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NEED FOR NONFUEL MINERALS AND THE DESIRE FOR ENVIRONMENTAL INTEGRITY—A COMPATIBLE RELATION

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Introduction

This paper examines the public perception of minerals, the role of minerals in our society, the past practices of mining and processing minerals, mining's new ethic, and the challenges in achieving a compatible relation between mining and preserving our environmental integrity.

In the preface of his book, "Mineral Resources, Economics, and the Environment," Kesler stated that the book had been cited as too "industry oriented" by some and too "environmentally oriented" by others. The same philosophy applies to this presentation in that it does not take an advocacy position with regard to the views of mining industry or environmental organizations. Hopefully, the ideas presented here will bring to mind that unless we are willing to make a dramatic reduction in our standard of living, we must find a compatible way to produce and consume the minerals we need without significant degradation of the environment (Kesler, 1994, p. iii-iv).

We are reminded by natural resource agencies and mining industry organizations that the origin of minerals and materials used in our daily lives can be stated as, "What is not grown must be mined." No matter how complex or simple a finished product may be, it exists because of something found in the ground that we can mix, mold, melt, cast, extrude, alloy, grind, stamp, or stretch into something useful (U.S. Bureau of Mines, 1995). Mining products have enabled wider distribution of advanced products, such as computers and satellites, and have made the information age possible (National Mining Association, September 1998, The future begins with mining,—A vision of the mining industry of the future accessed February 26, 1999, at URL http://www.oit.doe.gov/mining/vision.shtml). The extraction, processing, and consumption of minerals, however, pollutes our air, earth, and water resources. Today, our standard of living is the highest ever, but the cost to maintain this standard is high in terms of the amount of minerals needed and their associated degradation of the environment. At the center of this dilemma is the need for this country to have an adequate and dependable supply of minerals and materials to meet its economic and defense needs at acceptable environmental, energy, and economic costs.

Public Perception of Minerals

Children and adults play a guessing game in which the question asked is whether the object is animal, vegetable, or mineral. Animals and vegetables are alive; nonfuel minerals are not. Likewise, public reaction to animals and vegetables tends to be positive while reaction to minerals

is oftentimes negative. Furthermore, nonfuel minerals are a nonrenewable resource and raise questions of sustainability (Strauss, 1986, p. 1-2). Sustainable development is about meeting the needs of the present without compromising the future. In addition, pollution as a result of mining and smelting activities is significant in comparison with other industries, and mining has become a dirty word (Mining Journal Books Ltd., 1995, p. 3-4). In recent years, citizen groups, governmental agencies, and the mining industry have confronted each other over such issues as destruction of the landscape, degradation of the visual environment, disturbance of water courses, damage to public and private lands, noise and dust pollution, truck traffic, and vibrations from blasting (Sengupta, 1993, p. 1). Much of the public views mining as a "rape of the earth" but is ignorant as to the essential role that minerals play in their daily lives (Strauss, 1986, p. 2). Mining's paradox is that much of the public does not recognize this role despite the fact that "everything begins with mining" (National Mining Association, 1998, The future begins with mining, accessed February 26, 1999, at URL http://www.oit.doe.gov/mining/vision.shtml). Moreover, when they considered mining, some of the public think it so environmentally disruptive that it is unnecessary for the greater good of society. Many persons who intellectually accept the necessity of mining in society do so only if the activity is out of sight and sound (Marcus, 1997, p. 719).

Role of Nonfuel Minerals in Our Society

From an economic standpoint, the mining of nonfuel minerals creates value by taking national resources from the earth and converting them into useful products. Mineral products are key inputs in durable goods and in manufacturing and construction which account for almost 25 percent of the United States gross domestic product (U.S. Department of Commerce, 1998). In 1998, the U.S. mining industry accounted for about $40 billion of mineral production, and processed materials of mineral origin were valued at $415 billion. The United States imports about $63 billion of raw and processed materials of mineral origin and exports about $35 billion (U.S. Geological Survey, 1999).

Although mining is shrinking in importance to the overall U.S. economy, contributing only 1.5 percent to our gross domestic product, it is still important in many regions of the United States. For example, the U.S. Department of Commerce reports that in 1996, the latest year for which data are available, mining contributed 3.5 percent to the gross State product of Kentucky; 4.8 percent, Oklahoma; 6.8 percent, Texas; 6.9 percent, New Mexico; 10.9 percent, West Virginia; 21 percent, Alaska; and 32 percent, Wyoming.

The United States will continue to need minerals to maintain its national security, standard of living, and place in the global economy. This maintenance is predicated, in part, not only upon the prevalence of such consumer durable goods as automobiles, telephones, refrigerators, and washing machines, but also upon the ability to furnish housing, to construct highways and bridges, to manufacture agricultural equipment, and to generate electricity. All these goods and services require minerals that are either produced domestically or imported.

Access to raw materials is essential to prosperity not only in peacetime, but in wartime also. Since the end of the Cold War, the ownership or control over sources of raw material no longer appears to confer special peacetime economic advantages. So why does the United States need a domestic

minerals industry? Why not just import all the minerals that are needed? Then domestic environmental problems associated with minerals extraction and processing would not be of concern. The answer lies in the fact that if permanent peace were assured, then perhaps the issue of control over mineral supplies as an instrument of national policy could be disregarded (Strauss, 1986, p. 158-159). The National Materials and Minerals Policy, Research and Development Act of 1980 declared ". . . it is the continuing policy of the United States to promote an adequate and stable supply of materials necessary to maintain national security, economic well-being and industrial production with appropriate attention to a long-term balance between resources production, energy use, a healthy environment, natural resources conservation, and social needs." In a less than peaceful world, however, permanent peace is not assured. Therefore, the United States still needs to be concerned about minerals availability and accessibility and its significant amount of net import reliance for many nonfuel mineral materials, including those deemed to be "strategic and critical" (figure 1). A study by the Office of Technology Assessment (1985, p. 11) identified strategic and critical materials thusly: "What makes a material strategic? Two factors must be considered: the critical nature of its uses and the vulnerability of its supply. The criticality of a material is measured by its degree of use in applications essential to the United States, both civilian and military. Vulnerability is assessed on the basis of the risk that the supply of the material may be interrupted, and the scale and duration of the potential interruption. Thus, a strategic material may be briefly defined as follows:

> A strategic material is one for which the quantity required for essential civilian and military uses exceeds the reasonably secure domestic and foreign supplies, and for which acceptable substitutes are not available within a reasonable period of time.

Because many materials are essential in some applications but not others, difficulties may arise in defining a material as critical. Definition of vulnerability poses still more difficulties, since the assessment of the risk of supply interruption involves a subjective analysis of the behavior of other nations. Altogether, the definition of a 'strategic material,' combining uncertainties both of criticality and of vulnerability is not a cut-and-dried matter."

Despite the dramatic changes in military readiness strategies in present years, the uses of these minerals are still critical, and most sources of supply are unchanged. For example, chromium is a metal that is used in stainless steel and in alloys in high performance aircraft. Chromium has no substitute in either application. Of the world's identified resources of chromium, which is extracted from chromite ore, however 95 percent is located in southern Africa. The United States has no chromite reserves and only limited occurrences of chromite resources at all. As a Nation, 80 percent of the chromium used is imported; the remaining 20 percent is acquired through recycling. Although uses of chromium have changed over time, the supply of chromium has been a major concern since World War I.

Past Practices of Mining and Processing Minerals

The results of some past practices for producing minerals demonstrate that these ways are not adequate for the job today. The total cost of past minerals extraction practices has been high

because many early miners disregarded the damaging environmental consequences of their activities, which were legally and morally acceptable at that time. In short, mining was conducted with limited environmental awareness or regulation (Webster, 1998). Only recently has the extent of environmental damage associated with some of these operations been realized. The Summitville Mine, located in south-central Colorado, is one example of this dilemma. In 1992, the full effects of the mining operation were disclosed—prolific acid drainage and the leaking of cyanide for example (Marcus, 1997, p. 687-697). In many such cases, the damage has been realized and understood long after those operations had shut down and their owners were gone. The situation can be further complicated by a multitude of owners.

Many of the most harmful environmental problems of yesteryear still exist in the form of abandoned radioactive tailings piles or even Naturally Occurring Radioactive Materials (NORM) Waste. Also, mercury and other toxic heavy (base) metals are entering the food chain, tailings dams are leaking and failing, aquifers are being invaded and depleted, surface land is subsiding and caving, mine drainage is affecting wide areas, and abandoned mines are requiring remediation. Finally, more than 60 mining sites, most of which are abandoned, are now in the National Priorities List for cleanup under Superfund (Marcus, 1997, p. 724).

Much of the environmental damage associated with nonfuel mineral production is attributable to metals via acid mine drainage and emissions from smelters, although the processing of industrial mineral ores certainly has its side effects as well (Kesler, 1994, p. 43, 80). For example, cement, lime, and gypsum require actual decomposition of the original ore material via heating, resulting in acid drainage from coal piles and atmospheric emissions. Atmospheric emissions were particularly serious prior to the installation of electrostatic precipitators and other pollution abatement equipment, which did not begin in earnest until the 1960's.

Some of the most critical concerns for the environmental effects of mineral extraction are centered on mine wastes, which contain metals and other potentially toxic compounds that were dispersed into the surrounding surface and ground waters. A cost of several billion dollars has been estimated for cleanup of these wastes (Kesler, 1994, p. 73-75). The older plants and wastes are the major sources of environmental pollution. For example, at some of these sites, metal sediment from tailings were dumped into streams and are finding their way into aquatic plants and animals. Currently, the only real solution is massive and costly—the complete removal of the contaminated sediment.

In addition, metals are also cited for polluting the atmosphere. Smelting is one of the final stages in metals processing and is of great environmental concern because of production of gases and dust. The effects of smelter-induced precipitation are made obvious by the lack of vegetation in the vicinity of those older smelters (Kesler, 1994, p. 79-81).

Mining's New Ethic

Two of the most significant reasons why mining companies have "turned the corner" and become active environmentalists are increased public awareness and regulations. The concern about

environmental issues felt by many Americans, who consider themselves to be environmentalists or at least environmentally aware, is unprecedented in U.S. history (Marcus, 1997, p. 719). These reasons have caused mining companies to strive to switch from a reactive mode to one that anticipates and incorporates environmental management throughout a mine's development and operation.

Legislation of new environmental controls and resource-management procedures has resulted in a number of significant changes to mining's traditional approach (Marcus, 1997, p. 8-10). A list of the development of major Federal actions regarding mining is given in table 1.
For example, this development includes the following:

- Environmental impact statements (EIS)
- Conditions for permit approval
- Resource management and land-use planning
- Land reclamation and rehabilitation (Sengupta, 1993, p. 3)

As a consequence, the mining industry now has to comply with the environmental regulations of more than 50 Federal agencies, in addition to those at the State and local levels. From an international perspective, no other Nation surpasses the United States in terms of care for the environment (Lawson, 1999, p. 4-5). The use of careful and formalized proposals for all major resource developments and of EIS's as a guide to the development and management of a new project have increased. For example, the paperwork for a BHP Mining Company EIS for a particular project weighed 65 pounds and cost $14 million to produce; it was cited as one of the most comprehensive, authoritative considerations of the environment ever produced. Some States require bonding even before a mining company can explore within the State's borders (Crawford, 1997).

Throughout the development and operational stages of a mine, two parallel processes exist—the engineering design, layout, and technological requirements normally associated with mining and an environmental program that meets all existing regulations and standards for air, water, and land quality (Sengupta, 1993, p. 3). The acquisition of the permits and post reclamation bonds is a lengthy process. Although the permitting process usually takes several years to complete, it does offer the public several opportunities for comment.

The permitting process has, however, become increasingly more complicated and involves the collection of baseline environmental data, ground-water modeling, archeological studies, and socioeconomic analyses. The Stillwater Mining Company in Montana reported that it takes about 5 years and $5 million to get permits for a small mine in the State, and a company in Washington State reported that permitting costs in that State for one of its projects are about $15 million (Crawford, 1997).

During the last 20 years, the societal effects of mining, such as visual impact, natural resources, and land use, have become an increasingly important consideration in the development of a mine. These effects, which were once regarded as too intangible to be addressed definitively, are now considered to be important parts of the planning process by many permitting and land-use authorities. Once

accepted as an unavoidable consequence of progress, visual impact is now considered to be an unacceptable imposition upon citizens' rights by local governments. This imposition has, however, been somewhat reduced via technology, which has facilitated agreements between more owners and city and county planning commissions, State regulatory agencies, and Federal land-management authorities who participate in the land-use and mine-plan approval process. For example, alternate mine plans with various appearances can now be readily assimilated by using current technology in a cost-effective manner that allows for informed decisionmaking (Marcus, 1997, p. 263-264).

Land reclamation and rehabilitation planning have become integral and normal parts of the mining process. Mining companies are reporting environmental costs of about 5 percent of their operational budget (Crawford, 1997). For example, Cyprus Amax Minerals Co. spends more than $100 million each year on environmental work; Homestake Mining Co. reclaimed 1,100 acres at a cost of more than $15.5 million in 1996; and Newmont Mining Corp. accrued $20.8 million for reclamation and rehabilitation in 1996 (Webster, 1998). Several environmental case studies from the hard rock industry have shown that modern methods of mining can rehabilitate an area during and after production (mine closure) with a considerable reduction of overall remediation costs (Marcus, 1997, p. 687). The design of any environmental monitoring program can, however, be an "evolving science" until natural site conditions are better understood (Scheiner, 1995, p. 138).

There are examples where mining companies have gone "above and beyond the call of duty" to alleviate environmental concerns. In 1993, Placer Dome, Inc., acquired land known as the Alligator Ridge Property in the Bureau of Land Management's (BLM) Ely District in Nevada. As a result of intense prior exploration drilling, this property had a maze of roads, pods, and trenches that had been left unreclaimed. The new owner funded a joint Placer Dome-BLM helicopter tour of the area to assist in accurately identifying and mapping the disturbances and eventually reclaimed even more of the roads as they were discovered. BLM nominated the company for their Health of the Land Award and noted the company's "outstanding communication, cooperation, and extra efforts that were well above what would normally be expected or required" (Lawson, 1999, p. 14). In 1994, ASARCO and Phelps Dodge Corporation's Chino Mines Company launched a voluntary cleanup program to stabilize the Black Hawk Mill site near Silver City, NM. One of the key benefits of this effort is that the results of recent soil metal studies at the site have shown that the soils contain only natural mineralization. The New Mexico Energy, Minerals, and Natural Resources Department, Mining and Minerals Division, honored the company for its efforts (Lawson, 1999, p. 14-17).

Challenges in Achieving a Compatible Relationship between Mining and Preserving our Environment

Although a clean environment is undeniably a worthy goal, it cannot be pursued without considering other goals that are important to the way of life of most Americans. The U.S. standard of living is the driving force behind the desire to achieve a quality environment. Prosperity and the prospects for its continuation enable the enhancement of the environment and the ability to pay for it (Lawson, 1999, p. 5).—the political pressure of environmentally aware citizens is in direct proportion to the wealth of a nation. In other words, the wealthier the country, the more "progressive" the environmental legislation in terms of using the most recent technology and eliciting public participation in authorizing projects (Tilton, 1995, p. 59). The fundamental question has been how to balance the requirements of society for continued growth with its desire to preserve the environmental quality of the land resource base (Sengupta, 1993, p. 4).

One of the more obvious challenges is the need for access to land to extract minerals and to preserve it at the same time. Mining is a unique industry in that its location is determined almost entirely by geologic factors. Land access to ore deposits is essential if mineral supplies are to be maintained (Kesler, 1994, p. 97). In other words, minerals must be produced where the deposits are found. Although mining is a temporary use of the land, land disturbance is inevitable in order to take minerals from the ground and turn them into useful products (Lawson, 1999, p. 5), and the legacy of that activity may be evident for much longer. The U.S. Environmental Protection Agency (EPA) estimated that 50 billion metric tons of nonfuel minerals waste had been generated by 1985 and that more than 1 billion tons of waste is added every year (Marcus, 1997, p. 723). The development of most deposits will require the acceptance of land disruption as a necessary price for the benefits that accrue to society from the extraction of minerals (Kesler, 1994, p. 32). Despite the fact that former mining practices left the land unfit for other uses, we need to remember that modern mineral extraction is much cleaner today (Kesler, 1994, p. 81). Some deposits, however, will never be mined because of controversial withdrawals that preclude them from mining. Some of these land areas have been determined to have environmental, cultural, or religious values (Marcus, 1997, p. 724). But is total withdrawal the solution? One possible solution is "multiple land use," a philosophy that recognizes that modern reclamation and remediation techniques have been proven to work. For example, Butchart Gardens, one of the main attractions in Victoria, British Columbia, was once a rock quarry, as was Queen Elizabeth Park in Vancouver. Sections of Park City, Utah, a popular ski area, were reclaimed by covering them with layers of dirt. Another possible solution in some areas when environmental, cultural, or religious aspects are not involved could be granting preference for mineral production over other uses that can be relocated easily. The bottom line is that not enough minerals will be available for the next generation if all wilderness land is withdrawn from exploration (Kesler, 1994, p. 73- 97).

Making environmental decisions that include the integration of costs and benefits on a scientific basis is a challenge that the Federal Government has been successfully addressing. One example is the recently completed Interagency Agreement (IAG) between the U.S. Geological Survey (USGS) and the EPA. The USGS lent scientific credibility to this effort by revising and updating a study regarding NORM Waste Characterization involving 30 minerals industries associated with

NORM waste. The study will be used by the Congress to establish public policy regarding the NORM issue.

In addition, the USGS copper commodity specialist is working with personnel from EPA's National Center for Environmental Assessment, at their request, to establish a baseline for atmospheric dioxin emissions. (Dioxins are very toxic compounds that are prevalent in such chemicals as "agent orange.") Although the EPA is aware that copper smelters are the second largest source of these emissions, it has little, if any, scientific data upon which to base any decisions. The point to be made here is that Federal, State, and local governments should not try to establish standards if there are substantial scientific uncertainties that remain to be resolved (Ebetino, 1998, p. 1).

In other areas, Federal, State, and local governments have not been as successful. The permitting process, for example, has increased public awareness by allowing the public to scrutinize the environmental aspects of various mining projects. Kesler (1994, p. 115-116) argued, however, that the time required to find and develop mineral deposits is so lengthy as to cause excessive delays or even cancellation. The challenge is to strive to make the period of time between the discovery and development of mineral deposits as short as possible without jeopardizing important environmental and economic goals. Another example of needed governmental resolution pertains to issues relating to proposed reform of the 1872 Mining Law. The challenge here is to resolve the conflicts that have emerged over the years (Marcus, 1997, p. 36).

Another challenge is the establishment of national mineral policies that link mineral supplies and economic policies. In a free-market economy, mineral producers expect to have a reasonable return on their investments, and by the same token, governments could have a fair share of the profits from public lands, and citizens need a clean environment (Kesler, 1994, p. 116).

Fostering new technologies is also a challenge where progress is being made through partnerships between industry and Federal and State agencies. For example, ASARCO and Freeport-McMoran Copper & Gold were venture partners in the Santa Cruz In Situ Research Project in Casa Grande, AZ, which is managed by ASARCO and 75 percent-funded by the Federal Government. The project objective, which was based on earlier research conducted by the former U.S. Bureau of Mines, was to recover copper from deep mineralized zones through surface injection of an acid solvent to dissolve the copper. The pregnant leach solutions would be recovered through adjacent wells and processed for recovery of copper. The results indicated that the grade of the ore body was too low for economic recovery of copper by using underground mining methods and too deep for open-pit extraction. The viability of the project was determined, and engineering parameters for future operations were established by this research effort (Edelstein, 1998).

In addition, at its Morenci Mine in Arizona, Phelps Dodge Corporation has improved recovery efficiencies through advanced leaching technologies. Waste or overburden material, formerly placed in uncontrolled dumps, is now placed on carefully designed pads and acid leached. This not only improves the overall recovery of copper per ton of material disturbed by mining, but also reduces such environmental concerns as acidic mine drainage through the careful design and control of

leachate recovery systems (Giancola, 1999, p. 199). Mining's challenge for the future will be to halt the use of unsustainable and damaging technologies (Joyce, 1998).

The last challenge I am addressing is the need to move toward sustainable solutions, not only for our Nation, but for the planet as well. One such solution, which is an aspect of sustainability, is industrial ecology, in which former waste materials are regarded as raw materials—useful sources of materials and energy for various processes and products (Interagency Workgroup on Industrial Ecology, 1998, p. 21). In the mining and minerals processing sector of the economy, government and industry have made progress in achieving a better understanding of industrial ecology. The increased amounts of Government and industry literature available on the subject, as well as the establishment of an interagency work group (devoted to addressing industrial ecology as well as related issues) at one of the highest levels of Government, is testimony to increased understanding and emphasis on this matter. One aspect of industry's contribution to industrial ecology is the fact that industry has significantly improved the recycling of minerals (metals in particular). Themelis and Wernick (1998, p. 465), however, argued that governments should institute policies that remove barriers to the economically and environmentally sound recovery of secondary metal production.

The International Iron and Steel Institute (IISI) has noted in their policy statement that "Sustainable development is a complex subject that involves not only environmental protection but such issues as economic prosperity, population growth and poverty. Relative priorities and relationships must be established if progress is to continue." The IISI urged their member companies to cooperate with governments in a responsible manner and to contribute "to the development of cost-effective legislation and regulations that are based upon sound science, technical possibilities and the true environmental and economic priorities of the global community." The IISI also stated "environmental regulations require a balancing of social economic and environmental goals." And, finally, the IISI stated that they support, in concept, the International Chamber of Commerce (ICC) Business Charter for Sustainable Development and the ICC Environmental Guidelines for World Industry (International Iron and Steel Institute1998, Policy statement-environmental principles, accessed March 29, 1999, at URL
http://www.worldsteel.org/environment/env_policy/policy_A.html).

The USGS has made significant contributions to the understanding of industrial ecology. One such contribution was the 3-day national workshop "Science, Sustainability, and Natural Resources Stewardship—The USGS and Research on Materials and Energy Flows" in November 1998. Materials flow is a systems approach to understanding what happens to mineral materials from the time they are extracted through processing, manufacturing, and disposition. In addition, the USGS has conducted materials flow studies for 11 minerals and materials and will do 25 more in the next 2 years. These analyses identify areas where adverse impacts could be minimized through reducing wastes at the source of materials, improving waste utilization, and enhancing efficiencies (Sznopek and Brown, 1998).

The recycling of metals, a significant factor in the supply of many of the key metals used in our society, provides environmental benefits in terms of increased energy savings, and reduced volumes of waste, and emissions. These reductions, in turn, result in reduced disturbance of land, reduced

pollution, and reduced energy use. The recycling rates of key metals in the United States in 1997 vary from highs of 65 percent for lead and 58 percent for iron and steel to a low of less than 25 percent for chromium (U.S. Geological Survey Staff, 2000). The dilemma between protecting the environment while fostering industrial ecology lies, in part, at least, with some of our environmental regulations that conflict with industrial ecology goals. For example, the Resource Conservation and Recovery Act (RCRA) defines "solid waste" to include recyclable materials, which places the full regulatory burden of waste disposal on scrap handlers. Another example is the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA/Superfund), which affects the secondary metals industry by holding liable "potentially responsible parties" that generate, transport, or treat metal wastes associated with a Superfund site. Themelis and Wernick (1998, p. 490-491) argued that the collection, transport, and recovery of metal wastes are impeded without necessarily improving environmental protection. Furthermore, they argued that although regulations have been effective in controlling air and water emissions from point sources, much remains to be done not only to protect the environment, but to encourage optimal metals recovery as well.

Summary

The need for minerals to meet the Nation's economic and defense needs is easily understood. It is also easy to point to examples of some of mining's worst past practices— the unreclaimed phosphate mines in central Florida or some of the effects of acid mine drainage in Colorado (Joklik, 1996, p. 6); many industry detractors have convinced the public that mining today will create environmental problems similar to those created by past mining practices (Scheiner, 1995, p. 24). Consequently, the environmental future of mining will be radically different from its past—some conflicts will be avoided because land withdrawals and decisions to mine are being carefully scrutinized for possible adverse consequences. The mining industry needs to regain public confidence (Marcus, 1997, p. 725). The ability of the U.S. mining industry to convince the public and the regulatory community that the industry has the necessary science and technology to develop, operate, and reclaim environmentally responsible mining projects will be critical to its survival (Scheiner, 1995, p. 24). Furthermore, the minerals industry needs a more proactive attitude in preventing pollution, designing for the environment, and voluntarily cleaning up historic contamination (Joklik, 1994, p. 7).

Governments, on the behalf of the public, have a key role in mining and the environment. Regulations can restrict or encourage mining and protect or, if not well designed, even harm the environment. Governments must have a strong scientific basis for the tough decisions that need to be made when, for example, there is a conflict between economic development and ecosystems (Price, 1996). In addition, more positive consensus building between the House and the Senate is urgently required to resolve such issues as the 1872 Mining Law (Marcus, 1997, p. 36).

Finally, sustainable development, including industrial ecology, needs to be a part of the planning process for the mineral industry and governments. Interagency industrial ecology within the economy should bring significant benefits, such as reduced resource use via recycling and lessened environmental degradation with improved technology (Interagency Workgroup on Industrial Ecology, 1998, p. 19). For example, redesigning products, such as fasteners on automobiles, which

result in their ease of disassembly during the recycling process, can have economic advantages (Phoenix, 1999).

Obtaining the minerals and materials that the United States needs without compromising its environmental integrity will require more teamwork and less "fingerpointing" than has been exhibited thus far among the general public, governments, and the mining industry.

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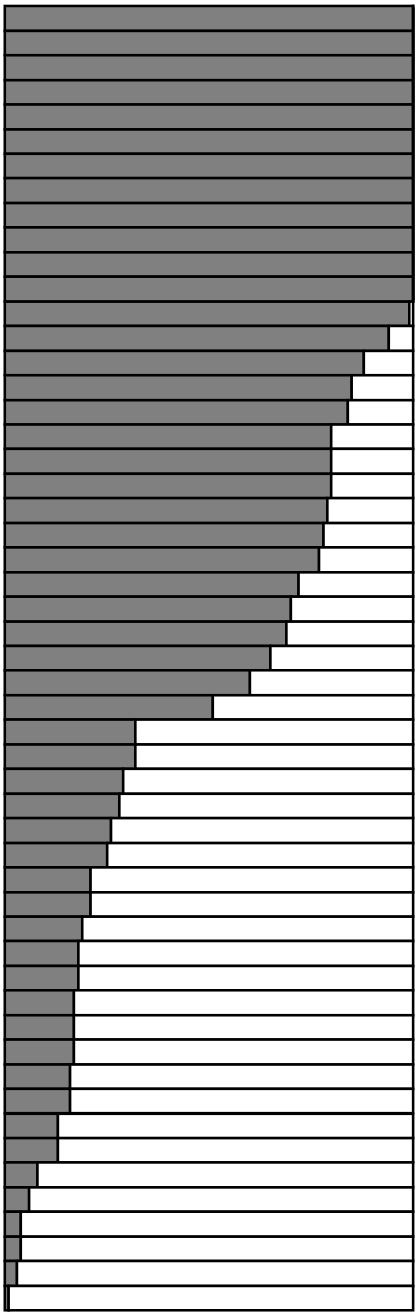
Figure 1. 1998 U.S. NET IMPORT RELIANCE FOR SELECTED NONFUEL MINERAL MATERIALS



Commodity	Percent	Major Sources (1994-97)[1]
ARSENIC	100	China, Hong Kong, Japan
BAUXITE and ALUMINA	100	Australia, Guinea, Jamaica, Brazil
BISMUTH	100	Belgium, Mexico, United Kingdom, China
COLUMBIUM (niobium)	100	Brazil, Canada, Germany
FLUORSPAR	100	China, South Africa, Mexico
GRAPHITE (natural)	100	Mexico, Canada, China, Madagascar
MANGANESE	100	South Africa, Gabon, Australia, France
MICA, sheet (natural)	100	India, Belgium, Germany, China
STRONTIUM	100	Mexico, Germany
THALLIUM	100	Mexico, Belgium, Canada, Germany
THORIUM	100	France
YTTRIUM	100	China, France, United Kingdom, Belgium
GEMSTONES	99	Israel, Belgium, India
PLATINUM	94	South Africa, United Kingdom, Germany, Russia
PALLADIUM	88	Russia, South Africa, Belgium, United Kingdom
TIN	85	Brazil, Indonesia, Bolivia, China
ANTIMONY	84	China, Mexico, Bolivia, South Africa
BARITE	80	China, India, Mexico, Morocco
POTASH	80	Canada, Russia, Belarus
TANTALUM	80	Australia, Thailand, China, Brazil
CHROMIUM	79	South Africa, Russia, Turkey, Zimbabwe, Kazakhstan
TUNGSTEN	78	China, Russia, Germany, Bolivia
COBALT	77	Norway, Finland, Zambia, Canada
IODINE	72	Chile, Japan
ZINC	70	Canada, Mexico, Spain, Peru
STONE (dimension)	69	Italy, India, Brazil, Canada
NICKEL	65	Canada, Norway, Russia, Australia
PEAT	60	Canada
DIAMOND (dust, grit, and powder)	51	Ireland, China, Germany
PUMICE	32	Greece, Ecuador, Turkey
SILICON	32	Norway, Russia, Brazil, Canada
RARE EARTHS	29	China, France, Japan, United Kingdom
MAGNESIUM COMPOUNDS	28	China, Canada, Austria, Greece
GYPSUM	26	Canada, Mexico, Spain
ALUMINUM	25	Canada, Russia, Venezuela, Mexico
CADMIUM	21	Canada, Australia, Belgium, Mexico
LEAD	21	Canada, Mexico, Peru, Australia
NITROGEN (fixed), AMMONIA	19	Trinidad and Tobago, Canada, Mexico, Venezuela
IRON and STEEL	18	European Union, Canada, Japan, Brazil
SULFUR	18	Canada, Mexico, Germany
CEMENT	17	Canada, Spain, Venezuela, Greece
IRON ORE	17	Canada, Brazil, Venezuela, Australia
SALT	17	Canada, Chile, Mexico, The Bahamas
COPPER	16	Canada, Chile, Mexico
MAGNESIUM	16	Canada, Russia, China, Mexico
MICA, scrap and flake (natural)	13	Canada, India, Finland, Japan
PERLITE	13	Greece
SODIUM SULFATE	8	Canada, Mexico
ASBESTOS	6	Canada
BERYLLIUM	4	Russia, Kazakhstan, France, Canada
PHOSPHATE ROCK	4	Morocco
IRON and STEEL SLAG	3	Canada, South Africa
LIME	1	Canada, Mexico

[1]In descending order of importance

Additional commodities for which there is some import dependency but data are withheld or are insufficient to determine import-reliance levels:

Gallium	France, Russia, Canada, Germany
Germanium	Russia, Belgium, United Kingdom, China
Ilmenite	South Africa, Australia, Canada
Indium	Canada, Russia, China, France
Kyanite	South Africa
Lithium	Chile
Mercury	Russia, Canada, Kyrgyzstan, Spain
Rhenium	Chile, Germany, Kazakhstan, Netherlands
Rutile	Australia, South Africa
Selenium	Canada, Philippines, Belgium, Japan
Tellurium	United Kingdom, Canada, Philippines, Peru
Titanium (sponge)	Russia, Japan, Kazakhstan, China
Vanadium (ferrovanadium)	Canada, Russia, China, Czech Republic
Vermiculite	South Africa, China
Zirconium	Australia, South Africa

Table 1. Chronological Development of Major Federal Actions that Control Mining

Event	Date	Importance
Mining Land Ownership Laws I initiated	March 3, 1807	Reserved from settlement or sale the lead deposits of Indiana Territory and Louisiana Purchase
Appointment of U.S. Army Lt. Martin Thomas as "Superintendent of U.S. Lead Mines"	1824	Initial federal authority over U.S. mineral rights by instituting a leasing system
Supreme Court case United States v. Gratlot	1840	Established right of Congress to manage public domain including mining sites
Mining Act	July 11, 1846	Entered first attempt to regulate public mineral reserves by leasing
Mining Act	July 26, 1866	First attempt to control mining of lode claims
Mining Act	July 9, 1870	Amended previous act to include placer claims
General Mining Law of 1872	May 10, 1872	Current mining law still in use with key modifications
Mining Act	March 3, 1873	Entry allowed on vacant coal lands
Establishment of the U.S. Geological Survey	March 3, 1879	Duties include geologic (strategic) studies on the public lands
Establishment of the U.S. Bureau of Mines	May 16, 1910	Initially covering health and safety, conservation, and (tactical) research
Mining Leasing Act of 1920	February 25, 1920	Provided that non-metallics be acquired through leasing system and specifies amount of royalties, lease size and duration
Materials Act of 1947	July 31, 1947	Provided for competitive bidding on certain non-metallic deposits
Atomic Energy Act of 1954	August 30, 1954	Authorized AEC right to issue mining permits to fissionable materials on public lands
Clean Air Act	July 14, 1955	Ensures that all air emissions from mining meet stringent air quality standards
Solid Waste Disposal Act Resource Conservation and Recovery Act/RCRCA amendment passed in 1976)	October 20, 1965	Regulates generation, storage and disposal of solid waste and hazardous waste
National Environmental Policy Act	January 1, 1970	Requires interdisciplinary approach to environmental evaluation in federal decision-making related to mining
Geothermal Steam Act	December 24, 1970	Act authorized leasing of geothermal resources through competitive leasing
Occupational Safety and Health Act of 1970	December 29, 1970	Passed to ensure "so far as possible every man and woman in the nation safe and healthful working conditions and to preserve our human resources"
Event	**Date**	**Importance**

Table 1. Chronological Development of Major Federal Actions that Control Mining - Continued

Noise Control Act of 1972	October 27, 1972	Passed to promote an environment for all Americans to be free from noise that jeopardizes their health or welfare
Endangered Species Act	December 28, 1973	Threatened plants and animals and their habitats are listed; protection plans mandated
Safe Drinking Water Act	December 16, 1974	Directs standards to be set for quality of drinking water and regulates underground injection systems
Toxic Substance Control Act	October 11, 1976	Requires regulation of chemicals that present risks to health or environment
Federal Land Policy and Management Act (FLPMA)	October 21, 1976	Requires recordation of mining claims with the BLM. Requires prevention of undue and unnecessary degradation of federal lands where mining occurs.
Surface Mining Control and Reclamation Act (SMCRA)	August 3, 1977	Established the Office of Surface Mining, Reclamation, and Enforcement (OSM) apart from the Bureau of Mines; also requires reclamation of all surface mine coal lands
Federal Mine Safety and Health Amendments Act	November 9, 1977	Repealed Act of 1966 and amended Act of 1969. Responsibilities for mine health and safety transferred from DOI to DOL which establishes the Mine Safety and Health Administration (MSHA)
Soil and Water Resources Conservation Act of 1977	November 18, 1977	Passed to ensure sustained use of the Nation's soils, plants, woodlands, and watershed protection and flood prevention
Clean Water Act	December 27, 1977	Requires mining operations to meet standards for surface water quality and for controlling discharges to surface water. Requires protection of wetlands
Federal Mine Safety and Health Act of 1977	March 27, 1978	Passed to ensure the health and safety of the mining industry's most precious resource--the miner
Deep Seabed Hard Mineral Resources Act	June 28, 1980	Established interim procedure for the development of hard mineral resources in the deep seabed pending adoption of international protocols
National Materials and Minerals Policy, Research and Development Act of 1980	October 21, 1980	Continuing policy of the U.S. to provide an adequate and stable supply of materials necessary to maintain national security, economic well-being, and industrial production
Comprehensive Environmental Response, Compensation and Liability Act (Superfund)	December 11, 1980	Requires operations to report releases of hazardous substances to the environment and requires cleanup of sites where hazardous substances are found

Table 1. Chronological Development of Major Federal Actions that Control Mining - Continued

Oil Pollution Act of 1990	August 18, 1990	Streamlined and strengthened EPA's ability to prevent and respond to catastrophic oil spills

Sources: Kesler, 1994; Marcus, 1997; Lawson, 1999.