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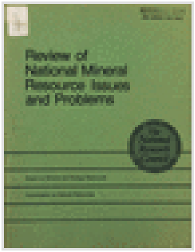

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The report attempts to highlight contemporary mineral resource problems that merit particular attention. It reviews the major problems in mineral resource development and places in perspective the magnitude and relationship of these problems to mineral exploration, extraction, and processing. Some of the topics covered include depletion of resources, future mineral requirements, future sources of mineral materials, energy use and mineral production, lead time in mineral production, technology and mineral supply, mineral development and public-land use, mineral development and environmental quality, conservation of mineral materials, socioeconomic impacts of mineral development, capital flows into mining, institutional conflicts and government involvement in mineral resource affairs, and manpower resources and needs.

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Review of National Mineral Resource Issues and Problems

A Report Prepared by the
Board on Mineral and Energy Resources
Commission on Natural Resources
National Research Council

NATIONAL ACADEMY OF SCIENCES
Washington, D.C. 1978

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NOTICE

The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the Councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the Committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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PREFACE

The development of our nation and its position of world leadership have come about in large part because of our rich mineral heritage and its contribution to our industrial economy. The continued and traditional uses of mineral materials have been responsible for unprecedented economic growth and improvements in our standard of living. Many have seen little reason to believe this would not go on, even though for the past twenty five years there have been occasional expressions of concern for the adequacy of mineral resource materials.

Today, however, we find ourselves in a period of mineral resource development that is in many ways quite unlike anything we have experienced before. Not only have our domestic reserves declined and our dependence on imports increased greatly, but attitudes toward mineral development have changed profoundly. Many people have serious reservations about the continuing of certain traditional practices of the mineral industry. There is a particularly strong concern for social, environmental, and socioeconomic consequences of mining, with many questioning the need for mineral materials if land must be preempted or blighted or the way of life jeopardized to obtain them. There are sharply increasing costs for meeting land reclamation and other environmental protection mandates. And increasing costs for energy itself add to the problems of mineral production.

At no time in the past has our mineral economy faced so many and diverse problems bearing on mineral production and commodity uses. Resolving or accommodating the divergent viewpoints of the producers, processors, and users of mineral materials, as well as the views of those indirectly affected by mineral production processes is a forefront problem in the United States today. The following review of national mineral resource issues and problems discusses those aspects of mineral resource affairs believed to be especially significant to our mineral resource future. It has been prepared in response to the concern of the Board on Mineral Resources that today's complex mineral resource affairs are insufficiently appreciated and that without a broader understanding of mineral resource issues and problems we invite serious consequences for our citizens, all of whom are affected in one way or another by mineral development. It is hoped that this overview report will contribute to that broader understanding of mineral resource affairs.

SUMMARY

One of the most basic and major problems facing the U.S. economy is that of mineral resource adequacy. This long-standing problem has become increasingly complex as our industrial society has evolved. The heyday of domestic mineral production from rich ore deposits is over, and we must now mine lower grade ores, often under restrictive--albeit sometimes desirable--conditions that did not exist in the past. In addition, we must continue to import certain mineral raw materials from abroad. The system of providing mineral raw materials from some combination of domestic and foreign sources has worked reasonably well in years past, but today a variety of social, political, and technological concerns have come together with severe impact on mineral production and mineral resource supply.

It is no longer possible simply to explore for and mine new mineral deposits with regard only for the resulting mineral commodity produced. We now must deal with the external impacts of mining and processing of mineral resources. Requirements now exist for restoring land surfaces disturbed by mining, for eliminating or reducing pollution caused by mining and mineral processing, and for protecting the health and safety of those associated with mineral operations. As the mineral industry responds to these social concerns, the costs of mineral production will rise.

Political concerns have also profoundly affected mineral development and production. Access to mineral sources abroad is becoming more difficult because of the increasing authority exercised by foreign governments in the production and sale of their mineral products. Involvement of our own government in domestic mineral resource affairs has also increased markedly, not only in the area of regulatory activities, but with respect to taxes, national security, and other traditional areas of government concern. In addition, there have been increasing institutional conflicts relative to mineral production, particularly between state and federal governments.

Existing mineral technology has probably been stretched to the limit of economic utility already, and there seems

little doubt that in the years ahead new technology will be required to exploit our reserves of mineral materials and to convert subeconomic or uneconomic resources into reserves. The rate of technological advancement does not seem adequate for meeting our long-term mineral needs.

These problems, together with those involving long lead times in mineral production, increasing capital costs for major mineral operations, the impact of energy costs and restricted energy supplies, and the need for an improved manpower base, are major concerns for the mineral industry and for the long-term outlook on mineral supply capability. Clearly, we must continue to assess our mineral resource position if we are to maintain a timely and orderly flow of mineral raw materials to industry. Such assessments should consider not only the factors that bear on the supply of primary mineral commodities, but also those that bear on the potential recovery of materials from waste products, the potential for substitute materials, and conservation of resources.

In this overview report the Board on Mineral Resources has attempted to highlight contemporary mineral resource problems that now merit particular attention. Those problems felt to be of special concern are summarized below.

- Depletion of resources. A fundamental characteristic of mineral resources is that they are depletable and nonrenewable. Once a mineral commodity has been mined and processed it is in effect used up, except for the recycling of a few materials. As high-grade ore deposits become depleted, more and more attention must be directed to lower grade ores, which have their own set of problems, namely, huge capital and energy requirements, need for new mining and processing technology, waste disposal, pollution control, land restoration, and ultimately, resource depletion.

- Future mineral requirements. The forecasting of future mineral requirements is a difficult but necessary aspect of any assessment of our mineral resource position. However, the past basis for mineral demand projections--the assumption that traditional mineral sources and mineral needs will remain much as they are today--seems untenable because compound growth rates in demand, based on present use patterns for energy and most commodities, cannot be sustained. Despite the difficulties of forecasting, the estimation of future mineral requirements is critical in minimizing the effects of market instability and in evaluating the adequacy of our mineral resources.

- Future sources of mineral materials. Future mineral needs will undoubtedly continue to be met through some combination of (a) production from domestic sources using existing and improved technology, (b) imports of foreign materials, (c) substitution of new materials for traditionally used ones, and (d) recycling. However, the future mix among domestic deposits, foreign supply, and secondary and substitute sources is likely to be quite different than it is today. It will depend on the influence that new technology may have on mineral operations and commodity uses, domestic government policies affecting mineral operations, and foreign government actions relative to mineral production and sales.

- Energy use and mineral production. A major problem in future mineral production will be mounting requirements for energy that will be increasingly costly and perhaps less available than it is today. Energy demand will grow especially as leaner, more refractory, and more deeply buried ore bodies are exploited. There is a particular need to improve energy efficiencies in the processing of mineral materials. Conservation of energy through recycling also merits attention.

- Lead time in mineral production. The lead time between discovery of an ore deposit and initial production is usually measured in years. Improved technology has reduced the lead time required for major construction, opening underground workings, and processing mineral ores. However, increasing societal concerns for maintaining environmental quality and protecting worker health and safety have combined with government regulations such as those involving the use of public lands to extend the time required to bring a mineral deposit into production. Because the mineral industry is becoming increasingly involved with the social and environmental consequences of mineral production and development, lead time will continue to be a major concern of the mineral industry.

- Technology and mineral supply. Technology continues to play an essential role in converting mineral resources into usable commodities, even though much of the technology used by the mineral industry has been developed by equipment manufacturers and other suppliers to the industry. The mineral industry has been unwilling to take heavy risks in technological R&D in the past because superior ore deposits could generally be found to maintain a company's competitive position. However, with the depletion of high-grade ore deposits there is increasing need for innovation in mineral technology. Research should focus not only on maintaining a productive capability for primary materials, but also on reducing air, land, and water pollution, improving energy efficiencies in mineral extraction and recovery, and devising new methods of reclaiming land disturbed by mining.

• Mineral development and public-land use. Historically, much of the U.S. mineral wealth has come from federally owned lands. Early laws and regulations encouraged mining activities on the public lands, but in recent years society has recognized the benefits of alternative land uses, and laws have been enacted that control mining activities in much of the public domain. Nearly 70 percent of our public land areas is currently withdrawn from any mineral exploration and development. Much of our past mineral production has come from federal lands and because the prospects for new mineral discoveries on these lands are especially favorable, there are understandable reservations in the mineral industry about the increasing withdrawals from mineral entry and about legislation that severely restricts mining on those lands that remain open. Clearly, a need exists for a better-informed perspective on land-use alternatives and a sensitivity to the various contributions to be made by each. In particular the role of the public lands in mineral production appears to need reassessment. Such a reassessment would benefit from an up-to-date nonfuels mineral policy.

• Mineral development and environmental quality. Conflicts between mineral development and preservation of environmental quality will continue simply because mining does disturb and pollute the environment, even if only temporarily. Even so, the environment can be protected to a significant degree during mineral development and the landscape and original quality of many areas can often be restored after mining has ceased. However, the public must be willing to pay for this through higher prices in the marketplace. What is needed is a compromise between resource development and environmental protection that will best serve society at a price society is willing to pay.

• Conservation of mineral materials--methods and motivations. Few would challenge the worthiness of the conservation ethic, even though what might be accomplished through conservation is not always well understood and its practice is rarely without cost. Nevertheless, conservation has a place in any scheme for efficient use of limited resources. The effectiveness of conservation practices depends on (a) market forces that motivate conservation interests, (b) government policies and regulations that help shape market forces or consumer behavior, and (c) educational programs that inform and encourage the public about conservation.

• Socioeconomic impacts of mineral development. Mineral development necessitates an infrastructure which frequently usurps the facilities of the region in which it is located. Whether the development activity is located near an existing community or whether a new community has to be established, the social and economic changes to the region can be severe and are often abrupt. Even under the best of conditions the establishment of a well-balanced community is difficult, if not impossible, making the community greatly dependent on the health of the mineral development activity. When the activity is healthy, the community thrives. However, when it is not healthy the community can suffer greatly. The accelerated growth of the community makes proper planning and the establishment of the necessary community institutions almost impossible. Concern for the socioeconomic impacts and quality of the human environment resulting from mineral resource development have become major issues in the consideration of new projects. As a consequence, local, state and federal government agencies are becoming increasingly involved, primarily through their regulatory powers, with the development of new major mineral operations.

- Capital flows into mining. Capital flows into mining relative to capital flows into all business have decreased since World War II. Likewise, mineral production has fallen in comparison to general business production. This relative decline in mineral industry output cannot be laid to vagaries of the import/export market. The role of minerals in the economy has simply declined. Still, despite the increasing importance of nonmineral goods, the mineral industry continues to be vital to the strength of our economy, and adequate flows of capital to the industry are necessary if our national security and economic well-being are to be maintained.

- Institutional conflicts and government involvement in mineral resource affairs. Past policy developments with respect to mineral resources were initiated for the most part by state governments. In recent years, however, national interest has stimulated more and more federal involvement in an increasing number of mineral resource activities. Much federal policy has tended to be restrictive on the mineral industry. There seems to be a particular need to establish and define federal mineral policy in relation to that which is to be reserved for state government, since conflicts are common. In this way the federal role, individual state responsibilities, and the private sector's sphere of operation could be clarified. Federal responsibility should probably remain broad, while the states should focus more on local and regional problems of mineral development.

- Manpower resources and needs. Our trained manpower base must be increased if we are to maintain a capability for bringing domestic mineral materials to market. A greater number of skills are now required to maintain normal levels of production. Use of increasingly lower grade ores calls for technological skills not needed in the past. In addition, industry must now contend with the technology of environmental, safety, and pollution problems. Projected major increases in coal production pose a special need for additional trained manpower as well. Although new technology might reduce some manpower requirements, the increased attention that must now be given both to new social concerns and traditional aspects of mineral production suggest a strong need for improving our manpower base. Indeed, the need to develop new technology will in itself require trained mineral scientists and engineers.

INTRODUCTION

Mineral resource problems are largely repetitive in character and an examination of most current problems generally shows them to be old familiar issues or political confrontations reappearing in a new guise. It is rare for really new kinds of problems to surface. However, new dimensions in resource issues do appear--how best to resolve conflicts between environmental protection and mineral development is a case in point--and thus a continuing assessment of our mineral resource position is essential if the best solutions to contemporary problems are to be found. Indeed, the solution to any immediate mineral resource problem should be viewed as part of a continuum of policy formulation and implementation. Policies that were appropriate to the United States as a sparsely populated frontier area with many undiscovered mineral bonanzas and modest commodity needs must over time be replaced by policies and programs suitable to a mature industrial nation with a population of 210 million people, a drastically reduced stock of high-grade deposits, extensive commodity requirements, and a growing commitment to social goals that conflict strongly with mineral exploration and production.

The following text reviews the major problems in mineral resource development, places in perspective the magnitude and relationship of these problems to mineral exploration, extraction, and processing, and thus calls attention to those problems that are in need of particular attention today. Although the report applies generally to all mineral resources, it does not address the special problems of crude oil, natural gas, or water. These topics are receiving special attention in a variety of studies by the Academy, government, and others.

CHAPTER 1

DEPLETION OF RESOURCES

Mineral resources are nonrenewable and depletable and economic concentrations of mineral materials in the earth's crust are rareties rather than commonplace. Once they have been mined and processed into manufactured goods they are in effect used up, except for those materials that can be readily and profitably recycled. Most high-grade and easily found deposits were worked out long ago, and the U.S. mineral industry is increasingly turning to lower grade ores in its domestic mining operations.

It is generally felt that complete physical exhaustion of our domestic mineral resources is unlikely. Depletion in the economic sense, however, is a strong possibility, despite technological advancements. Once the unit cost of various mineral commodities has risen in the United States to a point where foreign mineral supplies, commodity substitutes, or changing use patterns have precluded further production from domestic sources, the remaining minerals in place will cease to be reserves, and depletion in the economic sense will have taken place. Normally, this process is gradual, and in the past most changes in source and use patterns have occurred without much attention on the part of the commodity consumer except for a casual awareness of ghost towns and abandoned mines.

Historically, mineral resource production for a nation has been shown to evolve through a period of abundance to one of scarcity. In effect, mineral production has a life span, and the United States at present appears to be near its midpoint. The production of metals seems near its peak, but the number of working mines is decreasing and the amount of mineral supplies being imported is increasing. Yet, life spans can be extended, and indeed the extractive mineral industry appears to have been fairly successful for over a century in advancing the technology to make it possible, without increasing real unit costs, to discover, recover, and use ever-increasing quantities of materials from ever-decreasing grades of ore and less accessible sources. Nonetheless, the question remains whether the mineral industry can perpetuate these accomplishments in the future, and whether or not there are adequate incentives--or even a need--to do so.

In the past, the practical need for special incentives to develop new technology for mineral exploration or for converting low-grade deposits to commercially usable forms has always been debatable, given the availability of relatively plentiful high-grade or low-cost deposits, both domestic and foreign. As long as more profitable investment could be made in rich mineral deposits, either in the United States or abroad, than could be made through investment in research and development required to exploit low-grade ores, R&D has not been particularly encouraged. Though many industries can cope with foreign competition through the use of advanced technology, it is the company or country with the richest and most extensive ore reserves that has an advantage in the mineral supply market. Obviously, given an option, a company will choose to develop a high-grade, low-cost deposit with its potential for the greatest return on investment. Unfortunately, new discoveries of high-grade deposits are likely to be very rare in the United States and unless rich foreign deposits can continue to be tapped, an expanded technological base will have to be developed to exploit our leaner domestic ores.

For certain mineral needs, however, the United States has always relied and will continue to rely on foreign sources of supply simply because we have none of our own. A key question is whether it is in the nation's long-term interest to minimize its dependence on foreign supplies of those mineral commodities for which we do have some domestic sources. Recent actions of mineral-rich less-developed countries indicate that some foreign governments can be expected to exert more and more control over their production and export of mineral commodities. Thus, sustained and perhaps increased production from domestic mineral resources may be a more desirable goal than in the past.

Some assessments of the prevailing mineral position of the United States show that development of our available resources, in particular additions to reserves, is limited by the lack of aggressive exploration and development programs. The absence of incentives to develop new reserves is attributed to unfavorable tax and other policies at home and to nationalization and related developments abroad. But the main concern seems to be whether exploration for new sources and the development of new reserves is economically possible if prospects for sufficient profit in the face of escalating capital investments are not favorable.

The Mining and Minerals Policy Act of 1970 addressed the problem of depletion of domestic resources by stating that the policy of the federal government is to foster and encourage private enterprise in meeting the nation's needs in minerals and mineral fuels. The Act specifically states that it is also the continuing policy of the federal government to foster and encourage the research necessary to assure that these needs are met. Similarly, the National Commission on Materials Policy, authorized under the Resource Recovery Act of 1970, recommended that agencies with responsibilities in the materials and resources fields undertake appropriate research and development to generate new knowledge and technology, and that they also intensify their efforts to capitalize on available knowledge in the development of our raw materials supply. In each of these Acts, and in associated reports, there has been repeated reference to the need for the United States to develop its technology as an aid in the discovery, extraction, and use of the nation's mineral resources with minimum environmental disturbance. Vigorous pursuit of research and development in mineral technology, as authorized under these Acts, would almost surely help to alleviate the impacts of depletion on our mineral resources, perhaps primarily through improved recovery efficiencies for ores now being mined but also through the development of substitute materials to replace or limit the use of certain scarce mineral commodities.

Most current assessments conclude that there is little reserve mineral technology in the United States to draw upon and that the present programs in government, industry, and universities are not developing new technology at a rate appropriate to future needs for mineral raw materials, even though these needs may grow more slowly than they have in the past. Mineral resource technology programs need to be fostered and encouraged if the rate of depletion of domestic resources is to be abated.

CHAPTER 2

FUTURE MINERAL REQUIREMENTS

The magnitude of our resources only has meaning within the context of the needs of mankind and individual nations. Without demand, there is no need for production; thus estimates of reserves and resources are functions of the present and future demands for particular minerals, metals, and fuels. Primitive economies needed a limited array of useful, low-technology commodities such as flint, copper, salt, and turquoise. The early industrial economies of a few hundred years ago depended heavily upon coal, iron, and the base metals. Today's industrial complexes measure their resources in terms of over one hundred mineral commodities. Simple agrarian economic systems functioned quite nicely without mineral fertilizers. The Iron Age had little need for a spectrum of ferroalloying elements, and early twentieth century analysts of the era of coal and steel had little reason to pay attention to resources of uranium and titanium.

It is thus to be expected that an appraisal of mineral resources a hundred years hence might be quite unlike that of today. However, it is unlikely that man's demands at that time will be significantly less than at present; indeed, it is expected that they will be greater. It can be anticipated that there will be few if any remaining unexploited deposits of highly concentrated metallic ores, and natural liquid and gaseous hydrocarbons may be rarities. Yet it remains conceivable that the world's mineral resource position could be better than it is today if changing demands were to be satisfied by using plentiful materials not now being exploited.

Man has rarely if ever used a resource solely because it was abundant or cheap. When some function needed to be performed he sought out those resources that were technically and economically most available for that purpose. Key resources a hundred years from now may be solar energy, aluminum, and inorganic compounds rather than petroleum, iron, and plastics. If so, the world's resource position in basic commodities could be quite reassuring because a shift would have occurred toward reliance on more abundant materials. There might still be a need for many minerals that are relatively scarce and irregularly distributed. But that reliance could be considerably less threatening to national security or economic well-being than our present circumstances would seem to indicate.

Over shorter periods of time, however, nations may be temporarily trapped by existing patterns of use, the limits of their current technology, and the availability of capital. Thus, from the suite of mineral resources required to perform essential tasks, we are able to identify those that seem limited in supply in terms of current reliance upon them. The fact that sodium, potassium, and calcium are relatively abundant elements provides little comfort in a resource assessment of an economy dependent upon copper, lead, and zinc.

Dramatic changes in existing commodity supply or demand relationships are usually viewed as something to be deferred, avoided, or somehow overcome. This attitude is understandable, since customary practices and past investments are threatened. Unfortunately, it also means that many assessments of the national mineral supply position rest upon the assumption that traditional sources and mineral needs will remain much as they are now and that R&D should be directed toward meeting them. This conclusion is reached although even casual inspection demonstrates that compound growth rates in demand, based upon present use patterns for energy and most commodities, cannot be sustained. Pessimistic assessments of future mineral supplies have been common in recent years and emphasize the fact that resources are finite.

The reality of future depletion should be coupled with a realization that demand is flexible. Indeed, society's concern for a cleaner environment and a better quality of life is forcing a new look at the materials that are being produced and how they are being used. We can expect that certain materials posing a health hazard will be in less demand. Others requiring huge energy inputs for their production may be replaced by materials whose production is less energy-intensive. The flexibility of demand may provide an answer to those who have pessimistically assessed the nation's future mineral supplies and requirements. Almost certainly the traditional outlook on future demand for mineral materials will have to be modified.

Mineral requirements are occasionally affected by interruptions in the flow of mineral materials to the consuming industries, particularly when substitute materials are readily available or can be easily developed. Manufacturers sometimes change the materials they use even when supply interruptions--such as those resulting from labor problems, market instabilities, or normal cyclical use patterns common to mineral commodities--are short term. When long-term disruptions in supply take place, for example as a result of international conflict, manufacturers may be forced to abandon some products or to develop alternative materials for given products. Whenever major uses of materials are eliminated and alternative materials become extensively used there clearly will be a strong effect on the mineral market.

So many factors bear on mineral demand that it is very difficult to predict with any degree of certainty what our future mineral requirements will be. Precise short-term forecasting of total demand and of demand for specific mineral commodities has always been difficult even under the best of circumstances. Indeed, short-term imbalances between mineral supply and demand are endemic to a complex mineral economy, and we can expect them to continue. Until now, long-term forecasting of generalized levels of mineral demand has been relatively successful, but even long-term demand forecasts become more uncertain when we face the realization that the continuously growing demands for traditionally used mineral materials simply cannot be sustained. Yet, despite forecasting imperfections, the estimation of future mineral requirements is critical in minimizing the effects of natural market instability and in evaluating the adequacy of our mineral resources. The difficulties of demand forecasting cannot be eliminated. They can be reduced, however, through a continuing assessment of the availability of mineral supplies and an evaluation of the magnitude of change in use patterns for traditionally used and newly developed materials.

CHAPTER 3

FUTURE SOURCES OF MINERAL MATERIALS

Ideally, a country's basic mineral needs would be met using those of its natural resources that are economic and that offer the desired properties in the manufacture of specific products. Unfortunately, geologic concentrations of mineral materials are irregularly distributed in the earth's crust and are unrelated to political boundaries. No single nation has within its borders the variety of mineral materials it requires. The supply system of industrial societies, especially, is highly interdependent and encompasses the entire world. Thus, while the problem of replenishing our industrial stocks of mineral materials is in its simplest form one of a continuing flow of subeconomic resources into producible reserves and the development of new reserves through exploration, in actual practice alternative ways of supplying needed raw materials are also operative. Our options for meeting current and future mineral material needs are, in some combination: (a) to develop domestic resources through improved technology and to bring new resources into production through exploration; (b) to continue importing those materials for which no domestic supply exists or for which we have only uneconomic low-grade ores, or to purchase foreign supplies because of favorable prices; (c) to modify the requirements or change the manufacturing process so that a given product can be fabricated from domestic materials with only minimal reliance on foreign supplies; and (d) to recycle those commodities not extensively dissipated through normal use.

The development of domestic resources would seem to be an obviously desirable way of assuring future sources of certain mineral materials. However, depletion of our high-grade resources, decreasing grades of ore currently being mined, and increasing regulations affecting mining and processing operations combine to make domestic mineral supply and replenishment of working stocks much more difficult than in the past. A particular problem is the development of subeconomic resources into reserves. In the past, innovative technological advances have made possible high productivity and profitability for many domestic ores, has brought submarginal ores into production and provided a means to continue reliance upon domestic supplies. How aggressively and effectively technological advances will be encouraged in the future, and to what extent they will be applied to those domestic resources that remain to be discovered and developed, is a dominant question in any speculation about domestic supply. A much more rapid and aggressive technological advancement in all aspects of the mineral sciences--including those that bear on the quality of the environment and related social problems associated with mining and processing of ores--seems essential if we are to maintain a suitable mineral production capability and ensure the proper role of domestic resources in replenishing our industrial stocks of mineral materials.

However, our domestic mineral position does not depend solely on technology but is to a considerable extent a reflection of government policy. Thus, we could establish limits beyond which imports of a mineral commodity are not considered tolerable, and have done so. Decisions concerning the whole array of incentives--taxes, tariffs, price levels--can mitigate to a limited extent the rate of exhaustion of domestic resources through their impact on exploration, development, and substitution. On the other hand, political decisions--such as those concerned with environmental and other social consequences of mining and mineral processing--may exacerbate the problems of mineral production. This in no way suggests that the social impacts of mining and mineral processing are not important, but rather emphasizes that future mineral production increasingly will involve public policy decisions, as well as new technological developments.

The extent to which domestic requirements for mineral raw materials should or need to be met from foreign sources varies greatly with each mineral commodity. Consequently, generalizations about the degree of United States import dependency are misleading. Future requirements for some mineral commodities, now considered essential, will always have to be met from foreign sources simply because no domestic supply exists. Other commodity requirements will be met from foreign sources whenever the cost of foreign materials is below that of domestic supply. Given unrestricted free market international trade and an absence of governmental constraints on the flow of materials between nations, dependence on foreign materials would not be a critical matter. However, history shows that international free trade rarely, if ever, prevails. Cartel actions, nationalization, and occasionally wars all have serious impacts on the flow of mineral materials from one country to another. Especially in recent years, there have been unpredictable proclivities on the part of intergovernmental mineral-producing groups and the threat of future OPEC-like supply discontinuities for certain mineral commodities.

Thus, the uncertain reliability of foreign supplies looms as one of the greatest threats to the continued and timely flow of mineral commodities to industrial markets in the United States. However, because we need foreign materials for which we have no domestic supply and because favorable foreign market prices can be expected to exist (at least for some mineral materials and for some periods of time), a combination of foreign and domestic production will continue to supply our mineral needs in the future. The degree to which foreign imports will contribute to our future mineral needs will vary with the political actions of foreign governments and the behavior of the international mineral market.

The future need for mineral materials also is likely to be strongly affected by a change in product requirements. For some products a substitute material may displace a certain mineral material simply because it is more efficient or less costly, but for many others the substitute material will be developed because traditionally used mineral materials have become scarcer either through depletion of primary sources or prohibitive costs of production. These substitutes may be more plentiful naturally occurring mineral materials, they may be synthetic mineral materials, or they may be plastics and other nonmineral materials. At some unpredictable future time the development of substitutes will become a necessity for some products or those products will vanish from the marketplace. However, substitutes will not magically appear as traditionally used materials become scarcer. As pointed out by the Committee on Mineral Resources and the Environment (National Research Council [NRC] 1975:66), "...the discovery and development of new and improved materials as possible substitutes for existing ones takes time and...the process is generally driven by clearly-perceived functional objectives...." Whatever those objectives, the problem of lead time, which may be several years, must be taken very seriously. It would be desirable for industrial R&D to include long-term research programs in the development of substitute materials. Such programs are not widespread today despite the knowledge that future material needs for many products will probably be markedly different from what they are today.

The prospect of recycled materials as a future source of some of our mineral needs has always had an appeal because the reuse and conservation of materials--the primary sources of which are diminishing--have in themselves been viewed as basically desirable goals. In addition, recycling has a potential for reducing the energy requirements, capital costs, and disruptions of the environment when contrasted to the recovery of virgin ores. Practically, however, the supply of minerals through recycling has depended heavily on economic considerations. If reprocessing of materials was profitable, then recovery of metals from discarded products would be pursued. Unfortunately, few materials are profitably recoverable at present, although lead, copper, and iron (steel) in municipal wastes are notable exceptions. Given the increasing concern for the adequacy of reserves of primary mineral materials, the problem of mounting labor and energy costs for mining and processing virgin ores, and the emerging social feelings about protecting an environment disturbed by mineral operations, there seems little doubt that recycling will receive increased attention as a means of supplying certain of our future mineral needs. The many problems of material recovery from secondary sources have been addressed in a number of earlier publications (see National Academy of Sciences 1975:107-109, National Commission on Supplies and Shortages [NCSS] 1976:155-172, NRC 1975:60-64, National Commission on Materials Policy [NCMP] 1973:4D-1 to 19).

From the broad viewpoint, many considerations affect the options available for maintaining the flow of materials through our resource channels. These include pollution and environmental factors, availability and use of energy and water, influence on the balance of trade, reciprocity of trading, and technological ability to use minerals. Depending upon the mineral, one or more considerations may be of paramount importance at any one time. In determining the optimum mix among domestic deposits, foreign supply, and substitute and secondary sources, particular attention must be given to accessibility and reliability for continued supply at reasonable cost plus a concern for our balance-of-payments position.

CHAPTER 4

ENERGY USE AND MINERAL PRODUCTION

The energy demands of the mineral industry are very large, with more than ten percent of the total national energy budget going to the production of basic mineral materials (Hayes 1976:661-665, Kellogg 1977:61-65). These demands can be expected to grow even greater as lower grade ores are exploited in the future. A principal reason for this growth is that for ores amenable to physical concentration, increasingly immense tonnages of material must be mined and processed to recover a given quantity of the commodity sought.[1] For many ores that must be treated by chemical or thermal methods the energy requirements are also extremely large. We must also consider the energy required to satisfy environmental and other concerns (for example, restoring areas stripped of soil and vegetation cover by surface mining). For future mining and processing of mineral commodities, energy will become a critically limiting factor. A major problem of the mineral industry will be how to cope with increasingly costly and perhaps limited availability of energy as it exploits leaner, more refractory, and more deeply buried ore bodies.

The fact that increasingly lower grade ores are being mined puts mining and processing on a collision course with increasing energy costs and needs. Thirty to forty years ago the average grade of copper mined in the United States was 1.1 percent; today it is only 0.65 percent. Continuous decline remains evident, and a grade near 0.20 percent copper by the year 2000 seems a reasonable extrapolation. When the average copper ore grades reach 0.20 percent we must be prepared to use roughly three times as much energy to recover one ton of copper in the form of concentrate as is employed today, and we must also find room for disposal of three times as much overburden and tailings--close to two billion tons per year. In a society where some forms of energy are becoming scarce and almost all are becoming more costly, the tyranny of decreasing ore grade will be a foremost problem of the mineral industry.

It is important to note that total energy requirements in the mineral industry involve a complex interrelationship that involves not only the ore grade, but also the tonnage produced and the inherent energy required for mineral and metal processing. For example, the production of sand/gravel/crushed stone requires very little energy per ton but the enormous amounts produced (1.9 billion tons per year) make this industry a substantial energy consumer. The production of aluminum, on the other hand, is inherently so energy-intensive that, even though only 4.6 million tons are produced per year, the energy requirements of the aluminum industry (the second largest energy consumer in the entire mineral industry), are 40 times that of the gravel and stone industry.

Compounding the problem of ore grade is a variety of other considerations, particularly the less-than-desirable process efficiencies of many mineral recovery operations. For example, in 1970, the industry-wide average flotation recovery for several different types of copper was slightly less than 82 percent. A great deal of money and energy was expended to mine, haul, crush, grind, and float these ores, and then 18 percent of the value was allowed to go to waste. Similarly, the proportion of mineral and metal values lost as slime in some ore processing is immense. The problem is that slime particles (with their included mineral content) often interfere with or even prevent the flotation of coarse particles, so that many ores must be completely deslimed and the slimes discarded along with their valuable components. A prime example is that roughly one-third of the phosphate mined in Florida is lost as unrecovered fine particles. Copper, tungsten, zinc, iron, fluorspar, and barite come in as close seconds in the same category. These losses are indeed impressive, and become even more so considering that finely dispersed ores will be mined increasingly in the future. Not only is the problem of energy efficiency in mineral recovery serious, but so are the environmental consequences of developing huge volumes of waste resulting from the mining of finely dispersed, low-grade ores.

Because primary mineral production will gradually become more energy-intensive as a result of the larger energy inputs required by the mining and beneficiation sectors to exploit increasingly lower grade ores, the energy efficiency of replacing primary materials by secondary materials recycled from scrap or wastes should be given particular attention. Even though recovery of metals by processing of scrap and other waste materials today offers little appeal to those involved in the primary metal industry, the advantages of recycling in conservation of energy, conservation of mineral resources, and elimination of some of our waste disposal problems combine to suggest secondary metal production be pursued vigorously as a way of meeting a greater part of our future needs for mineral materials.

A variety of factors impinge on the increasing problems of mineral production, but none is perhaps as significant as the requirements for energy and the need to improve energy efficiency in the mineral industry. A foremost contribution to energy efficiency can be made through technology, and government incentives would seem especially appropriate as a means of encouraging technological contributions to energy effectiveness. The charter of the Mining and Minerals Policy Act of 1970 is broad enough to permit support of such developing technology, but legislation more specifically focused on energy effectiveness appears needed. In addition, federal and state governments should encourage through appropriate incentives the use of secondary metal production through recycling of scrap and waste materials. A conservation ethic could be highly energy effective, although the voluntary elimination of wasteful practices (e.g., the "throw-away" syndrome, designed obsolescence) in an affluent society will come only with great difficulty.

NOTE

1 The amount of energy required to mine a ton of ore is roughly constant and does not reflect the ore grade. It takes just as much energy to mine a ton of hard-rock gold ore with a gold content of 0.001 percent as it does to mine a ton of hard-rock copper ore containing 1.0 percent copper. Ore concentration by physical separation of the minerals (size reduction followed by gravity, magnetic, or flotation separation) shows similar characteristics to mining, that is, the unit energy required per ton of ore for concentration depends on the physical and chemical characteristics of the ore (fineness of disseminated minerals, grindability of the rock), but is largely independent of ore grade.

CHAPTER 5

LEAD TIME IN MINERAL PRODUCTION

It is not unusual for major new ore deposits to require ten years or more for their development, that is from the date of discovery to the date of initial production.[1 2] This period of time, commonly referred to as "lead time," is affected by many activities, such as drilling of an ore body to delimit its extent and to sample the ore, constructing transportation facilities, developing underground or open-pit workings, building mills and related facilities, and, more recently, taking steps to address environmental problems and other social concerns. Lead time, as used in this general discussion, assumes that once an ore deposit has been discovered there is a continuing activity to bring it into production. Lead time in this sense does not include exploration time prior to discovery.

Lead time has always been extensive, but as technology improved over the years, many of the earlier lead-time problems, such as constructing transportation facilities in remote areas, have been mitigated. Countering this in recent years, however, has been the emergence of social concerns, such as protection of the environment, which have increased the lead time in mineral production. As a consequence, lead time continues to be a major concern of the mineral industry. Because of new social concerns it is clear that the historical perspective must be used with caution in evaluating today's lead-time problems.

Whatever the causes, long lead times are significant because they add to the costs of mineral production; unit production costs obviously could be reduced by shortening the lead time between discovery of a mineral deposit and the delivery of a mineral commodity to market. However, it may not be easy to reduce lead time because of the variety of factors that must be considered in developing a mineral supply. These factors range from the need for new technological tools or methods of processing ores to requirements for meeting legal obligations in mineral production, such as meeting health and safety standards or restoring land surface disturbed by mining. They may also simply involve the availability or lack of manpower or hardware that are essential to the speeding up of production.

Although producers are highly aware of the significance of lag time between initial discovery and actual production, legislators and policy planners need to be better informed on this subject. Because they commonly deal with problems that require short-term solutions, most legislators and policy planners are more attuned to the immediacy of current problems than to the long-term outlook so critical to the mineral industry. The fact that federal and state legislation has often tended to lengthen the lead time in mineral production clearly demonstrates the impact of political actions on the deliverability of mineral commodities and emphasizes the need for an informed political perspective on mineral resource problems.

The steps involved in bringing a mineral deposit into production are numerous, but of particular importance is the fact that these steps are major time-consuming activities that generally must be performed sequentially, usually over a period of several years. Once a mineralized area is discovered it must be further explored by diamond drilling, pitting, trenching, or other techniques necessary to examine the subsurface and determine the extent and grade of ore bodies present. Mine planning then follows to develop a mining method that will extract as much of the resource as possible while protecting the safety of the men who must enter the workings. The mine or mining unit must be engineered, again, with economy and operational safety in mind. Even if surface mining rather than underground mining appears to be the most appropriate activity, mine development can be a major, expensive, and time-consuming undertaking.

Finally, the facilities that convert the ore into a usable product for the manufacturer must be designed and treatment plants constructed. Because different ore deposits are composed of different combinations of minerals it sometimes takes years of research to find the proper design of a concentration plant. The nature of the minerals involved may require multiple steps in the refining process. For example, in the development of a metallic ore, the minerals must be concentrated and then subjected to a series of refining processes to obtain the purity required of that particular material. As technology for producing new products advances, the demands for materials of high purity have increased. Research and work on improving the purity of materials are sometimes as costly and time-consuming as all the foregoing processes combined.

Other factors that affect traditional practices of mining, beneficiation, and processing are various government regulations imposed over the past few years that require mineral producers to commit additional time, money, and effort to problems that were largely ignored in the past. New regulatory agencies have emerged at the state and federal levels, and they currently exert great influence on the conduct of mineral resource operations. It is essential, for example, to clear many of the planning steps for mineral production with numerous regulatory agencies before actual construction and mining begins. In many places, especially on the public lands, it is necessary to obtain not only the right to explore for mineral materials but also the right to develop and later mine them. The time required to obtain various permits, approvals, and clearances is often many months, or even years. Finally, the requirements for restoring areas disturbed by surface mining, meeting health/safety standards, and minimizing pollution to air and water all add to the increasing time span for mineral production.

Whereas the lengthening of lead time is normally to be avoided, it is no longer possible to ignore environmental, health/safety, and other more recent social concerns, even though they have been a basis for legislation that has delayed the marketing of mineral commodities. These legitimate concerns must be accepted and addressed in a manner that will best minimize their impact on extending lead time in mineral production. The mineral industry must accept the social/environmental consequences of mineral production and develop compromises in its operations that satisfy the consuming public, environmentalists and others--including the producers themselves. By the same token, legislators and policy planners must give more attention to the characteristics of the mineral industry for time could be saved by streamlining the regulatory process. Lead time could also be shortened by improving management of mining and processing operations, but technological developments will undoubtedly play the most significant role by increasing the efficiency with which ore is mined and processed. Such developments must also duly consider the energy requirements for production and the laws concerning environmental, health, and safety standards.

Physical location of deposits, availability of water and transportation facilities, and the capital necessary for major mining ventures can all have a profound effect on the time required to bring a mineral commodity to market. These factors--together with technological, sociopolitical, and environmental considerations--pose formidable challenges to the production of raw mineral materials.

NOTES

1 In the 1950s and 1960s an average time of about ten years elapsed between discovery and production of lead-zinc ores along the Viburnum Trend in southeastern Missouri (see Economic Geology [1977]).

2 For certain copper deposits in Arizona the U.S. Bureau of Mines has reported the amount of time required for the following operations: open-pit development, one to four years; underground development, four to eight years; construction of beneficiation plants, eight months to slightly more than two years (Burgin 1976).

CHAPTER 6

TECHNOLOGY AND MINERAL SUPPLY

Technology has always played an essential role in converting mineral resources into usable commodities. In the past, however, the mineral industry has used fairly uniform and well-proven technology in its operations, much of which has been developed by equipment manufacturers and other suppliers to the industry. There has been little incentive for the industry itself to risk heavy investments in technology--especially on low-grade, submarginal, or uneconomic resources--and consequently relatively little effort has gone into in-house research and development. What R&D the industry has done has been oriented largely toward short-term objectives involving existing production operations. Traditionally, the mining industry has maintained its competitive advantage in business by seeking out and controlling the best mineral deposits; thus, most of a mining company's new development funds have been spent on exploration.

Nevertheless, there have been notable innovative technological advancements in mineral resource production, particularly in beneficiation and extraction processes. Development of the froth flotation process, the pelletizing of magnetic taconite ores, and the introduction of liquid-liquid extraction processes into metal recovery circuits are examples of truly innovative technology that have had profound and beneficial effects on the mineral industry and the supply of mineral commodities. Such developments have occurred despite limited involvement of the mineral industry in R&D activities. However, events of recent years portend a dramatic change in operating philosophy of the mineral industry from mineral-deposit-centered to technology-centered. Not only are domestic bonanza deposits now a rarity--requiring the exploitation of low-grade, deeply buried, or refractory ores--but environmental protection mandates, occasional commodity shortages, increased costs of energy and labor, restrictions on access to public lands for mineral development, nationalism and other activities abroad are forcing the mineral industry to look afresh at the problem of meeting our mineral material needs. Existing technology probably has already been stretched to the limit of economic utility; new technology will be required to exploit many of our known reserves of mineral materials and to convert submarginal or uneconomic resources into reserves if we are to be sure of an adequate mineral supply. However, the mineral industry is unlikely to develop innovative technologies unless given some incentive to do so.

As new ore deposits become more difficult to find, the mineral industry will have to develop improved or innovative exploration technology, particularly for deposits lying deep in the earth's crust. Better mining techniques will also be needed for many deposits. As labor and material costs rise, underground mining operations will probably become increasingly mechanized. Mining methods that cannot accommodate increasing mechanization will probably disappear over the next decade or two. Continuous-mining methods will tend to replace cyclic mining methods for all but the hardest and lowest grade ores during the next 20 years. Mining methods will tend toward use of equipment that achieves low unit operational costs through application of flexibility, reliability, low maintenance costs, and worker acceptance rather than increased size or capacity. Research objectives and programs related to the increased mechanization of mining operations and the development of continuous-mining systems for so-called soft rocks have been reasonably well defined, and progress is being made. However, research on continuous-mining systems for hard-rock materials requires much more work. Open-pit hard-rock mining is especially in need of improvement; it is rapidly reaching its maximum efficiency because of energy constraints and the need to move large tonnages of rock and ore.

The developing technology for in situ leaching of fragmented ore bodies is particularly promising because it could reduce the capital costs, and perhaps operating costs, of producing metals from low-grade ores, e.g., some copper and uranium ores. It should also permit the mining of relatively small and deep deposits, and thus avoid some of the serious environmental problems encountered with conventional mining operations. More importantly, it would eliminate costly mine haulage, crushing, and fine grinding--the more energy-intensive operations in conventional mining and ore treatment. However, in situ leach mining uses considerable energy in preparing and fragmenting the ore body to be leached and in pumping solutions to fairly great heads. It is not yet possible to tell what the net energy savings might be.

New technological opportunities exist in extractive metallurgy for recovery of mineral values now lost in the slimes that result from treatment of finely ground ore particles. The value of these lost materials can be immense. However, the technology for processing fine particles to recover mineral values is largely undeveloped and the problems associated with finely divided waste materials are extensive.

Technological advancements in the recovery of trace elements as byproducts of the mining and processing of primary mineral commodities from low-grade ores hold considerable promise for meeting certain mineral supply needs. A long history of successful operations for recovering precious metal byproducts from a variety of ores already exists, but there will be an increasing need to develop and apply new techniques in byproduct recovery as more low-grade ore deposits are exploited. In addition, added revenues will be required to pay the costs incurred in processing these low-grade materials. An important consideration is the energy conservation that may result, as in the byproduct recovery of molybdenum from certain copper ores.

Although today's technology is adequate for meeting many of the nation's near-term mineral requirements, its rate of advancement does not seem to be consistent with the demands that are expected to be placed on the mineral industry in supplying many mid- to long-term mineral needs. In the absence of a national policy encouraging technological advancement, and in the face of severe operational restrictions and financial difficulties in recent years, the mineral industry has fallen behind technologically. Clearly, this trend must be reversed if we are to avoid a serious downgrading of our capability to provide mineral raw materials to our industrial economy.

Many Americans believe that substantial technological effort should be directed not only toward maintaining a mineral production capability, but also toward reducing air, land, and water pollution in mineral operations, improving energy efficiencies in mineral extraction and recovery, and devising new methods of reclaiming lands disturbed by mining. Some effort is being given to these problems by the mineral industry, but major technological developments designed to meet social concerns about mineral operations are not likely to be undertaken unless dictated by law or stimulated by incentives such as cost and risk sharing by government. In the absence of a profit potential it is also unlikely that extensive technological efforts in the near future will be devoted to recycling used materials, no matter how socially appealing this may be.

CHAPTER 7

MINERAL DEVELOPMENT AND PUBLIC-LAND USE

Historically, much of the U.S. mineral wealth has come from federally owned lands, particularly those in the west, where rock types and geologic structures favorable to the formation of ore deposits occur widely. However, in the early days of mining the public lands were vast and essentially unrestricted for mineral exploration and development. It was common in the late 1800s for public land areas to be preempted for mining activities. Indeed, mining on federal land was encouraged because it generated revenues for the government and promoted settlement of the interior and western parts of the country. These consequences of early mining were central to enactment of the Mining Law of 1872, which was passed to stimulate further mineral exploration and mining activities on the public lands.

However, there have been notable changes in attitudes and regulations concerning the use of our public lands. Americans have realized that other uses of the public lands might be equally, or even more, beneficial to society than mining; a great number of laws and regulations covering activities on those lands has resulted. Yet federally owned lands remain vitally important to our mineral economy because their extent is so vast, and because--on the basis of our geologic knowledge--they are the most likely areas in which new mineral deposits will be found. Of our 2.2 billion acres of land area, approximately 760 million acres are still federally owned (U.S. Department of the Interior, 1977). They represent an important source from which future mineral and energy supplies can be expected.

Early laws and statutes generally favored mineral exploration and development on the public lands, but more recent legislation has tended to exert more control on mineral activities. This change in outlook was perhaps inevitable as the country became more settled, sources of revenue became more diverse, and Americans increasingly recognized valid alternative uses of the public lands for a wide variety of activities ranging from recreation to the protection of wildlife. A new social concern for preserving the quality of the environment has also had a marked impact on current views about public land uses.

A particular noteworthy occurrence has been the withdrawal of public lands from mineral entry. Beginning with the General Withdrawal Act of 1910 and extending through the Federal Land Management and Policy Act of 1976, the controls on mining activities on the public lands have increased. A number of special acts, such as the Wilderness Act and Public Law 94-429 (1976) relative to mining in the national parks, have also specified certain conditions under which mining may and may not be carried out.

An unusual land withdrawal affecting mineral exploration and development was the Alaska Native Claims and Settlement Act of 1974. Subject to valid existing rights, it withdrew vast areas from mineral entry. Much of this land withdrawal was intended to be temporary, pending settlement of native claims. Certain areas may be reopened to mineral entry at some later date, but presently very large areas having a considerable potential for mineral discovery are closed to mineral entry.

Currently nearly 70 percent of the public lands of the United States is either closed to mineral operations or is highly restricted to mineral entry, much of this as a result of the Alaska Native Claims and Settlement Act. Although these lands could be opened by Congressional legislation at some future time, it seems likely that the total acreage restricted or closed to mineral entry will remain large for some time. Legislation is now pending that would increase the land areas withdrawn for new wilderness areas. Little effort is being made to reassess withdrawn areas to determine if their mineral potential warrants reopening them to mineral entry. Yet, the reopening of many such areas could be of significant benefit to the economy.

Those in the mineral industry feel that many of the regulations governing the public lands discriminate against mineral exploration and development, especially for those areas where multiple or sequential land uses might be practical. However, others outside the industry believe that land-use regulations are belatedly taking cognizance of significant nonmineral values that have existed for a long time. The increasing expressions of feeling for environmental protection and other societal concerns involving the public lands are receiving more consideration today than at any time in the past. As a result there are conflicts among those who see the value of public lands from restricted points of view.

Resolution of these conflicts will be difficult because policy planners and decision makers at various levels of federal and state government now recognize legitimate ownership claims and alternative use potential for the public lands. As a consequence, many land-use decisions will be very difficult to make solely through a careful and orderly appraisal of factual information, and will have to consider value judgments, made through the political process, about tangible and intangible benefits to society. It is clear that the historical dominant-use concept of exploiting public lands for mineral materials no longer provides a completely acceptable basis for allocation and management of these lands.

As attitudes have changed about the management and use of public lands, better-informed perspectives and policies on land-use alternatives have become more vital. In particular need of reassessment is the contribution that can be made by federally owned lands through mineral production. However, the public lands must first be satisfactorily inventoried. Because much of the Mining Law of 1872 and Mineral Leasing Act of 1920 is outdated, we also need an up-to-date national nonfuels mineral policy. Such a policy, in concert with an adequate information base and provision for recurring review of the mineral potential of withdrawn public lands, would contribute markedly to establishing the proper role of these lands in supplying future minerals and mineral fuels to the national economy.

Resolution of the conflicts that involve vast areas of the public lands is a major concern for the mineral industry. Its achievement requires that the government come to grips with the long-standing problem of multiple or sequential use versus single or dominant use of our lands. A wide base of knowledge must be established so that informed judgments can be made about specific land uses. To withdraw public lands from mineral entry without an adequate information base about the mineral potential of those lands is ludicrous. Yet, large areas of the federal domain have not been evaluated for their mineral potential simply because the agencies now charged with that responsibility haven't enough manpower to do the job. The fact that various Congressional Acts provide for an assessment of the mineral resource potential of lands withdrawn for some other purpose is of little import if that assessment can be put off indefinitely. Until an adequate evaluation of mineral potential has been completed it will be difficult to resolve land-use conflicts for the maximum benefit to our society.

CHAPTER 8

MINERAL DEVELOPMENT AND ENVIRONMENTAL QUALITY

Multiple use of our land resources sounds excellent in theory but has its complications and pitfalls in practice. It is successful only where the activities, concurrent or sequential, are-- or can be made to be--compatible. Unfortunately, mineral exploration and development must take place where mineral deposits occur and cannot be relegated by law to more "suitable locations." As a result, a conflict with recreation, watershed protection, and preservation of environmental quality is unavoidable. This conflict is exacerbated by the fact that mining companies--relying on custom and practice, the several mining Acts, and the work of various commissions to support and to encourage the exploration, development and production of minerals on public and private lands--have tended to adhere to the dominant-use concept.

The public attitude, which once supported a preferred position for mineral resource development, has changed considerably in recent years, and may account for the lack of official attention given to implementing the broad provisions of the Mining and Minerals Policy Act of 1970. Instead of pursuing the Act's provisions for encouraging and fostering mineral development, federal action in the past few years has tended toward restraints on the mining industry's use of public land and control of the mineral processing industry's impact on the environment. Efforts of citizens and their elected representatives to protect air and water quality, to add to the National Wilderness Preservation system, to end mineral entries in the national park system, and to pass a strong federal surface-mining law demonstrate the public's unwillingness to rely solely on industry's good intentions and expressions of concern for the environment.

Determining the best use of land through a purely economic assessment of the most dollars generated per acre, which tended to favor mineral development over the short and mid term, is no longer acceptable. It is now public policy that mineral exploration, mining, mineral processing, and mine waste disposal be carried out with limited disturbance of the environment. In the process of striking a balance between the need to produce mineral materials and the need to protect the environment, standards and regulations have been established that place constraints on the mineral industry and add to its costs. The current price structure has been unable to sustain a rate of return on some commodities that justifies investment in mineral development. Delays and possibility of judicial interruption of a project further reduce private industry's incentive to develop mineral resources. Nevertheless, there are numerous ways in which the problems of mineral development and environmental quality may be addressed (see, for example, NRC 1973a, NRC 1973b).

Because the mineral industry must make a profit while meeting the public's material needs, it views the basic triad of material, energy, and environment differently from the way a person or organization concerned about our planetary life-support system sees the problem. Many of the differences can never be resolved to the total satisfaction of all. Yet it is essential that they be understood if the tradeoffs necessary to achieve an optimum compromise between the mineral industry, environmentalists and others are to be agreed upon.

Those responsible for mineral development do not believe that the general public accurately perceives the cost of environmental protection in terms of a possible reduction in their material standard of living and the eventual impact that restricting domestic mineral output might have on them personally. Nor are those sympathetic to industry needs certain that the public recognizes and is willing to accept the ultimate necessity for covering the cost of maintaining air and water quality and restoring the land. People directly engaged in promoting environmental goals, however, are not unaware that additional costs for meeting these goals must be passed along via some combination of higher prices, lower stockholder dividends, and perhaps even constraints on pay raises to workers. The informed environmentalist regards full cost pricing as a proper employment of the market system, for it places the burden of payment for environmental protection on the users of the product or anyone else who has received an unearned benefit. Although straightforward in concept, this pricing strategy is difficult to apply to a mineral commodity responsive to international markets, because its application could place the United States at a disadvantage in the world market and cause serious impacts on national security and consumer welfare.

In the extreme case, environmental protection can place a barrier against any development whatsoever. There is a social cost in denying mineral development, lumbering, or any other development, in terms of the various returns lost--such as jobs or lower cost goods for the consumer. However, there are certainly cases in which land uses other than mining are desirable. These other uses could provide as many or more jobs than mining. Tourism, recreation, and other activities with lower environmental impact are land-using, job-creating activities that may compete regionally with mining. In some cases, particularly if these alternative activities are labor-intensive, there may eventually be a net advantage in jobs if a region chooses a nonmineral alternative. Nonetheless, mineral production will continue to be essential to our economy, and in the national aggregate there must be a self-sustaining mix of mining, manufacturing, and service activities. The development of mineral resources, like agricultural production, represents new wealth to the economy.

Controversy between those favoring mineral development, alternative land uses, or even nonuse, reaches a particular intensity where public lands are concerned. These lands hold a large share of our mineral riches, but they also have a host of other attributes. Those interested in watershed protection, clean water, open space, recreation, or wildlife protection have a special concern for protecting the nonmineral attributes of public lands coupled with a sense of the public's ownership that they feel requires public participation in land-use decisions. Their strong feelings of heritage and intergenerational responsibility conflict with the feelings of those who are attracted by geologic conditions favorable to mineral exploration.

The miner sees the commitment of land surface to mineral extraction as limited and transient. The total surface disturbed at any given time is remarkably small and over a few decades some of the land will yield its mineral wealth, be rehabilitated, and then be turned to some other use. Given the tremendous rate at which Americans consume mineral products, then access roads, water consumption, spoil banks, settling ponds, and open pits seem to be a small price to pay for the mineral materials obtained. But rehabilitation and good land management are not without cost. Yet, without them roads and removal of vegetation can start erosion, leaching and silting can destroy downstream fish and wildlife, and some fragile areas can never be returned to their original state, or even an equivalent value of it, for some of the impacts of mining are unavoidable and irreversible.

The rapid change in the national energy position in recent years has provided warning that the impacts of mining on land use and natural environments may increase. Mining will become more energy intensive, while at the same time new energy facilities will require additional mineral materials; in effect, the two conditions will feed upon one another. The expansion of large-scale coal mining could result in major disruptions of the terrain and ecosystems in some regions. Solar, nuclear, and geothermal energy developments will create new demands upon land areas and in many cases these demands will be different, but no less important in scale and impact, from those that we have experienced before. Planning for such developments and their repercussions on land use and environmental quality will involve long lead times, and will require the anticipation of needs a decade or more in the future.

Resolution of the conflicts between mineral development and environmental issues will require research, reconsideration of policies, new legislation, and administrative changes. Research will be needed to make certain that standards are set at an optimal level to serve society's interests, that technology improves material handling to the point that the environment is safeguarded through every step of each process, and that all land subjected to surface mining is appropriately restored and revegetated. Conflicting policies must be reexamined and subsequently reformulated into policy suitable to the needs and desires of today's citizens. Administrative changes can remove some of the annoyances to industry: regulations should be simplified, repetitious reporting to numerous agencies reduced, and forms shortened.

Legislation may be needed to establish a compromise between resource development and environmental protection that will best serve society. Certainly Congress should exercise its oversight function vigorously as it did in passing the Surface Mining Control and Reclamation Act of 1977, which is aimed at protecting society and the environment from the adverse effects of surface coal mining. However, it is also important that laws remain unchanged long enough to be effective. Frequent amendment and modification invite those whose interests are affected to spend time and money seeking loopholes and litigating rather than sincerely working to meet the law's goals.

An acceptable balance between resource development and environmental protection is most likely to be achieved when industry, citizens, officials, and organizations enthusiastic about material development and those ardent for environmental quality accept the fact that both values are essential to society. Lip service to this effect must be replaced with genuine, sustained effort to work out compromises. Freezing to death in the dark or expiring from lung disease and toxic waters should not be alternatives posed by either side. Tangible and intangible factors on both sides of the issue must contribute to the end result.

No national mechanism currently attempts to integrate conflicting economic and environmental policy. Many federal agencies have legal responsibilities for dealing with the policy elements listed above. Congress has the constitutional responsibility to set national policy, and in the final analysis only it can develop a comprehensive national program that will balance mineral development with maintenance of environmental quality.

CHAPTER 9

CONSERVATION OF MINERAL MATERIALS: METHODS AND MOTIVATIONS

Concern for the finite limits of resources, particularly following a period when there have been dislocations in supply and sharp increases in price, has led to emphasis on national benefits from conserving materials. An appeal for more conservation rarely prompts major objections. To the contrary, it brings to everyone's mind an array of worthy objectives: elimination of waste, extension of the lifetime of mineral supplies, and protection of the environment. Little thought may be given to how effective conservation can be, the economic impacts that will accompany it, or the recognition that achievement of a desirable saving by one can place costs or burdens upon another.

The perception of "conservation" shifts depending upon the goals of the individual or organization involved. Conservation to the mining engineer suggests physical efficiency relating to maximum recovery of the mineral values from the deposit. To the consumer, it may denote using less, using it longer, or reusing it. For the preservationist, nonuse may represent ultimate conservation by preventing consumption. In its total context, conservation is all of these things, ranging from a need for austerity to capitalizing on conservation practices that would improve the public's welfare.

Despite its public acceptability and respectability, the practice of conservation is rarely cost free; the immediacy of its effects may be limited, and its initial impact may be diluted over time. An economist would wish to expose conservation programs--as are many development projects--to a form of national cost-benefit analysis. Although cost-benefit analyses rarely provide a clear choice of action, they do provide a better appreciation of all dimensions of the conservation process. Ultimately, however, many conservation programs will have to reflect differences in people's value systems and as a consequence decisions will tend to flow from the political process.

A critical examination of conservation in general, and programs or policies in particular, tends to be bypassed in our predilection to move directly from broad-gauged pronouncements that "we must conserve," to the operational particulars of such things as home insulation or improved programs of municipal solid waste management. At some point between goal setting and specific programs, an evaluation should be made of the social consequences of (a) altering a long-term behavior pattern with regard to material goods and energy, (b) investing in new capital and R&D for conservation and thus transferring funds away from current wasteful practices, and (c) reduced consumption.

Despite the good intentions of those who propose various forms of conservation, their individual goals and the consequences of their programs are not necessarily universally acceptable. Both the setting of objectives and the evaluation of conservation involve dealing with conflicts and tradeoffs. For example, an engineer may extract more ore per unit area of ground and thus enlarge our resource capability, but it may occur at the expense of more land disturbance and pollution. In the final analysis, the consumer serving the cause of conservation may pay more or may pay less for a particular product. An evaluation of conservation proposals does not always provide a neat and tidy answer as to the immediate net value of conservation to society.

The actual accomplishments of conservation are not always well understood. A plan that calls for less energy-intensive mineral processing, such as a change in steel or cement manufacture, or the use of recycled metals, can involve hidden costs, lag times, and physical limits. Time is required to get capital equipment into place and to meet logistic requirements before we can provide new mills or ovens or collect and process scrap materials. The feasible equipment replacement rate will determine how rapidly the national average consumption of energy per unit of output will change. But even if mineral processing plants begin to perform at a higher level of efficiency total energy consumption eventually will begin to climb again simply because of increasing numbers of processing units on line. The rate of increase in energy use per barrel of cement or ton of steel will obviously decline as plant and processing efficiency improve, but depending on one's perspective, conservation of energy may or may not seem to have taken place. Likewise, the limits to conservation in a recycling program is open to question for it is tied to the total stock of metals in use and by the proportion amenable to recovery that becomes available each year for recycling.

Even if the required value judgments have been made and anticipated benefits are found to exceed the estimated costs, conservation still must be made attractive by a policy strategy and careful selection of measures to be employed. Normally there are three courses open: (1) reliance upon market forces to motivate self-interest,(2) employment of government policies and regulations to shape market forces or consumer behavior, and (3) use of educational programs and promotional information tactics to inform the public about conservation and to encourage the practice of conservation measures.

The lack of administrative costs, the self-correcting features, and the constancy of the leverage applied to the firm or individual has always weighed heavily in favor of using the marketplace where possible. The response by industry to limited, higher cost of natural gas over the past several years has continued to be impressive. However, there are lags in the system due to the necessity of making changes in the stock of capital assets. Also, there are imperfections in the marketplace that may lead to reactions to the market signals that are complex and often perverse or unpredictable.

Government involvement in conservation brings taxes, incentives, compulsory standards, and other regulatory powers of government into play. Direct and predictable actions, which involve the greatest costs of any operation, are not always matched by real accomplishment and cost effectiveness. Yet, such direct actions as the introduction of taxes on horsepower, expansion of public services, or improvements in building methods offer attractive routes to mineral conservation.

It may be that government policies designed to guide consumption practices along more informed paths will become more common in the future. Information on energy efficiency in appliances is a prime example. It is a bit more complex to educate the consumer to more carefully balance price against operating costs and product life. Government purchasing policies and demonstration projects are other approaches. The indirect nature of such programs and the limited knowledge as to their effectiveness makes it difficult to determine how much and what kind of government effort will be worthwhile.

Conservation has always had a moral appeal even though it has not been practiced to the extent many felt to be appropriate. However, as concern for conservation has grown more serious in recent years, public attention has been directed increasingly to the need for its implementation. Energy conservation is currently in the limelight, and suggestions for specific programs are not lacking. Since conservation is expected to remain an important issue--for energy now and later for minerals--a greater appreciation of all its dimensions as an important element in our resource future is necessary.

CHAPTER 10

SOCIOECONOMIC IMPACTS OF MINERAL DEVELOPMENT

Contemporary public opposition to domestic mining operations may seem to be rooted in local reaction against any large-scale alteration of the natural environment by modern surface mining of coal, open pit recovery of ores, and other mining activities. But concern has become more broadly based because of the realization that mineral developments can have severe socioeconomic impacts on a community, or region, and its residents. "Socioeconomic impact" may be defined as an effect of rapid change, usually externally induced, on the social and economic conditions and on the people and institutions that make up a community or system of communities. If the impacts are disruptive or costly they are identified as negative.

Opposing disruptive mining activities and their negative socioeconomic impacts are environmental organizations made up of city dwellers seeking to preserve open space recreation areas, hunters and fishermen, farmers and ranchers, and many others who want to avoid possible pollution and environmental degradation. These organizations feel there is little reason to believe that there will be satisfactory reclamation of disturbed lands or that air and water quality standards will be observed. Even where assurances of environmental protection are made, there remains local opposition to developments which involve changes in the accustomed way of life and which threaten loss of direct control of the community over its future.

Changes affecting the general way of life are perhaps most severe in the mining boom town. Many people, especially in our western states, have experienced living conditions in mining boom towns and are well aware of the problems resulting from rapid urban growth, but attitudes toward such towns have changed. In the late 1800s and early 1900s a new mining town was a magnet attracting people seeking personal riches. The dream of personal wealth was incentive enough to keep men and their families in truly primitive communities. This is no longer true. There is now a growing feeling that the boom town is apt to be a bad place to live and to do business--even for the mining firms themselves. The last mining land rush that fascinated the individual prospector was in the late 1950s, when the public lands in Colorado were open to uranium claim locations. Few profited in any substantial way from this boom in uranium activities.

Current mining boom towns attract people looking for construction and mining jobs, but the people are different. So are their motivations. Both single and married men have higher expectations for their standard of living. Families are concerned about the adequacy of schools, health services, housing, and stores, because the mining boom town--its population growing as much as 40 percent per year--usually does not provide satisfactorily for these services. In the absence of the old dreams of quick fortunes, the present-day compensation often is not worth the deprivation that is encountered.

Workers' wives console themselves with alcohol, seek out the mental health center, or appear in the divorce court. The children get in trouble (in Craig, Colorado, crimes against persons increased tenfold between 1974 and 1976 as the population doubled). Dissatisfied workers with unhappy families leave their jobs or perform poorly when at work. Productivity in mining and construction can fall steeply, possibly as much as 25 to 40 percent in one year.

Concern for these negative socioeconomic impacts is evident in the National Environmental Protection Act (NEPA). The primary thrust of the Act and its mandatory environmental impact statements seems directed toward identification of the more traditional effects--the physical disruption--of activities on the natural environment. However, the Act also directs attention to federal actions that significantly bear on the quality of the human environment, either by directly affecting human beings or through adverse effects on the environment.

The guidelines for preparing environmental impact statements have been detailed in court decisions, one of which "held essential to a NEPA study" such factors as the impact of the proposed project on the "quality of the community services--such as deterrence of crime, police protection, schools, hospitals, fire protection, recreation, transportation, and commercial establishments" (Trinity Episcopal School Corporation vs. Romney [1974]). In another decision, a federal court held that an environmental impact statement must address the problems of mitigating an inadequate infrastructure to serve the population involved when a federal facility was moved to a new location (Prince George's County, Maryland vs. Holloway [1975]). As a consequence, addressing potential social impacts has become a major part of the work in preparing environmental impact statements for mineral developments.

Because resource extraction and its outputs are pervasive and intermingle with most of the social subsystems of American society, it seems evident that the socioeconomic impacts of resource development, substitution, and change can be expected to be far-reaching. In particular, energy development will precipitate many changes--often rapid and often externally induced--that affect a community's (or region's, or state's) social and economic systems or activities. Some of these changes are likely to be disruptive or costly to some element of the community.

Negative socioeconomic impacts do not occur only in booming mining towns. Other vulnerable targets are on-shore service centers for off-shore resource extraction and mineral processing or conversion facilities in isolated communities far from large urban centers.

In light of the foregoing discussion, several classes of negative impacts can be considered:

1. Jurisdictional conflict and mismatch. This occurs when one local governmental jurisdiction benefits from a new tax base and another hosts the additional population and must finance the services.

2. Competition for scarce resources. In the arid western states, the diversion of water from agriculture to mineral processing or transportation or to reclamation of mined land is seen by many as a serious threat or negative impact.

3. Shifts in comparative advantage. These involve threats to or degradation of the existing resources and services upon which a region's economic and social structures depend. Western tourism and agriculture may be threatened by mineral development, as may be east coast fisheries.

4. Urban boom problems: shortfalls in infrastructure financing, housing problems, and social disruption. Problems stemming from a population growing at too fast a rate to be properly accommodated in a community are among the severest negative socioeconomic impacts of resource developments. A notable and recent demonstration of this is seen in the growth of Ft. McMurray, Canada (see Maugh 1978:758).

Who deals with these negative socioeconomic impacts? The federal government seeks to anticipate impacts resulting from major federal actions with its environmental impact statements. Various suggestions for mitigating impacts (and occasional actions) come from these statements. Coastal zone management and its Coastal Energy Impact Program make planning and loans/guarantees/grants available in some cases. Increased mineral leasing royalty shares have been allocated to the public lands states for attempts at impact mitigation.

Various states have established mechanisms to ease impacts. Kentucky is taking initiatives to augment housing. Montana's 30 percent coal severance tax is partially earmarked for coal area roads (as is Kentucky's), for school equalization funds, and for grants to impacted communities for facilities and services that their regular revenue won't provide. Wyoming employs several of the above mechanisms and uses its plant-siting law (which also applies to large mines) to negotiate stipulated assurances from the applicant company that it will take actions to mitigate negative impacts.

Members of industry respond in varied fashions. Those in some firms avoid the socioeconomic issues entirely. Others make grants to local governments for planning or for schools and clinics. Many furnish and subsidize housing, and a few new company towns are found.

Negative socioeconomic impacts are merely inconveniences to some individuals but they may range from traumatic personal experiences to tremendous cost and time overruns on resource development projects. Development planners are finding them to be major management challenges. Few executives ignore them more than once. Ideally, attention to the socioeconomic impacts of mineral resource development should come at some early stage in planning a mineral operation. Indeed, timely anticipation of potential negative impacts is clearly essential if they are to be avoided or held to some minimal level of acceptability. Society's increasing concern for the consequences of mining suggest that the negative socioeconomic impacts of mineral development will receive greatly increased attention in the planning and conduct of future mineral operations. However, the positive consequences of mineral operations must also be given due consideration in any mineral production plan.

CHAPTER 11

CAPITAL FLOWS INTO MINING

From 1950 to 1957, annual expenditures by the mining industry on new plants and equipment grew from about $800 million to $1.7 billion. This outlay represented a relatively constant fraction of total U.S. business expenditures on new plants and equipment, ranging between 4.2 and 4.7 percent. Capital expenditures peaked in 1957 for all business, and then fell in the following years. By 1962, total business capital expenditures had regained the 1957 peak level, but recovery in mining was delayed until 1969. In terms of 1972 dollars, total expenditures of all business regained their 1957 level by 1963, but recovery did not occur in mining until 1972. In the absence of data on other uses of capital in mining (e.g., purchase of leases, expenditures for exploration), we can only assume that these outlays varied in accordance with expenditures on plants and equipment.[1]

Its lag in growth of capital equipment expenditures meant that mining accounted for a progressively declining share of new capital outlays. During most of the 1950s, mining accounted for about 4 to 4.5 percent of the total. In the 1960s, the fraction ranged between 2.5 and 3.5 percent, where it has remained through 1977, as estimated from preliminary data. This relative decline in the flow of investment capital into the mineral industry is also reflected in the volume of mineral materials produced. Between 1957 and 1974, the index of physical volume of production[2] showed that our mineral output rose about 40 percent. However, over the same period, the GNP--in constant dollars, which is as close as we can get to a measure of total physical output--rose by about 78 percent. Clearly, the mineral industry now constitutes a relatively smaller fraction of the total economy than it did in the late 1950s.

One might argue that the relative decline of capital flow into domestic mineral production as contrasted to total business capital flow resulted from increasing imports of mineral materials, but this is not the case. From 1955 to 1973, total imports of minerals and mineral fuels remained fairly steady at about $3 billion per year, a figure that probably represents an actual decline in imports if inflation is considered.

Imports and exports cannot account for the divergent rates of growth of capital investment in mining relative to the overall economy. The role of minerals in the economy has declined. The increasing importance of nonmineral goods has much to do with the relative decline of capital flow into the mineral industry, but we cannot conclude on that basis that the mineral industry is not vital to the national economy. It will continue to play a critical role in our national security and economic well-being.

If American demand for minerals rose to correspond to the relationship with GNP prevalent in the middle 1950s, a deficiency in production capacity would probably result because of the relative decline of capital flows into mining over the last 20 years. However, such a deficiency should be short-term unless special circumstances prevented the mining industry from competing effectively with business as a whole for its share of available capital. There is reason to suspect that the mining industry displays special characteristics that affect its attractiveness for new investment, but it seems unlikely that they could destroy the efficiency with which domestic capital markets behave.

Various factors determine the effectiveness with which mining and mineral processing are able to compete in capital markets for their share of capital funds. For example, the uncertainty and character of the exploration process is unique to the mineral industry, making the risk of investment much greater than for many other enterprises. Land-use regulations as well as modes of land allocation and administration by landlords are especially binding on the mineral industry and often place constraints on potential investment returns, thus discouraging investment flows and increasing the difficulty of obtaining capital funds for mining ventures. Further determinants of the ability of the mining industry to compete for capital are laws, some over 100 years old, relating to location of minerals on federal lands, rights of prospecting and patent acquisition, size of mining claims, nature of mining claim records, and efficiency with which landlord agencies administer the land. Not surprisingly, there are frequent calls for a revision of federal mining laws that would give public agencies more positive control over access to and exploitation of public lands, and extend greater protection to those who invest in exploration and development of mineral resources (NCMP 1973, Kneese 1976).

Tax and other special benefits granted to American corporations that do business abroad may favor investment in foreign rather than domestic mineral exploration and production. These benefits include insurance against certain political and business risks, favorable terms granted by the Export-Import Bank for exports of machinery and equipment, income tax credits for payments to foreign governments, tax deferrals on foreign subsidiary income until repatriated, and reduced corporate tax rates on Western Hemisphere trade corporations. These incentives for foreign investment, however, may be negated by political and other uncertainties in foreign operations. Existing federal policies toward foreign investment should be reviewed to determine if differential tax and financial advantages between investing at home and abroad are in need of adjustment. If they are, the differences in risks and benefits should be accounted for in capital markets and reflected in capital flows. Capital will then flow both domestically and abroad in amounts that reflect economic efficiency rather than in response to special subsidization by the American taxpayer.

Depletion allowances are still debated, with considerable authority to be found on both sides of the issue. The National Commission on Materials Policy recommended continuation of percentage depletion "...until a better incentive system [for discovery and development of mineral resources] can be developed" (NCMP 1973: 4B-12). More recently, the National Commission on Supplies and Shortage, concluded that "...the benefits do not appear to be proportionate to the cost" (NCSS 1976:164). The Commission's judgment relied considerably on the arguments of Edward Miller (1975:241-255), who pointed out that while the depletion allowance is computed as a deduction from gross income at the statutory rate multiplied by gross production, it is limited to one-half net income. This constraint means that a firm does not extend the margin of production significantly beyond the point it would if there were no depletion allowance. The depletion allowance offers very little incentive for a company to bring deposits of marginal profit into production. The NCSS believes that although percentage depletion attempts to encourage investment in mining, it has undesirable side effects such as the diversion of capital from geological and geophysical exploration to deductible expenditures. A more efficient method of investment support can probably be devised if special subsidization of the mineral industry is deemed to be in the public interest.

Another more general tax impact on investment flows is the corporate income tax. Since corporations must compete for capital funds against other monetary demands, pre-tax marginal corporate earnings may have to be larger than for other types of ventures if corporations are to offer an adequate return after taxes to the corporate investor. As a result, more money may flow into alternative uses and less money into corporate investment than is consistent with maximum economic efficiency in providing the goods and services supplied by the public and private sectors. As the amount of earnings necessary to attract capital increase, the time perspective of the corporate sector will shorten and compel it to favor projects with relatively rapid return. Mining that involves relatively long lead time or relatively heavy front-end investment per unit of product can be especially sensitive to a higher discount rate used in project evaluation. If changes in the corporate income tax reduce penalties against long pay-out periods, more funds would be attracted by corporate activities for which the marginal rate of return was lower than it is presently, and the incentive for long-term mineral development ventures would be increased. However, if any decrease in current production rates resulted, losses in public revenue would be suffered. These would have to be compensated for by greater reliance on other sources of taxation, such as personal income taxes, coupled with restrictions on corporations on their retention of earnings versus payment of dividends.

Other monetary and fiscal changes should be encouraged. High interest rates stimulate mining methods that emphasize current production at the expense of ultimate recovery and divert capital from activities that require long lead times. Such high rates are produced by economic instability, during which periods of lowered investment and increased unemployment alternate with periods of strong demand for capital, increased employment, and strong inflationary pressures. In recent years, inflation and economic stagnation have coexisted in reflection of peculiar combinations of cost increases or cost rigidities and declining markets. In response to worldwide economic uncertainties, the fluctuation of primary material prices, including minerals, has exceeded that of prices in general. Corresponding fluctuations have resulted in mineral output and investment in new capacity in the mineral industry. In short, a reduction in worldwide economic instability will have a relatively stronger beneficial effect on mining and mineral processing than on industry and economic activity in general.

Minerals are, for the most part, traded in world markets, and unless the United States severely restricts both imports and exports, the domestic industry cannot separate itself from world conditions and the need for flow of capital into world mineral resource development. To assure a stable economic environment that will encourage inflow of capital on terms comparable to those available to other industries, various forms of economic stabilization specifically devised for the mineral industry have come under closer scrutiny. Stabilization can be attained by international price agreements and internationally controlled stockpiles designed to make the price agreements effective, or by national stabilizing mechanisms coupled with some insulation from world markets. Even if there are international price agreements, the mechanisms devised to make them effective might be international, solely national, or some combination of the two.

Since the merits of stabilizing mechanisms rest upon effects on the rate of capital inflow, long-run efficiency of mineral production, and the degree to which stabilization policies achieve optimum rates of mineral exploitation, the issues are more complicated than are revealed by the arguments presented so far on either side. Further investigation will be necessary before a satisfactory conclusion can be reached.

Even if capital markets are made more efficient as a result of changes in the tax structure, and even if we realize increased economic stability by adoption of appropriate monetary, fiscal, and price stabilization policies, the long-run problems created by dependence on world markets and other nonmonetary elements of national objectives still remain. What is the worth of increased independence, or increased capability of controlling world markets, or increased concern for the welfare of future generations, and what devices are most suitable for attainment of these objectives? Possibilities that should be considered are stockpiling and direct subsidization through special financial agencies designed to stimulate capital flows into domestic industry and to provide funds at relatively low cost for exploration and developmental work that is too costly when measured against current interest rates.

In summary, proper policy toward the mineral industry will not guarantee adequacy of capital to achieve everything that the industry wants, since we live in an economy in which rationing by the market system and by occasional direct administrative control is unavoidable. However, by making appropriate changes in tax laws, by reducing severe fluctuations in the economy as a whole, by adopting specific stabilizing mechanisms for important minerals, and by using carefully devised subsidy methods for limited objectives where market processes fail, the normal functioning of markets should assure the mineral industry of sufficient capital to provide for the timely flow of the mineral materials needed to meet consumer demand.

NOTES

1 Data on expenditures for new plants and equipment and GNP taken from the Economic Report of the President, (1977) Tables B-43, B-1 and B-2, respectively. Plant and equipment expenditures were converted to constant dollars by use of the nonresidential fixed investment deflator, Table B-3.

2 Data on production taken from _Minerals Yearbook 1974_ (U.S. Bureau of Mines 1976), Tables 1, 2, and 3; _Historical Statistics of the United States_, Bicentennial Edition, Part I, pages 582, 584, 585 (U.S. Bureau of the Census 1975); _Statistical Abstract of the United States_ 1974 and 1976 (U.S. Bureau of the Census 1974, 1976), section on Mining and Mineral Products.

CHAPTER 12

INSTITUTIONAL CONFLICTS AND GOVERNMENT INVOLVEMENT IN MINERAL RESOURCE AFFAIRS

Public policy with respect to mineral resource issues is properly a governmental responsibility. Historically, the federal government has been concerned primarily with matters pertaining to minerals found on public lands, interstate commerce involving mineral commodities, import and export arrangements, and national security requirements. Most of the local, operational concerns were left to the states.

Regulation of mineral production practices, taxation of mineral commodities, and most beneficiation activities have been under the direct supervision of individual state governments, and each state's policy reflects a broad range of public attitudes toward mineral resource development (attitudes influenced to a significant degree by the role various mineral commodities played in the economy of the area). As an example, early steps to insulate petroleum from the market instability of the "rule-of-capture" era were taken by individual states rather than by the federal government. The Interstate Oil Compact Commission, chartered by Congressional action in 1935 to provide leadership in petroleum conservation, was an initiative of the individual states.

With a few exceptions, the states rather than the federal government were involved in developing policies with respect to mineral resource matters throughout the early history of our country. The regional nature of most mineral resource issues and the fact that much of the land undergoing mineral development was not sought for other purposes combined to account for an early lack of concern at the national level. The federal government did exercise more authority over mineral resource matters in times of national emergency, but such action was limited both in scope and duration.

An exception to this past practice was the federal government's role in the development of nuclear power. Uranium production, sale, beneficiation, and utilization have been continuously regulated by the federal government under a doctrine of overriding national interest. In recent years, however, national interest considerations have begun to spread across an ever-expanding number of mineral resource activities. Passage of legislation dealing with occupational health and safety and with environmental concerns of air and water have found federal involvement appearing in virtually all aspects of mineral development.

As the federal government continues to expand its mineral resource involvement, the line of demarcation between state and federal areas of responsibility has become increasingly difficult to determine. At present, federal interest in mineral resource policy extends beyond matters solely of national impact, and federal intervention frequently comes into conflict with existing state policies. Jurisdictional disputes occur more and more frequently, and are difficult to resolve, especially in the area of mineral production regulation.

An additional area of federal-state conflict exists where federal policies define a course of regulatory action but direct the states to implement that action. This imposes personnel and financial burdens on state governments--in many instances without appropriate federal support. Although reluctant to default to the federal government, the states recognize that they lack the skilled manpower needed for effective enforcement of many regulatory standards.

Moreover, because much of the federal role in public policy development with respect to mineral resources has received its impetus from growing public dissatisfaction with the quality of life, its impact on the mineral industry has tended to be restrictive. Lack of agreement within our society about what constitutes "the good life" has further compounded the problem and led to conflicting federal policy decisions within the federal establishment. These conflicts, together with federal-state jurisdictional disputes, can be detrimental to orderly development of the nation's mineral industry.

As we face the problem of dealing with the regulation and administration of regional resource development, the long-standing question of states' rights versus federal preemption will surface repeatedly. This is merely the upper layer of the jurisdictional problem; beneath it are found conflicts between individual states, between state and local governments, and between counties and communities. Each of these various political entities desires some positive role in the decision-making process--not necessarily control over the decision, or even a veto power, but at least a say in the magnitude of development, the pace at which it proceeds, and how sites are chosen and permits issued.

For some of the more sparsely populated areas of the United States large-scale modern mineral resource projects have caused concern, since they can create a large transient construction force followed by the immigration of 10 or 15 thousand new permanent residents. The millions of dollars of public funds required in advance of actual production to prepare for new residents is more than some communities can handle unaided. In the arid and semiarid states, the need for front-end financing is coupled with the problem of allocation of scarce water supplies.

The federal government must continue to meet its obligation to manage the public lands and to make appropriate use of their resources. This responsibility involves alternative use decisions, land-use controls when the federal government is the principle owner, exercise of environmental protection, disbursement of resource revenues, and timing of the commitment of resources to use. The states have a parallel set of concerns that encompasses the totality of private, state-owned, and federal lands within their borders. However, federal actions are not necessarily similar or even compatible with the preferences of individual states. The actual or latent conflict between the state and federal jurisdictions opens the door to delicate legal, constitutional, and political problems. The appearance of terms such as "balkanization" and "colonization" in the statements from resource producing states are countered by references to "OPEC-type" actions by the consuming states. Much of this can be discounted as rhetoric, but the potential for antagonism is real.

Still, the federal government, despite the size of its holdings, cannot "go it alone" and must seek some form of concurrence by the states. On the other hand, it cannot capitulate totally to the wishes of individual states. The national optimal resource and environmental strategy is not a sum of decisions that appear optimal to individual states or regions. Concurrence on what is optimal will be facilitated by state participation early in the resource planning process and by opportune expressions of preferences or choices among alternative resource development plans. Effective methods must be sought for developing resource strategies within a reasonable time span.

While federal environmental requirements can be exceeded by more stringent state standards, and a significant amount of the enforcement will be in state hands, the federal government is expected to exercise considerable influence on land-use planning where it's holdings are extensive.

However, the urge against isolating federal and state efforts seems strong.

The federal government has shown a sympathetic inclination toward the financial burdens of areas impacted by its decisions. The form and magnitude of any aid to relieve these burdens is still debatable. The states would probably gravitate toward a more-the-better position and sell their cooperation at the highest price the market will bear. The firms developing resources would also seek their share of contributions to the public funding efforts. A reasonable measure of restraint and skepticism would be needed to counter these demands. Otherwise, marginal projects would appear where the fact that the social costs outweigh the social benefits has been disguised by external assistance. Federal funds should not provide preferential treatment for state or private activities that cannot eventually pull their own weight.

A concerted effort should be made to establish and define the federal mineral policy in relation to that which is to be reserved for state government. This clarification will assist in developing the role of the federal establishment, the responsibilities of the individual states, and the private sector's sphere of operation. Whatever policy is developed, adequate incentives for free enterprise must be maintained, but within a framework that provides for appropriate environmental safeguards and accommodates decisions relative to the use of public and private lands. The federal responsibility is generally expected to remain broad, while the states deal with the specifics of mineral development.

Yet, the list of potential state-federal conflicts is a long one and will require continuing attention. The need to cope with rapid and large-scale changes will generate considerable stress in dealing with these conflicts. We are still far short of a point of complete confidence in our ability to manage institutional problems. Mutual confidence must be established between federal and state government, between environmentalist and industrialist, and between citizen and government official. Much of this trust will result from better performance at the administrative or operational level. While even good legislation cannot create cooperation, confidence, or compromise, it can foster them. The research community can provide information and understanding and thus help those who function within our institutional framework to make better decisions.

CHAPTER 13

MANPOWER RESOURCES AND NEEDS

Fundamental to a technological society is the availability of well-trained individuals who have the creative ability to innovate and the necessary skills to carry out the physical aspects of work in a given field. Of particular importance is the need for technically trained individuals having the knowledge, motivation, and support capability needed to improve our technology at a rapid enough pace to sustain our competitive position in the world economy and maintain our high standard of living. Skilled, physically capable individuals are also needed especially in areas such as the coal mining industry, where needs for increased production are already upon us.

Many feel that our trained manpower resource base must be increased, although some have argued that the need for increased manpower, especially for individuals with physical skills, will be more than offset by technological developments in mechanization, etc., and that higher productivity can be achieved with less total manpower. But technological progress in the United States appears to be slowing down, according to the Seventh Annual Report of the National Science Board (National Science Foundation 1975), which pointed to recent declines in overall industrial productivity, a continuing decline in the proportion of our GNP spent for R&D and the continuing decline since 1969 of the proportion of scientists and engineers engaged in R&D. Many foreign nations are outpacing us in these areas of endeavor. Our patent balance is also declining; an increasing number of patentable ideas is now coming from foreign countries.

The need to improve our manpower resource base in the mineral industry can be traced to a number of factors. First, the fact that the mineral industry is increasingly turning to lower grade ores calls for a technological skill not needed in the past. Second, industry must now contend with environmental, safety, and pollution problems, the resolution of which requires technically trained people. Third, some industrial activities will necessitate skilled labor to handle the physical aspects of mining and processing of materials. A notable example is found in the coal industry, where many hundreds of skilled employees will be needed to meet projected goals of doubling coal production in the next decade. Some feel that just to sustain our present standard of living will require increasing activity in materials technology (NRC 1975:41).

The need to increase the manpower base in mineral resource fields has been stressed repeatedly in the past, but few attempts have been made to articulate the problems since the NRC published its views nearly 10 years ago (NRC 1969). At that time, the Council reported that annual production of new mineral engineering graduates was not increasing and that the supply of trained individuals would be insufficient to meet predicted demands of the next several years. The study, which focused principally on the educational aspects of manpower problems, noted the decreasing number of institutions offering academic degrees in mineral science and engineering, the increasing scarcity of first-rate mineral engineering faculty, and the deterioration of physical facilities needed for top quality educational and research purposes. Current limited student enrollments are for all practical purposes even further reduced by the presence of foreign nationals who will not join the U.S. work force.

Despite the predicted shortages of trained personnel, the mineral industry in the late 1960s and early 1970s appeared to be satisfied with both the number and quality of mineral scientists and engineers being graduated. There was no upsurge in demand for trained manpower. Employment conditions definitely favored the employer as evidenced by the relative lack of employment opportunities and low to average salary offers for those few positions open. During the late 1960s, the federal government introduced no new major programs concerned with minerals or energy and appeared to be more concerned with defense, space, and Great Society programs than with raw materials and energy problems. Even the Mining and Minerals Policy Act of 1970 failed to have any significant effect on mineral supply problems, and had even less effect on the related manpower problems. Many people seemed unaware of such problems, and in fact the Bureau of Labor Statistics predicted in 1970 that mining engineering was a dying profession and that fewer numbers of trained mineral scientists and engineers would be needed in 1980 than in 1970 (U.S. Department of Labor 1971). Even as late as 1974, the Bureau advised high school teachers and counselors that fewer mining engineers than blacksmiths would be required (U.S. Department of Labor 1974), and that despite the relatively small number of graduates in mining engineering, the field was being oversupplied. In light of the current demand for trained manpower, such statements are absurd. At least 50 percent of the engineers employed in the mineral profession in 1976 were over 50 years old, an indication that we have come through a period of severe manpower stagnation in the domestic mineral industry. A substantial void in mineral science and engineering capability must now be filled.

The environmental concerns of the late 1960s, and the recognition of an energy crisis in 1973 have vastly increased the requirements for mineral engineers of all types. Metallurgical engineers are being called upon to make mineral processing and metal producing plants less polluting, mining engineers are asked to make mines safer and more environmentally acceptable, and petroleum and natural gas engineers are being called upon to increase production from existing oil fields and gas wells. As coal becomes more widely used as a primary energy source, the coal industry will place strong demands on the nation's colleges and universities that were unforeseen a few years ago. The coal industry needs not only trained graduate engineers, but experienced miners, too. According to United Mine Workers' president, Arnold Miller, nearly 30 percent of the union's membership will be eligible for retirement when the present contract ends a few years hence (U.S. Congress, Senate 1976).

Unfortunately, in spite of known employment shortages, no accurate manpower requirement survey exists for the mineral engineering disciplines. The 1970 Bureau of Labor Statistics projections badly underestimated the need for mineral scientists and engineers and its figures bear no valid relationship to existing needs. In an informal manpower survey performed in 1974, William H. Dresher, Dean, College of Mines, University of Arizona, contacted 250 mineral industry companies operating in the United States; 97 of them responded and expressed a need for 520 mining engineers in 1975 and predicted this number would increase to 730 in 1985. These firms also indicated a need for 229 metallurgical engineers in 1975 and for 302 in 1985. The numbers substantially exceeded the projected total of graduates in mining and metallurgical engineering for 1975 despite the fact that only a part of the industry responded to the survey.

The demand for coal miners, as well as increased emphasis on mining health and safety, has resulted in the establishment of 17 coal mining technology programs since 1970. These programs are offered at two-year community colleges located in coal producing areas. Additional programs of this kind are under development, although they can do little more than provide minimal technical training. There is clearly a need for more formally-educated engineers in the mineral resource fields to create and work with the technologies required to meet the nation's raw material and energy needs in the future. Yet, the education of an engineer is lengthy--four to five years for a bachelor's degree and six to eight years for the doctorate--and it is difficult to see how the present and near-term trained manpower shortages can be alleviated. The current demand for mineral scientists and engineers and the logical projection of increased demand for trained manpower in the mineral fields clearly calls for concerted efforts to improve the mineral resource manpower base. In a 1977 study by the American Mining Congress, a survey of 87 companies showed a need for almost two and a half times as many mining engineers within the next 10 years as they now employ (Johnson 1977).

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