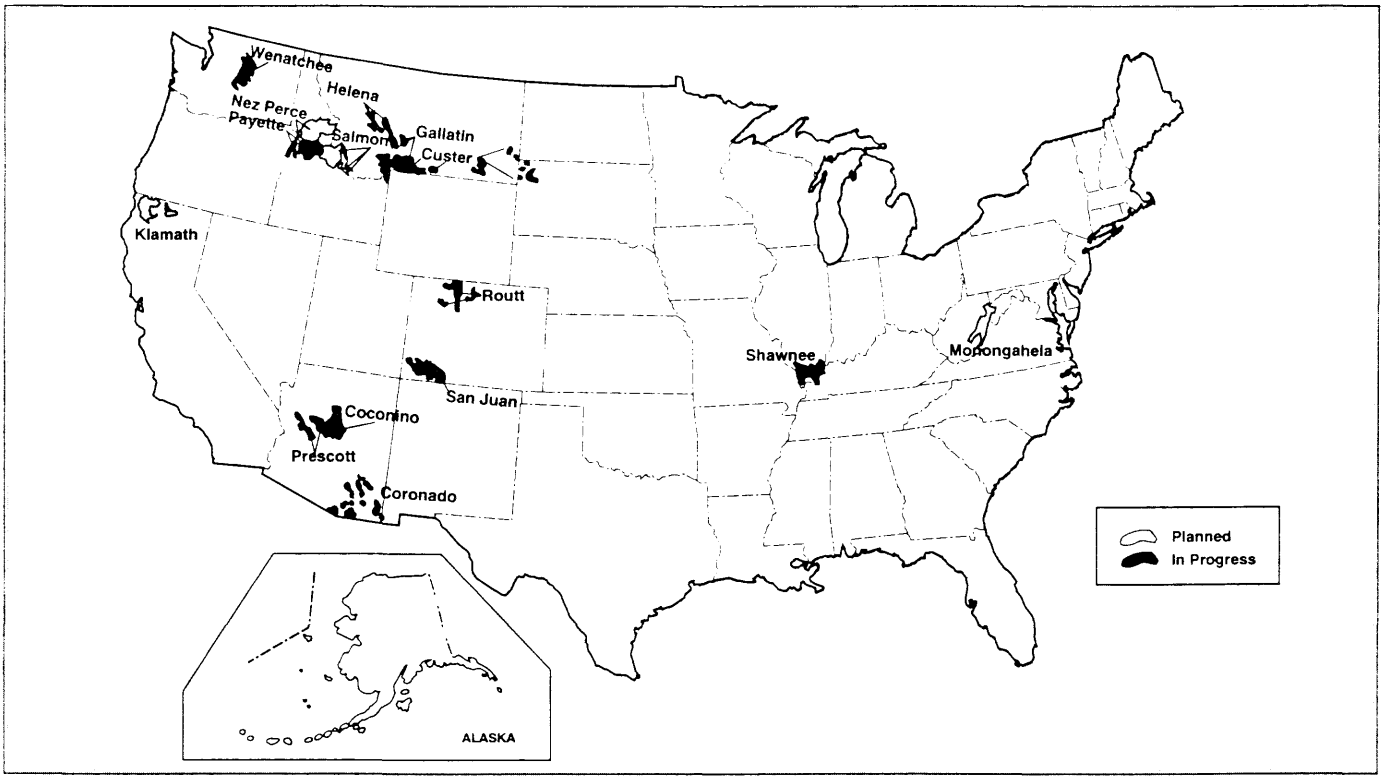


Figure 7. Status of mineral assessments in FS national forests

Table 2. Schedule for requested National Forest assessments (see figure 7)

National Forest	Program Year FY 1994	FY 1995	1	2	3	4	5
Coronado, AZ							
San Juan, CO							
Shawnee, IL							
San Bernardino, CA							
Coconino, AZ							
Custer and Gallatin, MT, SD							
Payette, ID							
Routt, CO							
Helena, MT							
Prescott, AZ							
Wenatchee, WA							
Nez Perce, ID							
Klamath, CA							
Salmon, ID							
Monongahela, WV							
Grand Mesa-Uncompahgre-Gunnison, CO							

Table 3. Schedule for requested BLM area assessments (see figure 8)

Resource Area (R.A.) or District	Program Year FY 1994	FY 1995	1	2	3	4	5
Winnemucca District, NV [Paradise-Denio R.A. Sonoma-Gerlach R.A.]							
Surprise R.A. CA							
Malheur-Jordan R.A. OR							
Mimbres R.A. NM							
California Desert District, CA [Barstow R.A. Ridgecrest R.A.]							
Andrews R.A. OR							
Dillion R.A. MT							
Central and Southern California areas, CA							
Seward-Noatak Area AK							
Caballo R.A. NM							
Northern California, CA [Eagle Lake R.A. Clear Lake R.A. Folsom R.A.]							
Shoshone-Eureka R.A. NV							
Forty Mile-Black River area AK							
Fort Greeley area AK							
Other California areas, CA [Redding R.A. Arcata R.A. Bakersfield District] (selected areas only)							
Lahontan R.A. NV							
Idaho statewide sand and gravel, ID							
Northern and Central Idaho garnet sands, ID							
Lower Gila R.A. AZ							
Headwaters R.A. MT							

Table 4. Schedule for special assessment studies (see figure 9)

Special Assessment Studies	Program Year FY 1994	FY 1995	1	2	3	4	5
Interior Columbia River Basin Ecosystem Management Project, Pacific Northwest							
Humbolt River Basin Study, Nevada							
Klamath-Trinity Basin Study, California-Oregon							
Sierra Nevada Ecosystem Project, California							
Southeastern Arizona Study Areas							
Sitka Quadrangle, Alaska							
Sleetmute Quadrangle, Alaska							
Lime Hills Quadrangle, Alaska							
Howard Pass Quadrangle, Alaska							
Industrial Mineral Assessments, Selected Regions							

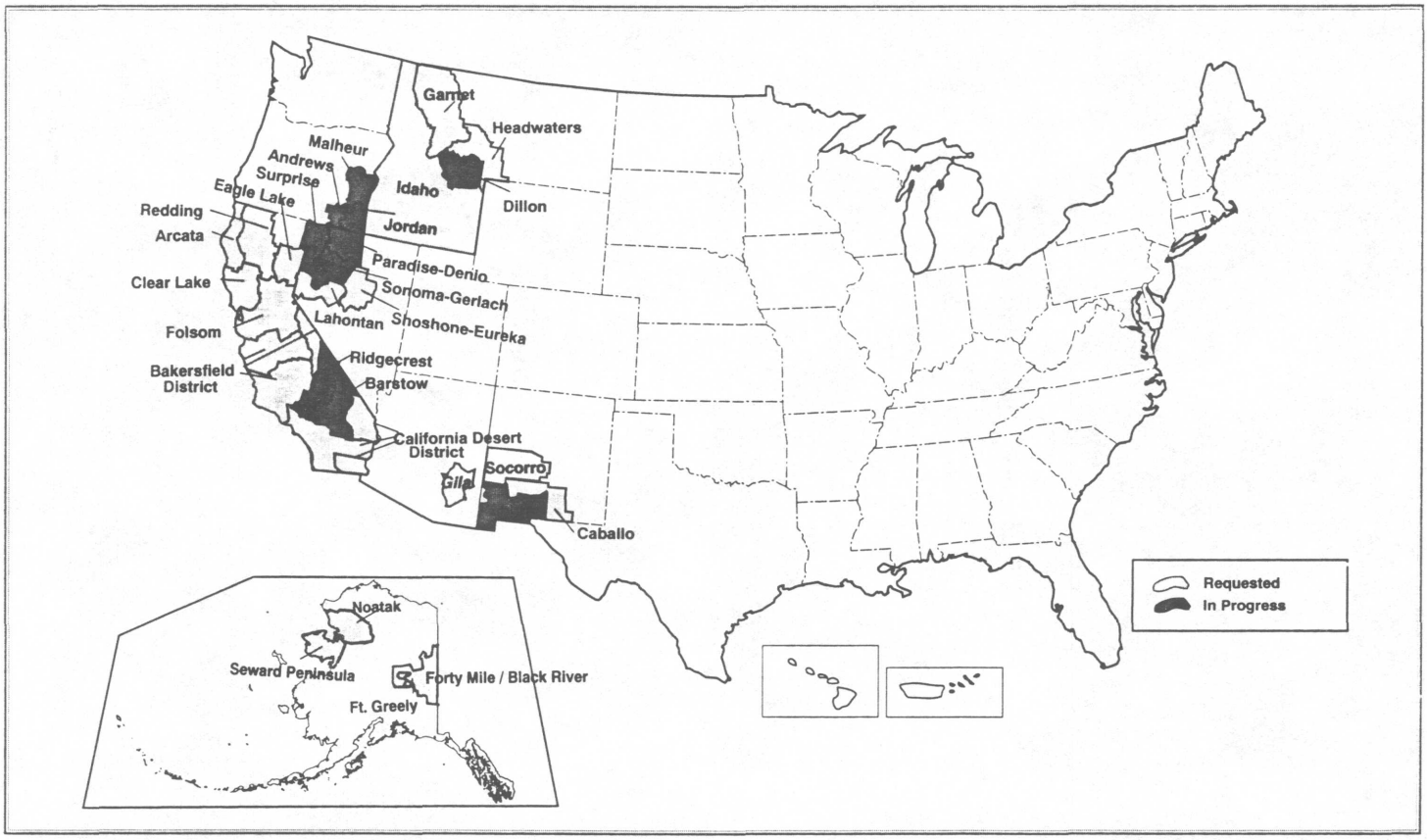


Figure 8. Status of mineral assessments of BLM resource areas

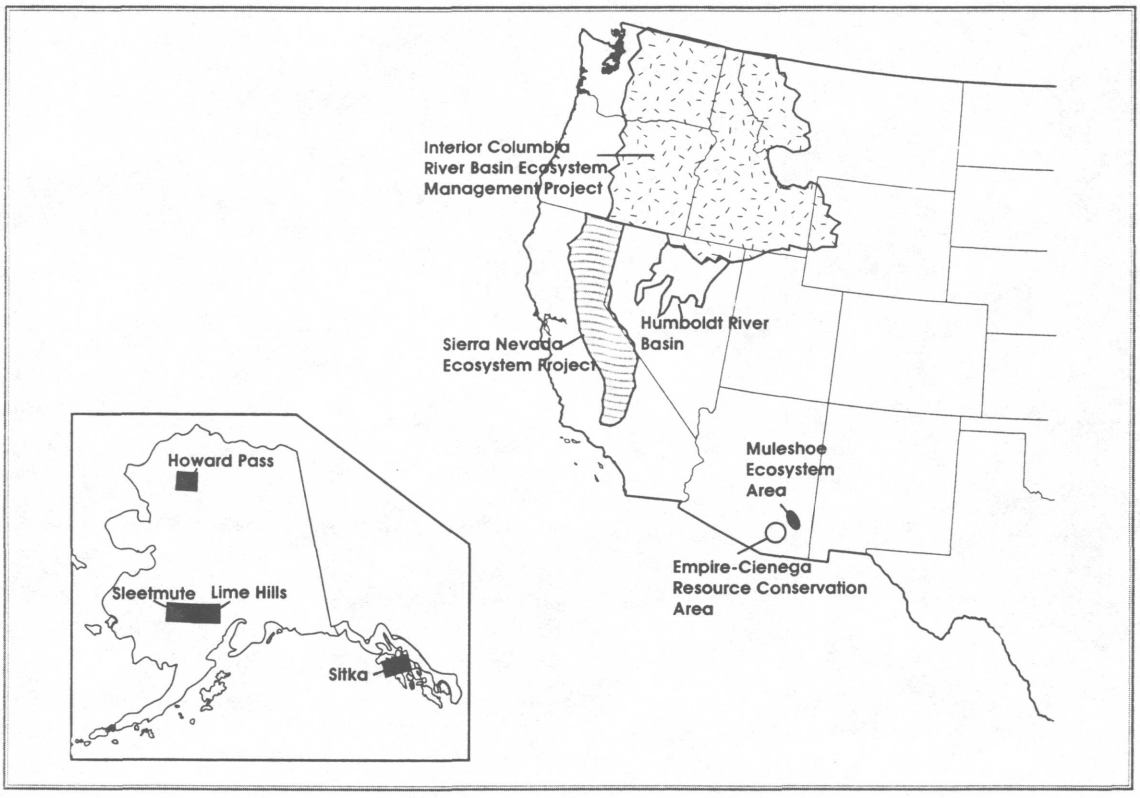


Figure 9. Special study areas

Mitigation Studies

Mitigation Studies identify processes that can result in minerals-related environmental impacts and provide information to assist in mitigation and remediation.

Mineral deposits contain anomalous concentrations of chemical elements, many of which can adversely affect the environment. Mining and mineral processing can result in increased physical and chemical dispersion of toxic materials that can increase adverse environmental effects. To determine the magnitude of these effects, both undeveloped and mined mineral deposits must be characterized with respect to their chemical composition and the mobility of toxic materials. This information is critical to the mining industry, as well as land-management and regulatory agencies, for establishing environmentally acceptable plans for future mining and for developing remediation strategies at inactive and abandoned mine lands. There are currently several hundred thousand abandoned mine sites in the United States for which reclamation efforts could cost billions of dollars. USGS studies help to reduce costs of mitigation and reclamation by determining the extent and character of problems as a basis for developing effective solutions.

USGS geoscientists work with biologists, botanists, soil scientists, hydrologists, and other researchers in the USGS and other Federal (such as USBM, FS, BLM, EPA) and State agencies, industry, and academia to characterize the environmental behavior of mineral deposits. Such interdisciplinary research provides greater understanding of the interrelationships between geology and flora and fauna and of the human activities that affect the environment. The results from such integrated scientific research contribute to more effective management of lands, less harmful development activities, cleaner water supplies, and better remediation plans. Products are designed to meet the specific needs of the user and include maps, briefing books, customized reports, data in digital formats, and nontechnical information. USGS mineral-environmental research complements and is coordinated with work conducted by the USBM.

Mitigation Studies are conducted by three interrelated components (fig. 10):

- **Geochemical Backgrounds and Baselines**, to determine the natural variations of minerals and chemical elements to compare with human-induced effects;
- **Studies in Support of Remediation**, to provide information on the geologic, geochemical, and geophysical factors affecting remediation plans and technologies; and

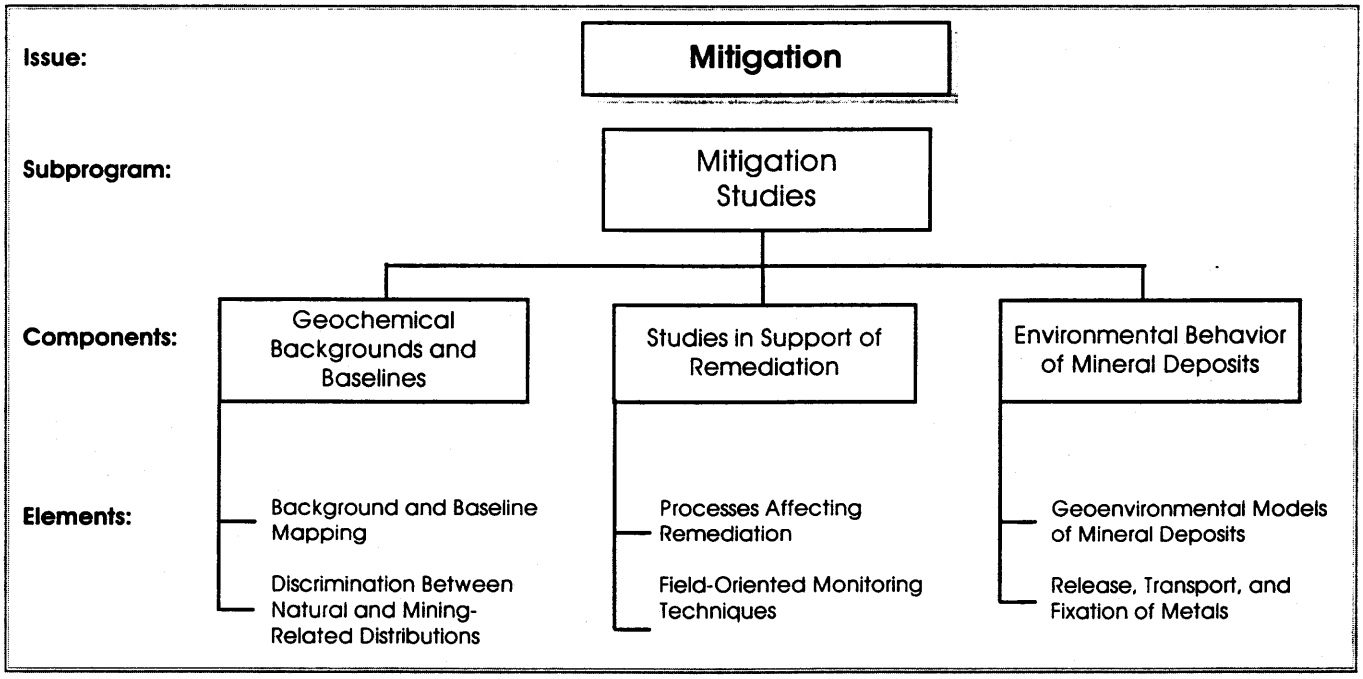


Figure 10. Organization of the Mitigation Studies subprogram

- **Environmental Behavior of Mineral Deposits**, to provide information for predicting the environmental effects of mineral deposits and their development.

Priorities and phasing of activities for these components are shown in table 5.

Backgrounds and Baselines

A geochemical background represents the concentrations of elements in natural materials that exclude human influence. In contrast, a baseline represents the concentrations present in areas disturbed by human activity measured at some point in time and is not generally a true background. Because human influence is widespread, background is typically more difficult to determine than a baseline.

Geochemical Backgrounds and Baselines

A geologic base of information is required to define the natural variations in the occurrence of minerals and chemical elements. This base of information forms the standard to compare with disturbances caused by human activity or natural events. For example, active hot springs in the Sulphur Creek district in northern California contribute particulate mercury and solutes of mercury, tungsten, and other metals to waters in the drainage basin. In contrast, studies have shown that previous mining activity in the district contributed only a minor component of these metals. Environmental baseline studies also increase understanding of natural processes associated with the formation of mineral deposits and with their destruction by surface processes such as weathering.

Objectives

- Establish pre-mining natural backgrounds in areas of mineral development to provide a standard for evaluation of mining-related environmental effects;
- Develop regional geochemical baseline maps through collection of new data and by applying information from existing data bases, such as the National Geochemical Data Base and the National Water Information System;
- Develop and improve methods for determining geochemical backgrounds and baselines.

Elements

The objectives of this component are addressed in the following two elements (fig. 10):

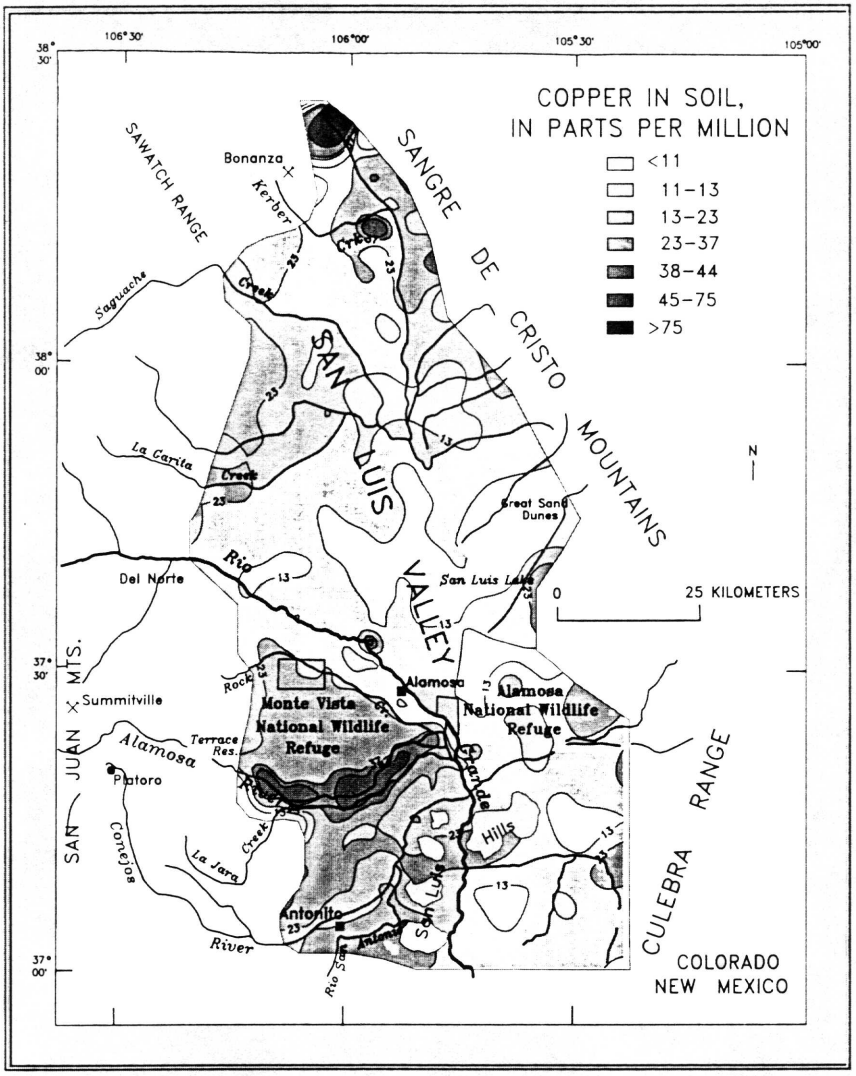
1. Background and Baseline Mapping: The background or baseline geochemistry of soils, sediments, waters, and biota is not well characterized for former and active mining districts in many areas of the country. Important activities of the MRSP during this 5-year plan are:

- Development of regional baseline geochemical maps for major areas of inactive and abandoned mines and selected priority remediation sites (see table 5). These regional baseline studies use information from and are coordinated with priority assessment projects done by the USGS for the BLM, FS, and other Federal agencies.
- Measurement of regional and site-specific chemical element baselines for different types of undeveloped mineral deposits to compare with changes in the landscape resulting from mining. Data obtained in the study of undeveloped deposits serve as analogs for the background conditions that may have existed in areas where mineral development has taken place.
- Development and improvement of methods used in measuring background and baseline conditions.

2. Discrimination Between Natural and Mining-Related Distributions: Mining of mineral deposits can accelerate and increase dispersion of potentially toxic metals and chemicals. Development of improved methods to help discriminate between natural chemical distributions and those resulting from mining, extraction, and smelting processes is a priority for the MRSP. For example, the USGS is studying the effects on water quality of undeveloped mineralized areas within the upper Alamosa River basin in southern Colorado to better determine how drainage from the Summitville gold mine has affected water quality in the Alamosa River. Determination of natural and mining-related element dispersion allows regulatory agencies to quantify the environmental impact of development on a region or watershed and assists industry in mitigation and remediation planning.

Studies in Support of Remediation

In many cases, adverse environmental effects of mineral extraction and processing can be reduced by use of development plans that incorporate appropriate earth-science information. Generally, the costs of correcting problems are far greater than the costs of advance planning to assure that development minimizes environmen-



Chemical analysis of soils collected by the USGS in the San Juan region of southwestern Colorado indicate that two mining districts, Summitville and Bonanza, contribute metal-bearing sediment to the San Luis Valley floor.

tal consequences. Plans for reclamation and for future mining that incorporate the results from geologically based investigations allow industry and Federal and State agencies to better predict and prevent adverse effects of mining and to control associated risks and costs.

Objectives

- Provide technical information and background data to assist the remedial efforts of others at sites where minerals-related contamination has been identified;
- Investigate the geologic and geochemical processes that affect mining and remediation plans and technologies so that they can be adapted and improved to minimize environmental changes.

Elements

Objectives of this component are addressed by two elements (fig. 10):

1. Processes Affecting Remediation: The successful application of remediation technologies depends on understanding how natural and human-induced processes can affect these technologies. For example, some mineral deposits are located in areas with numerous fractures and faults that can serve as pathways for fluids. Knowledge of the distribution of such faults and their effect on the movement of waters at a mine site can be critical to preventing problems with acid mine drainage. Information on the geologic characteristics of mineral deposits and their environmental effects help to increase the efficiency of mining and remediation technologies and increase our knowledge of the effects of mining on sensitive natural environments.

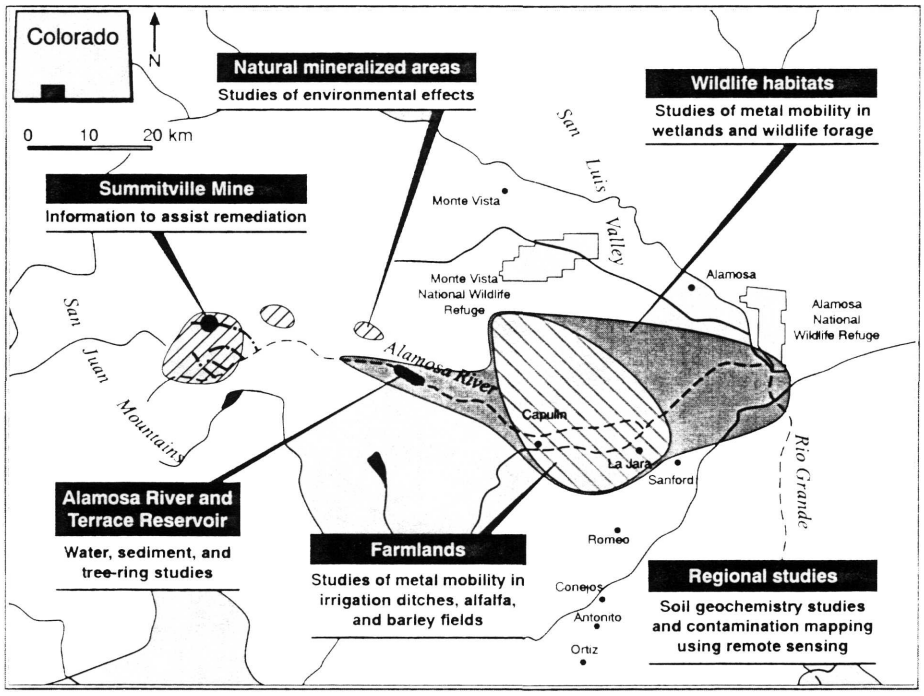
The USGS is currently working in cooperation with the USBM, EPA, FS, and FWS to evaluate the capacity of naturally occurring, widely available, and relatively inexpensive materials such as zeolite minerals to reduce acidity and toxicity of natural and waste waters. This work focused initially on the capabilities of a variety of zeolite-rich samples to remove toxic metals from mine drainages of the Colorado mineral belt. The study will expand to test other potentially important applications, including for agricultural drainage in the San Luis Valley of southern Colorado and the Snake River Plain area of southern Idaho, and for industrial drainage related to phosphate mining in southern Idaho.

2. Field-Oriented Monitoring Techniques: A priority of the MRSP is the development and effective application of field monitoring techniques that help assess the relative efficiency and success of remediation efforts. Activities related to this include:

- Development and testing of new geochemical methods and geophysical techniques such as remote sensing, land-based electromagnetic methods, and ground penetrating radar for use in monitoring remediation efforts;

U.S. Geological Survey studies provide information crucial to the remediation of environmental damage at the Summitville Mine, southwest Colorado

Water from the Alamosa River, which runs through the San Luis Valley in southwestern Colorado, is used extensively for irrigation, domestic purposes, and water supply to the Alamosa National Wildlife Refuge and nearby wetlands. Increasing concentrations of heavy metals and acid in the river water, attributed to recent mining at Summitville, Colo., have drawn national attention. These environmental problems are compounded by the erosion of natural sources of highly mineralized rocks in the San Juan Mountains and by contamination from historical mining. To address these problems, the USGS recently undertook site-specific studies at the now-abandoned Summitville gold mine and detailed geologic and geophysical work in the San Luis Valley.



Environmental studies in the Summitville Mine area, southern Colorado

At Summitville, USGS scientists evaluated the contamination problems at and downstream from the mine. Geologists and geophysicists made a detailed map of the fracture systems and chemically toxic zones at the mine site to establish the hydrologic pathways of contaminated water. The USGS also provided information on the concentrations of chemical elements that have not been monitored previously in the Summitville drainage, on the geologic and geochemical processes that control the drainage chemistries, and on baseline geochemical conditions present on the site before any reclamation or remediation began. The information provided by the USGS is being used by (1) the U.S. Environmental Protection Agency, to help improve site remediation; (2) the State of Colorado, Federal land-management agencies (BLM, FS), and the mining industry to help understand and prevent similar environmental problems at other mines; and (3) downstream water users such as farmers, water conservancy districts, and the Alamosa National Wildlife Refuge (managed by the U.S. Fish and Wildlife Service) to evaluate potential impacts of Summitville on agriculture and wildlife ecosystems.

USGS studies of the downstream environmental effects of the Summitville Mine have also helped avert a crop and food scare that could have cost farmers in the southwestern San Luis Valley hundreds of thousands of dollars in lost revenue. Studies of 1993 alfalfa and barley crops showed that metal concentrations in crops irrigated with water affected by acid-mine drainage from Summitville were far below toxic levels and were well within concentration ranges measured in alfalfa and barley crops elsewhere in the United States. In fact, local farmers feel that increased copper levels measured in alfalfa crops have actually increased the crops' value because copper is an essential nutrient for cattle that is typically added to cattle feed.

Results of USGS studies at Summitville are published in: "Environmental Considerations of Active and Abandoned Mine Lands—Lessons from Summitville, Colorado" (USGS Bulletin 2220, 1995).

- Development of real-time monitoring capabilities, combining remote-sensing methods with GIS and other computerized data-processing techniques; and
- Development of expert system computer programs that can be used to identify the most appropriate geochemical and geophysical techniques and technologies to characterize the degree and extent of contamination at various hazardous material sites.

Environmental Behavior of Mineral Deposits

The environmental behavior of mineral deposits is defined as the suites, concentrations, residences, and availabilities of chemical elements in soils, sediments, airborne particulates, and waters that result from natural weathering of mineral deposits and from mining, mineral processing, and smelting. Along with geochemical processes and biological mediated processes, the geologic characteristics of mineral deposits exert fundamental controls on how the deposits and their mining and mineral processing byproducts interact with the environment. Other important controls, such as climate, topographic setting, and mining and mineral processing methods, generally modify the environmental effects controlled by mineral deposit geology and geochemical processes. A detailed understanding of mineral deposit geology and geochemical processes, which control element dispersion into the environment, is crucial for effective prediction, mitigation, and remediation of the environmental effects of mineral-resource development.

Objectives

- Improve predictive capabilities by developing geoenvironmental mineral-deposit models that characterize the environmental behavior of different type of mineral deposits;
- Increase understanding of the process that affect the availability, transport, and deposition of metals, chemical compounds, and particulate rock materials into the environment from mineral deposits and mineral development.

Elements

The objectives of this subprogram component are addressed by two elements (fig. 10):

1. Geoenvironmental Models of Mineral Deposits: Geoenvironmental models that characterize the environmental behavior of a class of deposits are a fundamental tool for predicting the environmental impacts of mineral deposits and mineral development. Such models are based on descriptive and empirical studies of the natural and human-induced effects associated with mineral deposits. A geoenvironmental model for a given type of mineral deposit characterizes the environmental behavior of rocks, soils, sediments, and waters prior to mining. It also describes and predicts the environmental effects likely to result from mining and processing of metals from such a deposit—the character and size of mine workings, the character and mass of waste products, and the processes of their interactions with the environment. At present, geoenvironmental models are available for only a few deposit types. Development and improvement of geoenvironmental deposit models are high priorities of the MRSP during this 5-year plan.

2. Release, Transport, and Fixation of Metals: Dispersion of potentially toxic metals and chemical compounds from historical mining sites is a growing land-management concern. Research is being conducted to gain greater understanding of the fundamental geochemical and biogeochemical processes that affect the release, transport, and fixation (deposition) of toxic metals. Such knowledge is required to evaluate and predict the environmental effects of mining and mineral development, develop geoenvironmental deposit models, and design effective mitigation and remediation technologies. This research, conducted in cooperation with scientists from government, industry, and academia, provides information applicable to dealing with a wide variety of environmental contamination issues.

Table 5. Schedule for Mitigation Studies activities

Subprogram Component and Activity	Program Year: FY 1994	FY 1995	1	2	3	4	5
Geochemical Baselines and Backgrounds							
Baseline and Background Mapping							
Colorado	—	—					
Montana		—	—				
Arizona			—	—	—		
New Mexico				—	—		
Idaho				—	—		
Washington					—	—	—
Oregon					—	—	—
California						—	→
Nevada							→
Utah							→
Discrimination Between Natural and Mining-Related Distributions	—	—	—	—	—	—	→
Studies in Support of Remediation							
Processes Affecting Remediation							
Summitville Mine, southern Colorado	—	—					
Coeur d'Alene Mining District, northern Idaho	—	—	—	—			
Blackbird Mine, Idaho	—	—	—	→ ?			
Mercury Districts, California, Pacific Northwest	—	—	—	—	—		
Motherlode District, CA					—	—	—
Northern Great Basin, NV				—	—	—	
Phosphate, Florida						—	→
Field-Oriented Monitoring Techniques	—	—	—	—	—	—	→
Environmental Behavior of Mineral Deposits	—	—	—	—	—	—	→

Resource Investigations

Resource Investigations provide information that aids the Nation in the development of policies and new mineral resources required to maintain a secure and reliable supply of mineral raw materials.

A secure and reliable supply of mineral materials is critical for the Nation's economy and defense. In the past, supplies have come primarily from domestic mineral production and imports. However, the current national trend is toward greater import dependence for many mineral commodities. To anticipate future changes in resource availability and supply requires that up-to-date, objective information be available concerning undiscovered mineral resources, exploration patterns and strategies, and global mineral-resource issues.

Resource supply issues are important even during times when mineral raw materials are relatively abundant. Mineral deposits are finite resources. The exhaustion of mineral raw materials from current mines will require that new discoveries and mine development take place to meet the growing demand for resources. Decisions must be made regarding where future development will occur, considering all aspects of economy, environment, and technology. Further, future shortages may occur as demand increases, deposits are depleted, local or regional political instability curtails supplies, and environmental concerns restrict mining. The United States must continue to monitor global sources of minerals so that possible shortages are anticipated far enough in advance to allow alternative sources or materials to be identified and secured.

Domestic mineral exploration is approaching a stage in which the easily found deposits have been discovered. Continued long-term domestic supply of minerals depends on defining new areas of mineral potential, identifying new and unconventional deposit types, and improving predictive capabilities for mineral-resource assessments.

The USGS continues to be at the forefront in development of new mineral-deposit concepts and in identifying new regions of mineral-resource potential. The USGS studies improve capabilities to predict where mineral resources will be sought and developed in the future. They also help identify concerns and issues regarding global mineral supply and availability. Such frontier research is not generally undertaken by the private sector, which focuses its efforts on well-known deposit types in more traditional mineral-producing regions that have more immediate prospect for financial return.

Resource Investigations are conducted under three interrelated components (fig. 11):

- **Mineral-Resource Frontiers**, to identify new types of mineral deposits and areas of mineral potential;

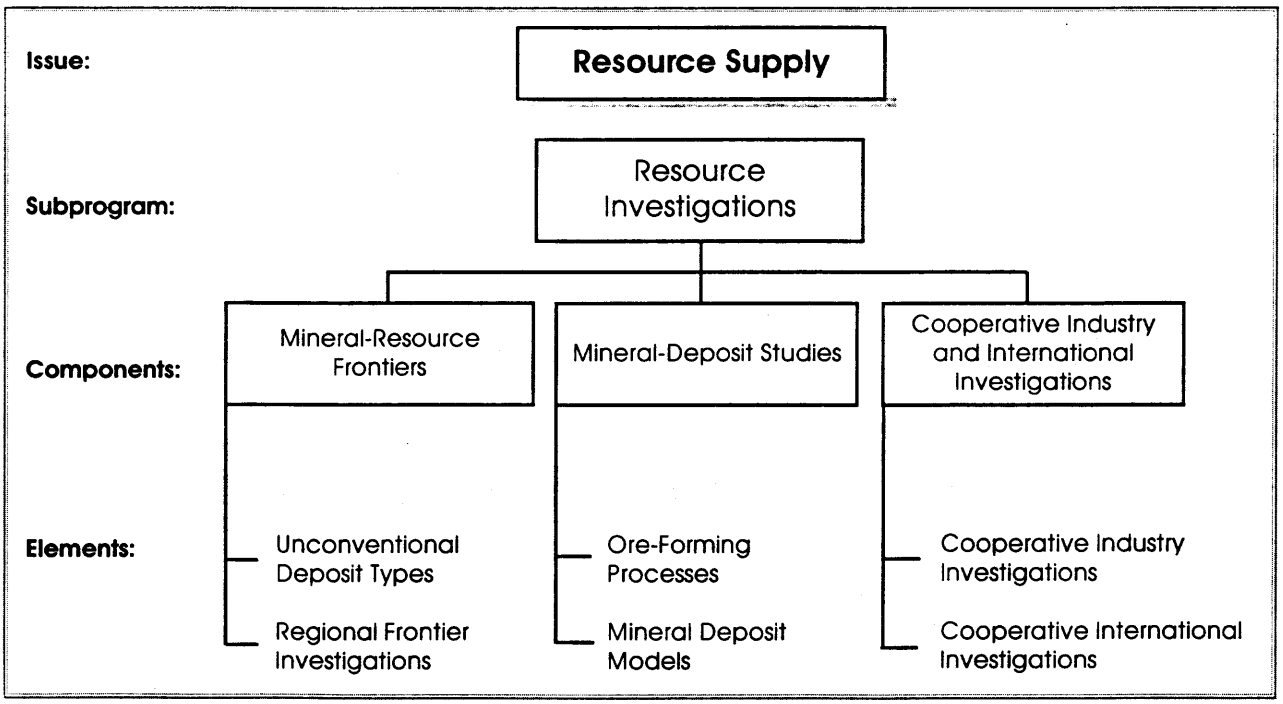
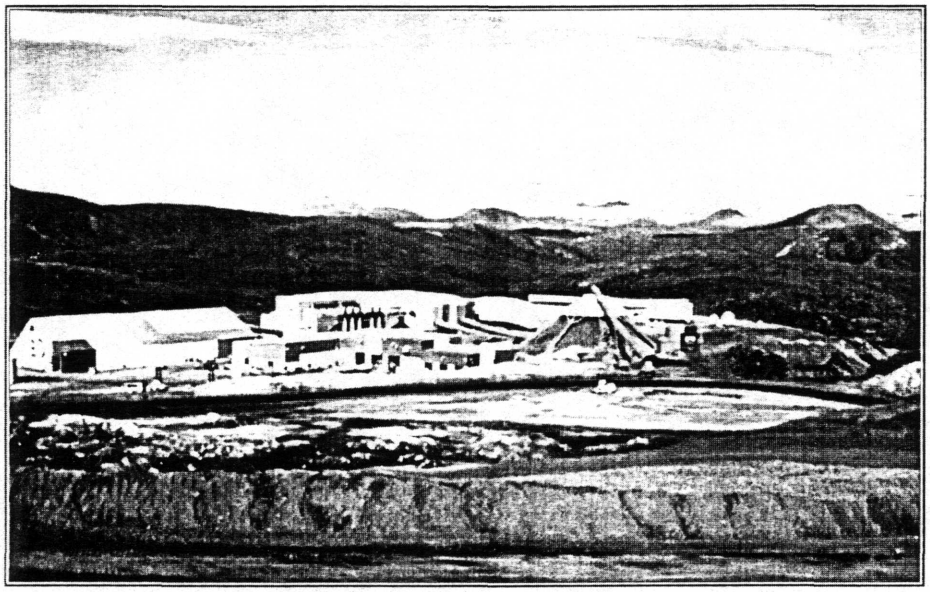


Figure 11. Organization of the Resource Investigations subprogram

U.S. Geological Survey investigation leads to discovery and development of the Red Dog Mine, Alaska

The orange- and red-stained creek bed that drains the area known as the Red Dog Mine was known for generations to the local Inupiat Eskimos, because fish didn't live in the mineral-rich waters of the creek. But it was not until the late 1960's, after Bob Baker, a pilot and part-time prospector from Kotzebue, Alaska, saw the area and suggested that USGS geologists investigate the staining in the creek, that the possibility of a mineral deposit in the area was recognized. USGS geologists flew to the remote creek in northwest Alaska and conducted a quick sampling of the creek bed. Later, replicate analyses of two samples revealed up to 10 percent lead—an exceptionally high mineral content. In the first published report on the area, released in 1970, Survey geologists recommended further exploration of Red Dog Creek. As a direct result of the data released by the USGS, both industry and the U.S. Bureau of Mines conducted studies that led to the discovery of the Red Dog lead-zinc deposit. Based on results from these subsequent studies, the area of Red Dog Creek was excluded from Federal land withdrawals that would have precluded the possibility of mining. In 1978, the NANA Regional Corporation, one of 13 Alaska Native regional corporations, selected the lands containing the Red Dog deposit as part of the Alaska Native Claims Settlement Act. NANA entered a joint agreement with Cominco Ltd. to develop the property in 1982.



The Red Dog Mine went into production in late 1990 after 10 years of exploration and development work. As of February 1994, reserves were estimated at about 13.3 million tons of zinc, 3.9 million tons of lead, and 190 million ounces of silver. These reserves make the Red Dog a world-class deposit, ranking as one of the largest zinc deposits in the world. It contains about two-thirds of all U.S. zinc resources, and approximately doubled the U.S. output of zinc. Since the ore is shipped overseas for refining, the production from the Red Dog Mine has a positive effect on the U.S. trade deficit. The mine cost about $400 million to develop, and it is expected to have a mine life of at least 50 years. About 280 new jobs were created by the mine, with an annual payroll of more than $15 million. These jobs and the resulting income are highly significant in an area of mainly subsistence living where unemployment rates range from 20 to 70 percent. Over the life of the mine, royalties to the NANA Regional Corporation will amount to about $1 billion, and the mine will inject at least $5 billion into the economy of Alaska.

As in most major mineral-resource operations, successful development depends on a chain of events, and each event is critical to the discovery and development process. The USGS played a significant role in bringing the Red Dog deposit to the attention of the public. The USGS continues to provide information on the complicated factors that controlled the formation of mineral resources at the Red Dog Mine and at other similar deposits. USGS research has been instrumental in defining geologic models that characterize the Red Dog deposit and explain how it was formed. These models are used for mineral-resource assessments and benefit industry in their exploration for similar deposits in Alaska and elsewhere.

- **Mineral-Deposit Studies**, to improve predictive capabilities by investigating and modeling the processes that form mineral deposits; and
- **Cooperative Industry and International Investigations**, to promote information and technology transfer.

Priorities and phasing of activities for these components are shown in table 6.

Mineral-Resource Frontiers

Long-term mineral supply from both domestic and imported sources requires development of new and unconventional concepts of mineral-deposit formation and identification of regions that have potential for new, particularly unconventional, mineral deposits. USGS frontier research helps to prioritize areas for mineral potential, thereby helping improve regional and national mineral-resource assessments. The minerals industry benefits from frontier research through the identification of areas with potential for new discoveries, which improves exploration efficiency and reduces financial risk.

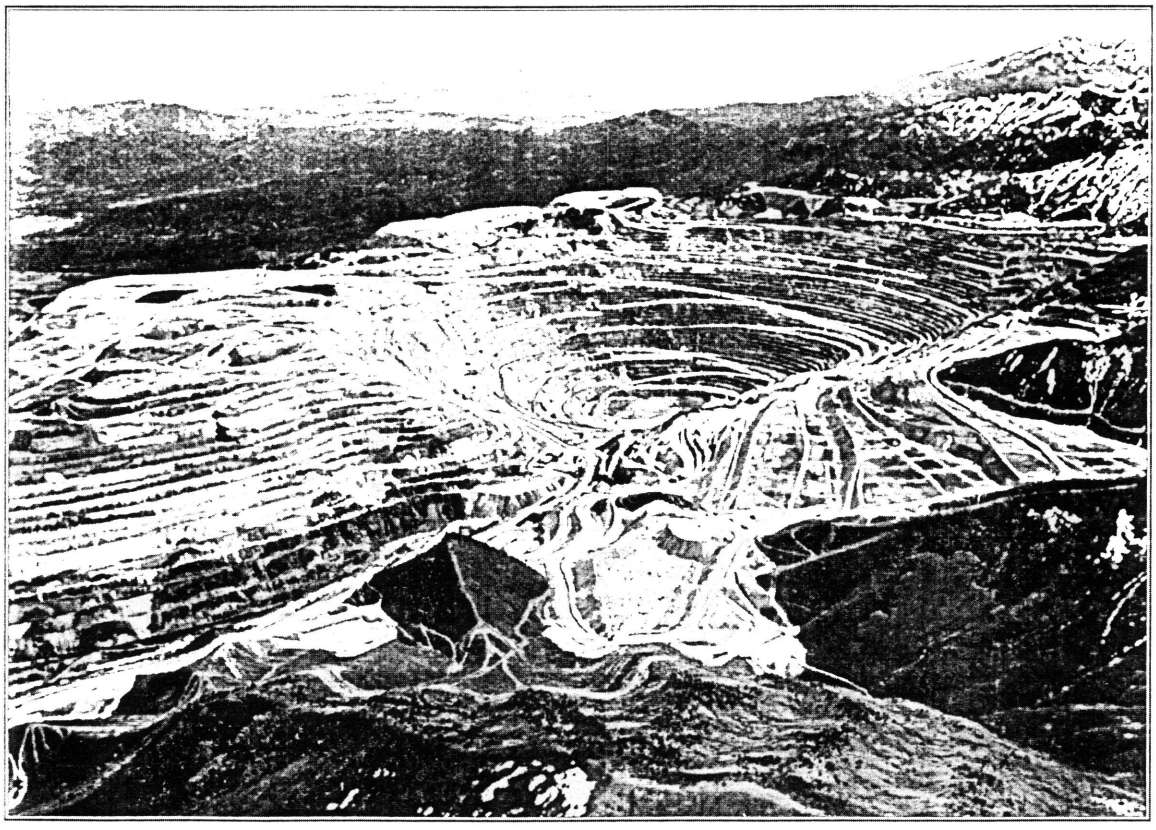
Objectives

- Identify new type of mineral deposits, particularly unconventional mineral deposit types, through development and testing of new theories of mineral deposit formation and occurrence;
- Identify new areas for mineral potential through mineral district and regional investigations and testing of new mineral-deposit theories.

Elements

The objectives of this component are addressed by two elements (fig. 11):

1. Unconventional Deposit Types: Mineral assessment and industry exploration are necessarily directed toward types of mineral deposits whose characteristics and mode of occurrence are well-known. Through years of research, exploration, and production, these conventional types of deposits are relatively well-understood and form the basis of our current mineral supply. Geologic and geochemical theory predicts, however, that many additional types of mineral deposits exist but remain unidentified.



The Bingham copper mine in the Oquirrh Mountains southwest of Salt Lake City, Utah, was opened in 1904 as the first open-pit copper mine in the world. Although it has produced nearly 12 million tons of copper, an unequaled record, the Bingham deposit is also a significant producer of molybdenum, gold, silver, and lead. Other byproducts include bismuth, platinum, selenium, rhenium, and sulfuric acid.

Research on unconventional deposit types employs innovative interpretations of data and principles to form new theories of mineral-deposit formation and to predict new types of geologic environments that might host deposits. For example, recent USGS research, done in cooperation with international scientists, led to the recognition of enrichments of platinum-group elements (PGE's) in sulfide-rich layers in certain unusual marine sedimentary rocks. Platinum-group elements are of particular interest because of their use in catalytic converters to reduce air pollution from automobile exhaust. Economically significant PGE concentrations are reported from certain sedimentary rocks from China, Canada, and Poland. The origin of these extreme metal enrichments is currently being investigated. The results of this basic research are fundamental in identifying new frontier areas for exploration for similar deposits. Rocks similar to those containing known PGE mineralization are widespread in parts of the United States, especially Alaska, and may have potential for PGE deposits similar to those in China and Canada.

Research on unconventional deposits also includes identifying potential byproduct commodities from mineral deposits. Although mineral deposits have varied compositions and mineralogy, they are often mined only for major components such as copper sulfides. Ores may also contain other commodities in lesser but sufficient quantities to warrant recovery. For example, certain copper deposits, such as the Bingham deposit in Utah, mined for their copper sulfides, can also produce significant amounts of other metals including gold, silver, platinum, and palladium. Studies of potential by-product commodities in different types of mineral deposits promote the efficient use of the Nation's mineral resources. Such studies also aid mineral-environmental assessments and studies because mineral deposit byproducts, such as radioactive minerals in some gold and base-metal deposits; cadmium in some zinc deposits; and arsenic, mercury, tellurium, and selenium in some gold deposits, can contribute significantly to environmental contamination and risk to human health. Studies also identify those deposit types that could be developed with minimal environmental consequences.

2. Regional Frontier Investigations: Some types of mineral deposits commonly occur in clusters covering regions of tens to hundreds of square miles. These groups of mineral deposits formed in response to chemical and physical systems that operated on a regional scale. Many regions of the United States have geologic characteristics that are generally suggestive of undiscovered mineral resources. However, many of these regions lack sufficient data to make more precise evaluations of their undiscovered mineral resources, particularly for new, unconventional deposit types.

Regional frontier investigations are designed to test new theories of mineral deposits and collect and interpret geologic, geochemical, and geophysical data needed to identify potential for undiscovered mineral resources. These investigations help define the potential for discovery of new deposits in both known mineral districts and new frontier regions. The studies provide minerals-related data bases, physical and conceptual models, and maps. Frontier studies contribute to our understanding of how and where mineral deposits form and how they interact with the environment. Priority regions for investigation during this 5-year plan are given in table 6. The regions selected for study have geologic characteristics that suggest they may have considerable potential for undiscovered mineral resources.

Mineral-Deposit Studies

Assessment of mineral-resource potential is becoming increasingly difficult since most significant near-surface metal concentrations have been identified, except in the most remote and inaccessible areas. Continued research is required to improve capabilities to evaluate the potential for covered or concealed mineral resources at ever increasing depths in the Earth. MRSP scientists conduct research to develop new concepts, models, theories, and techniques needed to improve mineral-resource and related environmental assessments and investigations. This research also benefits the minerals industry by increasing understanding of how and in what environments mineral deposits form.

U.S. Geological Survey scientists improve Russian technology for use in mineral-resource assessment, environmental monitoring, and mineral exploration

The NEOCHIM method, an electro-chemical technique developed by USGS scientists in part through a Cooperative Research and Development Agreement (CRADA) with the minerals industry, provides a novel way to measure the availability and mobility of chemical elements in the Earth's low-temperature, near-surface environment. USGS scientists are applying this new technique to mineral-resource assessments and environmental monitoring while the minerals industry is employing it in exploration for buried mineral deposits.

NEOCHIM was derived from the CHIM electro-chemical method, developed about 25 years ago in the former Soviet Union for exploration of buried mineral deposits. Soviet scientists reported that the CHIM method could locate mineral deposits buried beneath hundreds of feet of rock that were undetectable by more conventional geochemical methods. This was accomplished by the unique way the CHIM method samples materials dissolved in the natural moisture that is present in rocks and soils. Measurements are made by applying a direct electrical current to the Earth through special sampling electrodes. The electrical current causes ions present in rocks and soil to migrate into the electrodes. USGS scientists began researching the CHIM method in 1989 and identified significant problems with the conventional electrodes developed for CHIM by the Russians. To overcome these problems, the USGS scientists developed new electrodes and NEOCHIM. The new electrodes sample ions that are dissolved in rock and soil moisture with greater efficiency than the original Soviet electrodes.

Numerous USGS studies have shown that buried mineral deposits are often surrounded by anomalous chemical element concentrations, called geochemical haloes. These haloes have traditionally been detected by using chemical extraction methods on soil samples. However, whereas chemical extractions are normally conducted on samples of less than 1 $inch^3$, the NEOCHIM method easily samples volumes 100,000 times as large without moving the soil. The greater sensitivity provided by NEOCHIM can easily detect even weak geochemical haloes that may be associated with buried mineral deposits.

The NEOCHIM method can identify mobile chemical components in rocks and soils whether of natural or human origin. NEOCHIM can be used for: determining the influence of geologic variables on the chemistry of soil moisture; identifying changes in soil moisture chemistry caused by distant sources of pollution; evaluating the effectiveness of soil remediation efforts; and increasing our understanding of chemical processes occurring in the unsaturated zone above the water table.

Mineral resource studies by the USGS improve understanding of how and where mineral deposits form

- **Hot Spring-type Gold Deposits:** Geologic and geochemical studies by USGS scientists over the past decade have improved knowledge of the origin of an important new type of mineral deposit in the western United States, hot spring-type gold deposits. These studies, such as those conducted at the McLaughlin gold deposit in California, have improved USGS capabilities to assess the potential for hot spring-type deposits. The results from these studies have also been used by industry to focus their exploration efforts for this new deposit type.
- **Northwest Nevada–Southeast Oregon–Southwest Idaho:** Regional mineral-resource assessments and district studies (such as McDermitt and Quartz Mountain districts) in the late 1970's to early 1990's identified potential for significant mineral resources in the region. The results of these studies have been used by mineral companies to plan their exploration activities in the region and resulted in discovery of major resources of lithium, uranium, and specialty clays (presently being mined) in the McDermitt area.
- **Southeast Missouri Lead-Zinc District:** Research by USGS scientists, in cooperation with scientists from State geological surveys, universities, and the Geological Survey of Canada, has contributed to improved models for the distribution and formation of the famous Mississippi Valley-type lead and zinc deposits of the Tri-State District, Viburnum Trend, and the Old Lead Belt of southeast Missouri. These models have provided a basis for delineating permissive areas for new deposits in the mineral districts of the Midcontinent region of the United States. In addition, USGS scientists are using the results from the Midcontinent mining district studies to aid assessments for similar deposit types in countries with developing economies, including Poland and Eastern European countries, under the U.S. Department of State Science and Technology Program.

Objectives

- Improve predictive capabilities by increasing understanding of the physical and chemical processes that lead to the formation of mineral deposits;
- Improve assessment capabilities by developing mineral deposit models that describe the geologic and grade and tonnage characteristics of different types of mineral deposits.

Elements

The objectives of this component are addressed by two elements (fig. 11):

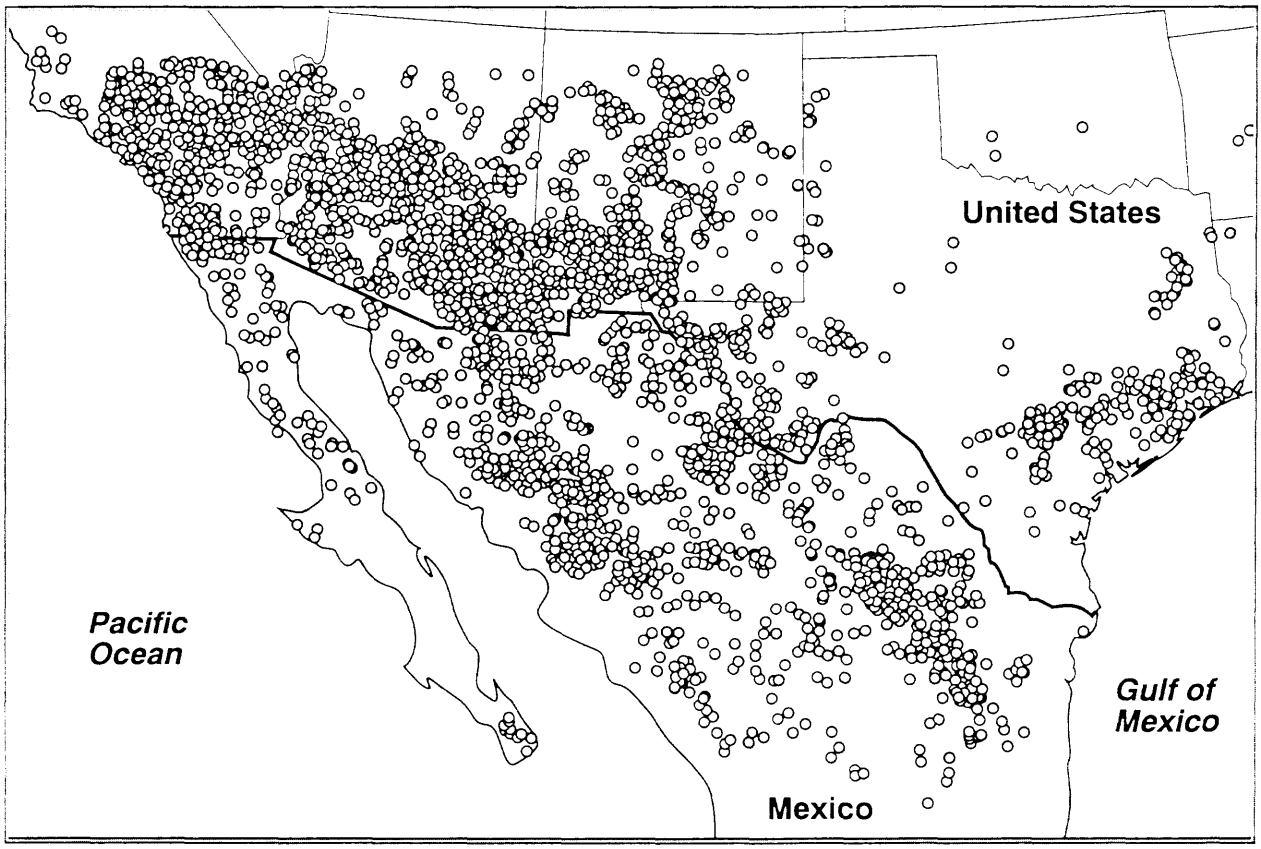
1. Ore-Forming Processes: Understanding the natural processes that form mineral deposits and the conditions under which those processes operate is essential for improving mineral-resource assessment methods. USGS scientists conduct multidisciplinary studies to define such features as temperature and pressure of mineral-forming reactions, the source of ore-forming metals, and the mechanisms by which those metals are transported and deposited. Quantitative computer methods are developed to model and visualize oreforming processes. Results of these studies improve predictive capabilities by refining models of mineral-deposit formation.

2. Mineral-Deposit Models: Mineral-deposit models serve as conceptual analogies, incorporating a variety of intersecting geochemical, geophysical, and geologic attributes, for assessing mineral resources. Because every mineral deposit is different, models must progress beyond the purely descriptive to represent more than single deposits. Deposits sharing a relatively wide variety and large number of attributes can be characterized as a "type." Deposit models describe the geologic environments in which the deposit type is found, and they identify the common characteristics of the deposit type including tonnages and average grades of well-explored deposits. The models allow geologists to discriminate: (1) possible mineralized environments from barren environments; (2) types of known deposits from each other; and (3) mineral deposits from mineral occurrences (a mineral deposit is a mineral occurrence of sufficient size and grade that it might, under the most favorable circumstances, be considered to have economic potential). As new data on the origin, occurrence, and characteristics of all types of mineral deposits are obtained, this information is integrated and used to refine

The USGS Center for Inter-American Mineral Resource Investigations (CIMRI) works to expand the Mineral Resource Data System (MRDS)

CIMRI obtains data on mineral deposits, prospects, and occurrences throughout Central and South America and through the MRDS makes these data available to government, industry and the public. CIMRI provides MRDS software to Latin American organizations and trains their personnel in how to enter data and maintain the system. The system is currently installed and in use in many Latin American countries including: Argentina, Bolivia, Costa Rica, Dominican Republic, Ecuador, Guyana, Jamaica, Mexico, Peru, and Venezuela. In exchange for installing the Spanish or English language version of MRDS and supplying the Spanish language instruction books, the USGS receives the records entered into the MRDS system by the foreign agencies. The MRDS network standardizes mineral site data and serves as a national data base in some foreign locations.

The MRDS data base contains information for more than 110,000 mineral sites worldwide; more than 10,000 of these sites are within the U.S.-Mexico border region. Ratification of the North American Free Trade Agreement (NAFTA) with Mexico may accelerate economic growth and trade along the U.S.-Mexico border. Mines, prospects, and mineral occurrences within the U.S.-Mexico border region are sources of wealth to local and national economies of Mexico and the United States. Some of these sites are also potential sources of environmental contamination; other sites are potential sources of materials used in environmental remediation. MRDS data on the distribution and characteristics of the mines and deposits are essential for planning industrial and urban development and improving the quality of life in the border region. These data are available to the public through USGS Minerals Information Offices and will shortly be released on CD-ROM as a USGS Digital Data Series publication.



Distribution of all mines, prospects, and occurrences of metallic and industrial mineral commodities in and adjacent to the U.S.-Mexico border region for which the MRDS includes records

existing mineral-deposit models and to develop new ones. Specific priorities for the MRSP during this 5-year plan are to:

- Continue systematic development of new mineral-deposit models and revision of existing models including tonnage and grade information;
- Develop a consistent format for all mineral-deposit models to facilitate standardization and computer manipulation of data;
- Develop local mineral-deposit models including tonnage and grade information as appropriate for specific geologic regions and environments; and
- Increase on-line access to mineral-deposit model information.

Cooperative Industry and International Investigations

Maintaining a reliable, cost-effective supply of mineral materials requires accurate, up-to-date global mineral-resource information. This information is used by the Federal Government to develop resource policies and by the U.S. minerals industry to maintain its competitiveness in the world economy. Cooperative investigations with industry provide USGS scientists with access to important deposits and mining districts and to information otherwise unavailable. Similarly, cooperative international investigations provide access to data sources, mineral deposits, and regions that would not otherwise be accessible or known. The cooperative investigations help the USGS maintain a global mineral-resource data base and promote the efficient transfer of minerals information and technology.

Objectives

- Maintain accurate and up-to-date global mineral-resource information;
- Promote the efficient transfer of information and technology to industry and foreign cooperators;
- Advance U.S. foreign relations through assistance to foreign governments on issues related to mineral resources.

Elements

The objectives of this subprogram component are addressed by two elements (fig. 11):

1. Cooperative Industry Investigations: Partnerships with industry are developed as opportunities arise that are consistent with MRSP goals and objectives. Arrangements may be informal or may be formalized through instruments such as CRADA's. In these agreements, industry typically provides the USGS with access to data, to mine workings, and exploration drilling results and other data that would otherwise be unavailable. These data are often critical to developing and refining models and theories of mineral-deposit formation and occurrence that are required for accurate mineral-resource and related environmental assessments. Results from these studies are made publicly available. These cooperative investigations benefit industry in solving specific minerals-related problems and help them to maintain a competitive edge in mineral exploration.

2. Cooperative International Investigations: The USGS conducts selected international studies in cooperation with foreign governments at scales ranging from individual mineral deposits to entire nations. These investigations are commonly funded in whole or part with money external to MRSP appropriations. International cooperation serves three objectives:

- Supports U.S. foreign outreach and assistance;
- Allows USGS scientists to learn about important deposit types currently unknown or poorly represented in the United States; and
- Provides U.S. companies with objective international mineral-resource information.

The USGS has cooperated with the governments of Costa Rica, Bolivia, and Venezuela to produce countrywide mineral-resource assessments, and it has recently completed a 3-year cooperative project with Peru, Chile, and Bolivia to investigate the precious- and base-metal mineral resources of the Andes Mountains. This Andean project, funded by the Inter-American Development Bank provided for training and technology transfer by USGS per-

The International Studies of Minerals Issues Working Group

The International Studies of Minerals Issues working group "undertakes cooperative studies that address global issues related to the sustainable development of mineral resources and the supply of mineral commodities needed to meet the material demands and environmental concerns of a growing world population." ISMI includes agencies from Australia, Canada, Germany, South Africa, the United Kingdom, and the United States which pool their efforts in gathering, interpreting, and publishing information on selected global mineral resources.

sonnel, as well as for field investigations and mapping of mineralized areas similar to areas in the United States that are less exposed. The success of this project has led the Inter-American Development Bank to support development of a new 5-year project plan for further cooperative mineral-resource work with Peru, Chile, Bolivia, and Argentina.

The USGS also participates with earth science and mineral-resource agencies of other countries in specific mineral-resource-related activities such as the International Studies of Mineral Issues (ISMI) working group. The USGS and other participating organizations share information with each other and provide information, analysis, and advice for mineral-policy decisions to their respective governments. For the USGS, such cooperative activities help establish and update resource information in the Mineral Resource Data System and aid in the continuing analysis of global and regional mineral-resource availability.

Table 6. Schedule for Resource Investigation activities

Subprogram Component and Activity	FY 1994	FY 1995	Program Year 1	2	3	4	5
Mineral Resource Frontiers							
Unconventional Deposit Types	———	———	———	———	———	———	———→
Regional Frontier Investigations							
Carolina Gold District, NC-SC	———	———	———	———			
Lake Superior Region, MI-WI-MN	———	———	———	———	———	———	———
Midcontinent Region	———	———	———				
Rio Grande Rift, NM	———	———	———	———			
Wyoming		———	———	———	———	———	
Northern Nevada		———	———	———	———	———	———
Eastern Oregon-Western Idaho			———	———	———	———	———
Colorado Desert Region, Western AZ-Southern CA			———	———	———	———	———
Kuskokim-Fairbanks Mineral Belt, AK			———	———	———		
Aleutian Islands and Western Alaska, AK				———	———	———	
Ambler District, AK					———	———	———
Southeastern Alaska						———	———→
Zinc Deposits of Interior Alaska							———→
Mineral-Deposit Studies	———	———	———	———	———	———	———→
Cooperative Industry and International Investigations	———	———	———	———	———	———	———→

Information and Technology Transfer

Information and Technology Transfer provides timely, useful, and efficient transfer of minerals-related information and technology in formats tailored to the needs of diverse users.

Informed decisions by government, industry, and the public are the basis of wise stewardship of the Earth's environment and mineral resources. The MRSP addresses the availability, accessibility, and interpretation of minerals-related information, as well as the ways in which minerals-related geoscience expertise and information are provided to Federal, State, private, and foreign users.

Mineral information is available in several formats including maps, reports, data bases, geographic information systems, models, and assessments. The ability to locate and rapidly access information, in digital formats where possible, is a major goal of the MRSP, as is the interpretation of data using GIS and other scientific visualization techniques. MRSP researchers are working with customers to determine how best to meet their needs and to provide the necessary information and interpretations in usable and appropriate formats.

Mineral information needs are addressed by two interrelated components (fig. 12):

- **Data Bases and Information Analysis**, to develop, maintain, and improve minerals-related data bases and technologies for information analysis; and
- **Information and Technology Transfer**, to improve the access to and distribution of minerals-related information and technology.

Data Bases and Information Analysis

The USGS has systematically acquired minerals-related information for more than 100 years. This body of information includes topical and regional information regarding the occurrence and distribution of mineral resources as well as understanding of the physical processes that concentrate and disperse minerals and chemicals in the environment. The minerals-related information can be applied to issues well beyond those related directly to mineral resources. For example, information on the processes leading to dispersion of toxic metals in the environment also contributes to evaluations of surface- and ground-water quality nationally.

Scientific data are maintained in archives (samples, field notes, commodity files, and maps), published reports, digital data bases, and geographic information systems. Much of this information is most readily accessible in maps and reports published by the USGS as well as in externally published books and journals. Increasingly, such information is entered into digital data bases. Digital directories are created and maintained for data and information that cannot be stored in a digital format.

During the last two decades, several digital data bases, including the Mineral Resource Data System (MRDS), the National Geochemical Data Base (NGDB), and various geophysical data bases, were developed and have been maintained to support research and assessment activities within the MRSP. These digital data bases are also used for other important research activities conducted within the USGS, other Federal and State agencies, industry, and academia. For example, Federal and State wildlife agencies use the USGS geochemical data to assess conditions of wildlife habitats. USGS scientists also participate with other geological organizations, such as the ISMI working group, to provide information and expertise regarding global mineral supply issues.

Objectives

- Develop and maintain comprehensive geochemical, geophysical, mineral-resource, and mineral-environmental data bases in digital format.
- Develop and improve GIS and other spatial analysis tools for scientific visualization and analysis.
- Improve capabilities to distribute, analyze, and integrate minerals-related data and to establish on-line access to data bases through information networks.

Elements

The objectives of this program component are addressed by three elements (fig. 12):

1. Data Base Development and Management: The development and management of digital data bases and map coverages on computer systems are vital to the research of

V.E. McKelvey Forum on Mineral and Energy Resources

In 1985, the USGS held the first V.E. McKelvey Forum on Mineral and Energy Resources entitled "USGS Research on Mineral Resources—1985." This annual forum was established to improve communication between the USGS and members of the private sector, academia, and other government agencies by presenting the results of current USGS research on nonrenewable resources in a timely fashion and by providing an opportunity for individuals from other organizations to meet informally with USGS scientists and managers. Since 1985, the subject of the McKelvey Forum has alternated between mineral and energy resources.

the MRSP and to our customers. Software is developed and upgraded to make it interactive and openly accessible in multiple formats. Other activities include:

- Expanding site coverage and adding environmental information to data bases such as MRDS;
- Full implementation of the National Geochemical Data Base; and
- Integration of MRSP data bases with other data bases, such as those containing water quality and environmentally related analytical data.

2. Information Analysis: The MRSP increasingly employs new analytical technologies such as GIS to improve visualization and analysis of minerals-related problems. These technologies allow efficient handling and archiving of large data sets and they change the ways in which data are used and analyzed. For example, investigators can exploit visualization techniques such as GIS to detect otherwise hidden patterns and trends in geologic data. GIS helps to create digital mineral-deposit models that use all available geologic, geochemical, geophysical, and environmental information in an integrated, interactive mode. MRSP research focuses on further developing efficient applications of these new technologies to address mineral-resource and mineral-environmental issues.

3. Mineral Resource Specialists: Mineral-resource specialists are USGS scientists who have expertise in particular mineral commodities including knowledge of important types of mineral deposits, their modes of occurrence, and status of global mineral-resource availability. Over the years, these specialists have helped to build and maintain data bases on global mineral resources. They respond directly to inquiries from the public and private sector. They serve on interagency and government-industry committees and publish research and general interest reports on the geology and resources of mineral commodities. Studies that include production and processing of mineral supply for such commodities as aluminum, copper, and titanium have been accomplished through cooperative research with mineral-commodity specialists of the USBM. Commodity specialists focus on commodities of special interest to land and resource planners, and those for which the United States is critically dependent on foreign supplies.

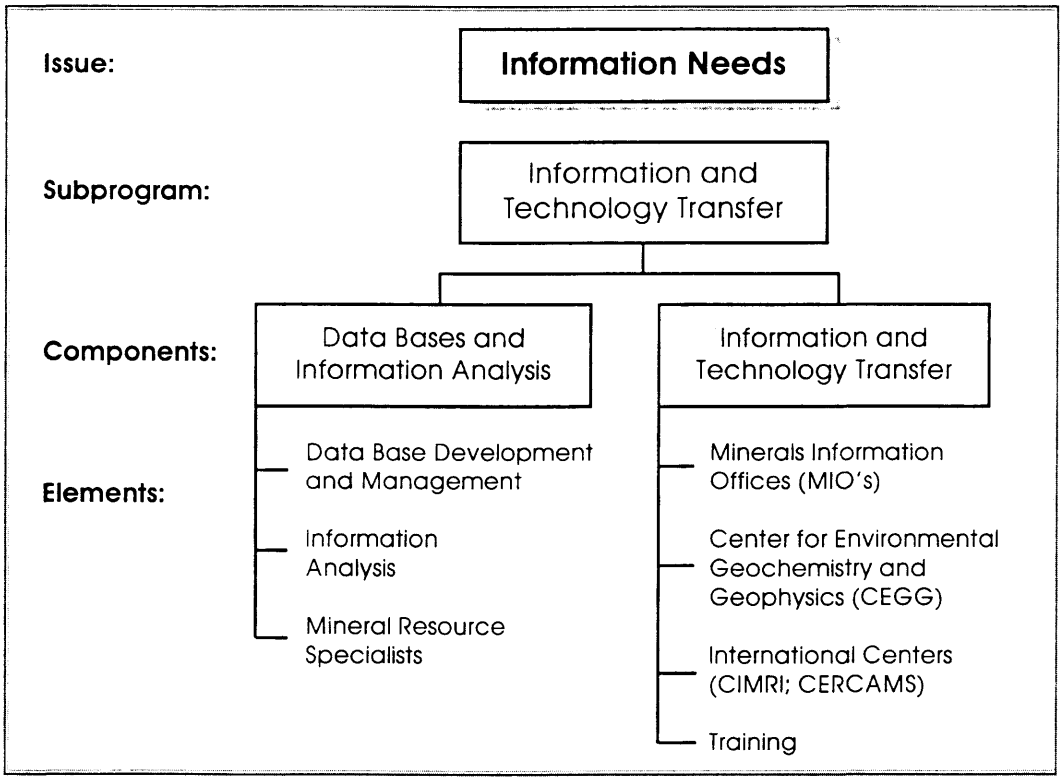


Figure 12. Organization of the Information and Technology Transfer subprogram

Information and Technology Transfer

Minerals information should be easily accessible and in a format appropriate for effective use by government, industry, academia, and the public. Historically, the MRSP has provided a wide variety of maps, reports, and data bases that present new data and summarize results of minerals-related activities. Increased emphasis on digital information requires development and improvement of capabilities that facilitate searching, retrieving, manipulating, and visualizing geologic information and that improve access to the overall scientific expertise that is the core of the MRSP.

The MRSP communicates with the users of minerals information to identify their needs. USGS managers and scientists work to anticipate national needs, identify emerging trends and minerals issues, and ensure that MRSP products are applicable and presented in a format appropriate for the users' needs. The MRSP also provides objective, instructive information that can be used to inform the public and to increase awareness of local, regional, national, and global minerals-related issues.

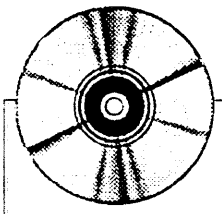
Objectives

- Facilitate the exchange of minerals information with other government agencies, industry, academia, and the public.
- Provide timely and efficient distribution of minerals information, including distribution on information networks and CD-ROM's.
- Improve understanding by information users of the significance and limitations of mineral-resource data and information.
- Increase awareness of local, regional, national, and global minerals-related issues through publications, training, and outreach.

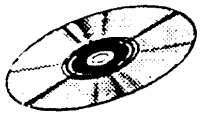
Elements

The objectives of this subprogram component are addressed by four elements (fig. 12):

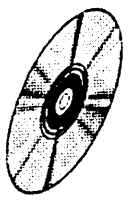
1. Minerals Information Offices (MIO's): The MRSP maintains Minerals Information Offices in Denver, Reno, Spokane, Tucson, and Washington, D.C., to facilitate information exchange and technology transfer with program customers. MIO's translate and format electronic data for public distribution so that customers can use the information on personal computers with commercially available software. MIO's maintain domestic and international technical data bases, international economic cables from the State Department, and specific regional and international mineral-resource files. They also provide information on products and services available from both USGS and non-USGS sources. In response to direct inquiries, cus-



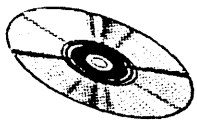
Recent USGS CD-ROM's provided by the Mineral Resource Surveys Program



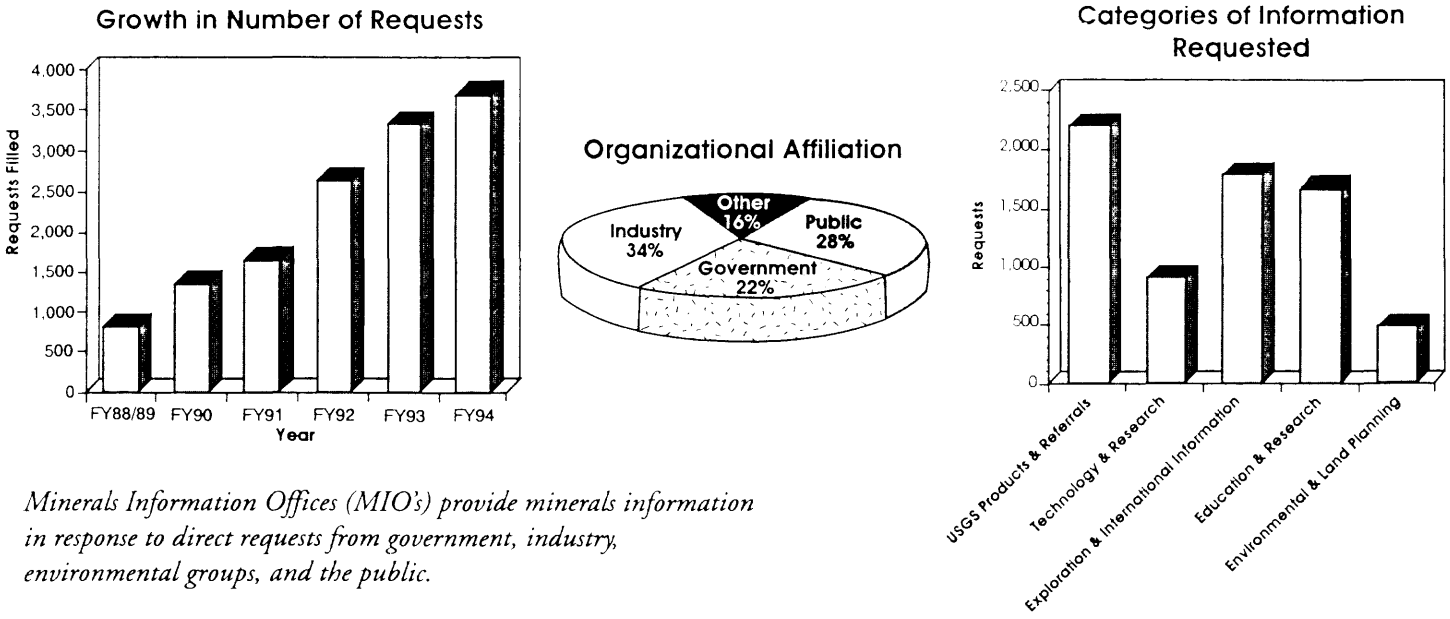
- National Geochemical Data Bases: National Uranium Resource Evaluation Data for the Conterminous Western United States: U.S. Geological Survey Digital Data Series DDS-1.



- Geology of Nevada: A Digital Representation of the 1978 Geologic Map of Nevada: U.S. Geological Survey Digital Data Series DDS-2.
- National Geophysical Data Grids: Gamma-Ray, Gravity, Magnetic, and Topographic Data for the Conterminous United States: U.S. Geological Survey Digital Data Series DDS-9.
- Geology of the Conterminous United States at 1:2,500,000 Scale—A Digital Representation of the 1974 P.B. King and H.M. Beikman Map: U.S. Geological Survey Digital Data Series DDS-11.



- National Geochemical Data Base: National Uranium Resource Evaluation Data for the Conterminous United States: U.S. Geological Survey Digital Data Series DDS-18-A.



Minerals Information Offices (MIO's) provide minerals information in response to direct requests from government, industry, environmental groups, and the public.

tomized maps and documents are produced using these data. MIO's are expanding the information that can be accessed, including (1) indexes to exploration assistance file records, including location and accessibility of the information, (2) published digital information of MRSP activities, and (3) geochemical and geophysical data bases.

2. Center for Environmental Geochemistry and Geophysics (CEGG): The CEGG, located in Denver, is a new center that coordinates environmental geoscience research and the exchange of information. CEGG (1) initiates and coordinates environmental geochemical and geophysical research, (2) facilitates exchanges of information with government agencies and industry, (3) links society's research needs to USGS scientists and research capabilities, (4) conducts training and information seminars, and (5) obtains information, technology, and funding for environmental studies from other government agencies and industry.

3. International Centers (CIMRI, CERCAMS): The MRSP includes two centers dedicated to gathering, interpreting, and disseminating international minerals information, one on Latin America (CIMRI) and the other on Russia and Central Asia (CERCAMS). These Centers promote technology transfer and training, cooperative mineral-resource investigations, and mineral information exchange and outreach. Other centers may be established in the future (such as centers focused on the Southeast Asia and Eastern Europe) to help meet program goals and if permitted by MRSP staffing and funding.

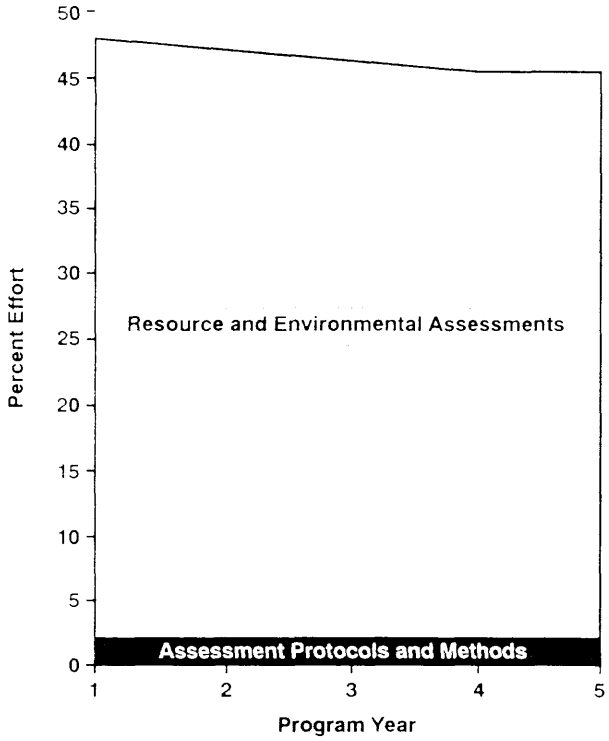
4. Training: Effective use of the profuse amount of data, technology, and products on mineral-resources and related environmental issues requires that users understand the significance and limitations of these materials. The USGS provides training to users of minerals information through workshops, publications, and formal and informal meetings. For example, the USGS provides annual minerals-related training to U.S. Department of State Regional Resource Officers. This training provides the resource officers with scientific background and understanding to assist them in collecting useful data and in communicating with U.S. companies during their foreign assignments.

To meet the changing needs for minerals-related information, such as mineral-environmental assessments, the MRSP provides cross-training of its personnel to assure a broad understanding of our customers' needs. Through this training, methods for data collection and interpretation can be standardized and new studies can be effectively integrated with work in progress. Training also encompasses aspects of (1) GIS and other scientific visualization methods needed to meet customer needs, and (2) mineral-resource assessments to incorporate new data and methods. In-house seminars and short courses and specialized readings are used to provide the requisite level of knowledge to MRSP scientists. ❑

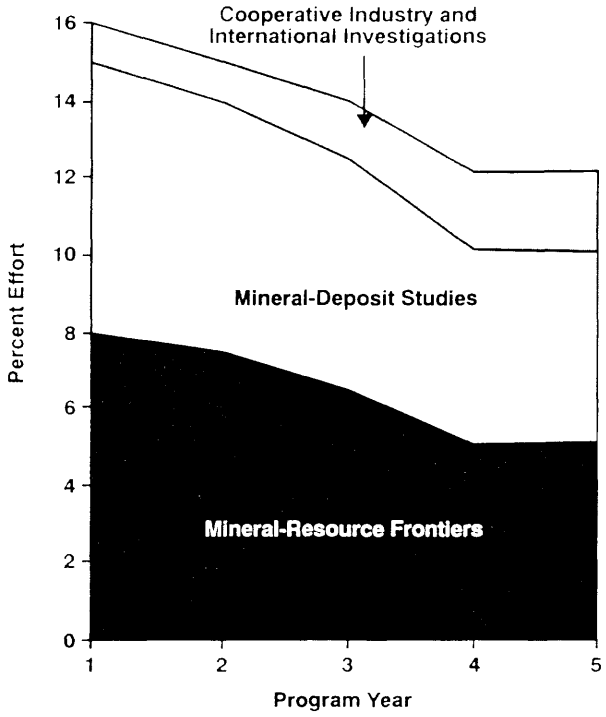
Appendix A

Graphs showing percent effort of subprogram components during the period of this 5-year plan

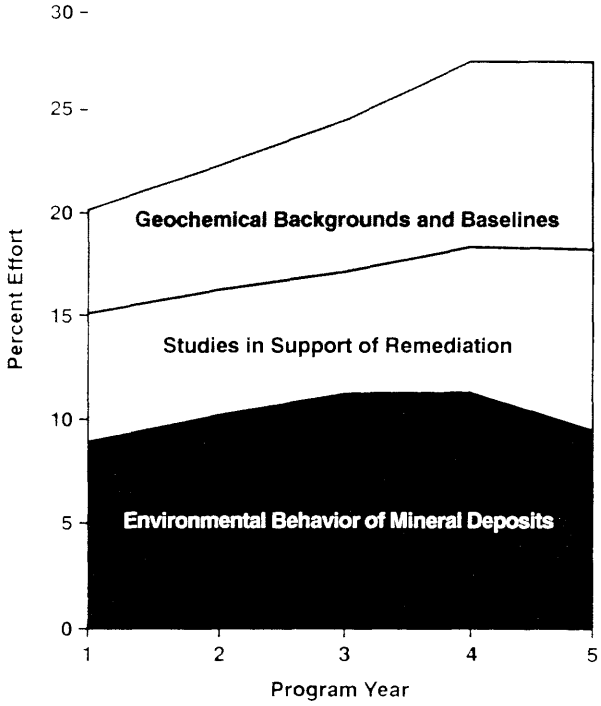
Assessment Subprogram



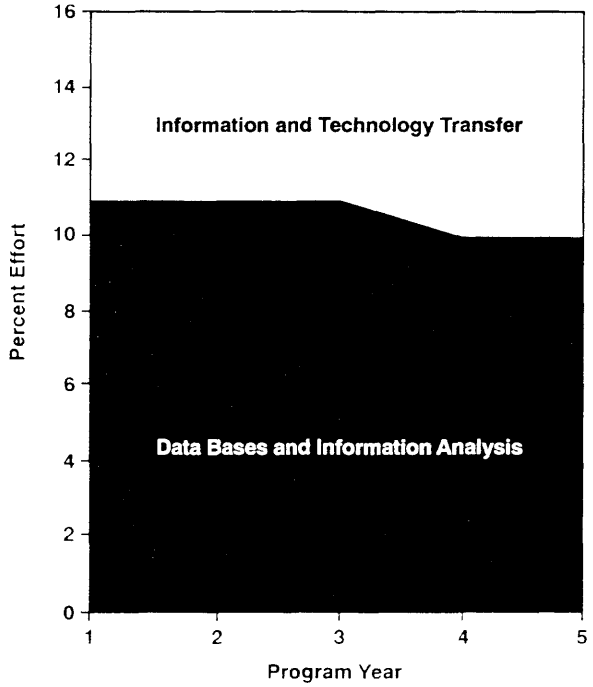
Resource Investigations Subprogram



Mitigation Studies Subprogram



Information and Technology Transfer Subprogram



Appendix B

Budget for Subprogram components based on FY 1995 appropriation ($M)

Assessments Subprogram	**YR1**	**YR2**	**YR3**	**YR4**	**YR5**
Resource and Environmental Assessments	20.61	20.16	19.71	19.26	19.26
Assessment Protocols and Methods	0.90	0.90	0.90	0.90	0.90
Total	**21.51**	**21.06**	**20.61**	**20.16**	**20.16**
Mitigation Studies Subprogram					
Geochemical Backgrounds and Baselines	2.24	2.69	3.14	4.03	4.03
Studies in Support of Remediation	2.69	2.69	2.69	3.14	3.14
Environmental Behavior of Mineral Deposits	4.03	4.48	4.93	4.93	4.93
Total	**8.96**	**9.86**	**10.76**	**12.10**	**12.10**
Resource Investigations Subprogram					
Mineral-Resource Frontiers	3.58	3.36	2.91	2.24	2.24
Mineral-Deposit Studies	3.14	2.91	2.69	2.24	2.24
Cooperative Industry and International Investigations	0.45	0.45	0.67	0.90	0.90
Total	**7.17**	**6.72**	**6.27**	**5.38**	**5.38**
Information and Technology Transfer Subprogram					
Data Bases and Information Analysis	4.93	4.93	4.93	4.48	4.48
Information and Technology Transfer	2.24	2.24	2.24	2.69	2.69
Total	**7.17**	**7.17**	**7.17**	**7.17**	**7.17**