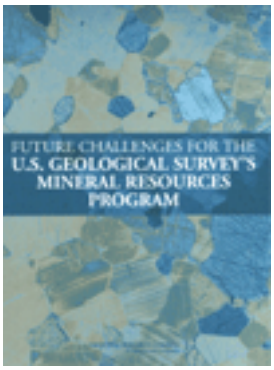

Future Challenges for the U.S. Geological Survey's Mineral Resources Program

Committee to Review the U.S. Geological Survey's Mineral Resources Program, Committee on Earth Resources, National Research Council

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Board on Earth Sciences and Resources
Committee on Earth Resources
Division on Earth and Life Studies

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This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's (NRC) Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their review of this report:

Alex Glover, Feldspar Corporation
Jean-Michel M. Rendu, Mining Consultant
Jeffrey Christian, CPM Group
Larry Grayson, University of Missouri-Rolla
Joaquin Ruiz, University of Arizona
Iddo Wernick, World Resources Institute
James Davis, California State Geologist (retired)
Samuel S. Adams, Independent Consultant
Ann S. Maest, Buka Environmental

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Geoffrey P. Feiss, College of William and Mary, Provost. Appointed by the NRC, he was responsible for making certain that an independent examination of the report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

Preface

The very importance of minerals to the economy and security of the United States demands that a vast amount of information on the geological, economic, and environmental aspects of minerals from all parts of the world is readily available to government, private, and public sectors. Since 1879 the U.S. Geological Survey (USGS) has been the preeminent organization providing vital minerals information not only on a national basis but internationally as well. In 1995 the USGS developed a plan for its minerals program, a mission-driven research program specifically focused on mineral issues that integrates environmental, resource, and economic factors. In 1996 the National Research Council (NRC) conducted a critical evaluation of this plan and provided input on how it could be modified to improve its effectiveness in meeting the long-term needs of the nation. The committee concluded that the plan represented a significant departure from the past and that its implementation would result in important directional changes in the USGS's mineral resource activities (NRC, 1996).

Since the 1996 NRC evaluation, the USGS minerals program has indeed undergone significant changes, including a new moniker, the Mineral Resources Program (MRP). The program changes resulted not only from incorporation of the 1996 recommendations but also assimilation of the minerals information function from the U.S. Bureau of Mines, decreases in budgetary allocations, and managerial reorganization. These substantial program transformations prompted the USGS to request a re-assessment

by the NRC of its minerals program. This re-assessment examines the USGS's response to the 1996 report, evaluates the minerals information function, examines changes in the MRP's customer base, and offers recommendations for the program's future.

This report is the culmination of many hours of evaluation, deliberation, writing, and rewriting by a dedicated committee whose expertise and experience were invaluable to the final product. The committee thanks Keri Moore for her unwavering enthusiasm and persistence in obtaining necessary information, and we offer our very best wishes to her in her new career. The committee is especially indebted to Tammy Dickinson, who stepped in mid-report and ably guided us to a logical conclusion and contributed substantially to the final report.

Corale L. Brierley
Chairman

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Executive Summary

Like food, air, and water, minerals[1] are a fundamental ingredient of human life. As the population has increased and our society has developed, the need for minerals has grown and diversified. As minerals have been the basis of breakthroughs in civilization, they are now essential for the present and future technological revolution. The United States is generously endowed with mineral resources. It is one of the world's largest consumers of many mineral products and one of the world's largest producers. The demand for metals and industrial materials in the United States will remain for the foreseeable future, and information on all aspects of production and consumption is critical for ensuring that these materials are available for the United States as well as other countries. In addition, information is needed to improve understanding of the potential impacts of development of these resources.

As a heavy user of minerals from both domestic and international sources, the United States requires quality minerals science and information to make sound policy decisions. Over time, advances in minerals science and improvements in minerals information contribute to greater availability of minerals, at lower cost and with less environmental damage; help society respond to the depletion of known mineral deposits and contribute to the substitution of relatively abundant minerals for increas-

[1] In this report, minerals are defined as all nonfuel mineral resources, including industrial minerals such as aggregates.

ingly scarce ones; and help develop alternative sources of supply for minerals subject to unexpected supply disruptions.

Housed within the Department of the Interior, the U.S. Geological Survey's (USGS) Mineral Resources Program (MRP) provides domestic and international science and information to other programs and disciplines within the agency, other agencies within the department, and other departments within the U.S. government. In addition, state agencies, private industry, academia, U.S. citizens, and the international community use information provided by the MRP. The USGS has carried out these functions in the past, and is respected nationally and internationally for the quality of its information.

In 1996 the National Research Council (NRC) reviewed the USGS's Mineral Resource Surveys Program (MRSP) plan. The recommendations from that study were used by the USGS in redirecting the program. Shortly after the 1996 NRC assessment was completed, the Department of the Interior's Bureau of Mines was abolished and that agency's minerals information function was transferred to the USGS.

The minerals information function, now executed through the Minerals Information Team, was incorporated into the new MRP. Six years following the 1996 NRC evaluation of the USGS's MRSP plan, the NRC was asked to examine the USGS's actions with respect to the 1996 recommendations and incorporation of the minerals information function and to consider future aspects of the MRP. The NRC was not asked to conduct a comprehensive review of the program or the projects within the program. Specifically, the NRC was asked to (1) assess the USGS's response to the 1996 review of the MRSP plan; (2) evaluate the contributions of the minerals information functions in meeting the goals of the USGS and its partner agencies; (3) characterize how the customer base for the program has changed since the 1996 review (who are the appropriate customers?); and (4) examine how the program's vision and activities should evolve to meet the nation's future needs over the next decade.

THE MRP TODAY

Since 1996 the MRSP has undergone substantial changes, including a change in name to the Mineral Resources Program. These changes resulted from several factors, including recommendations made in the 1996 NRC report, significant decreases in budgetary allocations, and manage-

rial reorganization. The program's organization changed from subprograms to teams, and the entire USGS converted to matrix management. The MRP has developed a new five-year plan (Kathleen Johnson, USGS, personal communication, 2002).

The MRP is the largest program in the geology discipline at the USGS. MRP funding has remained rather constant since 1997. The diminished buying power results in a decrease in the ability of the program to meet its vision, mission, and program objectives.

One result of the matrix management style is that on an annual basis since 1997 the USGS has not been able to easily determine the exact number of people actually working within the program because staff effort is allocated across different programs. In addition, staff tend to work on more projects than in the past. The committee is concerned that the fragmentation of staff effort may create unexpected long-term consequences for staff performance, quality of MRP work, and documentation.

The MRP has a strong tradition for reporting its science. Technical publications document the science performed by MRP researchers, make detailed research data and conclusions available to users, and represent the quality of work performed within the MRP. In meetings with MRP staff, the committee heard concerns about how costs for publishing USGS open file reports, professional papers, bulletins, and circulars—the USGS's traditional modes of data dissemination—are passed down to researchers. The staff expects that in the future less research will be published in these traditional and highly respected publications and that more will be published in refereed journals, trade journals, and conference proceedings. While publication in refereed journals validates research quality and is encouraged by the committee, the committee is concerned that, since outside journals are often hesitant to publish large quantities of data, this might lead to less data being published. The committee also heard concerns that there might be a trend to publish more information as fact sheets. The committee recognizes that fact sheets serve a niche, especially for the general public. The USGS may wish to document its success using fact sheets given their inherent value to society. However, fact sheets should not replace publishing in peer-reviewed journals and traditional USGS technical publications. Because the free and open exchange of information and interpretations is critical to the traditions of science generally, the committee believes that trends that place high-quality publications at risk should be resisted if not reversed. **Specifically, the committee recommends that comprehensive, mineral-**

related data and research continue to be published in the USGS's traditional modes of data dissemination.

Projects are a reflection of program goals and objectives. One of the MRP's largest projects is the global mineral resource assessment, which is a cooperative international effort to assess the world's potential for undiscovered nonfuel mineral resources. The committee learned from discussions with stakeholders and MRP scientists that, although the global resources assessment may be important, there is a question as to whether it is scientifically valid, accurate, and precise. *The committee concludes that the global mineral resource assessment would benefit from additional collaboration with potential users as well as from an outside review panel, which could provide objective guidance and balance.* **The committee recommends that an external review panel be inaugurated to gauge methods and results of the global mineral resource assessment and other similar types of assessments.** The committee proposes that the MRP follow the model used by the USGS's Energy Resources Program.

In 1996 the clients and users of MRSP products included federal land management agencies, the mining and quarrying industries, environmental organizations, state geological surveys, state regulatory agencies, local governments, universities, other federal agencies (particularly the Environmental Protection Agency and Army Corp of Engineers), and other groups within the USGS, particularly the Water Resources Division and others in geological mapping, energy, and marine and coastal programs. Currently, the MRP divides its user base into five categories (cooperators, collaborators, clients, grantees, and customers), which define both the nature of the relationship and the products delivered. For purposes of this report all of the above categories will be referred to collectively as "users." The top three users since 1997 include the federal government, trade associations, and the news media, followed closely by state and local agencies. The most significant increase since 1997 is a 5 percent growth in the number of mining companies listed as MRP users. *The committee concludes that the types of users have not changed significantly since 1996, but the number of users has increased by approximately one-third. The committee concludes that the current MRP customer base is appropriate, but could be expanded.*

RESPONSE TO 1996 RECOMMENDATIONS

In 1995 in response to congressional direction, the USGS developed a plan for its mineral resource activities, *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* (USGS, 1995), and requested an evaluation of this plan from the NRC. The 1996 NRC committee determined that the plan was a logical and necessary continuation of the mineral resources objectives and programs at the USGS and praised the program for moving beyond its traditional role of activities, for advancing the understanding of mineral deposits, for providing the basic geological information for new areas with mineral potential, and for facilitating land-use planning by federal and state agencies. The 1995 program plan proposed strengthening activities for understanding the environmental consequences of minerals development and including these activities within the broader scope of mineral deposits research.

Although the context that the program is functioning in today has changed considerably since 1996, this committee believes that the general recommendations of the 1996 NRC report remain directly relevant to the MRP. These recommendations were in four areas: program vision, mission, and objectives; increased collaboration with users, balanced with independent research; maintaining and increasing core competence; and planning, prioritization, and performance. The current committee examined the 1996 recommendations and corresponding responses prepared by the MRP coordinator and staff. While overall the program has been guided by the 1996 report, the MRP five-year plan, and the goals established by the USGS Geologic Division Science Strategy (USGS, 1998a), there are some areas where the current committee believes the MRP would benefit from additional consideration of the 1996 recommendations.

Vision, Mission, and Objectives

The first general recommendation states: "The plan should be modified to include new, clearly articulated statements of vision, mission, and objectives" (NRC, 1996). The 1996 committee believed that the formal statement of the program's vision, mission, and objectives is necessary

for the program's planning, prioritization, and assessment of performance.

The committee could not find any official public statement of the vision and mission, although the concepts are implied in the MRP planning documents. The committee had to rely on MRP personnel to provide the following vision and mission statements:

MRP Vision Statement

> MRP is the sole federal provider of high-quality scientific information, objective resource assessments, and unbiased research results on mineral potential, production, consumption, and environmental behavior.

MRP Mission Statement

- Provide information on regional, national, and global context for mineral resources
- Develop and enhance understanding of relations between minerals, mineralizing processes, and their contributions to our quality of life
- Transfer technologies beyond minerals sciences
- Support land management and the nation

The vision statement does not read like a vision statement but rather like a statement of what's true. The committee believes that a vision statement should be a more lofty, something to reach for, even if it has essentially the same phrases. The committee also found the MRP's mission statements vague and unclear.

The objectives and goals of the program are listed in MRP planning documents and on the program's Website (Kathleen Johnson, USGS, personal communication, 2002). The committee notes that the goals and objectives are written as vague, open-ended, deterministic statements rather than definitive goals and objectives against which progress can be measured. The committee is concerned that there is no mention of research in the operational objectives. It is not clear to the committee what the core functions are or how they are prioritized. The committee believes that the lack of clarity in the goals adversely affects the MRP's ability to plan and communicate the value of its work to others.

In summary, the vision, mission, operational objectives, and goals themselves are confusing and do not provide the guiding light that they should for the program. Planning activities for each year should clearly show that topics respond to the vision and mission (and objectives), thereby reinforcing their importance throughout the organization.

The committee concludes that the MRP has not adequately responded to the first general recommendation of the 1996 review. **The committee recommends that the MRP develop simple, clear mission and vision statements, goals, and objectives that will serve as the guiding principles for the program.** In addition, the mission and vision should be clearly articulated in MRP planning documents, Website and other materials, in statements by leadership and in communications with other parties inside and outside the Department of the Interior with whom the MRP must work, so that they all present a clear vision of future directions for the MRP.

Research Balanced With Increased Collaboration With Users

The second general recommendation states: "To fulfill its mission, the MRSP and its plan should move away from an organizational culture dominated by self-direction and independent research toward one that also embraces projects developed through collaboration with users" (NRC, 1996). Currently, MRP projects are developed in collaboration with internal and/or external users, and most projects involve interdisciplinary teams (Kathleen Johnson, USGS, personal communication, 2002). The committee heard presentations from several agencies relating to collaborative efforts with the MRP. Interactions with some agencies are active and result in extensive collaboration. The committee also heard that some opportunities to develop collaborative arrangements have been missed. *The committee concludes that there is more collaborative project work being done now by the MRP than in 1996. However, there is still some need for improvement in communication and collaboration with some users.*

Maintaining and Increasing Core Competence

The third general recommendation states: "The MRSP should place more emphasis on maintaining and continuing to develop its core compe-

tence in mineral deposits research and minerals-related environmental research in order to anticipate and respond to national needs for mineral resources information" (NRC, 1996). The 1996 committee defined the program's core competence as (1) excellence in mineral deposits research, (2) scientific integrity, and (3) expert professional staff. The committee recommended that research on geology, geochemistry, and genesis of ore deposits be continued. The committee also noted that this research should include both applied and basic research.

Core competence is a popular and much utilized concept for developing a business strategy. It has many definitions, and although the 1996 committee did not specifically define the term, this committee understands it to mean the following: core competency is fundamental knowledge, expertise or skill in a specific area. The committee notes that the term "core competence" is used in the MRP's five-year plan (Kathleen Johnson, USGS, personal communication, 2002). However, it does not appear that the MRP has established the elements that make up its core competence. It is difficult to assess whether or not the MRP has maintained its core competency in mineral deposits research and minerals-related environmental research using easily tracked, strictly quantitative criteria. The committee was not able to obtain from MRP staff the necessary and appropriate information to make direct comparisons between 1996 and 2002. The committee therefore attempted to qualitatively evaluate whether the MRP has maintained its core competence. The MRP has continued research on the geology, geochemistry, and genesis and environmental characteristics of mineral deposits and has taken steps to ensure data integrity. However, the committee was unable to determine if the MRP continues to maintain its core competence in mineral deposits research and minerals-related environmental research because the MRP has not documented its continued core competence in these areas. **The committee recommends that the MRP perform and publish a self-assessment to identify and define its core competence, to evaluate actions needed to maintain such competence into the future, and to relate those findings to its staffing and staff development plans.** As the MRP evolves (see Chapter 5), it must build new core competence in selected new disciplines that address important issues that the organization and its stakeholders think should be addressed.

Planning, Prioritization, and Performance

The fourth and final general recommendation states: "The MRSP and its plan should place greater emphasis on improving mechanisms and procedures for comprehensive planning, setting priorities, and evaluating and enhancing performance, particularly through external reviews or advisory panels. The level of funding for MRSP and the balance of funding among its subprograms deserve thorough review by the MRSP staff, users, and collaborative agencies and organizations" (NRC, 1996).

The USGS has developed a program and project planning process that takes place across organizational structures and disciplines and reflects matrix management, enhanced regional leadership, and an enterprise approach to science. The committee has several concerns relative to program and project development and selection. The committee heard from collaborators, stakeholders, and USGS personnel that program planning is complex and inconsistent. The MRP uses external reviews to provide input; however, these reviews are not as comprehensive as suggested by the USGS program review plan. *The committee concludes that the MRP would benefit significantly by having a highly focused central organization, which is objective driven and possesses clear lines of responsibility for each project. The committee further concludes that the current process of program planning and prioritization is unnecessarily complex and confusing in the context of the MRP's priorities, operational objectives, and goals.* The committee found it difficult to determine how MRP performance is actually measured. The committee was concerned about the lack of external review of projects. **The committee recommends that the MRP establish an external documented review procedure in accordance with the USGS guidelines that will evaluate program outcomes relative to those that were planned.** The committee believes that the absence within the MRP of a well-defined and implementable programmatic vision is the cause of many of the deficiencies in the planning process and performance criteria. Without established direction, program selection can easily shift in response to external review and user requests. **The committee recommends that the MRP implement a management review of proposals to align the work with strategic objectives, a rigorous external review process, and an internal review process that cuts across organizational units.**

Recommendations for MRSP Subprograms

Because of programmatic changes, it was difficult to assess the MRP's response to the specific recommendations related to its subprograms. The present committee believes that the MRP has responded to the spirit of many of the specific recommendations, but that there are areas where the specific recommendations are still relevant and further improvement is warranted.

Specifically, the 1996 NRC committee recommended that the MRSP rigorously document the specific contributions and impacts of past resource assessments related to land management decisions. That committee strongly recommended that the MRSP publish a single document, written for the lay audience, which documents, explains, and discusses the usefulness of mineral resource assessments and their applications in land management. The MRP responded to this recommendation by stating that efforts to implement it were stymied by difficulty in obtaining information from land management agencies (Kathleen Johnson, USGS, personal communication, 2002). **The present committee recommends that the MRP document the contributions and past impacts of resource assessments and other MRP work products.** The committee believes that such documentation would help communicate the usefulness and current and past value of assessments to a broader audience (e.g., the Office of Management and Budget) and as part of a broader evaluation of the extent to which mineral assessments and other MRP work products are worth the time and effort devoted to them.

Other examples from the 1996 report where the specific recommendations are still relevant and where further improvement is warranted include (1) external input to and review of resource assessments; (2) more research on the differences between natural and man-made geochemical anomalies; (3) increased leveraging of funds from outside sources, including foreign sources; and (4) enhancing the mentoring program to encourage the hiring of young scientists of excellence.

MINERALS INFORMATION TEAM

The Minerals Information Team (MIT) collects, analyzes, and disseminates information on domestic and international supplies and demands for minerals and materials essential to the U.S. economy and na-

tional security. MIT activities are guided in part by statutory requirements in laws and executive orders, which assign the Department of the Interior responsibilities linked to national security and emergency preparedness.

A variety of speakers from government agencies, many of them partner agencies of the USGS, spoke to this committee about the continuing value of the MIT's traditional functions and products. There was wide praise for the availability and usefulness of the statistical data generated by the MIT. These representatives indicated that the data are used in many arenas, ranging from foreign policy to international and domestic commerce. Several of the agency representatives stated that the advice and information provided informally by the mineral commodity and country specialists were just as valuable as the published data.

The committee concludes that the MIT has done a good job of making the transition from the Bureau of Mines to the USGS and, moreover, has performed very well in helping the USGS and its partner agencies meet their goals. This committee has recommendations in three areas aimed at enhancing the already important work of the MIT.

Many, if not most, of the data series collected by the MIT have been collected for many years by the USGS and previously the Bureau of Mines without an ongoing and systematic review of the nature and overall scope of the data collected. In an era of declining real (inflation-adjusted) budgets, the MIT needs to consider carefully which data it collects and needs to assess whether there continues to be a national need for these data. Furthermore, the team's core competencies of producing data and information products should be examined in light of the many data collection and survey needs in other parts of the USGS.

The committee recommends that the MIT establish a permanent advisory committee consisting of a wide range of users of MIT data and analysis to ensure that its activities are fully updated and of relevance to its users. The advisory committee would review the nature and overall scope of MIT activities, including what data should and should not be collected. The membership of the advisory committee should be rotated so that it has an appropriate balance between new blood and historical memory at each meeting.

The MIT is so active in collecting data that qualified mineral commodity specialists, country experts, and researchers in the minerals and materials analysis section are hindered in contributing to basic research and to advising other federal entities on public policy matters. The more

purely statistical functions such as survey response rates, format of data delivery, and timeliness of data release need to be carried out optimally to increase time for research and advisory activities. One of the important areas in which the MIT should have analytical activities is mineral availability—not just the purely physical (or geological) availability of mineral resources but also the economic and environmental dimensions of availability. The important availability concerns center on the location-specific issues of costs of production, potential environmental issues associated with mining and mineral processing, and the potential social disruptions sometimes caused by mining. Material flows analyses, which attempt to quantify some of these availability issues, represent one important area for MIT analytical activity. Material flows studies require significant data on production, consumption, waste, recycling, and appropriate substitutes in order to provide an accurate balance calculation and to provide public policy guidance. Detailed interaction between team members and research scientists could improve data collection and data products for the material flows studies. Information provided by these studies could be incorporated into the global mineral resource assessments and could significantly enhance their value.

The committee concludes that the expertise and experience of the MIT mineral commodity specialists, country specialists, and researchers in the minerals and materials analysis section are important resources. **The committee recommends that the MIT's analytical activities and capabilities be strengthened so that mineral commodity specialists, country specialists, and other MIT researchers can conduct more material flows studies and work more directly with the mineral assessment and environmental scientists in their basic research.**

The relocation of the MIT within the MRP of the USGS provides an opportunity for collaboration with other parts of the MRP, which in turn could enable a beneficial broadening of the role of the MIT to satisfy national needs. For example, communication and interaction between mineral deposits geologists within the MRP and the appropriate mineral commodity specialists within the MIT would broaden the horizons of both groups and create an understanding of strategic resources throughout the world that would provide the federal government with additional information necessary for sound public policy decisions. The MIT needs to take better advantage of the geoscience expertise of the MRP in designing and carrying out MIT projects and should increase its contribution to the MRP's geoscience activities.

The committee concludes that the MRP produces and maintains a large volume and variety of minerals information, which is not easily used in the estimation of resource potential. Having increased interaction and partnerships with MRP staff would be one way to leverage the expertise from each group and provide more easily analyzable data. **The committee recommends that the MIT work with the MRP resource assessment team to improve the classification and usefulness of its data.** This would be a particularly important contribution to the MRP's global mineral resource assessment project.

ENVISIONING THE FUTURE

In developing a vision and mission for the future, the committee suggests that the MRP consider five questions, the answers to which will frame (or define the scope of) the MRP of the future.

1. How should "mineral resources" be defined?
2. How should "information" be defined?
3. What is the appropriate balance between research and service?
4. How "international" should the MRP be?
5. Who are the appropriate users and partners?

The committee recommends that the MRP develop an expanded vision that embraces a broad definition of mineral resources, including a focus on life cycle and sustainable development; a strong international role, which will expand the current users; and a balance between basic and applied research, recognizing that many of the program priorities are oriented toward more applied research. An expanded vision will most likely require the USGS to reevaluate its core competence—building new core competence in selected new disciplines.

As the nation's need for minerals science and information evolves, the MRP must evolve to meet these needs. The committee strongly encourages the MRP to consider broader programmatic elements, namely (1) environmental stewardship with special emphasis on developing postmine land-use alternatives integrating GIS-based information from mines and urban planners and addressing unique environmental issues associated with mine closures, (2) data integration/data mining accentu-

ating the capture and storage of irreplaceable mining district data and the use of such archived data for creating the first national three-dimensional database to support minerals evaluations and contribute to broader crustal interpretation, (3) an expanded regional and global perspective focusing on life-cycle studies of mining districts for developing and applying sustainable mining models for global application, (4) methods and technology development in minerals technology to support the U.S. minerals industry in a global economy, and (5) sustainable land use planning centering on scientific and technical leadership for evaluating national mineral resources for improved land management decisions. The MRP is a logical organization to conduct these five, broad programmatic areas, and is involved in projects in some of these areas, because it already focuses on three central mineral issues: the economy and public policy; the environment and public lands; and sustainability and societal need. The MRP also provides information on land stewardship, material flows and other vital information to government policy makers for responsible management of public lands. The MRP also possesses a vast array of tools and technology (for example, modeling, data integration, sophisticated analytical capabilities, mineral exploration techniques, and partnering experience with other agencies and organizations) that can support initiatives in these five programmatic areas. **The committee recommends that the MRP develop and expand its vision and program objectives to incorporate components of the existing program and elements of the new programmatic areas.** Other government agencies may already be doing some work in these areas. The MRP should determine what ongoing activities exist in these areas and initiate its work in a collaborative manner.

IMPLEMENTATION

The committee examined several aspects of potential program evolution, including changes in the mission and vision statements, changes in the breadth of the program, and new programmatic areas that the MRP could undertake. As noted earlier, the committee believes that planning, goal setting and outcomes measurement are important and have not been adequately addressed by the MRP. *The committee concludes that, to implement new programmatic areas within the existing MRP, mechanisms for prioritization and planning, project selection, review, performance*

assessment, and determining value to the nation need to be established. A simple and transparent planning process that results in fully documented program and project plans is essential. These plans should be easily understood by other federal agencies, Congress, and MRP staff. The committee urges the MRP to devote substantial efforts to recruiting and retaining staff for new program areas and to also look to interagency/university employee exchanges and an external grants program to gain the necessary expertise. As the MRP's responsibilities increase, the budget should be commensurate with the assumed tasks.

1

Minerals Science and Information: The Federal Role

Like food, air, and water, minerals[1] are a fundamental ingredient of human life. There is compelling evidence for mining and metallurgy in Spain dating back at least 4,500 years. As the population has increased and our society has developed, the need for minerals has grown and diversified. As minerals have been the basis of breakthroughs in civilization, they are now essential for the present and future technological revolution. Communications and transportation systems, computer networks, and space exploration all rely on the availability and sustainability[2] of mineral resources. Individual nations tend to follow a systematic pattern of change in fulfilling their mineral commodity needs. Initially, nations often obtain most of their requirements from within their own boundaries. However, as local supplies become exhausted and lands are used for other purposes, it becomes necessary to obtain minerals from more distant sources, depending on the commodity's value compared to transportation costs. Many countries in Europe currently import essentially all of their mineral resources, except for those of lowest cost (e.g., construction materials such as rock, sand, and gravel).

[1] In this report, minerals are defined as all nonfuel mineral resources, including industrial minerals such as aggregates.

[2] Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs (International Institute for Environment and Development and World Business Council for Sustainable Development, 2002).

U.S. MINERALS PRODUCTION AND CONSUMPTION

The nature and status of mineral resources and mining in the United States have changed dramatically since the U.S. Geological Survey (USGS) was founded in 1879. At the beginning of the 21st century, the United States is one of the largest mineral producers in the world (see Table 1.1). The United States is generously endowed with mineral resources. Spanning diverse geologic terrains, this country hosts an enormous range of mineral deposit types (Ashley, 1991; Tooker, 1991; Brobst, 1991). Metals from aluminum to zinc and nonmetals from construction aggregate to specialty clay minerals are illustrative of this mineral resource endowment. Mining of sand, gravel, or crushed stone for construction aggregate takes place in all 50 states; mining of other commodities is widespread.

Today the United States is one of the world's largest consumers of many mineral products. The average American born in 2001, with a lifespan of 76.9 years, will need the mining of 3.6 million pounds of minerals, metals, and fuels to maintain his or her standard of living during their lifetime—averaging 47,122 pounds of new mineral and energy resources every year for each American (see Figure 1.1). The value of processed materials of mineral origin produced in the United States in 2000 has been estimated to be $374 billion (USGS, 2002a). However, the $39.4 billion value of the nonfuel minerals mined in this country in 2000 (Smith, 2002) was less than one-half percent of the U.S. gross domestic product. The

TABLE 1.1 Examples of U.S. Minerals Production Relative to Other Large Mineral-Producing Countries

	Percent of World Production		
	U.S.	Brazil	Canada
Aluminum	10.8	5.3	9.9
Copper Mine	9.8	0.2	4.7
Gold	13.0	2.0	6.0
Iron ore	4.4	19.8	3.4
Cement	5.3	2.4	0.8

NOTE: Copper mine refers to copper production from mines, rather than from refineries.
SOURCE: Data for the United States from Smith (2003); Data for Brazil and Canada from Gurmendi et al. (2002).

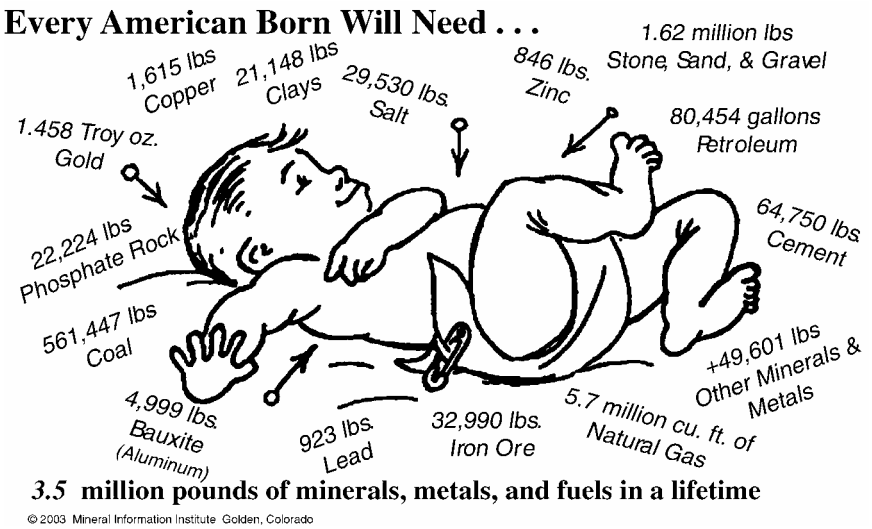

FIGURE 1.1 U.S. per capita lifetime use of new minerals, metals, and fuels. SOURCE: Mineral Information Institute, Golden, Colorado, 2002. (Available online at http://www.mii.org).

$39.4 billion value of nonfuel minerals comprises $10.2 billion from metals and $29.2 billion from industrial minerals (Smith, 2002) (Sidebar 1.1). The true contribution of mining to the U.S. economy is not fully reflected by these figures. The contribution extends to jobs and related benefits to downstream products such as automobiles, railroads, buildings, and other community facilities.

U.S. production of metals has remained rather constant since 1992. However, in a trend with direct implications for the USGS's Mineral Resources Program (MRP), industrial minerals production increased by slightly less than 50 percent between 1992 and 2000 (see Figure 1.2). As a comparison, in 1998 there were just over 300 metals mines in the United States, but over 10,000 industrial minerals mines (MacDonald, 2002).

The United States satisfies some of its demand for minerals through imports, including 100 percent of several commodities and significant proportions of other critical minerals (see Figure 1.3).

SIDEBAR 1.1

Industrial Minerals

Industrial minerals include any rock, mineral, or other naturally occurring substance of economic value, exclusive of metallic ores, mineral fuels, and gemstones. Major industrial minerals are crushed stone, sand, and gravel, which are lumped together as aggregates. A wide variety of other materials are also mined, such as limestone, building stone, specialty sand, clay, and gypsum for construction; phosphate rock, potash, and sulfur for agriculture; and salt, lime, soda ash, borates, magnesium compounds, sodium, sulfur, rare earth elements, bromine, and iodine for the chemical industries. Industrial minerals also include substances used in pigments, coatings, fillers and extenders, filtering aids, ceramics, glass, refractory raw materials, and other products.

Industrial minerals comprise well over half of the mineral value production each year in the United States (USGS, 2002a). However, since few of these materials are sold directly to consumers, the industrial mineral industry is not well known to the American public (William Ford, personal communication, National Stone, Sand and Gravel Association, 2002). Industrial minerals, particularly aggregates, are often ignored in the public discussions on mining. Aggregates are the highest-volume industrial mineral mined in this country. Because of the relatively low value per ton of these minerals, transportation costs often dictate where resources can be obtained. While metals such as gold and copper can be delivered globally, aggregates are usually obtained near the ultimate use site, with the result that aggregate mines are typically in close proximity to urban settings (NRC, 2002a). Therefore, the type of information required for mining and using industrial minerals increasingly depends on the reclamation and varied options for postmining land uses, particularly in large urban settings. The USGS began a 5-year study in 1996 to develop methods for assessing infrastructure resources and to characterize the location, distribution and quality of the infrastructure resources as part of the Colorado Front Range urban corridor between Denver and Fort Collins, Colorado (USGS, 2002b).

The demand for metals (e.g., copper, zinc) and industrial materials in the United States will remain for the foreseeable future, and information on all aspects of production and consumption is critical for ensuring that these materials are available for the United States as well as other countries. In addition, information is needed on secondary recovery of metals and minerals from recyclable materials.

Extraction of mineral deposits can degrade the environment. The effects of mining are not confined to the United States. Developing nations with mineral wealth often have less experience in dealing with mine wastes, reclamation, and associated environmental issues. As

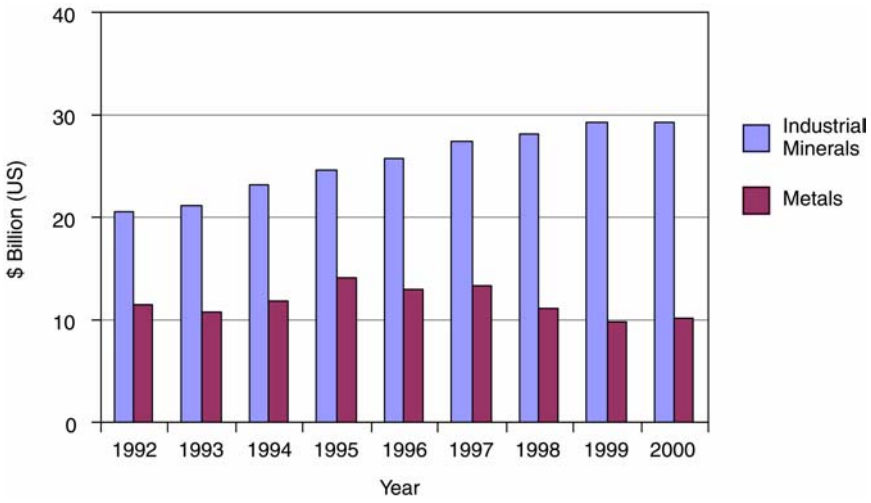

FIGURE 1.2 U.S. production of nonfuel minerals
SOURCES: Data compiled from Smith (1996, 1998, 2000, 2002).
NOTE: Where there were discrepancies between the *Minerals Yearbook,* data were taken from the latest publication.

American consumers directly or indirectly obtain more of their mineral resources from such countries, there will be an increasing need, in terms of both economics and policy, to ensure that minerals are developed in an environmentally responsible manner and to consider our place in a sustainable global environment.

WHY A FEDERAL MINERALS PROGRAM?

Considering the small contribution of direct domestic mineral production to the overall U.S. economy, it might not be apparent that there is a pressing need for a continued U.S. federal presence in minerals science and information. Mining continues to decline in importance to the economy both as a share of overall economic activity (USGS, 2003) and as a source of employment (ftp://ftp.bls.gov/pub/suppl/empsit.ceseeb1.txt), even though it is important in certain communities or regions of the country. There are no shortages of imported minerals available at prices at or below historical averages.

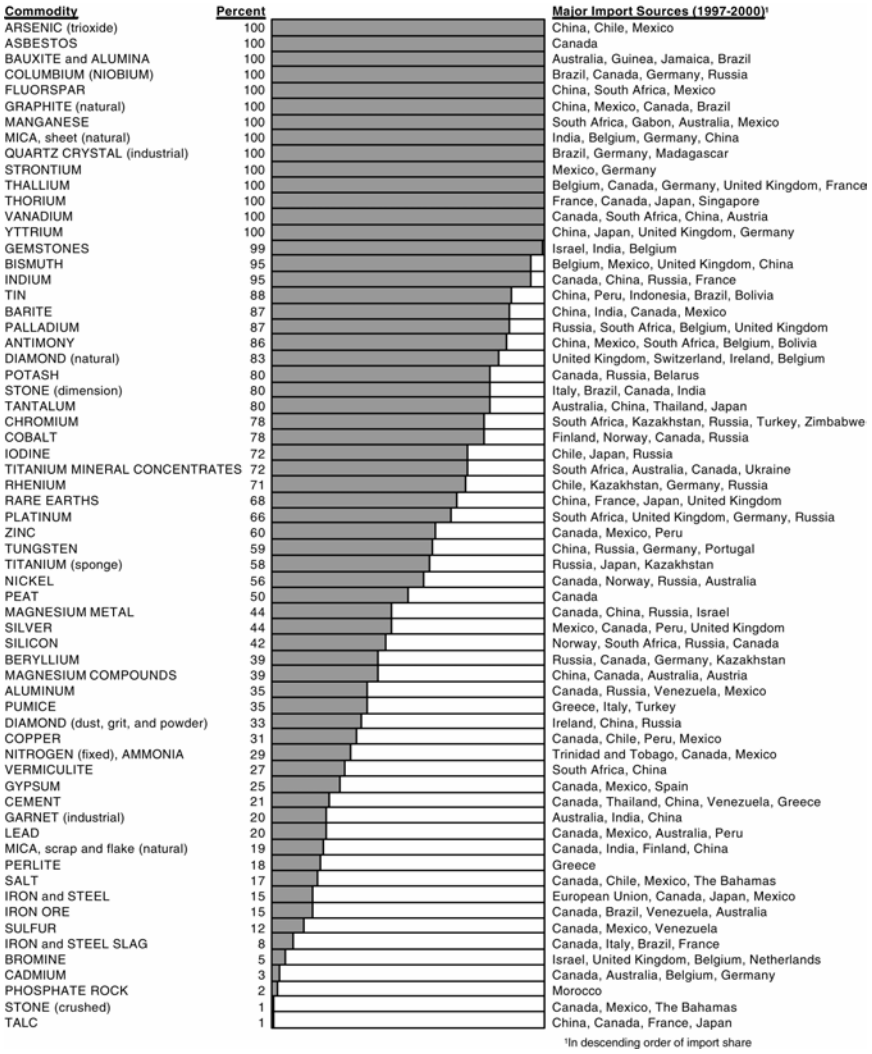

FIGURE 1.3 U.S. dependence on commodities from foreign sources.
SOURCE: USGS (2002a).

There does not seem to be the level of concern about the acquisition of strategic materials as there was in the past, such as during World War II. The United States has the ability to mine some strategic minerals domestically and/or to stockpile them by purchase from foreign entities.

SIDEBAR 1.2

Minerals Science and Information

The USGS's MRP creates two types of intellectual products: minerals science and minerals information. Minerals science is based on investigation and analysis and can have more interpretative results. For example, the MRP's work on geoenvironmental and ore deposit models and on interpretive geological mapping falls within the category of minerals science. Minerals information includes mineral production and consumption statistics and baseline geochemical sampling data.

Currently, mineral materials are being sold from the National Defense Stockpile. For example, in fiscal year 2002 the Defense Logistics Agency sold $359 million of excess minerals from the stockpile. The USGS advises the Defense Logistics Agency on acquisitions and disposals of mineral materials from the stockpile (McCartan et al., 2003).

Minerals are essential for consumers and important for the individuals, companies, communities, and nations that depend on mineral production as a source of income and, more broadly, for economic development. As a heavy user of minerals from both domestic and international sources, the United States requires quality minerals science and information to make sound policy decisions. Housed within the Department of the Interior, the USGS's MRP provides domestic and international science and information (see Sidebar 1.2) to other programs and disciplines within the USGS, other agencies within the department, and other departments within the U.S. government. In addition, state agencies, environmental groups, private industry, academia, U.S. citizens, and the international community use information provided by the MRP.

Over time, advances in minerals science and improvements in minerals information contribute to greater availability of minerals, at lower cost and with less environmental damage. Minerals science and information help society respond to the depletion of known mineral deposits and contribute to the substitution of relatively abundant minerals for increasingly scarce ones. Minerals science and information help develop alternative sources of supply for minerals subject to unexpected supply disruptions. The USGS has carried out these functions in the past and is respected nationally and internationally for the quality of its information. It

has the expertise and experience to provide unbiased[3] information on domestic and foreign mineral resources in the future.

The MRP has been and remains a significant source of minerals information and, in some cases, was the initial developer of the models used for study of deposits. Ore deposit models summarize the understanding of how mineral deposits form and, in effect, help mineral exploration teams predict where undiscovered mineral resources occur and how to search for them. Geoenvironmental models summarize the basic science surrounding the source, transport, and fate of contaminants caused by the interaction of mineral deposits and the surrounding natural environment. These models help assess potential environmental consequences of developing a mine of a particular type in a specific location and, in the case of abandoned mines, assist in understanding what the baseline environmental quality may have been prior to mining. Baseline geological, geochemical, and geophysical data help mineral exploration teams narrow their searches to the most promising targets. Statistics and information on mineral production and consumption, recycling and the life cycle of materials, international trade, and other aspects of mineral production and use inform investment and production decisions by private industry and public policy decisions by government agencies.

The simple need for minerals science and information does not justify federal government activities in this area. After all, in market economies there are natural and strong incentives for private entities producing and consuming minerals to carry out the scientific research and to collect and disseminate information that is relevant and necessary for informed decision making. Nevertheless, in several specific circumstances, private markets are likely to yield suboptimal outcomes from the perspective of society as a whole—justifying four federal roles in minerals science and information. Three of these roles (informational, advisory, and foundational through basic research) were identified in the 1996 National Research Council (NRC) review of the USGS Mineral Resource Surveys Program (MRSP). The current committee adds a fourth role—international—because the United States is importing more of its mineral needs and because of the global nature of the economy today.

[3] The terms "unbiased", "impartial", and "independent" in this context mean that the individuals within the MRP are not economically beholden to special-interest groups or private industry. Hence, others view their work product as not being compromised by significant conflict of interest that might impair objectivity.

The first role is as an unbiased national *source of science and information.* Government agencies need information in carrying out their regulatory and administrative responsibilities. In addition, the private sector uses basic geological, geochemical, geophysical, and other forms of minerals information to support its decisions and activities—minerals exploration, mine development, and appropriate environmental protection on mineralized lands. Private-sector sources of the information are often proprietary and unavailable to the public. In other cases the private sector does not collect the information because the costs are prohibitive from the perspective of a single company relative to the benefits it receives, even if from society's perspective the aggregate benefits would justify the costs. Although state geological surveys play an important role in generating and disseminating information related to mineral resources, the federal government has a unique role in addressing issues of national jurisdiction and significance (NRC, 1996). Other government agencies (e.g., the National Science Foundation, Environmental Protection Agency, and National Aeronautics and Space Administration) fund research but not a significant amount of mineral resources research. In addition, non-mission-driven agencies, such as the National Science Foundation, do not fund mission-driven mineral resources research. Another recent NRC report (2001) concluded that the USGS is an important provider and coordinator of information critical to issues in the natural sciences. The same report recommends that the USGS should provide national leadership in the provision of natural resources information (including energy, minerals, water, and biological resources). Examples of activities within the MRP, which fulfill this role, include mineral assessments and databases.

The second function involves *basic research* on mineral resources. Basic research would most likely be underfunded if left solely to the private sector, in part because the return on investment in basic research is not necessarily captured by the organization that conducts the research (NRC, 1996, 2002a). Many nations have found that public investments in research on mineral resources, which benefit society at large, are best accomplished through a combination of efforts conducted by universities and government agencies that have national jurisdiction, long-term continuity, large multidisciplinary teams of scientists, and highly specialized facilities (NRC, 1996). The argument is that certain types of information are what economists call public goods, which are likely to be undersupplied by the private sector acting alone (see Sidebar 1.3). Examples of

SIDEBAR 1.3

Public Goods

Economists distinguish between *private* and *public* goods. Purely private goods have characteristics such that (a) one person's use of the good necessarily reduces the amount available for other people (if I eat a hamburger, you cannot also eat it) and (b) it is relatively easy to exclude consumers who do not pay for the good (the restaurant where you ate the hamburger will call the authorities if you refuse to pay). Most goods and services that households and businesses purchase—food, clothing, vehicles—are private goods. Economists believe that, because of the characteristics noted above, we can usually rely on private markets to provide such goods in appropriate quantities and at appropriate prices.

Purely public goods, in contrast, are such that (a) one person's use of the good does not reduce in a one-for-one manner the amount available for other people (e.g., once national defense is provided, one person's benefit from this defense does not diminish the benefit that another person receives) and (b) it is difficult to exclude consumers who would choose not to pay for the good if it were provided in private markets (e.g., if national defense were funded by voluntary contributions, it would be difficult to exclude someone from enjoying the protections of national defense if that person did not pay for it). An implication of these characteristics is that the total benefits to society of the public good are greater than the sum of the benefits accruing to individuals willing to pay for the good—as a result, private markets alone are likely to underprovide public goods from the perspective of society as a whole. Governments often step in to correct the failure of private markets to provide appropriate levels of public goods.

Minerals information and basic research are at least partially public goods. The benefit that one person receives by using information on minerals production and consumption does not reduce the benefit that another person might receive from the same information. The same holds true for basic research on, for example, the genesis of mineral deposits. Thus, as long as benefits of the minerals information and basic research are likely to exceed the costs, government should consider facilitating the provision of this information and research by public agencies (such as the USGS) or by universities or other nongovernmental entities.

MRP activities that fulfill the basic research role include geoenvironmental models and minerals deposit research.

The third role is *advisory*. Federal agencies within the Department of the Interior and elsewhere in the government need to make public policy decisions related to mineral issues—for example, land management, environmental remediation of abandoned mines, international trade, and foreign policy. A major responsibility of the USGS is to serve as the science

SIDEBAR 1.4

Crisis Contributions of Mineral Resources Geoscientists

Dust and Debris Analysis at the World Trade Center

Immediately following the September 11, 2001, attack on the World Trade Center in New York City, several federal agencies requested that dust and debris in the area be evaluated. The USGS, along with several other organizations, sampled and analyzed more than 35 localities near the site and material coating a steel beam in the debris. In addition, the Crustal Characterization and Imaging Team of the USGS (see Chapter 2) used a hyperspectral remote sensing instrument called the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) to generate mineral distribution maps. The maps, used in conjunction with field tests, showed trace levels of asbestiform minerals in dust samples. This information supported recommendations of the Environmental Protection Agency and New York Department of Public Health that clean up of the area be done with appropriate respiratory protection and dust control measures (Clark et al., 2001; *http://pubs.usgs.gov/of/2001/ofr-01-0429/feats-asb.html).*

Rescue of Quecreek Miners

When miners became trapped in the Quecreek Mine in Pennsylvania in July 2002, rescuers searched the *Aggregates Industry Atlas CD* to locate two nearby aggregate producers, who rushed high-capacity water pumps to the mine and donated time and gear to the rescue effort. The *Atlas* was a cooperative effort of the USGS and the National Stone, Sand, and Gravel Association. It contains a searchable database of some 6,000 U.S. aggregate mines (Pinsker, 2002).

arm for the Department of the Interior. In this role the USGS provides objective, nonadvocacy information to a number of the Department of the Interior agencies. If the information were not available from the USGS, similar expertise would have to be developed within the individual agencies (NRC, 2001). Private sources of advice often are available, but the USGS, as a mission-driven agency, serves as a national source of unbiased and impartial advice. In addition, in times of crisis the interdisciplinary expertise of mineral resources geoscientists (e.g., geochemistry, geophysics) can contribute to solutions of a variety of problems (see Sidebar 1.4).

The fourth federal role in minerals science and information is *international*—undertaking or supporting international activities that are in the national interest. The USGS, which has been operating internationally for more than 100 years, defines its role in the international arena in terms of promoting U.S. national security and policy interests, furthering U.S. pri-

vate aspirations in the global economy, addressing global environmental interests, and improving the utility or effectiveness with which the USGS carries out its fundamental domestic mission (NRC, 2001). Some of the international mineral resources activities are *narrowly or directly* in the national interest (e.g., facilitating more diversified sources of certain minerals through global mineral resource assessments). Other international activities are in the national interest in a *broader or less direct* sense—such as using mineral activities to support economic development and poverty alleviation in the poorest regions of the world, many of which are endowed with considerable undeveloped mineral resources, by providing technical assistance in assessments of resources. In addition, as the nation and world consider the reality of global environmental responsibilities and sustainable development, the United States has an opportunity to provide technical advice and assistance to developing nations for mineral development with a balance of environmental protection and economic growth. An example of an MRP activity that fulfils the international role is the global mineral resource assessment.

THE U.S. GEOLOGICAL SURVEY AND THE MINERAL RESOURCES PROGRAM

For 125 years the USGS has provided science, information, and advice on the interplay between Earth materials, processes, and the nation's resource needs (NRC, 2001). The national and international reputation of the USGS as a premier Earth science organization is based on the quality of its science and on its willingness and capability to evaluate the Earth and its resources in a global context. The USGS is the nation's principal agency for natural science and natural science information. The USGS conducts research, monitoring, and assessments to contribute to understanding of the natural world—lands, water, mineral, and biological resources. The USGS's mission is to serve the nation by providing reliable scientific information to describe and understand the Earth; minimize loss of life and property from natural disasters; manage water, biological, energy, and mineral resources; and enhance and protect our quality of life (USGS, 2000).

SIDEBAR 1.5

USGS Vision, Mission, and Strategic Direction

Vision: The USGS is a world leader in the natural sciences through our scientific excellence and responsiveness to society's need.

Mission: The USGS serves the nation by providing reliable scientific information to

- describe and understand the Earth;
- minimize loss of life and property from natural disasters;
- manage water, biological, energy, and mineral resources; and
- enhance and protect our quality of life.

Strategic Direction: The USGS will combine and enhance our diverse programs, capabilities, and talents and increase customer involvement to strengthen our scientific leadership and our contribution to the resolution of complex issues.

SOURCE: USGS (2000).

The current USGS strategic plan (USGS, 2000) corresponds to the period 2000 to 2005 and is an update of the first strategic plan (1997 to 2005) (USGS, 1996) and of the revised strategic plan released in 1998 (USGS, 1999a). The USGS modified the plan to more clearly present the bureau's goals and its strategies for achieving those goals. The plan was developed through feedback from stakeholders. The USGS's mission and vision statements are stated in the new strategic plan (see Sidebar 1.5). The USGS has organized its strategic plan into two mission goals: (1) hazards and (2) environment and natural resources. The USGS hazards activities are to describe, document, and understand natural hazards and their risks. The environmental and natural resource activities deal with physical, chemical, biological, and geological processes in nature and with the impact of human actions on natural systems. The MRP activities directly support the USGS mission goal on the environment and natural resources. Each of the USGS mission goals has a long-term goal with performance targets. The USGS mission and long-term goals support all five of the Department of the Interior's strategic goals but are most relevant to the goal of providing science for a changing world.

The MRP is the largest program in the Geologic Division of the USGS, and since abolishment of the Bureau of Mines in 1995, is the only federal mission-driven organization that focuses on mineral issues inte-

grating environmental, resource, and economic factors. The MRP supports about 475 full-time equivalents in five teams (Eastern Mineral Resources Team, Central Mineral Resources Team, Western Mineral Resources Team, Minerals Information Team, and the Crustal Imaging and Characterization Team), one science center (Anchorage, Alaska), and other specialists from across the USGS as needed. The teams are located in three regional centers (Reston, Virginia; Denver, Colorado; and Menlo Park, California) and four field offices (Tucson, Arizona; Reno, Nevada; Spokane, Washington; and Anchorage, Alaska). The programs that the MRP addresses can be grouped into three broad categories: environment and public health, sustainability and societal need, and economy and public policy. Information generated by the MRP is used by government decision makers to formulate national and domestic economic and environmental policy, by land managers to implement stewardship of public lands and resources, and by industry and academia to improve business and conduct research. Unbiased scientific analysis and advice on mineral resources have been a critical part of the responsibility of the USGS since its inception in 1879 (NRC, 2001). Mirroring the interdisciplinary nature of mineral resources, the MRP includes a variety of areas, such as geophysics, geochemistry, and statistics (see Chapter 2). A brief history of mineral resources at the USGS is summarized in Table 1.2.

STUDY AND REPORT

In 1996 the NRC reviewed the USGS's MRSP plan. The recommendations from the study, *Mineral Resources and Society: A Review of the U.S. Geological Survey's Mineral Resource Surveys Program Plan* (see Appendix A), were used by the USGS in redirecting the program. Shortly after the review was completed, the Department of the Interior's Bureau of Mines was abolished and that agency's minerals information function was transferred to the USGS. The minerals information function, now called the Minerals Information Team, was incorporated into the new MRP. Six years following its 1996 review of the USGS's minerals program, the NRC was asked to examine the USGS's actions with respect to the 1996 NRC recommendations and incorporation of the minerals information function and consider future aspects of the Mineral Resources Program. The NRC was not asked to conduct a comprehensive

TABLE 1.2 History of Mineral Resources in the Federal Government

Year	Event
1833	Letter from George Featherstonhaugh to Secretary of War outlining the virtues of expending federal funds to expand the nation's knowledge of its mineral resources
1866	U.S. Treasury establishes the Office of Commissioner of Mining Statistics to report on status of mining in the Western states and territories
1867-1879	Four "Great Surveys," led by Clarence King, Ferdinand Hayden, George Wheeler, and John Wesley Powell, survey the geography, geology, and natural history and resources of the American West
1878	National Academy of Sciences recommends that all federal geology programs be consolidated as the USGS within the Department of the Interior
1879	Congress creates the USGS within the Department of the Interior
1900	Mining and Minerals Resources Division is established within the USGS
1910	Bureau of Mines created to address mining safety issues
1917	Strategic Minerals Program is started within the USGS
1925	Mineral statistics function is transferred from USGS to Bureau of Mines and Bureau of Mines is transferred to the Department of Commerce
1934	Bureau of Mines is transferred back to the Department of the Interior
1970s	Development of ore deposit models started in the late 1970s, peaked in the 1980s and continues today
1977	Energy minerals statistics function is transferred from the Bureau of Mines to the Department of Energy
1982	Minerals Management Service established in the Department of the Interior
1984	Completion of mineral resource assessments on Forest Service lands as part of the Wilderness Act of 1964 (P.L. 88-577); Publication of Professional Paper 1300.
1987	National Research Council publishes critique of the program and management of the USGS Office of Mineral Resources (NRC, 1987)
1995-1996	Budget for USGS is cut; reduction in force for Geologic Division; minerals information function is transferred to USGS with the abolishment of the Bureau of Mines; and development of MRSP plan
1996	National Research Council reviews MRSP
1997-present	Evolution of present-day MRP

SOURCE: Adapted from NRC (2001) and John DeYoung, USGS, personal communication, 2002.

review of the program or the projects within the program. In July 2002 the NRC appointed a committee to address the Statements of Task set forth in the USGS's request:

1. Assess the USGS's response to the 1996 NRC review of the MRSP plan.
2. Evaluate the contributions of the minerals information functions in meeting the goals of the USGS and its partner agencies.
3. Characterize how the customer base for the program has changed since the 1996 review. Who are the appropriate customers?
4. How should the program's vision and activities evolve to meet the nation's future needs over the next decade?

The committee consists of 10 members drawn from the mining and minerals industry, environmental consulting, academia, state agencies, and the Geological Survey of Canada. Biographical sketches of the committee members appear in Appendix B. One member was also a member of the 1996 NRC committee. The committee met three times to gather and evaluate information and to prepare its consensus report—in September 2002 in Washington, D.C.; in October 2002 in Denver, Colorado; and in January 2003 in Washington, D.C. The committee was briefed by and received written information from USGS managers and scientists, federal land managers, and mineral resource and environmental experts from industry, nonprofit organizations, academia, and state and federal government agencies (Appendix C). Subgroups of the committee met informally with USGS staff scientists at the three USGS regional centers—Reston, Virginia; Denver, Colorado; and Menlo Park, California. Committee members also relied on information from published literature, technical reports (including previous NRC reports) and their own expertise.

While this report mainly provides advice for the USGS's MRP, it also contains advice for the USGS as a whole and for the users of MRP information, including Congress, federal and state agencies, the general public, industry, and academia. Chapter 2 reviews the recommendations from the 1996 report, and Chapter 3 profiles changes in the program from 1996 to today, including the customer base, and assesses the program's response to the 1996 report. Chapter 4 describes and evaluates the Minerals Information Team. Chapter 5 considers how the program's vision and activities should evolve to meet the nation's future needs.

2

The Mineral Resources Program Today

After 1996, the Mineral Resource Surveys Program (MRSP) underwent substantial changes, including a change in name to the Mineral Resources Program (MRP). These changes resulted from several factors, including recommendations made in the 1996 National Research Council (NRC) report, significant decreases in budgetary allocations, and managerial reorganization. The program's organization changed from subprograms to teams, and the entire U.S. Geological Survey converted to matrix management.

This chapter describes the MRP's current plan, organization, and activities. While the Minerals Information Team is included to a limited extent in this chapter's discussion, Chapter 4 contains a more detailed evaluation of it.

THE MRP'S PRIORITIES 1999 TO 2004

Rather than revise the MRSP plan reviewed in 1996 by the NRC, a new five-year plan, *Mineral Resources Program Priorities 1999-2004* (Kathleen Johnson, USGS, personal communication, 2002), was drafted. This five-year plan resulted from three events: the 1996 NRC review, transfer of the minerals information function from the former Bureau of Mines, and development of the USGS Geologic Division's Science Strategy (USGS, 1998a). Priorities emphasized in the plan for the five-

year period 1999 to 2004 encompass (a) major improvements to both content and delivery of the MRP's large data sets and (b) research on the processes through which mineral deposits form and are destroyed. The MRP plan places increased importance on application of the information and technologies derived from minerals research to (a) provide reliable regional, national, and global mineral resource and mineral environmental assessments; (b) understand the influence of mineralizing processes on environmental integrity, systems, public health, and hazards; and (c) provide objective information and analysis to support those who make decisions regarding national security, land use, resource policy, and environmental or public health.

The five-year plan is comprised of five primary scientific goals (see Sidebar 2.1) that provide a framework within which the MRP addresses three groups of minerals-related issues—sustainability and societal need, the environment and public health, and the economy and public policy—relating to basic human needs for mineral resources (see Figure 2.1).

The MRP five-year plan points to deficiencies in expertise and outlines specific actions to correct these deficiencies:

- Attract staff with expertise in low-temperature aqueous geochemistry, database development and management, industrial minerals, mineral economics, and GIS and spatial analysis.
- Obtain expertise in quantitative mineral resources assessment and industrial ecology.
- Provide training for existing staff to develop skills, knowledge, and expertise consistent with present and future core competency needs.
- Secure new skills and ideas through permanent and short-term hiring, participation by staff in internal and external educational activities, and partnering with USGS divisions, other agencies, and states.
- Maintain mineral resources expertise and facilities in the three USGS centers and four field offices.
- Provide opportunities for staff to move among centers or colocate with teams from other divisions or agencies to facilitate an exchange of expertise and ideas.

The five-year plan anticipates certain actions relating to MRP facilities, namely:

SIDEBAR 2.1

MRP Science Goals

Goal 1: Understand the geologic setting and genesis of the nation's mineral resources in a global context, in order to ensure a sustainable supply of minerals for the nation's future.

Goal 2: Understand the influence of mineral deposits, mineralizing processes, and mineral-resource development on environmental integrity, ecosystems, public health, and geological hazards.

Goal 3: Provide objective information and analysis related to minerals issues to support those who make decisions regarding national security, land use, resource policy, and environmental or public health and safety.

Goal 4: Collect, compile, analyze, and disseminate data and develop and maintain national and international databases for the timely release of information to all users.

Goal 5: Apply mineral resources expertise and technologies to nonmineral resources issues.

SOURCE: Kathleen Johnson, USGS, personal communication, 2002.

- Maintain and develop facilities to produce timely and high-quality geochemical research and chemical analyses.
- Conduct and foster geophysical technology development.
- Support certain computer capabilities.
- Seek opportunities to share facilities with academia.

The five-year plan foresees level funding for existing MRP projects and establishes a goal of finding ways to build new partnerships that will make more effective use of available funds. Cooperative activities across USGS divisional boundaries and between the USGS and other entities are also seen as a way to increase funding. The five-year plan proposes the slowing of certain programs, such as extending the time frame for completing the global mineral resource assessment and the less frequent publishing of certain mineral commodities information, as an approach for effectively operating with level funding and maintaining core competencies (Kathleen Johnson, USGS, personal communication, 2002).

The five-year plan addresses a number of opportunities for cooperative program efforts that also include reimbursable project development. In summary these opportunities include:

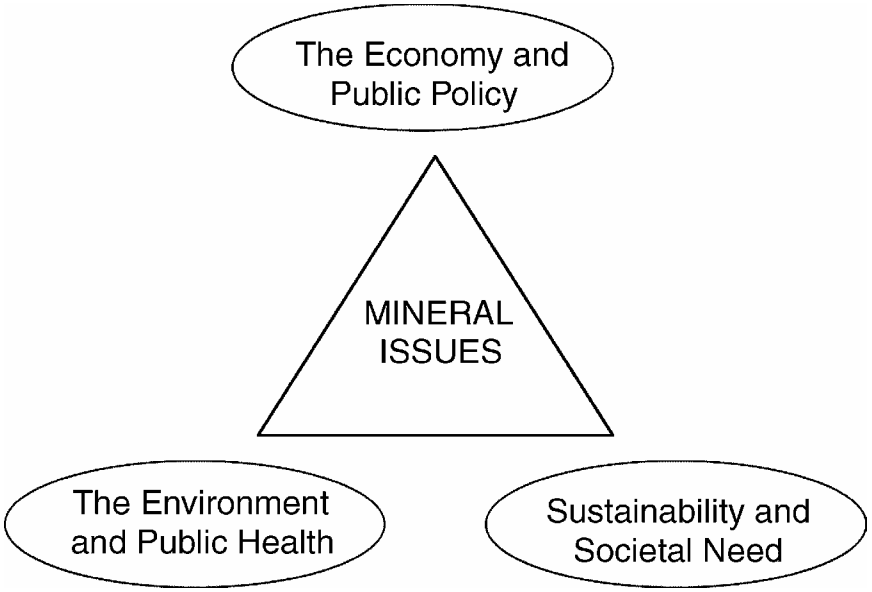

FIGURE 2.1 Mineral issues addressed by the MRP.
SOURCE: USGS (1998b).

- Participating with appropriate collaborators and customers in interdisciplinary studies.
- Continuing to adapt and apply geological methods developed for mineral resource investigations to support other goals and missions of the division and the USGS.
- Increasing efforts with specialists in human health, toxicology, microbiology, and other life sciences.
- Providing opportunities for staff to move among centers and colocate teams from other divisions or federal agencies to implement interprogrammatic activities and exchange expertise and ideas.

Reimbursable project development is proposed with foreign countries seeking mineral resources information and with international funding agencies such as the World Bank and foreign banks, requiring mineral environment assessment studies to ensure environmentally sound mining practices before resource development. Reimbursable projects

within the United States are proposed to continue for federal agencies such as the Department of Defense, Department of Energy, Environmental Protection Agency, and the Bureau of Reclamation.

ORGANIZATION

The MRP is the largest program in the geology discipline of the USGS (see Figure 2.2). The bulk of its funding goes to fund work in five teams and the Geology Office of the Alaska Science Center (formerly part of the Western Mineral Resources Team). These teams are the Eastern Mineral Resources Team, the Central Mineral Resources Team, the Western Mineral Resources Team, the Crustal Imaging and Characterization Team, and the Minerals Information Team (MIT). Each team focuses on a different aspect of the program. The Eastern Mineral Resources Team, in Reston, Virginia, includes efforts on mineral resource studies, resources and the environment, resources and the economy, and activities supporting all mineral resources studies, including a spatial data component, which focuses on databases and making data available (http://minerals/usgs.gov/east/projects.html). The Central Mineral Resources Team in Denver, Colorado, follows its historic mission to conduct research on basic understanding of metallic and nonmetallic nonfuel mineral deposits, their geological environments, and processes of formation; to apply this knowledge to assessments of the nation's nonfuel mineral endowment; and to determine the potential environmental consequences of mineral resource development (http://minerals.cr.usgs.gov/team/aboutus.html). The Central Mineral Resources Team was formed in 1995 by consolidating the former branches of Geophysics, Geochemistry, Central Mineral Resources, and part of the Branch of Resource Analysis. The Western Mineral Resources Team is composed of four offices, Menlo Park, California; Spokane, Washington; Reno, Nevada; and Tucson, Arizona (http://minerals.usgs.gov/west/offices.html). The Western Mineral Resources Team's projects include, among others, resource assessments, deposit model development, and environmental investigations. Mineral resources activities in Alaska, including new deposit modeling, Alaska data-at-risk, and mineral and environmental assessments, are coordinated through the Alaska Science Center. The Crustal Imaging and Characterization Team in Denver, Colorado, works on new methods in remote sensing,

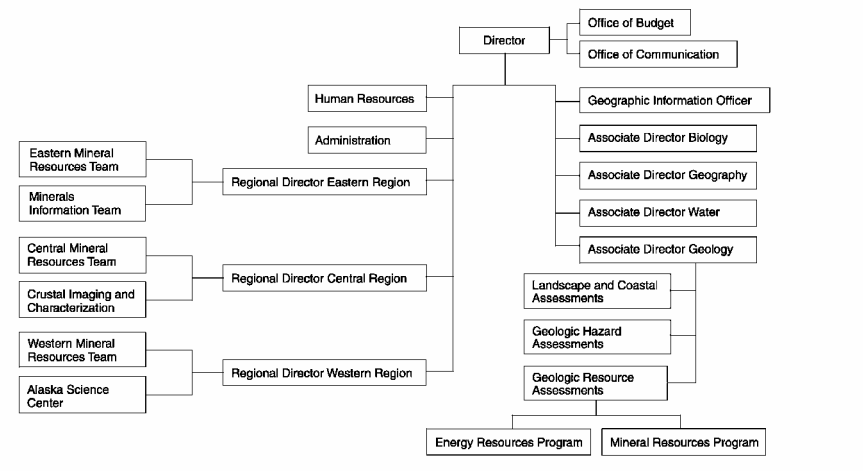

FIGURE 2.2 The MRP organizational structure.
SOURCE: Modified from Patrick Leahy, USGS, personal communication, 2002.

geophysics, analytical chemistry, and other disciplines for understanding the Earth and applying these methods in interdisciplinary research projects to solve pressing Earth system problems. Finally, the Minerals Information Team was added to the USGS in 1996 after the closure of the Bureau of Mines. This team is based primarily in Reston, Virginia, with the minerals and materials analysis group in Denver, Colorado. This team compiles and publishes production data on U.S. and global mineral commodities. This team was not part of the USGS at the time of the 1996 NRC review and is described in more detail in Chapter 4.

BUDGET

In 1996 funding for the MRSP was about $43 million. In 2002 overall program funding had increased to about $56 million, with $38 million for base program funding and two congressionally earmarked activities: approximately $16 million for the MIT and about $2 million for the Alaska data-at-risk program (see Figure 2.3). The MRP proposed fiscal

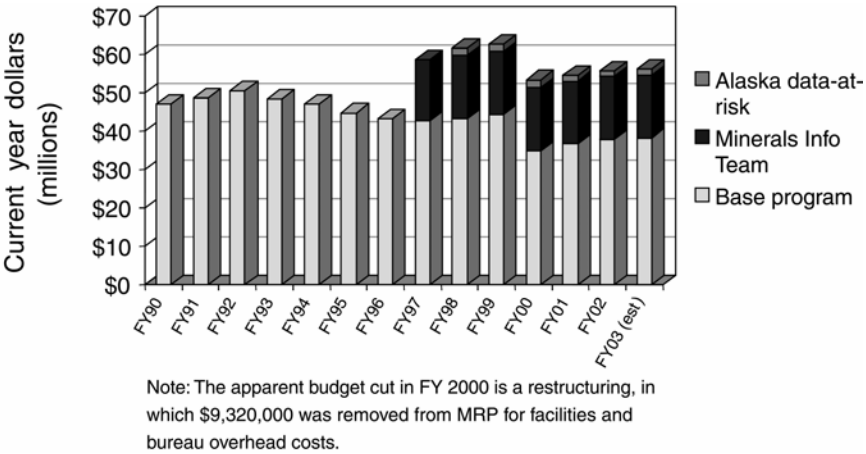

FIGURE 2.3 MRP funding for the period fiscal year 1990 to 2003.
SOURCE: Data supplied by the USGS.

year 2003 budget of approximately $56 million is allocated to the various teams and as administrative overhead as shown in Figure 2.4. Since 1997 the base funding and MIT funding have remained rather constant in nominal dollars. However, despite modest inflation rates over this period, the diminished buying power results in a diminished ability of the program to meet its vision, mission, and program objectives. As noted above, the MRP five-year plan assumes level funding through 2004.

STAFFING

The number of full-time equivalents in the MRP declined from 510 at the end of 1995 to about 275 by 1996, although 145 new full time equivalents were added with the transferred MIT (see Figure 2.5) (see also Chapter 4). At the end of 1997 the USGS instituted matrix management, in which headquarters personnel are responsible for results relating to long-term planning and regional staff is responsible for project-level planning and decision making (USGS, 2001). This form of management is designed to make personnel more fluid between programs and to

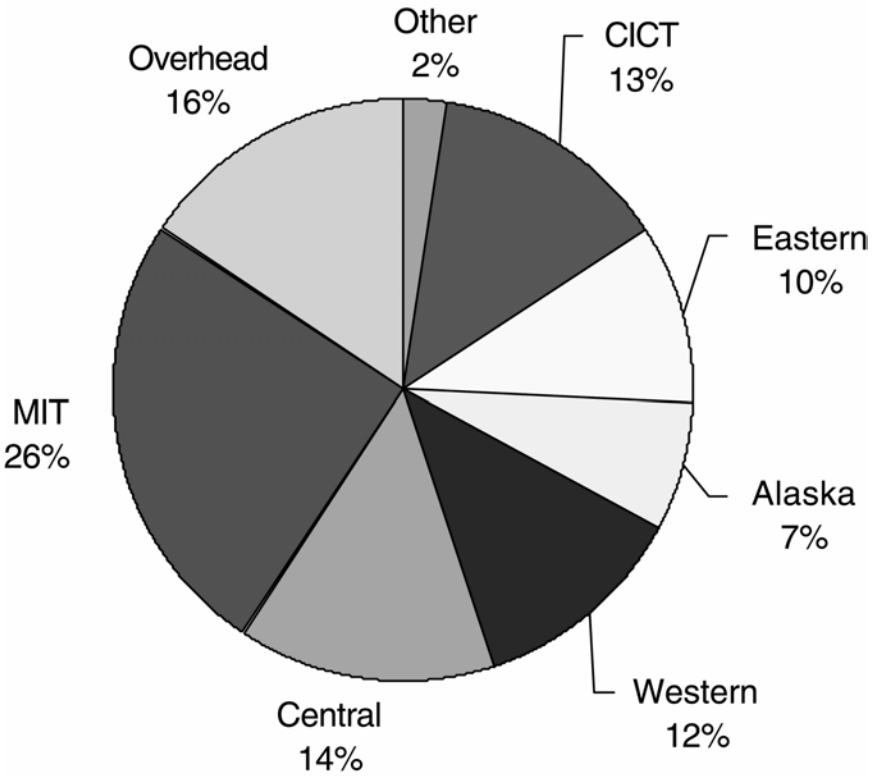

FIGURE 2.4 MRP team budget allocations for fiscal year 2003.
NOTE: CICT, Crustal Imaging and Characterization Team. "Other" includes funds used for other programs (including the Geology Discipline's Eastern Earth Surface Processes Team, the Eastern Energy Resources Team, the Central Earth Surface Processes Team, and the Volcano Hazards Team). "Overhead" includes funds for administrative activities and facilities.
SOURCE: Data supplied by the USGS.

promote interdisciplinary work. Another goal of the matrix management systems is for personnel to develop allegiances to the mission of the organization as a whole, rather than to a specific program (Vasella and Falvey, 2002). However, one result of this choice to manage the

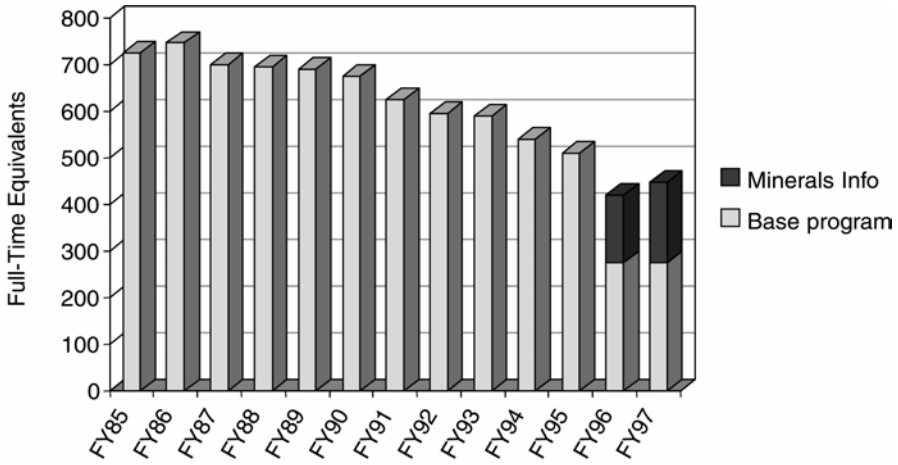

FIGURE 2.5 MRP staffing for the period 1985 to 1997.
SOURCE: Data supplied by the USGS.

programs separately from the personnel doing the work on those programs is that on an annual basis since 1997 the program coordinator has not been able to easily determine the exact number of people actually working within the program. The last figures available indicate that as of 1998 there were approximately 475 full-time equivalents supported by the MRP distributed according to the disciplines in Figure 2.6. The committee was unable to obtain from the MRP information on the number of staff with advanced degrees.

The committee learned that a number of senior scientists will be eligible to retire in the next few years and that there is a trend toward younger MRP staff (under age 50) being "survey-centric," meaning that their only professional experience is with the USGS or MRP specifically. However, no data were made available to support these statements. The Geologic Discipline of the USGS has implemented the Mendenhall Postdoctoral Research Fellowship Program, to provide an opportunity for postdoctoral fellows to conduct concentrated research in association with selected members of the USGS staff. This mentoring program has resulted in the hiring of a few young professionals. Core competency is an aspect of staffing and is discussed in Chapter 3.

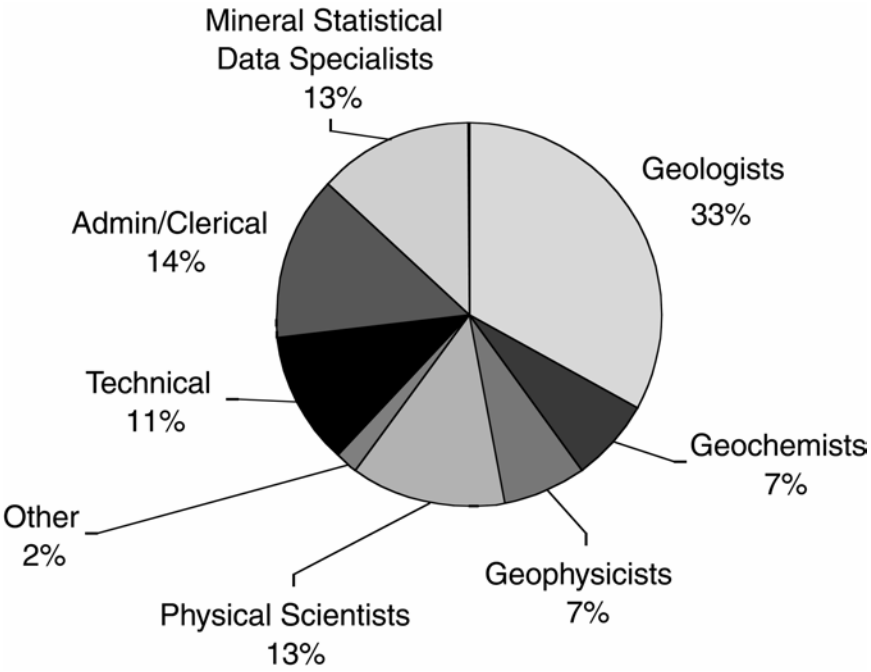

FIGURE 2.6 MRP staff distribution as of 1998.
SOURCE: Data supplied by the USGS.

PUBLICATIONS

Technical publications document the science performed by MRP researchers, make detailed research data and conclusions available to users, and represent the quality of work performed within the MRP. This is also accomplished through the scientific staff's participation at national and international conferences and meetings. During the period 1996 to 2002, MRP staff published approximately 2,400 publications (not including MIT publications) (Kathleen Johnson, USGS, personal communication, 2002). The majority of these publications are in outside refereed journals (33 percent), with another 30 percent as USGS open file reports. The committee was unable to obtain from the MRP information to directly

compare the publication record of the program staff in 1996 with that of 2002.

Although data collection, compilation, and statistical manipulations are important, minerals science requires more. In order to understand processes, which form the technical basis for decisions and policy, scientists and scientific teams need time to work toward analysis and interpretation, which are synthesized in completed, peer-reviewed reports. In meetings with MRP staff, committee members heard concerns about how costs for publishing USGS open file reports, professional papers, bulletins, and circulars—the USGS' traditional modes of data dissemination—are passed down to researchers. The staff expects that in the future less research will be published in these traditional and highly respected publications with more research published in outside refereed journals, trade journals, and conference proceedings. While publication in refereed journals validates research quality and is encouraged by the committee, the committee is concerned that, since outside journals are often hesitant to publish large quantities of data, this might lead to less data being published.

Committee members also heard concerns that there might be a trend to publish more information as fact sheets. The committee recognizes that fact sheets serve a niche especially for the general public. The USGS may wish to document its success using fact sheets given their inherent value to society. However, fact sheets should not replace publishing in peer-reviewed journals.

The reporting of data and the development of scientific reports has always been a tradition of the MRP but may be threatened in times of budget stress and increased orientation to shorter projects. Because the free and open exchange of information and interpretations is critical to the traditions of science generally, the committee believes that trends that place high-quality publications at risk should be resisted if not reversed. **Specifically, the committee recommends that comprehensive, minerals-related data and research continue to be published in the USGS's traditional modes of data dissemination.**

PROJECTS

Projects are a reflection of the program's goals and objectives. In 1996 mineral resources activities at the USGS focused on issues within

the four main subprograms (as described in Chapter 3): resource assessments, environmental impacts of mining, basic research on mineral deposits, and transfer of minerals information. As noted above, MRP activities today are grouped into three categories: environment and public health, sustainability and societal need, and economy and public policy (see Figure 2.1). Current projects in environment and public health focus on ecosystem health, land assessments of abandoned mines, natural and mined mercury and arsenic, and geochemical baselines and backgrounds. In the area of sustainability and societal need, current projects focus on infrastructure resources, assessment methods, national databases, and life-cycle studies of gold and copper. Finally, projects in economy and public policy center on land stewardship, national and international commodity studies, mineral conservation and material flows, and special international studies. The MRP also supports several national technical capabilities, including isotope laboratories, analytical laboratories, regional GIS laboratories, and petrographic and ore microscopy laboratories. Issues related to project selection and evaluation are discussed later in this chapter.

Committee members held numerous discussions with staff scientists who believe they are involved in too many projects and have too little time to be scientifically successful in all of them. This fragmentation of effort can create unexpected, longer-term consequences for the performance of the staff, for the quality of MRP work, and for its documentation. The committee is concerned about this fragmentation of staff effort, particularly with respect to project funding to support time and effort for review and finalization of interpretations and reporting. Committee members also heard that there is an apparent increase in the number of short turn-around projects. However, the committee did not have the appropriate data to verify this concern. The global mineral resource assessment project is the second most costly project for fiscal year 2003 (Kathleen Johnson, USGS, personal communication, 2002) (see Sidebar 2.2). This assessment began in 2003 as the result of a feasibility study conducted from 1999 to 2002. This project is an assessment of where and how much undiscovered nonfuel mineral resources remain on the planet. Committee members learned from discussions with stakeholders and MRP scientists that, although the assessment may be important, the question is whether it is scientifically valid, accurate, and precise.

SIDEBAR 2.2

Global Mineral Resource Assessments

The global mineral resource assessment project is a cooperative international effort to assess the world's undiscovered nonfuel mineral resources. The principal goal of the project is to outline the regional locations and estimate the probable amounts of the world's remaining undiscovered nonfuel mineral resources to a depth of one kilometer below the Earth's surface. To perform the assessment, the MRP has conducted a series of international workshops and intends to use regional and global maps and mineral deposit databases. The assessment will be conducted on a regional multinational basis and involve the cooperative participation of national and international geological, mineral resource, academic, industrial, and other organizations. The MRP points to many environmental uses of the global mineral resource assessment, including land use, water availability, quality and use, and environmental impacts of mining. The minerals industry does not use mineral assessments directly to discover new ore deposits but points out the assessments can be used, along with other measures, for long-term land-use planning, coordinating environmental issues and assisting with legal issues. The minerals industry underscores serious limitations of a global minerals assessment, namely the lack of data, issues associated with placing monetary value on deposits, and potential flaws in using existing deposit models to make such assessments.

SOURCE: Eastern Mineral Resources, http://minerals.usgs.gov/east/global/index.html; J .A. Briskey, USGS, personal communication, 2002; McKelvey, 2001.

The committee concludes that the global mineral resource assessment would benefit from additional collaboration with potential users as well as from an outside review panel, which could provide objective guidance and balance to the assessment. The NRC was not asked to conduct a comprehensive review of the global mineral resource assessment. The committee proposes that the MRP follow the model used by the USGS's Energy Resources Program. That program's assessment of U.S. and global oil and gas resources engaged an external review panel organized by the American Association of Petroleum Geologists to gauge the project's intended methods and final results (in part the latter were confidential), through criticism and recommendations from the review panel that both improved the methods and added credibility to the results. **This committee recommends that an external review panel be inaugurated to gauge meth-**

ods and results for the global mineral resource assessment and other similar types of assessments.

USERS

According to the 1996 committee, customers for the program were "First and foremost…the public and elected and appointed officials who represent them" (NRC, 1996). In 1996 the clients and users of MRSP products included federal land management agencies, the mining and quarrying industries, environmental organizations, state geological surveys, state regulatory agencies, local governments, universities, other federal agencies (particularly the Environmental Protection Agency and Army Corp of Engineers), and other groups within the USGS, particularly the Water Resources Division and others in geological mapping, energy, and coastal and marine programs.

Currently, the MRP divides its user base into five categories that define both the nature of the relationship and the products delivered (see Sidebar 2.3). For example, users may provide financial and/or logistical support and work closely with the USGS to set project goals or may simply use publicly available information. Depending on the category, users may receive reports and information tailored to meet specific customer needs or they may use information that is delivered in a standard format. Because many users of MRP information are federal agency partners that require a range of kinds of information and services from the MRP, a single agency may be included in more than one user category. For example, in 2002 the Bureau of Land Management was a cooperator, collaborator, and client. Many of the clients and customers utilize MIT information and statistics, including the *Minerals Yearbook*, which is used by representatives of 45 states. Grantees are a special category of users in that they do not actually use MRP research or information but instead are funded by MRP to carry out research projects themselves. Approximately 5 percent of users are grantees.

SIDEBAR 2.3

The MRP's User Base

Cooperators—Cooperators fund or provide logistical support for the USGS to produce scientific products or conduct scientific research that fosters the goals and objectives of the program (or have provided support in the past) and directly use program information. Information format is tailored to cooperator needs.

Collaborators—USGS works closely with scientific collaborators to produce products required by the collaborators or other clients. In some cases the USGS provides funding for the collaboration. In other cases a separate client provides the funding.

Clients—Clients directly use program information that is tailored to their needs. No funds or other program support is provided by clients.

Grantee—USGS provides funding for projects conducted by grantees at other federal, state, or local agencies or universities.

Customers – Customers use information that is easily and publicly available. The USGS does not specifically tailor the information to meet their needs. There is no exchange of funds or provision of support.

SOURCE: Kathleen Johnson, USGS, personal communication, 2002.

For the purposes of this report all of the above categories will be referred to collectively as "users." The top three users since 1997 are the federal government, trade associations, and the news media, followed closely by state and local agencies (Table 2.1 and Table 2.2). The most significant increase since 1997 is a 5 percent growth in the number of mining companies listed as MRP users. *The committee concludes that the types of users have not changed significantly since 1996, but the number of users has increased by approximately one-third. The committee concludes that the current MRP customer base is appropriate but could be expanded.* Future directions for the program are discussed in Chapter 5, including potential areas in which the user base could be expanded.

TABLE 2.1 MRP Users (percent by category)

User Type	1997	2002
Cooperator	8	7
Collaborator	20	30
Client*	34	28
Grantee	5	5
Customer	34	30

NOTE: Does not include 190 countries and 45 states listed by MRP as clients.
SOURCE: Data supplied by the USGS.

TABLE 2.2 MRP Users (percent by type)

	1997	2002
Federal government agencies	28	23
Environmental/conservation	4	5
Trade associations	20	20
Mining companies	1	6
News media/publishing houses	15	11
Financial institutions	7	6
International organizations	3	2
State/local agencies	13	15
Universities	9	12

SOURCE: Data supplied by the USGS.

As discussed above, the MRP five-year plan (Kathleen Johnson, USGS, personal communication, 2002) addresses a number of opportunities for cooperative program efforts including reimbursable project development. The MRP response to the NRC's 1996 general recommendation on increased collaboration is discussed in Chapter 3.

SUMMARY

In summary, there have been significant changes to the MRP since the 1996 NRC review. Some of these changes occurred in response to the NRC report, while others were set in motion by other influences. The

MRP is now organized by teams and operates under matrix management. It has developed a new five-year plan (Kathleen Johnson, USGS, personal communication, 2002).

The committee is concerned that the fragmentation of staff effort may create unexpected long-term consequences for staff performance, quality of MRP work, and documentation, which could threaten the MRP's strong tradition for reporting its science.

3

The 1996 National Research Council Review of the Mineral Resource Surveys Program and the USGS Response

In 1995 in response to congressional direction, the USGS developed a plan for its mineral resource activities, *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* and requested an evaluation of this plan from the NRC. The NRC convened a committee in late 1995 consisting of 12 geoscientists and resource experts from industry, environmental consulting, academia, state agencies, and the Geological Survey of Canada. The panel released its report, *Mineral Resources and Society: A Review of the U.S. Geological Survey's Mineral Resource Surveys Program Plan* (NRC, 1996), the following April and provided advice for the USGS's 1997 planning process.

The 1996 report addressed the following questions:

1. Evaluate the plan of the Mineral Resource Surveys Program (MRSP) in terms of the nation's long-term needs for minerals research and information; the completeness and balance of the program; and the scientific significance, credibility, and relevance of the overall program.

- Does the plan address the nation's needs in mineral resources, both present-day and long-term?

- What are the appropriate roles and responsibilities, and who are the appropriate customers for the USGS's MRSP?
- Does the MRSP duplicate the activities of other federal programs with responsibilities related to mineral resources?
- Are the program's priorities, products, and audience appropriate to the goals and objectives of the plan?
- Are the level, scope, and balance of research in the plan sufficient to provide a scientific basis for informed decision making and to build a scientific foundation for the future?

2. Provide recommendations as to how the plan could be modified to improve its effectiveness in meeting the long-term needs of the nation.

- What are future research needs, activities, and opportunities?
- What criteria should be established to evaluate the appropriateness and priority of suggested MRSP activities?
- What areas of scientific expertise will be needed by the MRSP to effectively respond to future issues?

The 1996 committee determined that the plan was a logical and necessary continuation of the mineral resources objectives and programs at the USGS and praised the program for moving beyond its traditional role of activities, for advancing the understanding of mineral deposits, for providing the basic geological information for new areas with mineral potential, and for facilitating land-use planning by federal and state agencies, to research on the environmental consequences of minerals development. The 1995 program plan proposed strengthening activities for understanding the environmental consequences of minerals development and including these activities within the broader scope of mineral deposits research.

1996 GENERAL RECOMMENDATIONS

Four general recommendations framed the 1996 NRC report. The 1996 committee was aware that, to be useful, specific recommendations on changes to the plan would need to be supplemented with a broader view of the program. For example, the 1996 committee considered the long-term view of mineral resources investigations and their importance

to the USGS mandate; the organizational and cultural changes that affect geological surveys, the relationships among MRSP subprograms with other USGS programs and disciplines and among customers and partners, and the stated goals and purpose for the program. Consideration of these issues resulted in general recommendations on the following:

1. the program's vision, mission, and objectives;
2. increased collaboration with users, balanced with independent research;
3. maintaining and increasing core competence; and
4. planning, prioritization, and performance.

The current committee examined the 1996 recommendations and the corresponding responses by the MRP prepared by the program coordinator and her staff (Kathleen Johnson, USGS, personal communication, 2002). While overall the program has been guided by the 1996 report, the MRP five-year plan and the goals established by the USGS Geologic Division's Science Strategy (USGS, 1998a), there are some areas where the current committee believes the MRP would benefit from additional consideration of the 1996 recommendations. Although the context that the program is functioning in today has changed considerably since 1996 (see Chapter 2), the four general recommendations remain directly relevant to the MRP.

Vision, Mission, and Objectives

The first general recommendation states: "The plan should be modified to include new, clearly articulated statements of vision, mission, and objectives" (NRC, 1996). The 1996 committee believed that formal statement of the program's vision, mission, and objectives is necessary for the program's planning, prioritization, and assessment of performance. While these elements were implied in the MRSP plan, the 1996 committee suggested that they should be articulated more clearly.

The MRP provided the current committee with its vision and mission statements (Kathleen Johnson, personal communication, USGS, 2002):

Vision

MRP is the sole federal provider of high-quality scientific information, objective resource assessments, and unbiased research results on mineral potential, production, consumption, and environmental behavior.

Mission

- Provide information on regional, national, and global contexts for mineral resources.
- Develop and enhance understanding of relations between minerals, mineralizing processes, and their contributions to our quality of life.
- Transfer technologies beyond minerals sciences.
- Support land management and the nation.

To achieve its vision and mission, the MRP has developed a set of scientific goals and operational objectives (see Sidebar 2.1 and Sidebar 3.1).

The MRP has developed vision and mission statements. However, the vision statement does not read like a vision statement but rather like a statement of what's true. The committee believes that a vision statement should be more lofty, something to reach for, even if it has essentially the same phrases. For example, the MRP vision statement might read: The MRP strives to provide the nation and the world with the highest-quality, most trusted scientific information and research on mineral deposits and their lifecycle and environmental behavior and to foster the use of its analyses and data in national and international policy arenas, especially those related to sustainable development. The mission statements are vague and unclear. For example, what does "context" refer to? How do mineralizing processes affect quality of life? What kind of technologies are envisioned and where should they be transferred? How does a general statement about supporting the nation help guide the program?

The committee could not find any official public statement of the vision and mission, although the concepts are implied in the MRP planning documents. The committee had to rely on MRP personnel to provide the vision and mission statements. Only the objectives and goals are listed in MRP planning documents and on the program's Website. The committee notes that the goals and objectives are written as vague, open-ended, deterministic statements rather than definitive goals and objectives

SIDEBAR 3.1

Mineral Resources Program Operational Objectives

Operational Objective A: Improve access to and ease of use of MRP's products, including both traditional (paper) products and digital data.

Operational Objective B: Improve the quality and completeness of MRP digital data through compliance with established standards and through application of consistent data management requirements.

Operational Objective C: Foster cooperation and coordination within the USGS and with other federal agencies, states, industry, and academia.

Operational Objective D: Prioritize MRP core functions and activities for the purposes of project planning, using internal and external reviews.

SOURCE: Kathleen Johnson, USGS, personal communication, 2002.

against which progress can be measured. The committee is concerned that there is no mention of research in the operational objectives. It is not clear to the committee what the core functions are or how they are prioritized.

This committee reiterates the 1996 committee's belief that the program's vision and mission statements are critical in planning, prioritization, and assessment of performance and should be highlighted on the MRP Website and in MRP communications. The committee believes that the lack of clarity in organization and goals adversely affects the MRP's ability to plan and communicate the value of its work to others. The vision, mission, operational objectives, and goals themselves are confusing and do not provide the guiding light they should for the program. Planning activities for each year should clearly show that topics respond to the vision and mission (and objectives), thereby reinforcing their importance throughout the organization.

The committee concludes that the MRP has not adequately responded to the first general recommendation of the 1996 review. **The committee recommends that the MRP develop simple, clear mission and vision statements, goals, and objectives that will serve as the guiding principles for the program.**

In addition, the mission and vision are not well communicated in the MRP planning documents, Website, and other materials, nor in statements by leadership, nor in communications with other parties inside and outside the Department of the Interior with whom MRP must work, and they do not address future directions for MRP effort. Incorporating vision and mission into external communications should be complemented by greater internal program cohesion intellectually.

Looking to the future, Chapter 5 of this review explores several ways in which the MRP's vision and mission might evolve over the next decade.

Research Balanced with Increased Collaboration with Users

The second general recommendation states: "To fulfill its mission, the MRSP and its plan should move away from an organizational culture dominated by self-direction and independent research toward one that also embraces projects developed through collaboration with users" (NRC, 1996). With respect to collaboration with users, the 1996 NRC report expresses the committee's doubts on whether the MRSP understood the needs of its clients or how its information was being used. On the other hand, the 1996 committee also determined that land management agencies did not understand the true value of resource assessment provided by the program.

The 1996 committee made the following suggestions for the program:

- The MRSP staff should actively involve users in planning projects to help determine the appropriate work products, analytical techniques, map scale, level of detail, and other parameters.
- The MRSP should seek partnerships with interested parties, in particular state agencies, industry, and academia, in the collection of data and conduct of projects.
- The MRSP should develop an external grants program to assist its basic research function.
- The MRSP should be responsive to the needs of users to have reports completed in a timely fashion.

The 1996 NRC report also reiterates findings from an earlier review of the USGS's Office of Mineral Resources (NRC, 1987). Presented in Sidebar 3.1 of the 1996 report, these comments highlight a lack of focus and extreme individualism of the staff, a need for improved communication and motivation, and insufficient time devoted to fieldwork, including geological mapping.

Currently, MRP projects are developed in collaboration with internal and/or external users (Kathleen Johnson, USGS, personal communication, 2002). Most MRP projects involve interdisciplinary teams of scientists, including scientists within the USGS and from other organizations (e.g., state government, academia). Examples include the following:

- the recently completed study on industry trends for mid-Atlantic region aggregates companies (Robinson and Brown, 2002);
- the recently completed integrated study of abandoned mine lands and water quality in the upper Animas drainage in the San Juan Mountains, Colorado (USGS, 1999c, 2002c); and
- the ongoing geologic and ore-genesis studies of the Red Dog deposit in Alaska, the world's largest zinc mine (USGS, 2002d).

The committee heard presentations from several agencies relating to collaborative efforts with MRP. Interactions with some agencies are quite active and result in extensive collaboration. For example, the MRP assists with mineral assessments for the U.S. Forest Service (Michael Greeley, U.S. Forest Service, personal communication, 2002) when such assessments are required as part of the Forest Service's Minerals Program Policy. The Abandoned Mine Lands Initiative, whose goal is to develop a watershed-based approach for cost-effective cleanup of legacy mining activities, is another successful collaborative effort with the U.S. Forest Service, Bureau of Land Management, and other land management agencies (USGS, 1999c). Several watershed cleanup efforts, including the Boulder River watershed in southwestern Montana, have benefited from collaboration. However, the committee noted that some opportunities to develop collaborative arrangements might have been missed.

One example involved a request by the Bureau of Land Management (BLM) for MRP to conduct a series of assessments (Sie Ling Chiang, BLM, personal communication, 2002). The collaborative effort, which may have involved funding from the BLM, did not go forward due to

misunderstandings between the BLM and MRP. Prior to 1996, the Bureau of Indian Affairs benefited from MRSP-provided geological information on tribal lands. However, this collaboration ceased in 1996, although the need for scientific and technical guidance by MRP appears to have increased. Tribes increasingly derive income and employment from natural resource development yet have little in-house geological expertise to make important decisions (Steve Manydeeds, Bureau of Indian Affairs, personal communication, 2002). There appears to be a continuing and unmet need for the MRP to reinstitute a productive collaborative effort with the Bureau of Indian Affairs as part of the Department of the Interior's trust obligations.

The committee concludes that there is more collaborative project work being done today by the MRP than in 1996. However, there is still some need for improvement in communication and collaboration with some users.

Maintaining and Increasing Core Competence

The third general recommendation states: "The MRSP should place more emphasis on maintaining and continuing to develop its core competence in mineral deposits research and minerals-related environmental research in order to anticipate and respond to national needs for mineral resource information" (NRC, 1996). The 1996 committee defined the program's core competence as (1) excellence in mineral deposits research, (2) scientific integrity, and (3) expert professional staff. The committee recommended that research on geology, geochemistry, and genesis of ore deposits be continued. The committee also noted that this research should include both applied and basic research.

Core competence is a popular and much utilized concept for developing a business strategy. It has many definitions, and although the 1996 committee did not specifically define the term, this committee understands it to mean the following: core competency is fundamental knowledge, expertise, or skill in a specific area. The committee notes the term is used in the MRP five-year plan (Kathleen Johnson, USGS, personal communication, 2002). However, it does not appear that the MRP has established the elements that make up its core competence. The committee believes that the MRP management would benefit from a self-assessment to define and identify its core competence (see Chapter 5).

The USGS has long been recognized for excellence in basic minerals research, and this core competency contributes to the agency's mission to provide "the Nation with reliable, impartial information to describe and understand the earth" (USGS, 2000). The MRP responded by including most aspects of this recommendation in one or more of the science goals listed in the five-year plan (Kathleen Johnson, USGS, personal communication, 2002) (see Sidebar 2.1). The committee notes that the five-year plan indicates a shift in emphasis toward information and away from minerals related research. The committee recognizes that the MRP has a vital role in providing information (e.g., Minerals Information Team [MIT]), but the committee cautions the MRP against becoming only an information agency. It is important for the MRP to balance these two functions.

It is difficult to assess whether the MRP has maintained its core competencies in mineral deposits research and minerals-related environmental research using easily tracked, strictly quantitative criteria. Possible criteria that could be used to determine whether core competency is being maintained include the number of projects per year categorized as mineral deposits research, the number of publications per year in refereed journals and professional papers, and the breakdown of staff per year by technical background (e.g., number of Ph.D.s). However, the committee was not able to obtain from the MRP the appropriate information to make these comparisons. The committee, therefore, attempted to qualitatively evaluate whether the MRP has maintained its core competence.

The 1996 NRC review also noted that the USGS has a long-standing and well-deserved reputation for scientific integrity and that the means of continuing that reputation lay in maintaining scientific and data standards. Specific descriptions of sampling and measuring methods should be reported, and analyses performed in outside laboratories should follow specific protocols.

At the time of the 1996 NRC report, several changes were taking place in the USGS that had the potential to impact data integrity, such as the move to more centralized labs where research scientists no longer analyze their own samples and therefore have less direct control over data quality and the move toward more data-intensive geochemical baseline studies. Concerned about data integrity, the 1996 committee recommended that the MRP adopt quality assurance and control protocols for data collection, handling, preservation, and analysis. To this end, proto-

cols have recently been updated to include newer analytical methods involving changes in instrumentation and detailed documentation of the procedures for quality assurance (Taggart, 2002).

Finally, the 1996 committee noted that the scientific credibility and respect of the USGS are the result of its high-quality scientific personnel and that this quality should be maintained through recruitment, hiring personnel with expertise in new areas, and utilizing personnel in other programs and disciplines if additional expertise is needed.

An essential part of maintaining and developing this professional expertise is attracting and retaining talented scientists with recognized expertise central to the MRP's research goals. Along with this effort there must be ongoing professional development to meet the changing needs of the organization. The MRP's five-year plan points to deficiencies in expertise and outlines specific actions to correct them.

The MRP has continued research on the geology, geochemistry, and genesis of mineral deposits and has taken steps to ensure data integrity. However, the present committee was unable to determine if the MRP continues to maintain its core competence in mineral deposits research and minerals-related environmental research. The MRP has not done all that is possible to document its continued core competence in these areas. **The committee recommends that the MRP perform and publish a self-assessment to identify and define its core competence, to evaluate actions needed to maintain such competence into the future, and to relate those findings to its staffing and staff development plans.** As the MRP evolves (see Chapter 5), it must build new core competence in selected new disciplines that address important issues the organization and its stakeholders think should be addressed.

Planning, Prioritization, and Performance

The fourth and final general recommendation states: "The MRSP and its plan should place greater emphasis on improving mechanisms and procedures for comprehensive planning, setting priorities, and evaluating and enhancing performance, particularly through external reviews or advisory panels. The level of funding for MRSP and the balance of funding among its subprograms deserve thorough review by the MRSP staff, users, and collaborative agencies and organizations" (NRC, 1996). The

1996 committee suggested this be implemented through the following activities:

1. *External review committees.* External review is a common activity for many federal programs and can be implemented through federal advisory committees, NRC committees, or other less formal groups.
2. *Improved communication with land management agencies.* The 1996 committee believed that employee exchanges would have many benefits, such as helping MRSP staff learn more about users' needs, providing an opportunity for other agencies to learn more about the uses and limitations of MRSP information, and supplementing MRSP employee expertise.
3. *Setting and maintaining program balance, in level, balance, and scope of research.* The 1996 committee did not believe it had enough information to assess the program's appropriate balance. The committee suggested that this determination would require extensive discussions within the MRSP, within the USGS, and with users and could be a potentially important activity for an advisory committee. However, the 1996 committee did urge that project scopes should be national and should not include activities more appropriately handled by state and local agencies. Criteria defining a federal role should include activities that are generic, affect multiple states, or are on federal lands.

The USGS has developed a program and project planning process that takes place across organizational structures and disciplines and reflects matrix management, enhanced regional leadership, and an enterprise approach to science (USGS, 2001). The USGS strategic plan (USGS, 2000) and the five-year program plans form the basis for annual project planning (USGS, 2001). Key responsibilities and roles are consistent with the USGS matrix management model. Headquarters personnel are accountable for results relating to longer-term planning—beyond the year of the program and project implementation. They are also responsible for project-level planning and for activities within their offices for the year of implementation. Regional staff is responsible for project-level planning and decision making for the regions for the year of implementation.

Program Planning

According to the documentation provided to the committee, users provide input on science needs, emerging issues and priorities that are incorporated into the five-year plans for the various programs (USGS, 2001). Users also provide external review of the plans.

Committee members heard during informal interviews with MRP collaborators, stakeholders, and USGS personnel that program planning is complex and inconsistent. According to some stakeholders, the frequency of meetings tends to be erratic, meetings are onesided (i.e., stakeholders relate their activities in a program area with little input from the MRP), and over time the involvement of stakeholders in program planning is limited. Some MRP staff at the team level indicated that the program planning process is not well understood and expressed concern that there appears to be no overarching plan. Some believe that the five-year plan is confusing and does little to focus the MRP on a long-term program mission. Some staff also reported that the teams have limited input into the program planning process because of inadequate communication among the centers and the program office.

The USGS has a plan for reviewing 29 of its science programs (USGS, 2002e). In general, a comprehensive review of each science program should occur every five years. The reviews are used to understand program performance and to evaluate program goals and objects (see Sidebar 3.2). Normally the USGS establishes an ad hoc external committee to perform this review. However, sometimes NRC or Federal Advisory Committee Act committees perform this function.

The MRP uses external peer review committees, such as the current committee. This is the third NRC report on the MRP and its predecessors (NRC, 1987, 1996). These reports, although limited in scope, provide useful input to the MRP. However, these reports have not all been comprehensive reviews, as suggested by the USGS program review plan. **The committee recommends that the MRP establish an external documented review procedure in accordance with USGS guidelines that will evaluate program outcomes relative to those that were planned.** The committee believes that such reviews will assist in justifying the program and showing its value to the nation. The committee cautions that external review alone does not substitute for program direction and leadership.

SIDEBAR 3.2

Guidelines and Questions for Framing Program Reviews

1. Evaluate the quality of USGS science.
   Are USGS scientific resources being effectively applied to pressing issues?
   Is USGS science well integrated with the larger scientific community?
   Do USGS activities represent the cutting edge of national and international science?

2. Ensure communication and collaboration among USGS scientists during the review process.
   Give scientists from multiple disciplines the opportunity to influence the future science conducted within the program.
   Promote interdisciplinary studies among USGS program and disciplines.
   Create synergistic relations among scientists and across regions.

3. Determine the relevancy of USGS science.
   Is the science relevant to issues facing the nation, both within the Department of the Interior but also outside its traditional responsibilities?
   Is the science relevant to long-term strategic issues but also meeting short-term needs that require an immediate response?

4. Evaluate USGS's efforts in meeting partner needs.
   Is USGS science applicable to the needs and responsibilities of primary partners and does it meet the overarching resource management and natural hazards and risk challenges facing these agencies?
   How well does USGS identify what studies are needed and conduct the science to support its partners in a timely manner?
   What customer outreach activities are under way? How are products of the program delivered?

5. Evaluate performance in meeting program goals.
   Performance is evaluated against previously determined goals and objectives.
   Revised program goals and objectives are a primary outcome of program reviews.
   Reviews provide the basis for revising program goals and objectives about every five years.

6. Guide future scientific endeavors by considering the following questions:
   What are the key scientific questions and issues related to this program?
   What is the current state of scientific knowledge of these issues and the role of the USGS?
   How effective has the program been in providing high-quality, timely products?
   Is the science making a difference to partners, stakeholders, citizens, and cooperators?

What gaps in the science should be addressed?
Are there activities in the program that are productive but have little relevance?
How can interagency coordination be improved or initiated?

7. Describe and reveal opportunities for budget and program development.
Identify new program budget initiatives that are potentially of interest to the USGS and other agencies.
What additional linkages with other USGS programs and the budget initiative development process would promote recommended changes?
Summarize the current funding levels and potential future needs.
Identify the conduct of cooperative and integrated science opportunities.

8. Summarize and analyze the data required to evaluate Bureau Government Performance and Results Act requirements.
How are the data being collected and interpreted?
Are the data to be collected the correct data?

9. Recommend a coordinated review timeline and plan with other programs where it is appropriate.
What goals and objectives of these programs warrant a coordinated review process?
Is appropriate coordination taking place between the program and the regions?

SOURCE: USGS (2002e).

Project Planning

The USGS planning model (USGS, 2001) specifies the agency's project planning procedures, which are outlined below. The USGS defines a project as a planned effort with a goal or set of goals, a staff, and a budget that result in a project or service. Annual project planning is the process by which the USGS defines its scientific and operational activities for the coming year. Project planning involves regional executives, cost center chiefs, program coordinators, and regional program offices (USGS, 2002f). Annual planning begins with annual guidance issued by the director in two documents: first the director's annual guidance, followed by the annual program direction. These documents, which do not reiterate the five-year plan, provide an opportunity for the USGS science leaders to collaborate on high-level strategic science opportunities, revise annual goals of the five-year plans because of funding changes or congressional mandates, and initiate development of new out-year or long-term science initiatives. Annual project planning and decisions are to be

based on the objectives and outcomes stated in the five-year plans and the annual guidance documents (USGS, 2001).

Some requests and project suggestions come into the MRP planning process from stakeholders (see Table 3.1). Requests and suggestions may come with financial and/or personnel commitments (see "users" section in Chapter 2). Project input is received both formally from within the USGS and other agencies of the Department of the Interior and less formally from other groups.

According to the USGS Annual Project Review Process (USGS, 2002g), a variety of reviews take place to assess the scope and direction of a project, the progress of work, and the delivery of products or services. Reviews generally focus on proposals and work plans for new projects and on changes to existing projects. The review process is designed to enhance cross-disciplinary and cross-region collaborations on project development and review and ultimately to improve the quality of science (USGS, 2002g). The USGS has defined four review criteria:

- Work being performed is of the highest quality and is likely to be successful in meeting the goals of the project as stated in the annual guidance as well as meeting the goals of the bureau's program.
- Work is based on sound scientific or technical concepts of guidelines.
- Human and budgetary resources dedicated to the project are sufficient to ensure project completion.
- Work is appropriately designed to meet partner and stakeholder needs, can be accomplished in the time frames identified, and will produce the products necessary to meet project objectives.

From 1997 to 2003, MRP project proposals were reviewed for scientific excellence and in the context of the program objectives by panels that included non-USGS scientists. This process was discontinued in fiscal year 2003, and the new procedures outlined above were implemented. However, based on discussions committee members had with MRP staff, it appears that the new procedures are not working. In addition, the committee notes with alarm that the new procedures, even if implemented flawlessly, appear to have no aspect of external review. Based on information obtained during the review process, the MRP program coordinator develops

TABLE 3.1 Examples of Groups that Make Requests and Suggestions for MRP Projects

USGS regional offices	Regional mineral resources chiefs, regional directors, and research scientists in the regional offices.
Other USGS divisions and programs	Water resources, biological survey, coastal and marine, energy, groundwater resources, regional hydrology.
Other bureaus/agencies within the Department of the Interior	Bureau of Land Management, U.S. Forest Service, Bureau of Indian Affairs.
Other government departments and agencies	State Department, Central Intelligence Agency, Commerce Department, Treasury, National Aeronautics and Space Administration.
External stakeholders	National Mining Association, state miners associations, state geological surveys, university research groups, local governments, industry groups including mining companies, and environmental groups.

SOURCE: Data supplied by the USGS.

a program that adheres to predefined USGS and MRP operational objectives set out in the five-year plan and addresses the highest-priority research areas and national needs (Kathleen Johnson, USGS, personal communication, 2002).

In discussions with MRP stakeholders and staff at the team level committee members heard that the project development and selection process is haphazard. Ideas for projects are typically formulated by a single scientist or among small groups of scientists, having been informed (through the guidance on annual program direction) as to what types of projects might receive funding. These project ideas may or may not have input from users or stakeholders. The project ideas are usually discussed with the chief scientist or other senior manager at the team level. The project proposal may also be subject to some internal review at the team level before being submitted to the program coordinator. Project selection rests with the program coordinator in consultation with regional managers. Committee members heard that new projects being funded are

trending toward compilation-type studies that provide simple, short-term products such as CDs, as opposed to fundamental research studies. Committee members also heard that a single scientist may be part of several project proposals being submitted for funding, and some may be working on as many as 10 projects to cover salary.

The committee has several concerns relative to project development and selection. The method of project assessment does not appear to offer a reliable and systematic mechanism for incorporating the MRP's program plan and overall mission into new projects. The committee is concerned that if there is too little input from the user community in project development, this could lead to projects producing products for which there is no customer or user. The lack of external review of new project proposals and systematic external reviews of ongoing multiyear projects may lead to erosion of technical credibility of MRP science and scientists. Other federal agencies that fund and/or perform research adhere to rigorous external reviews to ensure scientific credibility. The trend toward compilation-type studies is disturbing, particularly if the compiled data are not being used to solve problems.

The need for planning, goal setting, and outcome measurement was pointed out in the 1996 NRC report. The present committee does not believe that these issues have been adequately addressed. *The committee concludes that the current process of program planning and prioritization is unnecessarily complex and confusing in the context of MRP's priorities, operational objectives, and goals.* Because of this, the committee found it difficult to determine how MRP performance is actually measured. The committee was also concerned with the lack of external review of projects. **The committee recommends that the MRP implement a management review of proposals to align the work with strategic objectives, a rigorous external review process, and an internal review process that cuts across organizational units.**

The committee believes that the absence within the MRP of a well-defined and implementable programmatic vision is the cause of many of the deficiencies in planning processes and performance criteria. Without established direction, program selection can easily shift in response to external review and user requests. In the extreme, rather than refining the implementation of vision and mission in the MRP, the external review process could perpetuate the sense of a ceaselessly shifting target. External review alone does not substitute for program direction and planning.

The committee notes that in the Government Performance and Results Act era, anecdotal evidence of a program's contribution to society is not enough. Government now must demonstrate effective leadership to the nation's people and their representatives, as well as private and other public sectors, through reporting. This means that all government agencies must now convincingly demonstrate relevant accomplishments, clearly show significant outcomes and the value of all their work, and indicate their effectiveness in doing it. The Government Performance and Results Act goes beyond program and project planning and prioritization. The committee believes that it is more important than ever for the MRP to clearly articulate how performance is measured.

1996 RECOMMENDATIONS FOR THE MRSP SUBPROGRAMS

At the time of the 1996 NRC report, the MRSP was divided into four subprograms: assessments, mitigation studies, resource investigations, and information and technology transfer. Each subprogram was broken into components, which were then divided into elements (see Table 3.2).

The committee attempted to evaluate the MRP's response to the specific recommendation of the 1996 NRC review within the context of the current program structure. While the MRP has completed or addressed many of the recommendations, there are several areas that this committee believes have not been adequately addressed. Even though the MRP is no longer organized by subprograms, the committee has retained this organization in the following section to make correlation with the 1996 report straightforward.

Assessment Subprogram

Estimates of the quantity of undiscovered mineral resources expected to occur within a designated area were developed in the assessment subprogram. The 1996 NRC report notes that assessments are useful for land management decisions, stimulation of the domestic economy, understanding of strategic and critical minerals, providing data for consideration of environmental impacts, and ensuring an adequate domestic supply. Indeed, the 1996 committee received numerous briefings about the need for detailed geological maps, descriptions of known ore deposits, geochemical

TABLE 3.2 1996 Mineral Resource Surveys Program Organization

Subprograms	Components	Elements
Assessments	Resource and environmental assessments	National and regional assessments, requested and special-purpose assessments
	Assessment protocols and methods	Assessment protocols, assessment methods
Mitigation studies	Geochemical backgrounds and baselines	Background and baseline mapping, discrimination between natural and mining-related distributions
	Studies in support of remediation	Processes affecting remediation, field-oriented monitoring techniques
	Environmental behavior of mineral deposits	Geoenvironmental models of mineral deposits, release, transport, and fixation of metals
Resource Investigations	Mineral resources frontiers	Unconventional deposit types, regional frontier investigations
	Mineral deposits studies	Ore-forming processes, mineral deposits models
	Cooperative industry and international investigations	Cooperative industry investigations, cooperative international investigations
Information and Technology Transfer	Databases and information analysis	Database development and management, information analysis, mineral resource specialists
	Information and technology transfer	Minerals information offices, Center for Environmental Geochemistry and Geophysics, international centers, training

SOURCE: Modified from USGS (1995) and NRC (1996).

sampling, geophysical surveys, and other basic geoscience data. The 1996 committee recommended the following for this subprogram:

Specific Recommendation A

"The MRSP should incorporate data and invite expertise from outside the USGS, to the greatest extent practical and constructive, particularly from industry, academia, and state agencies" (NRC, 1996).

In designing the global mineral resource assessment (Chapter 2), the MRP is acting on this advice. This project involves both data and expertise from industry, academia, and other geological surveys. The committee learned from discussions with stakeholders and MRP scientists that, although the global resources assessment may be important, the question is whether it is scientifically valid, accurate, and precise.

Specific Recommendation B

"The MRSP should rigorously document the specific contributions and impacts of past resource assessments related to land-management decisions. The panel strongly recommends that the MRSP publish a single document, written for the lay audience, which documents, explains, and discusses the usefulness of mineral resource assessments and their applications in land management" (NRC, 1996).

The MRP responded to this recommendation by stating that efforts to implement it were stymied by difficulty in obtaining information from land management agencies (Kathleen Johnson, USGS, personal communication, 2002). The projects to which this recommendation refers are old enough now that there is no one in the land management agencies who can provide the information. The USGS believes that recent publications on the global minerals assessment are beginning to fill the niche implied by this recommendation.

The present committee is concerned that the MRP has not documented the contributions and impacts of past resource assessments. **The present committee recommends that the MRP document the contributions and past impacts of resource assessments and other MRP work products.** The MRP should seriously consider obtaining feedback from land management agencies and other users upon project completion. Qualitative and quantitative ratings on timeliness, relevance, and understandability of completed projects should be sought. The committee

believes that such documentation would help communicate the usefulness and current and past value of assessments to a broader audience (e.g., the Office of Management and Budget) and as part of a broader evaluation of the extent to which mineral assessments and other MRP work products are worth the time and effort devoted to them.

Specific Recommendation C

"Mineral resource assessments should be performed more efficiently, and the cost-savings should be directed to more fundamental investigations in other subprograms of the MRSP" (NRC, 1996).

The MRP approach to implementing this recommendation has been to terminate mineral resource assessments for individual national forests or BLM resource areas (Kathleen Johnson, USGS, personal communication, 2002). The MRP now works with the U.S. Forest Service and BLM to aggregate high-priority areas into regional assessments, which allows them to provide information for large areas in the same time once allocated to individual forests or resource areas. The committee notes that it is imperative that the Forest Service and BLM be involved in the project planning process to ensure that their needs for mineral resources information are addressed.

It is not clear that there has been any short-term cost savings to the USGS. However, the MRP believes that it can do a better job of meeting the needs of the land mangers through this approach.

Mitigation Studies Subprogram

The mitigation studies subprogram covered research related to the environmental impacts, both natural and anthropogenic, of mineral deposits. However, the 1996 committee was not convinced that remediation was a proper role for the program and suggested that some of the aspects included should be transferred to other areas (e.g., creating a separate subprogram for geochemical backgrounds and baselines and including environmental investigations under resource investigations) and that some should be terminated.

The 1996 committee identified an important need for methods to differentiate natural and anthropogenic geochemical anomalies associated with mineral deposits. In addition, the committee found significance in the

work to incorporate the processes underlying environmental impact into resource investigations. Finally, the 1996 committee noted that collaboration with users and particularly with the Water Resources Division (now the Water Resources Discipline) staff would be of great benefit to the program.

Specifically, the 1996 committee recommended the following for this subprogram.

Specific Recommendation D

"Merge two components of the Mitigation Studies Subprogram, namely, (1) Studies in Support of Remediation, and (2) Environmental Behavior of Mineral Deposits, into the Resource Investigations Subprogram" (NRC, 1996).

This recommendation was primarily organizational. Because the MRP is no longer organized by subprograms, the recommendation was not implemented as written. However, the intent of the recommendation has been implemented. The MRP no longer separates research that is designed to support remediation from research on the processes that occur when mineral deposits encounter surficial processes (Kathleen Johnson, USGS, personal communication, 2002). An example of this type of study is the abandoned mine land project.

Specific Recommendation E

"Elevate the Geochemical Backgrounds and Baselines component to subprogram status. Emphasize such elements as Discrimination Between Natural and Mining-Related Geochemical Distributions, to reflect the growing national and international importance of this activity" (NRC, 1996).

This recommendation was also primarily organizational. Because the MRP is no longer organized by subprograms, the recommendation was not implemented as written. However, the intent of the recommendation was implemented. The MRP has been doing work on geochemical backgrounds and baselines since 1996. Currently, the MRP funds geochemistry baseline work in the following areas: Coeur d'Alene basin, Idaho; Blackfoot River watershed, Montana; the Elizabeth mine, Vermont; at several national parks in Alaska; and in the Fortymile and Goodpaster River watersheds, Alaska. In addition, the MRP is embarking on a soil

geochemical survey, which will compile old data with new sampling and analysis. Some of these studies have identified the premining background and the distribution of mining-related materials through natural and anthropogenic processes. It is not clear to the committee how much emphasis is placed on understanding the differences between natural and man-made geochemical anomalies.

Specific Recommendation F

"Increase collaboration with WRD [Water Resources Division] staff to address such issues as chemical releases from mineral deposits, acid drainage prediction, and metal leaching" (NRC, 1996).

The MRP works with WRD staff on a variety of projects including abandoned mine lands. In addition, the MRP has recently completed a study of the Coeur d'Alene basin and are continuing a project examining pathways of metal transfer from mineralized sources to plants and animals (including humans). Some MRP projects also involve collaboration with Biological Resources Division scientists.

Specific Recommendation G

"Discontinue activities directed at the adaptation and improvement of remedial technologies, a part of the Studies in Support of Remediation component" (NRC, 1996).

The MRP agrees with the 1996 committee that it does not have the required expertise and is not the appropriate group for this activity. The MRP no longer conducts studies of this sort. In Chapter 5 the committee discusses methods and technology development as a potential new role for the MRP, requiring new partners and professional expertise.

Specific Recommendation H

"Use a multi-disciplinary approach to determining geochemical backgrounds and baselines by collaborating with other scientists such as microbiologists, soil scientists, aqueous geochemists, sedimentologists, hydrologists, and aquatic biologists" (NRC, 1996).

The MRP has made progress toward incorporating a variety of expertise in its projects. The MRP has used new hires, partnering with other programs or organizations, and contractors to obtain the necessary skills.

The committee encourages the MRP to continue to develop expertise as outlined in the five-year plan and encourages enhancement of the existing mentoring plan to attract outstanding, young scientists to the program.

Resource Investigations Subprogram

The resource investigations subprogram included research on the characteristics and interpretation of mineral deposits. The 1996 committee noted that the basic and applied research in this subprogram provided the technical background for the other subprograms and should not be diminished. This subprogram included mineral resource frontiers and mineral deposit studies, both of which the 1996 committee urged be maintained. In addition, the subprogram included a cooperative industry and international investigations component for responding to requests from industry and foreign governments; the 1996 committee believed that this area would benefit from leveraging funds through a Cooperative Research and Development Agreement (CRADA) system.

Specific recommendations for this subprogram were as follows:

Specific recommendation I is the same as specific recommendation D above. Specific recommendation J states: "Revitalize the core competence to conduct basic and applied research on mineral deposits under the Resource Investigations Subprogram, which provides essential information for other MRSP subprograms and numerous users" (NRC, 1996). Issues associated with core competence were discussed under general recommendation 3 above.

Specific Recommendation K

"Continue basic research conducted under two components in the Resource Investigations Subprogram—Mineral-Resource Frontiers and Mineral-Deposit Studies—such as low-temperature chemistry of water-rock interaction, timing of ore-forming processes, origin of giant ore deposits, and ore deposit evolution as related to continental reconstruction" (NRC, 1996).

Basic research continues but is organized as both environmental and resource activities. For example, low-temperature geochemistry is stud-

ied in support of remediation of abandoned mine lands. In addition, MRP funds a small project devoted exclusively to minerals-related research in aqueous geochemistry, as well as a project aimed at determining rates and mechanisms of sulfide mineral oxidation and toxic element release due to chemical and microbiological processes. On the mineral deposits formation side, the MRP funds work described as "Metals in Basinal Brines and Petroleum" (looking at the transport of metals and nutrients in reduced brines and petroleum), "Early Tertiary Slab Window in Alaska" (assessing the relationship between the formation of orogenic gold deposits and crustal evolution processes), and a newly established project looking at secular variation and ore deposit formation (beginning fiscal year 2003).

Specific Recommendation L

"Evaluate the feasibility of replacing the Cooperative Industry and International Investigations element with a CRADA system, whereby industrial and foreign government users would provide funding toward needed MRSP research" (NRC, 1996).

The MRP continues to partner with the minerals industry and with international geological organizations in order to achieve common goals. The MRP uses a variety of agreements for these partnerships, including memoranda of understanding and CRADAs where appropriate.

Specific Recommendation M

"The MRSP should be empowered, within budgetary limitations, to conduct selective mineral-deposits research in foreign terrains" (NRC, 1996).

The MRP has funded U.S. participation in cooperative work with a number of East Asian countries, including China, Mongolia, Russia, South Korea, and Japan. In addition, the MRP will include overseas deposit studies as part of the global mineral resource assessment (Chapter 2). In addition, the MIT's country specialists have close relationships with international government and industry organizations. The committee also notes that in the five-year plan reimbursable project development is proposed with foreign entities.

Information and Technology Transfer Subprogram

The information and technology transfer subprogram was designed for developing and maintaining state-of-the-art databases, facilitating the exchange of information with users, providing timely information, and improving understanding by users of the significance and limitations of the information. However, the 1996 committee stated that it was not appropriate for the program to develop spatial data analysis tools but that these tools should be obtained through commercial products or other agency programs. In addition, the 1996 committee noted that transfer of the minerals information activities of the Bureau of Mines (now the MIT, see Chapter 3) should be included in this subprogram.

The 1996 recommendations specific to this subprogram were as follows.

Specific Recommendation N

"The Plan should place greater emphasis on internal consistency and standardization in all aspects of databases and technology transfer" (NRC, 1996).

Technology has evolved significantly since 1996. Today most MRP activities are described on the World Wide Web. Technology now enables the MRP to serve spatial data through a single Website. All MRP databases are required to be Federal Geographic Data Committee compliant (Kathleen Johnson, USGS, personal communication, 2002). This means that they must produce and maintain metadata and achieve the standards applicable to their specific data type.

Specific Recommendation O

"The Plan should be modified to include activities recently transferred from the U.S. Bureau of Mines (USBM) to the USGS" (NRC, 1996). The current MRP five-year plan now includes this function as a separate team, the MIT (see Chapter 4).

Specific Recommendation P

"The Plan should not take on the task of software development for GIS technology but assign that responsibility to other departments in the USGS or obtain products from private vendors" (NRC, 1996).

The MRP agrees with the spirit of this recommendation and only develops software when a commercial product is not available (Kathleen Johnson, USGS, personal communication, 2002). For example, most of the software that drives the spatial data Website is off-the-shelf commercial software, but selected parts (e.g., a downloadable print file) were developed in house.

SUMMARY

Although the context that the program is functioning in today has changed considerably since 1996, the present committee believes that the four general recommendations remain directly relevant to the MRP. In addition, the committee is concerned about the lack of clear channels of responsibility, fragmentation of staff effort, failure to demonstrate satisfactory accomplishments or significance of outcomes of work, lack of established performance goals, lack of evidence that core competencies are in place, and an inability on the part of MRP leadership to answer basic questions on staffing and productivity. *The committee concludes that the MRP would benefit significantly by having a highly focused central organization, which is objective driven and possesses clear lines of responsibility for each project.*

Because of programmatic changes, it was difficult to assess the MRP's response to the specific recommendations. However, the present committee believes that, when considered within the broader context of current program activities, the MRP has responded to the spirit of many of the specific 1996 recommendations. The committee believes that there are areas where the specific recommendations are still relevant and further improvement is warranted. Examples include (1) external input to and review of resource assessments; (2) increased documentation of the value of MRP work; (3) more research on the differences between natural and man-made geochemical anomalies; (4) increased leveraging of funds from outside sources including foreign sources; and (5) enhancing the mentoring program to encourage the hiring of young scientists with

interdisciplinary training excellence, such as from National Science Foundation-funded Integrative Graduate Education Research and Traineeship programs.

4

The Minerals Information Team

The Minerals Information Team (MIT), funded by the Mineral Resources Program (MRP), is among the longest-running, systematic information collection, analysis, and dissemination functions within the federal government. This chapter evaluates the minerals information activities of the MRP. Since the transfer of these functions occurred after the 1995 USGS (USGS) Mineral Resource Surveys Program (MRSP) plan (see Chapter 3), these activities were not evaluated in the 1996 National Research Council (NRC) review of the plan.

Although many of the other MRP teams' products could be described as "minerals information" (see Chapter 2), this chapter deals specifically with information collected and disseminated by the MIT, which focuses on minerals and materials production, consumption, international trade, and other economic data. "Minerals information," as used in this chapter, does not refer to geological, geochemical, biogeochemical, geophysical, and other scientific data and information that are generated, compiled, and analyzed in the research activities of the MRP.

Recognition of the benefits to the United States from collecting minerals information predates the USGS. President Thomas Jefferson's 1803 letter to the Lewis and Clark Expedition is often cited as the first recognition of the public good derived from a national policy of collection of minerals information (Smithsonian Institution, 2001). In 1879, at the time of the founding of the USGS, the USGS Mining Statistics Division began collecting and disseminating information about the nation's min-

eral production and resources (Barsotti et al., 1998). Initially this information was collected only on public lands but was later expanded to include the eastern United States (Rabbitt, 1979, 1980, 1986, 1989). In 1925 the mineral statistics function was transferred from the USGS to the U.S. Bureau of Mines (USBM) and the USBM was transferred to the Department of Commerce, and in 1934 the USBM was moved back to the Department of the Interior (Table 1.2). Increased demand for minerals data resulted in the inclusion of commodity summaries and industry surveys. Data analysis by commodity experts and their statistician assistants was included in these annual updates.

In 1987 responsibility for energy statistics (e.g., oil, natural gas, coal) was transferred from the USBM to the newly formed Department of Energy. In 1993, budget constraints caused the USBM to cease providing detailed mineral trade statistics by country in each yearbook (USBM, 1993). In 1995 the USBM closed and the minerals information function was transferred in a modified form to the USGS as the MIT.

THE MIT TODAY

The MIT collects, analyzes, and disseminates information on domestic and international supplies of and demand for minerals and materials essential to the U.S. economy and national security. MIT activities are guided in part by statutory requirements in laws and executive orders, which assign the Department of the Interior responsibilities linked to national security and emergency preparedness—specifically, to provide data on national defense industrial base capacity and expansion capabilities and to provide guidance to the minerals industry for ensuring continuity of production (see Sidebar 4.1). There are 12 public laws and several executive orders that authorize and, in some cases mandate, that the Department of the Interior collect, evaluate, and analyze information concerning mineral occurrence, production, and use (John DeYoung, USGS, personal communication, 2002). The MIT fits within the MRP five-year plan (Kathleen Johnson, USGS, personal communication, 2002) under the fourth science goal: "Collect, compile, analyze, and disseminate data and develop and maintain national and international databases for timely release of information to all users".

SIDEBAR 4.1

Statutory Requirements for Minerals Information

Activities of the MIT are mandated or authorized in part through about 12 public laws and several executive orders (e.g., Organic Act of 1910, P.L. 61-179; Mining and Mineral Policy Act of 1970, P.L. 91-631; National Materials and Minerals Policy, Research, and Development Act of 1980, P.L. 96-479). These require or authorize:

- Collecting, evaluating, and analyzing information concerning mineral occurrence, production, and use;
- Carrying out a policy of fostering and encouraging economic development of domestic minerals;
- Providing data on national defense industrial base capacity and expansion capabilities;
- Providing guidance to the minerals industry to ensure continuity of production; and
- Advising on acquisitions and disposals of mineral materials from the National Defense Stockpile.

SOURCE: John DeYoung, USGS, personal communication, 2002.

The MIT is based in Reston, Virginia, with the minerals and materials analysis section in Denver, Colorado. For fiscal year 2002 the annual budget of the MIT was $16.4 million out of a total MRP budget of $55.7 million (Figure 2.3). The MIT employs 180 staff, including mineral commodity and country specialists (metals, industrial minerals, and international minerals), minerals and materials analysts, and various support personnel who engage in data collection, publication, statistical analysis, and electronic data processing (John DeYoung, USGS, personal communication, 2002) (see Figure 4.1).

Data Collection and Coordination

The data collection and coordination section conducts approximately 140 domestic company surveys annually. The MIT collects information on approximately 132 commodities ranging from metals to industrial minerals to gemstones (see Appendix D). Data analysts, statisticians, and computer specialists in this section design and automate survey forms, validate and

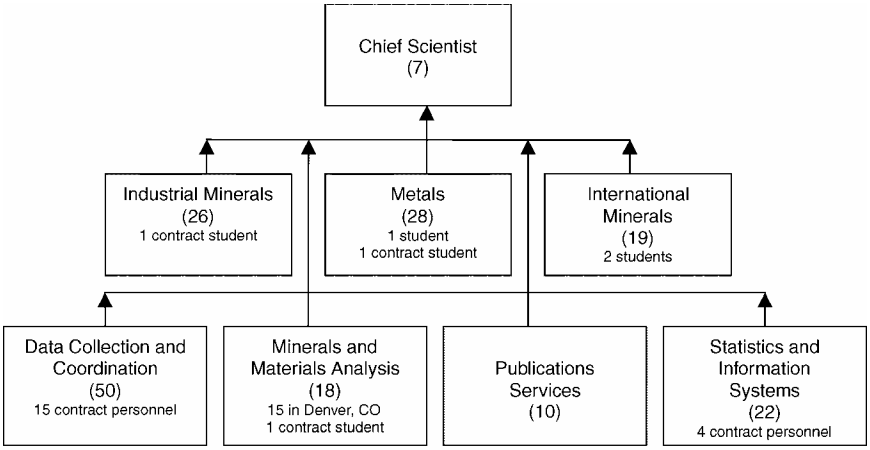

FIGURE 4.1 MIT organizational chart.
NOTE: Of the 180 employees, 22 are contract employees and 3 are student appointments. Staffing numbers are in parentheses and are as of August 26, 2002. These numbers include vacancies. Mineral commodity and country specialists are shown in this figure as industrial minerals, metals and international minerals specialists. SOURCE: Data supplied by the USGS.

enter data, produce statistical tables, archive survey data, and protect proprietary data (John DeYoung, USGS, personal communication, 2002).

The MIT's process of obtaining information today is much the same as it was under the former USBM, and its products are relied on by many of the same users. The surveys are sent to all known operations that produce, process, or consume the surveyed commodity. More than 36,000 forms are mailed annually to approximately 18,000 companies. The survey frequency is as follows:

Monthly	17,604
Quarterly	904
Semiannually	126
Annually	17,591

Company surveys are kept proprietary, which MIT personnel believe is an important factor in producing high response rates (John DeYoung, USGS, personal communication, 2002). The Office of Management and Budget requires that a survey achieve at least a 75 percent re-

turn rate to justify its continuation, although a lower response rate is allowed if the survey received represents at least 75 percent of the *volume* produced. In most cases, production information is aggregated to protect the proprietary nature of individual mining companies' production values. To maintain confidentiality if there are fewer than three companies producing a given commodity, the MIT does not provide data for that commodity.

The minerals archival and retrieval system captures incoming survey forms in both digital and microfilm media. Historical data that have been stored on 35- and 16-millimeter microfilm are being converted to digital images and managed using the Kofile visual information system. Conversion of current and historical data to digital media ensures their preservation for historical reference and retrieval. In addition, all digital data are backed up with an array of independent disks and on microfilms preserved by the National Archives.

Mineral Commodity and Country Specialists

Once minerals information and data have been obtained, they are compiled and analyzed by mineral commodity and country specialists. The mineral commodity specialists have a wide variety of academic training and relevant practical experience in the commodities for which they are responsible. They participate in industry-specific meetings and visit active operations periodically. Information from surveys is complemented by the specialists' various sources, including personal contacts. The specialists prepare chapters and reports for publication (see Table 4.1). Mineral commodity specialists are organized into two groups, Metals and Industrial Minerals. In each case a specialist is responsible for one or more commodities. Country specialists are responsible for data and analysis related to mining and minerals production in a country or set of countries in a particular region of the world. Like the mineral commodity specialists, they have a wide variety of educational and work backgrounds. Unlike the mineral commodity specialists, they are responsible for the entire range of mineral commodities produced in their countries. They are responsible for the accuracy of the data on minerals production, industry structure, international trade, and government policies affecting the minerals sector in their country or region. Country special-

TABLE 4.1 MIT Publications

Title	Periodicity	Quantity in Series	Total Published per Year
Minerals Yearbook			
Commodities	Annual	1	1
Countries	Annual	4	4
States	Annual	1	1
Mineral Industry Surveys			
Commodities	Annual	86	86
	Semiannual	2	4
	Quarterly	8	32
	Monthly	22	264
Directories	Annual	13	13
States	Annual	51	51
Countries	Annual	163	163
Metal Industry Indicators	Monthly	1	12
Stone, Sand, and Glass *(World Wide Web only)*	Monthly	1	12
Mineral Commodity Summaries	Annual	1	1 (91 chapters)
Minerals and Materials Information CD-ROM	Thirdly	1	3

SOURCE: Data supplied by the USGS.

ists often have knowledge of the languages of their countries. Not only do mineral commodity and country specialists have primary responsibility for the accuracy of the data on their industries and countries, they also, in effect, become the federal government's experts on their commodities and countries. They are consulted by professionals in other federal entities, including the Commerce Department, Congress, Federal Reserve Board, Treasury Department, and Environmental Protection Agency. Mineral commodity and country experts also respond to inquiries from state and local governments, private companies, students, and other individuals (Barsotti et al., 1998).

Publication Services

Once the reports are prepared, reviewed within the USGS, and approved for publication, the publications services section coordinates editing, proof reading, and timely publication of the various reports issued by the MIT. Publications are currently disseminated via electronic means (CD-ROM and World Wide Web). Dissemination in printed form by facsimile was terminated in March 2002 and by mail in January 2003. Of particular note are the number of downloads of MIT documents—some 1.8 million in 2002, compared to fewer than 100,000 as recently as 1996 (John DeYoung, USGS, personal communication, 2002).

MIT releases a number of periodic publications (Barsotti et al., 1998). The *Minerals Yearbook* is an annual report compiled and published in three volumes. These reports are generally published within nine months from when data gathering is completed. Volume I covers more than 90 mineral commodities and derivative industries worldwide, with special emphasis on domestic industries. Volume II is an area report on domestic production and industries by state. Volume III consists of international area reports of about 190 countries grouped into seven regions. Unlike Volumes I and II, the international reports also include data on the production of energy minerals. Because of the lag time between data acquisition and publication of the *Minerals Yearbook*, they are regarded as summaries of mineral industry events for that given year.

The *Mineral Industry Surveys* provide timely information about key domestic mineral and metals industries at the mine and processing levels of production. For many of these commodities, data on shipments, imports, and exports are also included. Depending on the commodity, *Mineral Industry Surveys* are published monthly, quarterly, semiannually, and annually. In general, *Mineral Industry Surveys* are completed and released to the public within 45 days from the time data gathering has been completed. Because of the relevancy of the data, these reports continue to be of paramount importance to the USGS minerals information mission.

Mineral Commodity Summaries is perhaps the most used annual report emanating from the USGS on mineral industry data. For each of more than 80 mineral commodities, earliest possible world production and resources statistics are combined with the most recent domestic supply, apparent consumption, and price information in a two-page synopsis. Similar data for the previous four years are also included. This report

generally comes out in February with the most current estimated data reflecting previous year-ending statistics. The *Mineral Commodity Summaries* has the widest distribution of all the USGS minerals information publications.

Metal Industry Indicators is a monthly publication examining the near-term economic health trends of the U.S. metals industry with the focus on primary aluminum, primary copper, and steel, by tracking the changes and trends in the business cycle and how those changes are related to the metals industry. These data complement the economic data—that is, production, shipments, consumption, and prices. Principal users of the *Metal Industry Indicators* are the federal government, financial institutions, and news organizations. Other users are mining companies, primary metal producers, manufacturers, and trade associations.

The MIT makes available, through the Government Printing Office, several CD-ROM products:

- *Minerals and Materials Information* is published three times a year and includes *Mineral Commodity Summaries*, *Mineral Yearbook*, and *Statistical Compendium* in Adobe Acrobat PDF and TextWare formats.
- *Indices to U.S. Bureau of Mines Mineral Resources Records*, which contains Minerals Availability System/Mineral Industry Location System (MAS/MILS) records.
- *Economic Analysis Tools for the Minerals Industry.*
- *Dictionary of Mining, Mineral, and Related Terms.*

In addition to the scheduled reports, mineral commodity and country specialists distill and combine minerals-related information from multiple sources in special studies and reports or papers on issues related to one or more specific mineral commodities or countries. Specialists author or coauthor mineral-commodity-related articles for industry and professional periodicals. USGS mineral statistics are also used and printed in many other annual publications, such as *The World Almanac* and the National Mining Association's *State Mining Annual—Mineral & Coal Statistics*. Approximately 740 minerals information publications, counting special reports, etc., are published annually by the MIT.

Statistics and Information Systems

MIT's statistics and information systems section collects, processes, and publishes mineral statistics through the following activities:

- Develop, disseminate, and update statistical standards for the MIT (e.g., survey forms, conversion factors, rounding, significant digits).
- Conduct and develop statistical methods for sampling surveys, estimation of nonresponse, forecasting, and data analysis methodology.

In addition, this section works to develop and implement management tools for evaluating programs with respect to timeliness and quality of MIT information products, and to provide factual information for management use to improve the accuracy and timeliness of mineral statistics (Mlynarski, 1997; Kenneth Mlynarski, USGS, personal communication, 2002). The section also prepares reports on the status of MIT's operations. A minerals information system timeliness report is issued monthly. The Office of Management and Budget requires that data collected under the Paperwork Reduction Act be made available to the public promptly. The MIT's goal is to do so within 45 working days. Statistical process control charts are issued semiannually to identify activities of the statistics and information systems section that require special attention to conform to publication timeliness targets.

The statistics and information systems section manages the design, modification, and printing of electronic survey forms. When necessary, new survey forms are designed or existing forms are modified in accordance with federal regulations and the requirements of program personnel. A survey forms catalog is prepared annually.

A major part of the section's responsibilities relates to the design and development of the automated minerals information system. This system assists in the management of U.S. import and export data, central mailing and respondent control, all data collected via surveys, and production of all statistical tables for inclusion in the MIT's various publications.

Survey response summary reports, issued quarterly, track the response rate of about 130 surveys to ensure that the 75 percent response rate required by the Office of Management and Budget is met (Mlynarski, 1997; Kenneth Mlynarski, USGS, personal communication, 2002). If this rate is not met, the section tracks whether the 75 percent goal for the key statistic reported, such as total production or total consumption, is met.

Minerals and Materials Analysis

The minerals and materials analysis section conducts research on material flows, sustainable development, industrial ecology, and other topics. Material flows are the subject of a concurrent NRC study assessing these needs for national material flows accounts (NRC, 2003). Some activity is also currently under way in the collection and maintenance of exploration statistics. The minerals and materials analysis section works primarily on self-generated projects, typically performed in collaboration with other parts of the USGS and other federal agencies. In some respects the minerals and materials analysis section represents MIT's attempt to maintain an analytical, as compared to data-collecting, capability.

Studies of material flows have been done on arsenic, cadmium, chromium, cobalt, manganese, mercury, salt, sulfur, tungsten, vanadium, and zinc. These studies entailed a description of the one-year tracking of the flow of these commodities from the time they were extracted, through processing, manufacturing, use, and their ultimate destination as a waste or reusable resource in the domestic economy. Losses at the extraction and various processing steps were identified and quantified where possible. Attempts were made to obtain a material balance in the flow for the given year. The reports from these studies of material flows provide a perspective on minerals as the basic raw materials of the economy, how society uses them, and what ultimately happens to them or their derived products. The information gained also provides insight on environmental and sustainability issues associated with these minerals (Barsotti et al., 1998).

PARTNERS AND USERS

The MIT considers its *partners* to be establishments and government agencies with which it works to collect domestic minerals data. The MIT estimates that more than 18,000 producer and consumer establishments voluntarily participate in data collection by completing some 40,000 canvass forms annually. In addition, the MIT has memoranda of understanding for data collection with 46 of the 50 states.

The MIT considers its *users* to be those entities that use MIT information and consult with the mineral commodity and country specialists. Use of the term "user" here is consistent with how the term is used in Sidebar

2.2 referring to the rest of the MRP. Much of the work of the MIT focuses on information relevant to mineral economics, and thus the group of entities using MIT information is somewhat different than the user group of MRP science and information. Representative users of MIT information and analysis include the following:

- Environmental Protection Agency (EPA), which considers MIT data and specialists the starting points for any analysis involving mining. The EPA consults the mineral commodity and country specialists in explaining and interpreting the data. Especially important for EPA analyses are historical data on minerals production. The EPA relies on the integrity of MIT information, which is almost never challenged (Steve Hoffman, EPA, personal communication, 2002).
- Department of Energy, which used MIT information to create its mineral profiles as part of its Mining Industry of the Future project.
- Federal Reserve Board, which uses MIT data as inputs to the indexes of industrial production index and capacity utilization.
- International Trade Commission, which makes extensive use of data on international trade in minerals and on minerals production outside the United States. The International Trade Commission would like to see greater emphasis placed on ensuring that MIT data conform to commonly used classification systems, such as the harmonized tariff schedule (Chris Mapes, International Trade Commission, personal communication, 2002).

Table 4.2 contains a more extensive list of users of MIT information and analyses.

DISCUSSION

The MIT produces high-quality data series on minerals production, consumption, and other market data. Country and mineral commodity specialists provide interpretations and analyses of these data. In addition, the MIT carries out a limited amount of analytical work transcending specific commodities and countries in areas such as recycling, industrial ecology, and material flows.

TABLE 4.2 List of Users of MIT Information and Analysis

Federal, State, and Local Governments
Department of Defense
Environmental Protection Agency
Mine Safety and Health Administration
Department of Energy
Department of State
Department of Justice
Department of Commerce (including Bureau of the Census and Bureau of Economic Analysis)
Federal Reserve Board
Office of the U.S. Trade Representative
Defense Intelligence Agency
Central Intelligence Agency
Congressional Budget Office
U.S. Customs Service
Department of the Interior
Department of Agriculture
Department of Treasury
50 States
Domestic Private Entities
Trade press (e.g., *American Metal Market*, *Metals Week*, *Engineering and Mining Journal*)
Trade associations (e.g., American Iron and Steel Institute, National Mining Association, National Stone Association)
Educational institutions, including universities
General public (including requests under the Freedom of Information Act)
International Organizations
World Bank
United Nations
Multilateral development banks
International commodity study groups (e.g., International Copper Study Group)

SOURCE: Data supplied by the USGS.

A variety of speakers from government agencies, many of them partner agencies of the USGS (e.g., the Federal Reserve Board and the International Trade Commission), spoke to this committee about the continuing value of the MIT's traditional functions and products. There was wide praise for the availability and usefulness of the statistical data generated by the MIT. These representatives indicated that the data are used in many arenas, ranging from foreign policy to international and domestic commerce. Several of the agency representatives stated that the advice and information provided informally by the mineral commodity and country specialists were just as valuable as the published data.

The committee concludes that the MIT has done a good job of making the transition from the Bureau of Mines to the USGS and, moreover, has performed very well in helping the USGS and its partner agencies meet their goals. This committee has recommendations in three areas aimed at enhancing the already important work of the MIT.

External Review

Many, if not most, of the data series collected by the MIT have been collected for many years by the USGS and previously by the Bureau of Mines without an ongoing and systematic review of the nature and overall scope of the data collected. In an era of declining real (inflation-adjusted) budgets for its activities, the MIT needs to consider carefully which data it collects and needs to assess whether there continues to be a national need for the data it collects. Furthermore, the team's core competencies of producing data and information products should be examined in light of the many data collection and survey needs in other parts of the USGS.

The committee recommends that the MIT establish a permanent advisory committee consisting of a wide range of users of MIT data and analysis to ensure that its activities are fully updated and of relevance to its users. The advisory committee would meet approximately once a year to review the nature and overall scope of MIT activities, including what data should and should not be collected. The membership of the advisory committee should be rotated so that it has an appropriate balance between new blood and historical memory at each meeting.

An additional benefit of an external advisory committee—beyond optimizing the scope of MIT activities—would be through the role it

could play in helping to explain the value of MIT information and analysis to Congress, the administration, and the public at large.

Information Analysis

The MIT is so active collecting data that qualified mineral commodity specialists, country experts, and researchers in the minerals and materials analysis section are hindered in contributing to basic research and in advising other federal entities on public policy matters. The MIT, as do all statistical agencies, always has to deal with the more purely statistical issues such as survey response rates, format of data delivery, and timeliness of data release. These functions need to be carried out optimally to increase time for research and advisory activities.

One of the important areas in which the MIT should have analytical activities is minerals availability—not just the purely physical (or geological) availability of mineral resources but also the economic and environmental dimensions. There is no foreseeable geological shortage of most minerals, at least on a worldwide basis. Rather, the important availability concerns center on the location-specific issues of costs of production, potential environmental damage associated with mining and mineral processing, and potential social disruptions sometimes caused by mining.

To the extent that resources are known and probably controlled by a mining company, information on location-specific issues will be available to the company. Current efforts by the mining industry and regulators may result in more of this information being made public. Cooperation between the USGS and mining professional societies will result in improved definitions and classifications of resources.

Material flows analyses, which attempt to quantify some of these availability issues, represent one important area for MIT analytical activity. Material flows studies require significant data on production, consumption, waste, recycling, and appropriate substitutes in order to provide an accurate balance calculation and public policy guidance. Another source of material flows inputs comes from the treatment of ground water (e.g., the new EPA arsenic standard) as well as treatment of "produced waters" from oil and gas wells and waste products from terrestrial desalination plants.

Detailed interaction between team members and research scientists could improve data collection and data products for the material flows

studies. Information provided by these material flows studies could be incorporated into the global mineral resource assessment (see Chapters 2 and 5) and could significantly enhance its value.

The committee concludes that the expertise and experience of the MIT mineral commodity specialists, country specialists, and researchers in the minerals and materials analysis section are important resources. **The committee recommends that the MIT's analytical activities and capabilities be strengthened so that mineral commodity specialists, country specialists, and other MIT researchers can conduct more material flows studies and work more directly with the mineral assessment and environmental scientists in their basic research.**

Integration

Relocation of the MIT within the MRP of the USGS provides an opportunity for collaboration with other parts of the MRP, which in turn could enable a beneficial broadening of the role of the MIT in satisfying national needs. The MIT is composed of individuals with a wide range of expertise whose primary focus is on past, present, and future minerals production. The databases are organized primarily on metal or mineral commodities. Classification by commodity is usually not compatible with resource identification and assessment of mineral resources used by MRP geologists, which is based on mineral deposit types. Estimating the probability of undiscovered resources existing in any specific region is based on a set of quantitative mineral deposits tonnage and grade models. This type of analysis may easily be transformed into predicted commodity abundances but not vice versa. Given that any interruption of supply due to unexpected political instability or terrorist activities could cause a significant rise in the prices of these commodities, conducting worldwide assessments of mineral resources is an important use of both deposit-type and commodity classifications of resources.

Communication and interaction between mineral deposits geologists within the MRP and the appropriate mineral commodity specialists within the MIT would broaden the horizons of both groups and create an understanding of strategic resources throughout the world that would provide the federal government with additional information necessary for sound public policy decisions. The MIT has considerable expertise in mineral economics and public policy. The geoscientists in the MRP have

considerable expertise in the scientific underpinnings of minerals potential and supply. The MIT needs to take better advantage of the geoscience expertise of the MRP in designing and carrying out MIT projects and should increase its contribution to the MRP's geoscience activities.

The committee concludes that the MRP produces and maintains a large volume and variety of minerals information, which is not easily used in the estimation of mineral resources. Having increased interaction and partnerships with MRP staff would be one way to leverage the expertise from each group and provide more easily analyzable data. **The committee recommends that the MIT work with the MRP resource assessment team to improve the classification and usefulness of its data.** This would be a particularly important contribution to the MRP's global mineral resource assessment project.

SUMMARY

The committee concludes that the MIT has done a good job of making the transition from the Bureau of Mines to the USGS and has performed very well in helping the USGS and its partner agencies meet their goals. This committee has three recommendations it believes will enhance the already important work of the MIT: (1) establish an advisory committee to ensure that MRP activities are fully updated and of relevance to its user base, (2) strengthen MIT's analytical activities and capabilities so that mineral commodity and country specialists and other MIT researchers can conduct more material flows studies and work more directly with the mineral assessment and environmental scientists in their basic research, and (3) work with the MRP resource assessment team to improve the classification and usefulness of domestic and global mineral resource assessment data.

5

Envisioning the Future Mineral Resources Program

FRAMEWORK FOR THE VISION AND MISSION

Mineral resources are important for all the nation's citizens and essential for those individuals, companies, and communities that depend on minerals production for income and broader economic development. Science and information on mineral resources, in turn, underpin private and public decisions that determine whether, under what conditions, and at what costs minerals become available to producers and consumers.

As discussed in Chapter 1, private markets are likely to yield suboptimal outcomes for scientific research and information collection and dissemination from the perspective of society as a whole—justifying four federal roles in minerals science and information. These roles are science and information, basic research, advisory, and international. In developing a vision and mission for the future around these four roles, the Mineral Resources Program (MRP) should consider the following five questions, the answers to which will frame (or define the scope of) the program's future. The MRP has already answered these questions to some degree. The committee suggests that in addressing changing national and global mineral issues, the MRP reevaluate its answers to these questions and thus the scope of its activities.

1. How should "mineral resources" be defined?

How narrowly or broadly mineral resources are defined affects the scope of MRP activities. Should the MRP focus narrowly on geological

science and information that foster the development of mines and metallic mineral resources in the United States? Such a focus would place considerable emphasis on fundamental ore deposit research, including mapping of known ore districts, to aid the exploration and discovery of domestic mineral deposits. Or should MRP activities be broader (as they are today) to include nonmetallic resources such as industrial minerals and construction aggregates?

On the other hand, the MRP might define its scope of activities around the entire life cycle of minerals, rather than focusing primarily on scientific understanding and discovery of mineral deposits. In other words, focus on science and information important for understanding and developing public policy for the broader context of minerals development. This life-cycle scope would include purely geological investigations and fundamental ore-deposit research, but it also would embrace multidisciplinary work (environmental, geochemical, geophysical, geobiological) and investigations into, for example, environmental aspects of minerals development, waste disposal, recycling of mineral-based materials, and material flows throughout the mine life cycle, including mine closure and environmental management in perpetuity.

Another view of MRP activities might take as a starting point the relationship between mineral resources and sustainable development. The MRP could define the scope of its activities around the economic and environmental dimensions of sustainable development—that is, activities facilitating both sustainable supplies of mineral resources over the longer term and appropriate environmental quality associated with their development. If the MRP frames its vision, mission, and strategy around "sustainable development," it would be essential that the MRP adopt a clear definition. When applied to mineral resources, sustainable development is often represented as the desire that mineral resources be developed and used in ways that appropriately protect the natural environment and that adequate attention be given to the potential social consequences of minerals development.

However the U.S. Geological Survey (USGS) decides to define resources, it should take into account recent reviews of these definitions made by the mining industry, regulators, and international equivalents of the USGS in Australia, South Africa, Canada, and other countries.

2. How should "information" be defined?

This second question also requires choosing how narrowly or broadly to define MRP activities. The MRP could limit itself to scientific information such as baseline geochemical sampling data. Or the program could continue to use a broader definition of information that would include minerals information such as minerals production, consumption, recycling, material flows, and the wealth of irreplaceable geological mapping, and geochemical and geophysical data that exist in mining districts. The broader definition might imply development and testing of methods and procedures to generate and evaluate recycling and material flows data and synthesis and archival management of multidimensional geospatial databases and digital maps.

3. What is the appropriate balance between research and service?

This third question, rather than focusing on how narrowly or broadly defined MRP activities should be, focuses on the balance between research and service or, to frame it another way, between basic and applied research. By applied research or service this committee means research that is directly responsive to the needs of government agencies for science, information, and advice.

Historically, the federal government has provided funding for long-term, high-risk research and technology development. In some cases this support is motivated by the need to solve a specific problem and is often referred to as applied research (National Research Council [NRC], 1995). In other cases the support is for pure science that creates new knowledge, which is referred to as basic research. Basic research usually is supported in the expectation that it ultimately will link in some currently undefined way to practical use. Whereas applied research usually is intended to address a specific problem, it can lead to a new fundamental inquiry as well. Most federally funded research is at once both basic and applied. In science supported by mission-oriented agencies, the belief that there is a sharp separation between basic and applied research is often wrong (NRC, 1995).

It is clear that the MRP currently conducts both basic and applied or service-oriented research. In redefining its mission and vision, the MRP might see its role as to conduct only basic or curiosity-driven research. At the other extreme, the MRP might decide to discontinue basic re-

search and instead respond to the needs of other government agencies. Any mission-related basic research needs could be conducted at universities through an external grants program.

4. How "international" should MRP be?

At one extreme, the MRP could consider itself the "minerals geoscientist" of the Department of the Interior and focus its activities on satisfying the needs of the department, including the Bureau of Land Management, Bureau of Indian Affairs, and National Park Service. A broader focus would be domestic—satisfying the needs of domestic users of mineral resources science and information, including other agencies of the federal government (e.g., U.S. Forest Service, Environmental Protection Agency), state governments, and private companies operating domestically. A slightly broader focus, still, would include a modest level of support on request for the Departments of State, Commerce, and Defense and the Central Intelligence Agency.

The most expansive MRP vision would be fully international. It would include the Department of the Interior and other domestic users of MRP science and information but would also embrace international activities that are in the national interest. As discussed in Chapter 1, some of these activities are narrowly or directly in the national interest, and others are in the national interest in a less direct sense. Four international roles for the USGS, all of which are applicable to the MRP, were identified in NRC (2001):

- Improve the utility or effectiveness of USGS's domestic mission (e.g., international studies of ore deposit or geoenvironmental models for ore types found in the United States).
- Contribute to the U.S. national security and foreign policy interests (e.g., technical assistance on mineral resources in developing countries, Minerals Information Team [MIT] information on mineral supplies in politically unstable parts of the world).
- Address global environmental issues (e.g., global geoenvironmental databases).
- Further private-sector aspirations in the global economy (e.g., global databases on mineral resources).

5. Who are the appropriate users and partners?

The MRP currently has a broad base of users (Chapter 2) ranging from federal and state agencies, industry, academic researchers, and the public. Cooperating with and listening to users will continue to be important to the MRP as a method of identifying the most important national issues to attack and as an opportunity to diversify the staff and increase budgets. Balancing service to other bureaus within the Department of the Interior and service to other users is and will continue to be a challenge to strategic planning in the MRP. Another recent NRC report highlighted opportunities for the USGS to improve interactions with partners (NRC, 2001), all of which are directly relevant to the MRP. These include:

- strengthen liaison and coordination with related federal agencies (e.g., National Aeronautics and Space Administration, National Oceanographic and Atmospheric Administration, the National Weather Service, Environmental Protection Agency, Department of Energy, and National Science Foundation);
- maintain and improve relations with state and regional government organizations and with nongovernmental organizations that are users of natural science information;
- facilitate the use of natural science information by the general public and by stakeholders for critical issues;
- increase interactions with the private sector, foreign customers, and partners;
- encourage USGS scientists to publish their research results promptly in journals, present papers at conferences, and convene workshops and seminars; and
- nurture student interest in the natural sciences.

The committee cannot overemphasize the importance of collaborating with the MRP's users. However, the committee cautions the MRP, as did the 1996 committee, on what is meant by collaboration. One might consider collaboration or partnering to be teamwork within the USGS on projects. However, the committee believes that partnering or collaboration is more than this. Collaboration between the MRP and users and even within MRP teams begins with project definition and concludes with project evaluation.

Committee's View on Summary of the Five Questions

The committee believes a broad definition of mineral resources is required by the underlying economic realities of mineral resources development and use in the United States. The committee also thinks that the MRP should consider focusing its activities around the life cycle of minerals and sustainable development and continue to expand its activities to address environmental concerns.

The committee also believes that the MRP should develop and adopt a broad definition of information that embraces both the scientific and MIT elements of mineral resources information. This definition of information is necessary to fully support the life-cycle definition of mineral resources. As noted in Chapter 4, there are unexploited opportunities for MIT information to inform the scientific work of the rest of the MRP, and vice versa.

The committee believes that the MRP should continue to have a mix of basic and applied research. The committee encourages the MRP to have a stronger international role but not at the expense of its domestic responsibilities. As stated in the MRP five-year plan, the committee suggests that the MRP expand its current partners and users both internationally and domestically. The committee encourages increased collaboration with a wide variety of users.

The committee recommends that the MRP develop an expanded vision that embraces a broad definition of mineral resources, including a focus on life-cycle and sustainable development; a strong international role, which will expand the current users; and a balance between basic and applied research, recognizing that many of the program priorities are oriented toward more applied research. An expanded vision will most likely require the USGS to reevaluate its core competence—building new core competence in selected new disciplines.

PROGRAMMATIC AREAS

As the nation's needs for minerals science and information evolve, the MRP must evolve to meet those needs. The committee has identified several examples of new topics that are regional, national, and international in scope and that coincide with an expanded vision for the program. The committee has not prioritized these topics. The committee

believes that it is imperative that the program address the many challenges identified in this report before expanding into new domains. **The committee recommends that the MRP develop and expand its vision and program objectives to incorporate components of the existing program and elements of the new programmatic areas.** Other government agencies may already be doing some work in these areas. The MRP should determine what ongoing activities exist in these areas and initiate its work in a collaborative manner. Potential administrative challenges associated with transitioning toward a more expansive role for the program are also discussed.

Environmental Stewardship

There is a growing need for information that will aid users in (a) predicting and minimizing environmental problems with new mines and (b) closing many existing mines in their terminal phase of production or initiation of long-term environmental management. With the current decline in domestic exploration and mine closure becoming more commonplace (NRC, 1999, 2002a), the MRP has an opportunity to expand this user base by providing data relevant to the spectrum of environmental issues facing the mining industry and the surrounding urban areas.

A shift by the MRP toward environmental stewardship is justifiable on several accounts. First, there is a need for such an activity as described above. Second, and most importantly, the MRP is a logical organization to conduct this activity because it already focuses on economy and public policy, whereby information on land stewardship, and material flows and other vital information are provided to government policy makers for responsible management of public lands. The MRP also possesses a vast array of tools and technologies (e.g., modeling, data integration, sophisticated analytical capabilities, and partnering experience with other agencies and organizations) that can support an environmental stewardship initiative.

Especially important is the development of creative and new postmine land-use alternatives that are mutually beneficial and cost effective. The MRP could play an important role in developing postmine closure land-use alternatives by integrating geographical information system (GIS) based information from mines and urban planners. Research on postmining use of these lands is needed to identify productive uses for

these excavations, including (depending on site characteristics) use as wildlife management areas, reservoirs, industrial sites, or municipal waste repositories. Because a major issue with in-pit disposal of solid wastes is the potential for impacts to ground water, MRP involvement in such land-use evaluations and planning would need to be coordinated with experts from the Water Resources Division. Regulatory and liability issues are also involved with in-pit solid waste disposal and necessitate close collaboration with relevant land owners or land management agencies; federal, state, and local regulatory authorities; and mining companies. Other examples of research areas for postmine closure of open-pit mines are additional studies on the evolution of pit lakes, biological processes that control contaminant release, and management of waste rock dumps. The MRP is currently involved in projects in some of these research areas.

While many examples of these environmental issues exist within the United States, they are also common to mining sites around the world, and pertinent environmental research will have international applicability. Where appropriate for basic science or policy demands, the MRP can and should be involved with specific sites outside the United States.

Data Integration and Data Mining

For over 150 years the United States has reaped enormous benefits from exploitation of its rich endowment of mineral deposits. The industrial development of the nation and its transcontinental infrastructure were partly financed by the profits from mining activity. During this period the USGS played a key role in surveying, mapping, and describing ore deposits. Geologists in many mining companies systematically mapped mine exposures and compiled maps and cross sections used in development and in formulating ore deposit genesis models that further advanced exploration and laid the scientific foundation necessary to integrate ore deposits into crustal genesis and plate tectonic theory. The scientific records of this monumental human effort are a national treasure for both scientific and historical reasons, but today with many large, long-lived, and famous mines closing with increasing frequency, these important geological and mining records are being lost. As noted by the NRC (2002b), geoscience collections and data are the foundation of basic and applied research and education and underpin industry programs

to discover and develop domestic natural resources to fulfill the nation's energy and mineral requirements. The geoscience community has amassed an enormous wealth of collections and data, most of which remain potentially useful and would be costly to replace, and much of which cannot be replaced once mines close.

There is at present no effective government plan for preventing this loss of data (NRC, 2002b, 2002c). Disappearance of the detailed district mapping records (NRC, 2002c) and three-dimensional geochemical data is a national scientific tragedy, particularly with regard to the potential scientific benefits of using those data in crustal-scale interpretations of regional controls on ore deposition and environmental management during mine closure.

The technical means are now available to capture and store the enormous volume of irreplaceable mining district data in three-dimensional GIS databases. Information in currently available paper records (maps, cross sections, and chemical data) that are vulnerable to permanent loss could be saved for this and future generations. Only when this wealth of data is in digital format can it be preserved, synthesized, and integrated with the national geophysical database.

A new opportunity exists for the MRP to capture and "mine" these data for archival and, more importantly, scientific purposes. The proposed MRP role would include archiving and digitizing mine geological records, and construction of a comprehensive three-dimensional digital GIS archive of all geological mapping done during the history of each deposit, including plans and cross sections. Assays as well as representative rock and core samples should be archived and located within the three-dimensional digital GIS archive, preserving data and samples that are unique in space and time after mining has consumed the zone of mineralization. The MRP now has an outstanding opportunity to expand its production of timely and useful data sets by assuming a national leadership role in data mining and by creating the first national three-dimensional mining district database to support broad crustal interpretation in important regions.

Understanding the geological setting and genesis of the nation's mineral resources in a global context remains a key scientific goal and operational objective of the MRP. Why many ore deposits occur where they do is still a major scientific question, so geological context remains as a frontier and vital area of applied multidisciplinary research. Similarly, what collective processes underlie the formation of giant ore de-

posits is still speculative. Ironically, the greatest density of three-dimensional geochemical and structural data on Earth is in mines, yet how these data relate to the surrounding geological environment is less clear. The United States has approached a crossroads that will determine if the crustal geological context of mineral resources will finally be illuminated by digitizing and incorporating mine data into the national mapping data base. Such "data mining" is more than plotting deposit size and grade of ore deposits in relation to crustal geological features, but rather the incorporation of all aspects of ore deposits (parent intrusives, sedimentary basins, vein and fault patterns, wall rock alteration, and exposure history) into detailed technical context of the surrounding geological host.

This archive has a wealth of scientific benefits besides its archival benefit. Important new scientific developments will emerge from small- and large-scale reinterpretation of the data when visualized as never before using modern information technology and three-dimensional GIS capabilities. The mining database can be overlain with airborne magnetics, gamma-ray and ground gravity data into regional crustal geophysical interpretations so that regional and temporal controls on ore deposition such as deep-seated faults could be discovered that may have guided the emplacement of plutonic rocks, hydrothermal fluid migration, and formation of ore deposits (Hildenbrand et al., 2000). This database would be unprecedented in the world and could help stimulate a renewed level of research activity within the MRP, in collaboration with other USGS divisions (Mapping, Geologic, and Water Resources), and it would help build a cooperative bridge between the mining industry, academia, state surveys, and the environmental consulting industry.

Regional and Global Views: Predicting Resources for the Future

The committee endorses the MRP focus on regional- and global-scale studies that underpin key needs of the U.S. government to establish knowledge of the worldwide supply of mineral commodities needed to sustain its economy. Further, such studies will provide an understanding of the sources and pathways of possible contaminants and assist local and federal agencies to assess possible risks related to past and present mining activities. USGS researchers should provide leadership in these programs, but to ensure the most efficient data delivery they should col-

laborate with all classes of users (other federal, state, university, and private-sector users, including international experts). This collaboration would help the MRP to achieve its objectives and thereby gain significant scientific and financial leverage.

Projects should be developed on a regional or district scale; these are commonly known as "regional metallogenic studies" and are aimed at developing an understanding of the critical geological factors that explain the presence of ore deposit types in geologically defined areas. These factors underpin successful assessments of resource potential and provide industry with key guides for exploration. The USGS already is doing several such studies; the "Tintina metallogenic province integrated studies" embody the type of work that might be done. This research is directed at understanding the reasons why world-class gold deposits are present in the Tintina area and, on the basis of its findings, what the potential might be for a similar resource elsewhere in the world. This project involves scientists from universities, state surveys, and several Canadian government agencies. Similar types of regionally based projects should be developed both nationally and internationally, with USGS scientists providing project leadership. In some cases, districts outside of the United States may have the best deposits for study.

Projects selected for the MRP team should focus on those that provide information that is needed for setting government policies and for supporting land management work in other agencies. They should address the life cycle of mining within a district and include information of potential environmental problems, with suggestions for ameliorating these. The information developed from life-cycle analyses can be used to underpin the evolving exploration strategies of U.S. and other corporations as they increasingly adopt sustainable mining models. It will also help to ensure a sustainable supply of mineral commodities.

Methods and Technology Development

A justifiable new role for the MRP is the development of innovative minerals technology and information that would support the advancement and growth of the U.S. minerals industry in a global economy. With the demise of the Bureau of Mines in 1995, mission-driven research related to methods and technology development for the minerals industry was ended. Although several other federal agencies (e.g., the Department

of Energy) do fund some minerals-related technology research, there is no mission-driven federal program that has replaced this important and much-needed activity once carried out by the Bureau of Mines. The MRP, with its highly experienced scientific staff and well-equipped research and analytical laboratories, is poised to participate in and support leading-edge minerals-based technology development. The MRP is attuned to the technological needs of the industry because its personnel are familiar with the tools and techniques of minerals exploration. The MRP already examines mineral resources availability for the future and thus has a unique perspective on the types of technology needed to assess and process these resources. The objective would be to bridge the gap between purely basic academic and purely applied industry research by conducting projects that focus on the development and application of novel approaches to solving minerals- and mining-based problems that are not typically within the capabilities or scope of industrial research and development departments. This research could include such areas as exploration technology, mineral processing, analytical methods, and biotechnology. It could also include areas related to understanding the colloid chemical and surface chemical behavior of mineral systems. The committee recognizes that expanding into these areas would necessitate staffing considerations, which are discussed below.

This research would, in many cases, require close collaboration among MRP, academic, industry, and other federal and state government agency scientists. Through these collaborative research projects there will be opportunities for new discovery and innovation, which will ensure a healthy U.S. minerals industry capable of meeting the growing public demand for minerals and mineral-based products.

When this research is done by private industry, the information typically is restricted and not freely available to all. A benefit of the MRP performing this research is that the results would be available to any interested party. Examples of countries that provide government-funded strategic research and development for the mining industry are Australia, Brazil, France, and Canada. These federally funded government agency and industry partnerships contribute to increased productivity by assisting minerals producers to improve existing operations and develop new technologies. The Department of Energy's Office of Industrial Technologies mining program, which is currently engaged in industry-driven mining technology development, serves as an excellent model for a new MRP role in national minerals research (NRC, 2002a). The program's mission is to re-

duce U.S. energy consumption and is therefore relatively narrowly focused on mining activities that consume energy. The two research areas the program has targeted are minerals processing and exploration and mining technology development. Critical areas not included in the program's scope are environmental protection, health, safety, remediation, and reclamation. Consequently, there is a potential role for a federally funded program that could assist the U.S. mining industry in these critical areas, and the technical expertise and experience of the MRP could be applied to problems of environmental protection and through its abandoned mine land experience to some aspects of remediation. If the MRP were to assume this role it would be important to avoid overlap with the current program and to look for opportunities to work with industry and other interested parties.

Supporting Sustainable Land-Use Planning

Over the past decade there has been growing interest in sustainable development, which has forced society to choose between competing land-uses including agriculture, mining, forestry, recreation, industrial development, residential development, and conservation. As the population grows, these choices will become increasingly important and will require an expanding knowledge base to ensure intelligent land-use decisions. Making these choices is difficult and requires not only high-quality data but also expertise and leadership from many different scientific disciplines, including geology, biology, wildlife management, forestry, and hydrogeology. Local governments and citizens must also participate in deciding how to use the land in a sustainable way. These decisions must be based on good science, including comprehensive, balanced, and integrated evaluation of all land resources (e.g., minerals, timber, water).

One of the MRP science goals is to understand the geologic setting and genesis of the nation's mineral resources in a global context, in order to ensure a sustainable supply of minerals for the nation's future (see Sidebar 2.1). The committee believes that the MRP should play a major role in sustainable land-use planning by providing scientific and technical leadership in the evaluation of national mineral resources with the objective of facilitating improved land management decisions. The MRP should explore new state and local partnerships where appropriate. Significant con-

tributions could be made by collecting data, coordinating data and information, providing minerals expertise where needed, and publishing regional minerals assessment reports that inventory known and potential mineral resources in an area. These reports should also include minerals value, their local economic impact (jobs, tax revenues, etc.) and potential environmental impacts associated with their extraction.

IMPLEMENTATION

The committee examined several aspects of potential program evolution, including changes in the mission and vision statements, changes in the breadth of the program, and new programmatic areas that the MRP could undertake. As noted in Chapter 3, the committee believes that planning, goal setting, and outcomes measurement are important and have not been adequately addressed by the MRP. *The committee concludes that to implement new programmatic areas within the existing MRP, mechanisms for prioritization and planning, project selection, review, performance assessment, and determining value to the nation need to be established.* A simple and transparent planning process that results in fully documented program and project plans is essential. These plans should be easily understood by other federal agencies, Congress, and MRP staff.

Program and Project Planning

The first step in the implementation is to ensure that the mission statement of the MRP is consistent with the mission of the USGS. The next step is the development of a new vision statement for MRP that encompasses portions of the existing program that would continue and incorporates the thrust of newly defined program areas. The vision statement and accompanying statement of mission are the foundation of a better planning and communications strategy that must underpin the MRP program. A sound foundation is essential if the MRP is to successfully convince Congress, Office of Management and Budget (OMB), and users of the value of its work and lead to increased support for critical activities.

General recommendation 4, set forth by the committee reviewing the MRSP plan (NRC, 1996) centered on planning, prioritizing, and per-

formance (see Chapter 3). The present committee, in Chapter 3, **recommended that the MRP implement a management review of proposals to align the work with strategic objectives, a rigorous external review process, and an internal review process that cuts across organizational units.** It is imperative that the MRP implement this recommendation as the program evolves. Program and project development should involve formal input from a spectrum of stakeholders and participants that would increase in number and diversity with adoption of the broadened programmatic areas discussed earlier. Mechanisms for input into the planning process might involve:

- Formal meetings with representatives of state geological surveys to receive suggestions for regional MRP projects and to develop better mechanisms for collaboration and joint program delivery;
- Annual meetings with major long-standing collaborators (e.g., Bureau of Land Management, U.S. Forest Service, Bureau of Indian Affairs) to discuss new proposals and review progress of ongoing projects;
- An annual forum with universities, especially those with interdisciplinary National Science Foundation-funded Integrative Graduate Education Research and Traineeship programs that are relevant, to outline new program directions and solicit participation in new projects;
- Organized meetings with the World Bank and foreign banks; and
- Forums involving mineral resources organizations from other countries and the mining and environmental industries.

Two products should emanate from the program and project planning process: (1) a predefined set of program objectives to facilitate the later evaluation of program and project accountability and efficacy and to enhance the ability of users, OMB, and Congress to see the high value of these activities and (2) a project proposal plan that uses a clear set of issues-based criteria and embedded performance objectives that assist the MRP in structuring projects for maximum effectiveness. Project proposals, submitted by MRP staff or outside participants, must be subjected to external review to ensure that they meet program objectives and other criteria set forth in the program and project plans.

Adoption of an expanded set of programmatic areas may lead to new collaborations. Advantages to this are widespread input into program and project development and an increasing potential for reimbursable research. Reimbursable work could enhance MRP activities, expand the

workforce, and keep the MRP in close contact with its users. However, if too much reimbursable research is undertaken, there is the potential to distort program priorities and lead to problems of conflict of interest (NRC, 2001).

The MRP might consider an external grants program involving academic, industry, and government scientists to perform research. Scientists in these organizations would be responsible for proposing projects consistent with the mission, vision, program plans, and project criteria of the MRP. The principal advantages of an external grants program are new opportunities for broad-based collaboration, which would leverage expertise across a broad spectrum of researchers, and increased communication with the external research community that would contribute to improved program and project planning. The main disadvantages are possible quality control and quality assurance issues that could undermine data quality and integrity, potential loss of timeliness in project completion, and possible distortion of the MRP mission.

Assessing Program and Project Outcomes

The committee agrees with the opinion expressed in USGS planning documents that periodic program reviews are important to understand performance and to evaluate program goals and objects (USGS, 2002e) (see detailed discussion in Chapter 3). Reviews of program efficacy are generally most credible if undertaken by external organizations. Other geological surveys, such as the British Geological Survey and the Geological Survey of Canada, have used this form of assessment very successfully.

The committee believes that external project review and assessment are also important. One aspect of this is external peer review of proposed new and ongoing projects to ensure that the highest-quality science is being done. Another aspect is a review of the "value for money" of some completed projects. This type of cost-benefit analysis is valuable in demonstrating to OMB, Congress, users, and the general public that the projects are relevant, cost effective, and of significant social and economic value. Some projects point to "cost avoidance" (e.g., identify geological hazards that if avoided would reduce the cost to society). Project results, value for money, and cost avoidance findings should be widely communicated to the public.

Staffing

The reputations of the USGS and the MRP rest, in large part, on the expertise of the highly regarded, scientific staff (NRC, 1996). An essential part of maintaining and developing this professional expertise is attracting and retaining talented scientists with recognized expertise central to the MRP vision, mission, and program objectives. As the MRP evolves to meet the nation's changing needs for minerals science and information, so must its workforce. High-quality personnel are essential for developing high-quality minerals science and information; therefore, the committee urges the MRP to devote substantial efforts to recruiting and retaining excellent staff. This initiative should be undertaken as part of the program's five-year plan and should take into account the new areas of expertise that will be necessary in the future.

The committee is aware that it has been difficult for many years to hire new staff because of severe budget constraints, and, as noted in Chapter 2, the committee is concerned about the apparent decline in the size of the workforce since 1996. If the size of the workforce remains the same as it is today or continues to decrease, the modes by which the MRP employs people in the future will have to be increasingly flexible. The program should look at methods other than hiring to gain required expertise. One such method is to exchange employees with other government agencies or universities through the Intergovernmental Personnel Act. Another method to gain needed expertise is to implement an external grants program (NRC, 1996), which would allow the program to buy the talents of university, government, and industry researchers. The committee realizes that it will be difficult to implement an external grants program without new funding.

Funding

Base funding for the MRP decreased between 1990 and 1996 (Figure 3.3). In 1997 the budget increased by approximately $16 million, which was for the newly transferred MIT. Since 1997 both base funding and MIT funding have remained rather constant in nominal dollars. However, even given low inflation rates over this period, the diminished buying power results in a decrease in the ability of the program to meet its vision, mission, and program objectives. This will become even more of an

issue in the future as the program's responsibilities evolve. The program may have to consider reallocating funds within the current budget. However, the committee believes that as the program's responsibilities increase, its budget should be increased to a level commensurate with the tasks. With an appropriate level of funding for research related to national needs, MRP will be better able to fulfill its mission, vision, and objectives.

SUMMARY

In summary the committee believes the MRP should adopt a broad definition of mineral resources—one that incorporates activities on the life cycle of minerals and sustainable development. To support the life-cycle definition of mineral resources, the committee encourages the MRP to develop and embrace a broad definition of information to include both scientific and MIT-type information. The committee endorses a stronger international role for the MRP but not at the expense of its domestic responsibilities and encourages increased collaborative opportunities commensurate with its expanded roles.

The committee strongly encourages the MRP to consider broader programmatic elements, namely (1) environmental stewardship with special emphasis on developing postmine land-use alternatives integrating GIS-based information from mines and urban planners and addressing unique environmental issues associated with mine closures, (2) data integration and data mining that accentuate the capture and storage of irreplaceable mining district data and the use of such archived data for creating the first national three-dimensional database in support of crustal interpretation, (3) an expanded regional and global perspective focusing on life-cycle studies of mining districts for developing and applying sustainable mining models for global application; (4) methods and technology development in minerals technology to support the U.S. minerals industry in a global economy, and; (5) sustainable land use planning centering on scientific and technical leadership for evaluating national mineral resources for improved land management decisions.

The committee recommends that the MRP develop and expand its vision and program objectives to incorporate components of the existing program and elements of the new programmatic areas. To implement new programmatic areas, the committee recommends that the MRP de-

velop specific program and project planning processes that include external reviews, ensure that projects fit with the USGS and MRP missions, and specifically respond to priority issues defined by Congress. The committee urges the MRP to devote substantial efforts to recruiting and retaining staff for new program areas and also to look to interagency and university employee exchanges and an external grants program to gain the necessary expertise. As the MRP's responsibilities increase, the budget should be commensurate with the assumed tasks.

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APPENDIXES

A

Mineral Resources and Society: A Review of the U.S. Geological Survey's Mineral Resource Surveys Program Plan

EXECUTIVE SUMMARY

In 1994, Congress directed the U.S. Geological Survey (USGS) to develop a program plan for its mineral resource activities. The resulting five-year Mineral Resource Surveys Program (MRSP) Plan (herein referred to as the Plan) represents a significant departure from the past, and its implementation is resulting in significant changes in the direction of USGS mineral resource activities. For example, the Plan highlights the greater emphasis to be placed on mineral-environmental assessments that provide predictions of the environmental consequences of mineral development as one consideration for land-use planning. It also calls for greater emphasis on research supporting mitigation of environmental impacts related to extraction and use of mineral resources.

The USGS requested that the National Research Council (NRC) conduct a study to (1) evaluate the MRSP Plan, and (2) provide recommendations as to how the Plan could be modified to improve its effectiveness in meeting the long-term needs of the nation. To conduct a review of the Plan, the NRC convened a panel that has expertise in mitigation of environmental impacts related to extraction and use of mineral resources, as well as in genesis, assessment, exploration, and development of mineral resources.

The MRSP Plan is a logical and necessary continuation of objectives and programs related to mineral resource studies that began with the establishment of the USGS in 1879. 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 research on the environmental consequences of mineral development because the nation's need for minerals must be balanced with environmentally sound methods for extraction.

There are important national needs for mineral resource information that should be provided by the USGS. Moreover, the panel strongly endorses the scientific values of continued mineral resource research. The panel's confidence in the overall value of the MRSP reflects past mineral resource program successes, the conviction that important resource problems of national relevance will have to be addressed in the future, and the uniqueness of the USGS in terms of technical capability, scope, national jurisdiction, international cooperation, and credibility.

The MRSP Plan describes important objectives and means to accomplish them. Among these objectives, the growing emphasis on research on the geochemical behavior of mineral deposits and the environmental implications of their development are properly emphasized.

The success of the MRSP Plan will be best measured against clear statements of vision, mission, and objectives. Although implied in the Plan, these planning elements are not clearly stated. The external environment within which the MRSP operates has changed more rapidly and extensively than the program itself. This requires that the MRSP reexamine how it operates, why, and for whom. The MRSP plan was formulated during a period of major organizational changes in the USGS, and these changes should be reflected in the planning elements.

The panel identified four general recommendations to improve and help direct future work. In addition, the panel presents a number of detailed recommendations regarding the four subprograms of the MRSP: assessments, mitigations studies, resource investigations, and information and technology transfer. The four general recommendations are:

General Recommendation 1: The Plan should be modified to include new, clearly articulated statements of vision, mission, and objectives.

General Recommendation 2: To fulfill its mission, the MRSP and its Plan should move away from an organizational culture dominated by self-direction and independent research toward one that also embraces projects developed through collaboration with users.

General Recommendation 3: The MRSP should place more emphasis on maintaining and continuing to develop its core competence in mineral deposit research and minerals-related environmental research in order to anticipate and respond to future national needs for mineral resource information.

General Recommendation 4: The MRSP and its Plan should place greater emphasis on improving mechanisms and procedures for comprehensive planning, setting priorities, and evaluating and enhancing performance, particularly through external reviews or advisory panels. The level of funding for MRSP and the balance of funding among its subprograms deserves thorough review by the MRSP staff, users, and collaborative agencies and organizations.

The General Recommendations are supplemented by more than twenty specific findings and recommendations about the Plan and the four subprograms that comprise the MRSP. The following issues emerge as significant themes among the specific findings and recommendations: the Plan does not give adequate consideration to the continuing national need for mineral resource supply as a rationale for all aspects of the MRSP; the panel perceives an imbalance between the level of effort placed on quantitative assessment of undiscovered mineral deposits versus the level of effort placed on detailed mapping and data collection; the panel finds that basic research on geochemical and geological processes related to ore formation is a prerequisite for credible mineral resource estimates and environmental assessments; the panel recommends substantive changes in the Mitigation Studies Subprogram.

SPECIFIC RECOMMENDATIONS

Specific Recommendation A: The MRSP should incorporate data and invite expertise from outside the USGS, to the greatest extent practical and constructive, particularly from industry, academia, and state agencies.

Specific Recommendation B: The MRSP should rigorously document the specific contributions and impacts of past resource assessments related to land-management decisions. The panel strongly recommends

that the MRSP publish a single document, written for the lay audience, which documents, explains, and discusses the usefulness of mineral resource assessments and their applications in land management.

Specific Recommendation C: Mineral resource assessments should be performed more efficiently, and the cost-savings should be directed to more fundamental investigations in other subprograms of the MRSP.

Specific Recommendation D: Merge two components of the Mitigation Studies Subprogram, namely, (1) Studies in Support of Remediation, and (2) Environmental Behavior of Mineral Deposits, into the Resource Investigations Subprogram.

Specific Recommendation E: Elevate the Geochemical Backgrounds and Baselines component to subprogram status. Emphasize such elements as Discrimination Between Natural and Mining-Related Geochemical Distributions, to reflect the growing national and international importance of this activity.

Specific Recommendation F: Increase collaboration with WRD staff to address such issues as chemical releases from mineral deposits, acid drainage prediction, and metal leaching.

Specific Recommendation G: Discontinue activities directed at the adaptation and improvement of remedial technologies, a part of the Studies in Support of Remediation component.

Specific Recommendation H: Use a multi-disciplinary approach to determining geochemical backgrounds and baselines by collaborating with other scientists such as microbiologists, soil scientists, aqueous geochemists, sedimentologists, hydrologists, and aquatic biologists.

Specific Recommendation I: Merge two components of the Mitigation Studies Subprogram, namely, (1) Studies in Support of Remediation, and (2) Environmental Behavior of Mineral Deposits, into the Resource Investigations Subprogram.

Specific Recommendation J: Revitalize the core competence to conduct basic and applied research on mineral deposits under the Resource Inves-

tigations Subprogram, which provides essential information for other MRSP subprograms and numerous users.

Specific Recommendation K: Continue basic research conducted under two components in the Resource Investigations Subprogram—Mineral-Resource Frontiers and Mineral-Deposit Studies—such as low-temperature chemistry of water-rock interaction, timing of ore-forming processes, origin of giant ore deposits, and ore deposit evolution as related to continental reconstruction.

Specific Recommendation L: Evaluate the feasibility of replacing the Cooperative Industry and International Investigations element with a CRADA system, whereby industrial and foreign government users would provide funding toward needed MRSP research.

Specific Recommendation M: The MRSP should be empowered, within budgetary limitations, to conduct selective mineral-deposits research in foreign terranes.

Specific Recommendation N: The Plan should place greater emphasis on internal consistency and standardization in all aspects of databases and technology transfer.

Specific Recommendation O: The Plan should be modified to include activities recently transferred from the U.S. Bureau of Mines (USBM) to the USGS.

Specific Recommendation P: The Plan should not take on the task of software development for GIS technology but assign that responsibility to other departments in the USGS or obtain products from private vendors.

B

Biographical Sketches of Committee Members

CORALE L. BRIERLEY, *Chair*, is a consultant with Brierley Consultancy LLC, which provides technical and business consultation to the mining and chemical industries and government agencies. Her research interests include the application of biotechnology to mine production and site remediation. Previously, Dr. Brierley worked as a chemical microbiologist at the New Mexico Institute of Mining and Technology, as chief of environmental process development for Newmont Mining Corporation, as general partner at Vistatech Partnership Ltd., and as the president of Advanced Mineral Technologies. She is a member of the Division Review Committee for the Risk Reduction and Environmental Stewardship Division at Los Alamos National Laboratory and is also a member of the International Biohydrometallurgy Symposia and the Editorial Board for *Hydrometallurgy*. Dr. Brierley was elected to the National Academy of Engineering in 1999 and has served on several National Research Council committees, including the Committee on Technology for the Mining Industries and the Committee on Earth Resources. She is a member of the Society of Mining Engineers of American Institute of Mining, Metallurgical, and Petroleum Engineers and the Mining and Metallurgical Society of America. Dr. Brierley holds a Ph.D. in environmental sciences from the University of Texas at Dallas and an M.S. in chemistry from the New Mexico Institute of Mining and Technology, Socorro.

GEORGE H. BRIMHALL is a professor of geology in the Department of Earth and Planetary Sciences at the University of California, Berkeley, where he has taught and conducted research for nearly 25 years. Previously he taught in the Department of Earth and Planetary Sciences at Johns Hopkins University and worked as a project and underground mine geologist for the Anaconda Company. Dr. Brimhall's research interests include digital field mapping, mining and exploration geology, ore deposit geology and geochemistry, and mineral resources issues. He currently serves on the California State Science Advisory Panel's Commission on Teacher Credentialing. In addition, he has been active with both the Society of Economic Geologists and the Geological Society of America; he was associate editor of the *Geological Society of America Bulletin* from 1992 to 1995. Dr. Brimhall was elected to the National Academy of Engineering in 2001 and received the UC-Berkeley Distinguished Teaching Award in 1999. He holds a Ph.D. in geology from the University of California, Berkeley.

RODERICK G. EGGERT is a professor and the director of the Division of Economics and Business at the Colorado School of Mines. He also is the editor of *Resources Policy*, an international journal of mineral economics and policy. Dr. Eggert specializes in natural resources and environmental economics, especially as they relate to mineral policy, mineral markets, and mining and sustainable development. Dr. Eggert was president of the Mineral Economics and Management Society from 1996 to 1997. He was a member of the National Research Council's Panel to Review the U.S. Geological Survey's Mineral Resource Surveys Program Plan and a member of the Committee on Earth Resources. He has written extensively on minerals exploration, mining and the environment, and public policy toward the minerals sector. Dr. Eggert holds a Ph.D. in mineral economics and an M.S. in geochemistry and mineralogy from the Pennsylvania State University, and a B.A. in earth sciences from Dartmouth College.

JAMES M. FRANKLIN is a consulting geologist with Franklin Geosciences Ltd., specializing in deposits of volcanogenic massive sulfide, gold, and platinum group elements and Precambrian metallogeny. He is also director of Patrician Consolidated Gold Mines Ltd., Kinloch Resources Ltd., Phoenix Matachewan Ltd., the Canadian Scientific Submersible Foundation, RJK Resources Ltd., and Project Neptune, which is

an international program to develop fiber-optic real-time monitoring of geological and environmental processes. Dr. Franklin is an adjunct professor at Queen's University, Kingston, and Laurentian University, Sudbury. In 1996 he became a fellow of the Royal Society of Canada and represents Canada's geoscientists on the Royal Society's Partnership Group for Science and Engineering. Dr. Franklin worked for the Earth Sciences Sector of the Geological Survey of Canada for 23 years, as chief geoscientist (1993-1998) and as a senior research scientist (1975-1998). He continues his research as a visiting research scientist and is co-editor of *Exploration and Mining Geology*. Dr. Franklin has received numerous awards from the Canadian Institute of Mining and Metallurgy, the Geological Association of Canada, and the Society of Economic Geologists. He holds a Ph.D. from the University of Western Ontario and an M.S. from Carleton University.

RHEA GRAHAM is director of the Planning and Communications Program for the New Mexico Interstate Stream Commission, a sister agency of the Office of the State Engineer, where she leads the effort to develop the state's first water plan, using a collaborative and public process. Previously, she was water resources manager for Pueblo of Sandia from 1997 to 2000, served as the nineteenth director of the U.S. Bureau of Mines from 1994 to 1996, and was director of the Mining and Minerals Division in New Mexico from 1991 to 1993. She is a registered engineering geologist and geologist in Oregon and is a certified professional geologist with the American Institute of Professional Geologists. She is a member of the National Research Council's Board on Earth Sciences and Resources. Ms. Graham holds an A.B. in geology from Bryn Mawr College and an M.A. in oceanography from Oregon State University.

JESSICA ELZEA KOGEL is principal research clay mineralogist and group leader for Thiele Kaolin Company, a major producer of kaolin. She directs research for two research and development groups and manages corporate analytical services laboratories. Previously, Dr. Kogel was a senior research scientist and manager of the industrial minerals group of McCrone Research Associates, where she coordinated industrial minerals research, developed x-ray diffraction methods, and provided applied research and consulting services to the mining, paper, paint, pharmaceuticals, ceramics, plastics and petroleum industries. She has served as an associate editor for *Clay and Clay Minerals* and is senior

editor for the seventh edition of *Industrial Minerals and Rocks*. She is on the Board of Directors of the Society for Mining, Metallurgy, and Exploration and was chair of the Industrial Minerals Division from 2001 to 2002. She is also president of the Clay Minerals Society and a member of other organizations, including the Mineralogical Society of America and the Georgia Geological Society. Dr. Kogel holds a Ph.D. and an M.S. in geology from Indiana University and four patents in clay processing methods.

MARK J. LOGSDON has been president and principal geochemist at Geochimica, Inc., since 1992 and specializes in hydrogeochemistry. His projects include hydrogeological and hydrogeochemical studies of acid mine drainage, planning mine closures, water-quality site investigations, and geochemical modeling. Previously, Mr. Logsdon was senior hydrogeochemist and vice president for Adrian Brown Consultants, where he conducted field and laboratory studies of contamination problems associated with tailing impoundments and acid mine drainage and reviewed major waste management projects for private clients and government agencies. Mr. Logsdon also worked as a project manager and hydrogeologist for the Nuclear Regulatory Commission's Division of Waste Management and as an economic geologist for the New Mexico Bureau of Mines and Mineral Resources. He is a member of several professional organizations, including the Association of Exploration Geochemists, the Geochemical Society, the Geological Society of America, and the American Association for the Advancement of Science. Mr. Logsdon is a Ph.D. candidate in hydrogeochemistry at the University of Waterloo and holds an M.S. in geology from the University of New Mexico.

DREW A. MEYER is a construction materials group vice president at Vulcan Materials Company, the nation's largest producer of construction aggregates. He coordinates marketing, marketing support services, marketing research, economic analysis and forecasting, and transportation sales and service. Mr. Meyer began his career at Vulcan Materials in 1966. He is currently the vice chairman at-large of the National Stone, Sand, and Gravel Association and is on the Board of Directors of the International Concrete and Aggregates Group. Mr. Meyer is a member of several professional and industry organizations, including the American Marketing Association, the National Association of Business Economists, and the Society of Mining, Metallurgy, Exploration, and the Min-

eral Information Institute. He has authored articles on the stone industry and made presentations on the extraction, processing, and consumption of magnetic metals from municipal solid waste. Mr. Meyer served in the U.S. Army from 1967 to 1970, where he attained the rank of captain and was awarded the Army Commendation Medal for Meritorious Service and the Bronze Star for Exceptionally Meritorious Service. He holds a B.S. and an M.S. in mineral economics from the Pennsylvania State University and has attended numerous seminars and short courses on marketing research.

GLENN C. MILLER is a professor of environmental and resource sciences at the University of Nevada, Reno. He is also director of the graduate program in Environmental Sciences and Health at UNR. He has a B.S. in chemistry from the University of California, Santa Barbara, and a Ph.D. in agricultural and environmental chemistry (1977) from the University of California at Davis. Following graduate studies, Dr. Miller spent a year of postdoctoral study at the Environmental Protection Agency's Environmental Research Laboratory in Athens, Georgia. His current areas of research include precious metals pit water quality, closure of precious metals heaps, and acid mine remediation using anaerobic sulfate-reducing systems. He also is working on the development of techniques to determine gas-phase sunlight photolysis rates of medium-weight organics and emission of organic compounds from two-stroke engines into lakes. In addition, Dr. Miller actively participates in the development of mining reclamation legislation for Nevada and on regulations mandated by that legislation. He is presently on the Board of Directors of the Mineral Policy Center, the Center for Science in Public Participation, Great Basin Mine Watch, and Environmental Law Alliance Worldwide.

ANTHONY J. NALDRETT is university professor emeritus with the University of Toronto, where he held the Norman Keevil Chair in Ore Genesis from 1997 to 1998 and taught from 1967 until 1998. His main research interests are magmatic sulfide ores—the tectonic settings in which they occur, the petrology of associated rocks, and controls on their composition (reaction between sulfide and silicate melts, fractional crystallization of sulfide melts, the role of hydrothermal fluids). He is noted particularly for his focus on the use of the platinum group elements in understanding the origin of magmatic sulfide deposits. In addition to his

research, he has served as consultant to many companies, including Chevron, Falconbridge Ltd., MRDI, Western Mining Corporation, BHP, Diamond Fields Resources (during their involvement with Voisey's Bay), COMINCO American, Donner Minerals, and Anzex Resources Ltd. Dr. Naldrett holds a Ph.D. from Queen's University, an M.A. from the University of Cambridge, and an M.S. from Queen's University. In addition, he received D.Sc. (honoris causa) awards from both Laurentian University and the University of Pretoria in 2000 and 2001, respectively. He is president of the International Mineralogical Association, a trustee of the Society of Economic Geologists Foundation, and president of the Geological Society of America.

NRC Staff

TAMARA L. DICKINSON, *study director***,** is a senior program officer with the National Research Council's Board on Earth Sciences and Resources, responsible for managing the earth resources activities of the Board. She was awarded the National Academies 2002 Distinguished Service Award. She has served as program director for the Petrology and Geochemistry Program in the Division of Earth Sciences at the National Science Foundation. She has also served as discipline scientist for the Planetary Materials and Geochemistry Program at National Aeronautics and Space Administration (NASA) Headquarters. As a postdoctoral fellow at the NASA Johnson Space Center, she conducted experiments on the origin and evolution of lunar rocks and highly reduced igneous meteorites. She holds a Ph.D. and an M.S. in geology from the University of New Mexico and a B.A. in geology from the University of Northern Iowa.

C

Information Provided to the Committee

Speakers at Committee Meetings

Steven Borrell, Alaska Miners' Association
Joseph Briskey, U.S. Geological Survey
J. Michael Canty, Office of Industrial Technologies, Department of Energy
Sie Ling Chiang, Bureau of Land Management
Vicki Cowart, Colorado state geologist
John DeYoung, Jr., U.S. Geological Survey
William Ford, National Stone, Sand, and Gravel Association
Jason Freihage, Office of Management and Budget
Michael Greeley, U.S. Forest Service
Murray Hitzman, Colorado School of Mines
Steve Hoffman, Environmental Protection Agency
Constance Holmes, National Mining Association
Bruce Johnson, U.S. Geological Survey
Kathleen Johnson, Mineral Resources Program Coordinator, U.S. Geological Survey
William Langer, U.S. Geological Survey
Patrick Leahy, U.S. Geological Survey
Ann Maest, Buka Environmental
Stephen Manydeeds, Bureau of Indian Affairs

Christopher Mapes, Office of Industries, U.S. International Trade Commission
Suzanne Nicholson, U.S. Geological Survey
Dianne Nielson, Utah Department of Environmental Quality
Troy Pederson, Office of Energy and Natural Resources, State Department
Rob Robinson, Bureau of Land Management
John Stevens, Federal Reserve Board
Spence Titley, University of Arizona

Individuals Who Provided Written Input to the Committee

Derry Allen, Environmental Protection Agency
John Barnes, Pennsylvania Department of Topographic and Geologic Survey
Thomas Berg, Ohio Geological Survey
Richard Bullock, University of Missouri, Rolla
George Coakley, U.S. Geological Survey
Richard Dalton, New Jersey Geological Survey
John Dilles, Oregon State University
Jeffrey Hedenquist, Colorado School of Mines
Robert Horton, former U.S. Bureau of Mines director, 1982 to 1987
Mike Howard, Arkansas Geological Commission
David John, U.S. Geological Survey
Greg Love, Center for Environmental Leadership in Business
J. David Lowell, Lowell Mineral Exploration
Jerry May, Idaho National Engineering and Environmental Laboratory
Mike McKinley, U.S. Geological Survey
Lloyd Mullikin, New Jersey Geological Survey
John Papp, U.S. Geological Survey
Jonathan Price, Nevada Bureau of Mines and Geology
Jean-Michel Rendu, Mining Consultant
Moira Smith, Teck Cominco Ltd.
John Thompson, Teck Cominco Ltd.
Roy Woodall, Earth Search Consulting, Crafers, South Australia

D

Commodities Surveyed by the Minerals Information Team

Abrasives
Aggregates
Aluminum
Aluminum Oxide, Fused (See Abrasives)
Antimony
Arsenic
Asbestos
Asphalt, Natural (See Cement)

Barite
Bauxite and Alumina
Bentonite (See Clays)
Beryllium
Bismuth
Boron
Bromine

Calcareous Marl (See Dimension Stone)
Calcium Carbonate (See Crushed Stone)
Cadmium
Cement
Cesium
Chromium
Clays

Coal Combustion Products
Cobalt
Columbium (See Niobium)
Copper
Corundum (See Abrasives)

Diamond
Diatomite
Dolomite (See Dimension Stone)

Explosives

Feldspar
Ferroalloys
Fluorspar
Fuller's Earth (See Clays)

Gallium
Garnet
Gemstones
Germanium
Gold
Granite (See Crushed Stone and Dimension Stone)
Graphite
Gypsum

Hafnium (See Zirconium)
Helium

Indium
Iodine
Iridium (See Platinum Group Metals)
Iron and Steel
Iron and Steel Scrap
Iron and Steel Slag
Iron Ore
Iron Oxide Pigments

Kaolin (See Clays)

Kyanite-Mullite

Lead
Lime
Limestone (See Crushed Stone and Dimension Stone)
Lithium

Magnesium
Magnesium Compounds (See Magnesium)
Manganese
Marble (See Crushed Stone and Dimension Stone)
Mercury
Mica
Mining and Quarrying Trends
Molybdenum

Nepheline Syenite (See Feldspar)
Nickel
Niobium
Nitrogen

Osmium (See Platinum Group Metals)

Palladium (See Platinum Group Metals)
Peat
Perlite
Phosphate Rock
Platinum Group Metals
Potash
Precious Metals (See Gold, Silver, and Platinum Group Metals)
Pumice

Quartz Crystal (See Silica)
Quartzite (See Crushed Stone and Dimension Stone)

Rare Earths
Recycling
Rhenium
Rhodium (See Platinum Group Metals)

Rubidium (See Cesium)
Ruthenium (See Platinum Group Metals)

Salt
Sand and Gravel, Construction
Sand and Gravel, Industrial (See Silica)
Sandstone (See Crushed Stone and Dimension Stone)
Scandium
Scoria (See Dimension Stone)
Scrap (See Iron and Steel Scrap)
Selenium
Shell (See Dimension Stone)
Silica
Silicon
Silicon Carbide (See Abrasives)
Silver
Slag (See Iron and Steel Slag)
Slate (See Crushed Stone and Dimension Stone)
Soda Ash
Sodium Sulfate
Statistical Summary
Staurolite (See Abrasives)
Steel (See Iron and Steel)
Stone, Crushed
Stone, Dimension
Strontium
Sulfur
Survey Methods

Talc and Pyrophyllite
Tantalum (See Niobium)
Tellurium (See Selenium)
Thallium
Thorium
Tin
Titanium
Traprock (See Dimension Stone)
Tripoli (See Silica)
Tungsten

Uranium, statistics only (See Vanadium)

Vanadium
Vermiculite
Volcanic Cinder (See Dimension Stone)

Wollastonite

Yttrium (See Rare Earths)

Zeolites
Zinc
Zirconium