STRATEGIC MATERIALS

ABSTRACT

A fundamental shift in thinking has occurred concerning the strategic and advanced materials industry in the United States. Historically, our concerns, policies, and programs were directed at items that were critical in a national emergency and difficult to supply. With the end of the Cold War and the increased globalization of national economies, a broader concept of strategic and advanced materials has emerged. The new perspective recognizes that national security planning encompasses the general welfare of a society, which includes economic and political considerations in addition to military considerations. This broader perspective on national security is evident in many countries. However, because each country has a different state of economic and political development, the role of the strategic and advanced materials industry in each country is different.

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International

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Chamber of Mines, Johannesburg, South Africa
Council for Scientific and Industrial Research, Pretoria, South Africa
Iron and Steel Institute, Pretoria, South Africa
Ministry of Minerals and Energy, Pretoria, South Africa
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INTRODUCTION

This report focuses on an evaluation of a nation's strategic materials and the governmental policies affecting them. It analyzes the United States, Canada, Brazil, and South Africa to develop a perspective on how strategic materials influence their status and security.

Materials contribute to the wealth and power of nations. In fact, Morganthau and Thompson (1985) list raw materials as one of the relatively stable factors that influence the status of countries. The importance of particular materials will change over time, but some materials are so interwoven with the history of civilization that they are associated with history itself (e.g., the stone, bronze, iron, and more recently, the silicon, ages).

Materials may be generally classified as minerals, organics, or advanced materials. The latter classification includes those that are transformed or combined by human labor to achieve a useful state. Much of this report will focus on mineral materials because of their naturally occurring distribution and their importance to the gross domestic product (GDP).

The globalization of industry and the essential contribution of raw materials are clearly evidenced by the following:

> The commuter slipped behind the wheel of his Detroit built sedan. Switching on an ignition system built with Zambian copper and Ghanaian aluminum, he drew on power from a battery of Missouri lead and South African antimony to start an engine of Pittsburgh steel strengthened by South African manganese and hardened with chrome from Zimbabwe. The car rolled on tire treads blended from natural rubber from Liberia and synthetic rubber from an Algeria petrochemical base. The exhaust from Nigerian gasoline was cleansed by Russian platinum. The commuter switched on a radio with its invisible traces of cobalt from Zaire and tantalum from Mozambique, heard a newscaster's report on the Communist-led coup in a small country in South Africa. "What's that to me?" he thought" (Sinclair and Parker, 1983).

THE INDUSTRY DEFINED

"Strategic materials" is not an industry in the traditional sense of the word. Nevertheless, materials are required in manufacturing industries and manufactured items are essential in service-based industries. Whether these materials are "strategic" or not, is a matter of perspective. A material strategic to one nation may be insignificant to another. For the United States, strategic materials have generally been defined as materials essential to military, industrial, or civilian needs in times of national emergency. However, this definition is ambiguous; it depends on how "essential" is interpreted and "national emergency" defined. More recently, the term "strategic" has been more broadly interpreted to include elements necessary for the general welfare.

Key Resources

For this report, we define strategic materials as key resources that transcend individual industries in their application. Strategic materials are obtained from several primary sources: the extraction of natural materials (minerals) from domestic or foreign sources, and from the creation and production of materials, also from domestic or foreign sources. Advanced materials are a subset of produced or created materials. These advanced materials may also be strategic.

Advanced Materials. Advanced materials contain two sectors, the specialty metals (titanium and beryllium), and the advanced composites: polymer, ceramic, and metal matrixes, and high thermal conductivity composites.

The specialty metals are found in many military applications such as airframes, turbine engines, optical systems, armored vehicles and nuclear weapons. Titanium provides high strength, and corrosion resistance, while beryllium is critical for its combination of low density, high stiffness-to-weight ratio, and thermal conductivity. Uses for titanium would probably increase significantly if prices were reduced by 40 percent—a reduction that industry is trying to accomplish through continuous processing techniques. Currently, the U.S. is a net exporter of specialty metals and maintains a strong position in total world production.

The polymer composites are the most mature of the advanced composites. The U.S. polymer industry receives annual revenue of approximately $2.3 billion dollars, 51 percent of the worldwide market.

Ceramic composite technology is less mature than the polymer industry. Ceramic matrix composites are primarily used as cutting tools. The U.S. percentage of advanced ceramic revenues is approximately 22 percent of the $15 billion in total worldwide revenues.

Metal matrix composite technology is even less mature than that of ceramics. Its small, unstable market is considered precompetitive. Metal matrix composites are used to reduce life-cycle costs and improve the performance of gas turbine engines. Although the worldwide revenues within this sector are only $55 million annually, the U.S. industry's share is $30 million or 55 percent—a dominant position.

High-thermal conductivity composites are the least mature of the advanced materials, and its industrial base is also precompetitive. The use of these composites is limited to very technical and unique applications with expensive production costs.

View from the United States. The United States holds a dominant share of the worldwide production capacity and revenues in several sectors of the advanced materials industry. Although it must rely on some imports, particularly for raw materials such as petroleum, natural gas, silicon and graphite, U.S. dependence on exports is quite low. The U.S. technology and industrial base for advanced materials is sufficient to meet expected requirements for the next 10-to-20 years.

Based on our decision to compare the United States, Canada, Brazil, and South Africa, the balance of this report focuses on the supply of natural strategic minerals and the governmental policies and decisions affecting them in these four countries. That is, it evaluates the influence of strategic and advanced materials on the security and status of nations by comparing attitudes and behaviors relative to these resources in Brazil, Canada, South Africa, and the United States.

CURRENT CONDITION

United States

Though much of the world's strategic mineral wealth is located outside the United States, within its boundaries over 90 minerals are mined and processed. The United States exports more than 60 different minerals and is especially rich in nonmetallic minerals. Although, the U.S. is one of the two top producers of nonfuel minerals, there are still many materials that the United States imports from foreign countries (Kessel, 1990).

Minerals are imported for a variety of reasons, often because it is economically advantageous to do so. In many cases, foreign ore deposits are richer than domestic deposits, closer to cheap energy sources, and mined by cheaper labor. The industrial demand in some mineral rich countries is lower than the available supply, making them ideal exporters. The growing interdependence of the world's supply of resources is very apparent. Table 1 depicts the U.S. reliance on imports for several minerals and their primary sources.

Canada

Canada's great wealth of land contains some of the world's largest reserves of natural resources. This country is the world's top producer of uranium, zinc, and potash; the second largest producer of nickel, sulfur, asbestos, and cadmium; the third-largest producer of aluminum, platinum, titanium, copper and gypsum; the fourth largest in cobalt and molybdenum; and fifth in gold and lead.

Canada is the largest exporter of raw minerals and mineral products in the world. These items are 16.2 percent of Canada's exports, and are collectively a major factor in its continuing trade surplus of over $10 billion. The mining industry is large, growing, and vital to Canada's economy. The Canadian government estimates that for every job created directly from the mining industry at least one indirect job is also created in the economy. Mines are opening or reopening each year in Canada — 21 in 1995, 24 in 1996, and 25 in 1997. By the year 2000, the government predicts an average of 20 new mine locations per year. This activity will create over 20,000 direct and indirect jobs throughout the country (Canadian Mining Facts).

The mining and mineral processing industry contributes $23 billion to the Canadian economy annually — about 4 percent of its GDP. Exports of raw materials from Canada increased by over 40 percent between 1993 and 1995, from $29 to $40 billion, thus ensuring that Canada will remain

Table 1.—U.S. Mineral Materials Ranked by Net Import Reliance, 1995.

Commodity	Percent	Major Sources (1991-1994)
Arsenic	100	China, Chile, Mexico
Columbium	100	Brazil, Canada, Germany
Graphite	100	Mexico, Canada, China, Madagascar
Manganese	100	South Africa, Gabon, France, Brazil
Mica	100	India, Brazil, Finland, China
Strontium	100	Mexico, Germany
Thallium	100	Belgium, Canada, UK
Yttrium	100	China, UK, Hong Kong, Japan
Bauxite and Alumina	99	Australia, Jamaica, Guinea, Brazil
Gemstones	96	Israel, India, Belgium, UK
Flurospar	92	China, South Africa, Mexico
Tungsten	87	China, Germany, Bolivia, Peru
Tin	84	Brazil, Bolivia, Indonesia, China
Cobalt	82	Zambia, Norway, Canada, Zaire
Tantalum	80	Australia, Germany, Canada, Thailand
Chromium	78	South Africa, Turkey, Zimbabwe, Russia
Potash	74	Canada, Belarus, Germany, Israel, Russia
Barite	65	China, India, Mexico
Iodine	62	Japan, Chile
Nickel	61	Canada, Norway, Australia, Dominican R
Antimony	60	China, Mexico, South Africa, Hong Kong
Stone (dimension)	57	Italy, Spain, India, Canada
Peat	55	Canada
Magnesium Compounds	50	China, Canada, Mexico, Greece
Asbestos	46	Canada
Zinc	41	Canada, Mexico, Peru, Spain
Diamond (dust, grit, powder)	36	Ireland, China, Russia
Selenium	33	Canada, Philippines, Japan, Belgium, UK
Silicon	33	Norway, Brazil, Canada, Russia

the world's largest exporter of minerals and mineral products (Canadian Mining Facts).

Brazil

Brazil, one of the world's leaders in mining, has reserves of at least 18 billion tons of high-grade iron ore (one third of the world's total). It is also a leading source of the world's iron with annual production of over 130 million tons of metal from over 200 million tons of ore. Brazil's bauxite output exceeds 11 million tons per year with reserves of 2.5 billion tons (the largest in Latin America). Brazil ranks fifth in aluminum production at 7.5 million tons. Annual manganese production runs at 2.6 million tons. Brazil is second in the world for tin production and reserves. Fully 90 percent of the world's niobium is located in Brazil. Chromium, copper, zinc, lead, nickel, cobalt, molybdenum, and titanium are abundant. Silver, quartz (about 95 percent of the known supply), and a wide variety of gemstones are plentiful. Brazil's gold reserves (35,000 metric tons), are the fifth largest in the world (EIU). Brazil is also fifth in the world for uranium and was the eighth nation to master the technology to enrich it for fuel (perhaps enough for weapons).

Brazil is the world's most significant producer and principal supplier of columbium to global markets. In 1994, it produced about 79 percent of the world's total supply of columbium concentrate, alloys, and oxides. Brazil was third in tantalum concentrate production in 1994, following Australia and Malaysia.

South Africa

Although government and industry sources provide somewhat inconsistent information on the South African economy, it is generally agreed that the minerals industry contributes 10 to 12 percent of the nation's GDP. At least 80 percent of all mineral production is exported, with mineral sales accounting for over 60 percent of the nation's export revenue. According to the Ministry of Mines and Energy, exports totaled US$17.6 billion in 1995, of which US$6.4 billion (36 percent) was for gold. Gold has been the main source of foreign currency for South Africa for many years. In 1980, when gold prices peaked, gold mining directly contributed 17 percent to the GDP. Gold mining currently contributes just under 5 percent directly to GDP, though indirect contributions may raise that closer to 10 percent. The South African minerals industry supports over 600,000 jobs, approximately 4 percent of all jobs in South Africa.

According to recent official estimates, South Africa has the world's largest reserves of six major minerals: alumino-silicates, chromium, gold, manganese, the platinum group metals and vanadium. For another 10 minerals, South Africa ranks in the top five nations. The South African mining industry collectively is the world's largest producer of gold, the platinum-group metals, vanadium, and alumino-silicates, and ranks in the top five for 10 other minerals, as summarized in the following table.

Table 2 — South Africa's Role In World Minerals Production 1992.

Mineral	Unit	Production	World	
			%	Rank
Alumino-silicates	kt	231	35	1
Antimony (metal content)	t	3, 951	10	4
Chrome ore	kt	3,364	30	2
Diamonds (gem and industrial)	k car	10,177	11	5
Ferrochromium	kt	771	21	2
Ferromanganese	kt	536	9	4
Fluorspar	kt	260	7	5
Gold	t	613	28	1
Manganese ore	kt	2,464	11	4
Platinum-group metals (metal)	kg	152,891	54	1
Titanium metals	kt	751	20	2
Vanadium (contained V_2O_5	t	25,052	42	1
Vermiculite	kt	170	36	2
Zirconium minerals	kt	230	29	2

CHALLENGES

Several challenges affect each of these countries and their continuing ability to provide mineral resources to the world. Among them are protecting the environment, coping with growing federal deficits and insufficient capital investment, inadequate or outdated infrastructure, and the globalization of the marketplace. Both the United States and Canada legislate and enforce environmental regulations. Although Brazil and South Africa articulate the need to protect their environment, policy is lacking and enforcement haphazard.

Another challenge shared by these nations is their growing federal deficits. A very small portion of the national budget is available for capital investment. Both the United States and Canada can easily borrow funds from foreign investors to finance their debt; however, borrowing is uncommon in Brazil and South Africa because the annual interest on capital is almost 50 percent. Officials in South Africa are unwilling to subject their countries to the rules and regulations that accompany funding from the World Bank. By contrast, in 1996 alone, Brazil requested and received approval for projects valued at over one billion dollars from the World Bank.

Brazil's financial challenges are massive. Since his election in 1994, President Cardoso has implemented comprehensive, market-oriented reforms of the public sector, and he is privatizing state-owned industry, and eliminating barriers to foreign investments. It will not be easy for Brazil to abandon long-standing practices of government intervention in the market economy, but the effective dismantling of its inefficient state structure is essential to its long-term survival and industrial competitiveness (Onis, 1989).

South Africa's major challenges revolve around maintaining its new government. Foreign individuals and organizations hesitate to invest until they can be satisfied that the South African government is stable. Among its many problems are violence, unemployment (at almost 50 percent), widespread poverty, and lack of education. The young government of South Africa must overcome many obstacles.

OUTLOOK

The threats inherent in mineral resource dependency are many, beginning with resource depletion, potential shortages, disruptions, economic fluctuations, or interdiction.

However, a nonfuel mineral dependency is not as threatening as it appears and no nation is completely self-sufficient in today's global economy. Globalization constrains national leaders from using historical market controls to leverage their positions. Today's world is interwoven with trade dependencies. Developing nations with vast mineral resources depend mightily on uninterrupted trade revenues. They are also the greatest importers of manufactured goods from the United States, comprising our fastest growing market (Castle and Price, 1983). Only eight of the world's 180 countries produce significant food surpluses. In fact, the United States could statistically hold a greater monopoly on food production than OPEC does on oil (Paone, 1992). As the Institute for National Strategic Studies noted in its 1996 Strategic Assessment: "purely national economies no longer exist.' Economic interdependence has reached an unprecedented level; no nation can stand alone.

The idea of strategic mineral cartels, price controls, and embargoes evokes images of gas lines from the 1973 and 1979 oil crises. The actual likelihood of such materials blackmail is remote. The success of cartels depends on a number of complex factors, and requires not only political, but also economic solidarity, which is difficult to maintain in today's environment (Tilton, 1977). The market's reaction to both price fixing and embargoes is the greatest deterrent to these tactics. As with any commodity, demand falls with price increases and other sources, alternative products, and conservation can frequently fill the void. In today's global market, the producer, rather than consumers, is injured when other producers gain market share.

Could we survive a cutoff of strategic materials? The answer is yes. Kenneth Kessel studied the effects of a yearlong cutoff of the "big four" strategic materials from South Africa: manganese, cobalt, chromium, and platinum. He found that, given the current U.S. position, induced shortages would be almost entirely absorbed by supplies in transport pipelines, industry inventories, and modest conservation. In no cases would shortages affect defense needs. Within six months to a year, new production and substitutions would more than offset the problem. Duration of the cutoff is the determining factor, whether in peace, crisis, or war.

Materials shortages are not critical in all war emergencies (Gill, 1984). The biggest threat would be a large-scale war that endures longer than our most recent experiences, but falls short of a multiple-year war that would allow for market and technology mobilization.

Resource depletion is likewise not as critical as some suggest. The projections on which this theory rests are based on current known mineral reserves and estimates of future consumption built on today's rates. But these methods are flawed. Reserves are only known if exploration, usually commercial ventures, finds them. Companies don't often spend much capital to look for reserves they don't yet need. Second, both reserves and consumption rates are based on current technology, while the impact of future innovation is impossible to calculate. Finally, depletion does not account for the fact that, except in nuclear processes, elemental materials are not used up in production processes. They are simply transformed. Future recycling technologies may offer far more opportunities for reuse (Tilton, 1997).

Technology and innovation have other possible impacts on material availability. Besides recycling, future technology may offer new exploration and extraction methods, more efficient uses for materials, new processes to use poorer grade ores, and improved conservation methods. There may also be new sources of mineral deposits, such as deep seabed, lunar, asteroid, or extra-planetary (Haag, 1997). Finally, new artificially structured materials, like advanced ceramics and composites, will undoubtedly replace many of our current construction and component minerals. Current technology in this area can virtually build new materials one atom or molecule at a time, giving advanced materials properties like none found in nature (Committee on Materials Science, 1989).

Recycling

Recycling and reuse are options to consider in lieu of new materials. Industries in the United States practice recycling when it is economically beneficial to them or when government legislation, focusing on environmental impact and protection, requires them to do so.

Canada has a much stronger national policy and programs for recycling than does the United States. The Canadian government subsidizes the recycling industry, including environmental research and development. Canada, like the United States, has no program specifically directed to recover and reuse strategic materials.

Brazil has recently added several articles to its Constitution that call for reclaiming environmentally degraded areas. Other resolutions require mining operators to act in an environmentally alert manner. Still other efforts address antipollution efforts. However, we found no policy in Brazil that specifically addressed the recycling of materials.

Recycling has great implications for energy and material resource conservation, waste reduction, and pollution prevention. The use of recycled materials has increased partly as a result of escalating prices, but also because of environmental concerns and energy costs. Thus, there are many success stories. Every ounce of gold that has ever been mined and refined is still in use in some form (National Mining Association, 1996). The secondary recovery of aluminum (7.8 billion pounds in 1994) uses 5 percent of the energy required to produce the same amount of aluminum from ore. Steel, our most recycled material, had a recycling rate of 68.5 percent in 1995. In 1995, automobile recycling rates were nearly 75 percent, leading to the recovery of large quantities of steel, aluminum, copper, lead, zinc, platinum (especially for catalytic converters), plastics, and glass. Virtually 100 percent of all titanium produced is reclaimed and reused.

There is still room for improvement. Of the 84 minerals listed in the 1996 Mineral Commodity Summaries, fewer than one third are recovered from previously used applications. The remaining two-thirds are either not recycled or the recycling effort is insignificant.

GOVERNMENT GOALS AND ROLE

The articulated goals of Brazil, Canada, South Africa, and the United States are very similar. Each recognizes the necessity of having active, competitive industries to compete in the global economy and promote the general welfare of its citizens. Similarly each of these nations is struggling with a history of spending in excess of revenue. Although foreign investment is essential, obtaining investment capital is more difficult for Brazil and South Africa than for the United States or Canada. Each nation recognizes the need for research and development. Methods for addressing these needs differ because of the different capabilities and styles of government among the countries.

United States Perspective and Policy

Two trends mark the U.S. perspective and policies: economic vibrancy and unmatched military hegemony. The United States is experiencing one of its strongest economic periods in the past 20 years. Unemployment is 5 to 6 percent and inflation is running less than 5 percent per year. Stock markets have shown steady and consistent growth for the past seven years. These positive effects have occurred within a significant period of industrial restructuring, and government downsizing. However, the country continues to run substantial annual budget deficits, though with decreasing trends the past few years. Now that Congress and the administration are committed to achieving a balanced federal budget, consumer and investor confidence are soaring to an all-time high as evidenced by the stock market's substantial growth in the past two years.

The end of the Cold War finds the United States as the lone superpower in the world with no known adversary capable of challenging or threatening its leadership or national security. The absence of any visible threat calls into question many of the programs that support our defense and national security. The nation is selling off defense resources such as the national stockpile and terminating numerous other programs now considered unnecessary. Other than stockpiling, there is no specific

U.S. policy or strategy for minerals, metals, or strategic and critical materials.

Following World War II, the United States actively supported science and technology by providing substantial funding for basic and applied research programs. Although much of this funding supported defense initiatives, the benefits were apparent in the spin-offs to commercial applications. The 20-year period following the Second World War was a renaissance for invention and commercial development. Funding for government-sponsored research in 1953 was $2 billion; the total budget was $74 billion.

Since 1994, as a response to the need to balance the federal budget and in accord with world changes, funding for science and technology programs has declined. Funding in fiscal year (FY) 97 is about $43.4 billion, in constant year dollars, or 9.7 percent less in real terms than FY 1994 funding levels. These figures include basic and applied research across the entire federal government, and all development programs except those managed by the Defense Department and the Department of Energy (National Academy of Science, 1997). These funding levels are surprisingly low in view of many foreign governments' efforts to increase their nondefense R&D. Foreign governments have recognized the connection between technology and successful economic growth (DOC, 1996).

Early in his administration, President Clinton announced that his technology policy would target economic growth. It contains four elements:

- initiatives that will help develop, commercialize, and deploy new technology;
- fiscal and regulatory policies that promote these same activities—ranging from R&D tax credits to changes in government procurement policy;
- investments in scientific and technical education and training; and
- projects that will help build critical transportation and communications infrastructure.

A recent report confirms the administration's long-term support for federal government investment in research and development. It also acknowledges the environment of reduced discretionary budgets, and indicates that in today's constrained resource environment, the administration's objectives can be obtained more efficiently by allocating funding for federal science and technology (FS&T).

The administration proposes consolidating the FS&T budget across all disciplines and agencies. This consolidation would allow projects to be ranked so that resources will be available for new and promising investment opportunities (Committee on Criteria for Federal Support, 1995). In addition, the current administration seeks to provide incentives for R&D in the private sector through legislation and regulation.

Canadian Policy Initiatives

Canada has suffered recent economic difficulties caused by deficit spending, accumulated debt, and substantial interest payments on the debt. Canada's expenditures have exceeded revenues for more than 20 years. Accumulated debt exceeds 70 percent of the GDP. Many economists believe that a legacy of many years of liberal social programs has taken its toll on Canada and its economy.

Recently, the Canadian government embarked on an ambitious recovery program, "Investing in growth." Its purpose is to promote economic growth and create well-paying jobs, and it has three policy initiatives: First, reduce the deficit and debt to GDP ratio; second, ensure stability and sustainability through social program reform. Third, and finally, provide Canadians and Canadian businesses the support they need to take full advantage of their modern economy (Canada Dept. of Finance, 1996).

These initiatives should improve Canada's competitiveness and trade posture in the global economy. The Canadian federal government is working quite hard to reduce the deficit and put the economy back on a steady path to recovery. Its approach—of addressing economic recovery vigorously through support and collaboration with Canadian businesses — strongly influences its minerals and metals policies.

Canada has formally articulated its minerals and metals policy (Partnership, 1996). This policy is an outgrowth and evolution of the October 1994 Whitehorse Mining Initiative and September 1995 National Resources Canada issue paper for "Sustainable Development and Minerals and Metals." Canada's federal government considers managing mineral and metal science and technology a core responsibility. This policy describes the role of science and technology and government's responsibilities.

The policy is written to reflect an overarching concept called "sustainable development." Sustainable development is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Natural Resources, Canada). The policy accommodates environmental concerns and enfranchises the aboriginal population within the broader arena of the minerals business. The Canadian government's science and technology goals are to

- promote enhanced productivity of the industry through collaborative efforts;
- provide a window and access point for Canadian companies—particularly small- and medium-sized firms—to acquire international science and technology;
- evaluate external technological developments to assess their usefulness and value to Canadian operations in the minerals and metals sector;
- promote the transfer of technologies within Canada to transform research into exploitable know-how and promote the sharing of expertise among all participants;
- provide Canadians with the geoscience, knowledge, and infrastructure to enable exploitation of domestic and foreign markets;
- facilitate collaborative approaches to national problems;
- share Canada's scientific and technological experience with the international community to implement sustainable development for minerals and metals;
- promote the development of environmental protection and pollution prevention technologies; and
- work with industry to realize more employment and revenue benefits from mineral and metal resources through valued-added manufacturing of mineral and metal-based products.

This policy provides the framework for developing and applying science and technology to enhance Canadian industry's competitiveness and environmental stewardship. The role of the government is clearly defined as a catalyst and facilitator to form partnerships with industry, provincial and territorial governments, international organizations, other countries, and academic institutions involved with science and technology. This policy supports the economic reform initiative and seeks to provide Canadian business with access to the technical information that ensures competitiveness in the global economy.

By 1998 the federal government plans to invest $250 million through its Technology Partnerships Canada program. These funds will be used to leverage additional investment from the private sector. Rather than serving as a grant to firms, these funds will be replenished by income and profits from the products developed using the new technology.

Brazilian Perspective and Policies

Two initiatives by the Brazilian government provide insight into their intentions. First, Brazil's geological survey contributes to strengthening the nation's mineral resources by actively pursuing programs to map Brazil and develop databases with geological and economic information. The government has concentrated its efforts on the basic geological mapping of the nation's minerals so that these valuable resources can be used productively.

Brazil's second significant venture was a $160-million loan acquired through the Inter-American Development Bank in 1995 to modernize this industry with new technology. This initiative broke with the government's 1980s legacy of not investing in technology improvement projects. Failure to fund science and technology programs has handicapped Brazil's industry, rendering it inefficient and less competitive in the global marketplace. Brazil's economy can't grow and compete unless these programs are sustained. The loan has precisely that objective: support industry to compete in the global market. The loan also funds needed and overdue R&D proposals by universities and research institutes. Brazil's extensive network of mineral research colleges and firms serve as a key resource supporting this initiative.

These initiatives are consistent with Brazil's continued efforts toward economic stabilization and a market driven economy, and its desire to shift industry from government ownership to operation in the private sector. Under President Cardoso, Brazil revised its Constitution to permit foreign ownership of mines, to increase government's transparency, and to improve the rule of law.

South African Perspective and Policy

As South Africa's major industry and employer, the minerals and mining industry is at the center of the South African debate to balance rights and realign resources. A government policy initiative, the Tripartite Discussion Document, states that government's role is to coordinate research essential for stimulating development of the country's mineral resources that aren't within the normal business and risk limits of private industry (Draft Mineral & Energy Policy). The paper defines the government role in research and development as consisting of the following tasks:

- direct research and development in areas of high need, particularly health and safety, small-scale mining, and beneficiation;
- provide matching grants for funding research and development projects;
- restructure the Safety in Mines Research Advisory Council (SIMRAC) to improve research management and oversight, and undertake occupational health research;
- manage government funds spent on joint research and development projects with industry;
- establish a mining and mineral processing research and development commission to make use of the best facilities, promote collaborative research activities and technology transfer, and ensure that minerals-related research and development is conducted in accord with the country's science and technology policy and national objectives; and
- ensure the SIMRAC's funding remains at a sensible level.

Some of these issues will pose difficult obstacles for the mineral industry, particularly with regard to the state's authority to direct research and development. The Chamber of Mines has commented on the draft policy on behalf of the mining industry. Industry welcomes the potential contribution that such R&D can make, provided that it is user-driven and complementary to private-sector activity. However, industry questions the government's strategic role and ability to formulate R&D policy. It also takes exception to the proposal in which government would intervene and add value to the relationships that industry already has with academic and research organizations. It concurs, however, with the government's cooperative role in health and safety research and that it should be funded by the government (Mining and Minerals Policy). These issues will be difficult to resolve. The established mining companies will be slow to give up authority in this area. In addition, industry funded the high risk research that allows deep-shaft mining (to 5 kilometers) under extreme environmental working conditions. They will be reluctant to share this technology.

The South African government wants to move the country to a market economy, and the mining industry is a major element of that effort. The major issue is how to enlarge the ownership of the mineral wealth currently controlled by a small group of companies so that its benefits are shared with all South Africa's citizens. The government will try to use public policy to level the playing field. This role seems appropriate for a government in a country where the majority was disenfranchised for so long. Many remnants of apartheid are still factors in the lucrative mining industry.

CONCLUSION

Many commonalties exist among the United States, Canada, Brazil, and South Africa concerning strategic materials. All discussions we had in Canada, Brazil and South Africa, whether with government officials or private industry and business representatives revealed similar concerns. All recognize the advantages of free international markets, insist that sustainable development is a necessary focus of any mining efforts, and describe the advantages of government involvement in long-term research and development. Brazil and South Africa are struggling to upgrade infrastructure and decrease costs and production inefficiencies.

Each country has different approaches for achieving its goals. The common thread is the goal: to achieve or maintain economic stability and the benefits that accrue with it. All four countries are actively negotiating new markets, for example, through NAFTA (the United States, Canada and Mexico), MERCOSUR (Brazil, Argentina, Uruguay, and Paraguay) and SADC (Southern Africa Development Corporation). Canada's very proactive approach focuses heavily on collaborating with industry to ensure the global marketability of its products. South Africa is developing and debating a policy that would expand ownership beyond the small group which has historically controlled the minerals industry. Another priority is to develop a value-added component to its minerals industry rather than simply exporting raw minerals. Brazil is privatizing enterprises, obtaining foreign funding to invest in infrastructure and R&D, and charting a course to exploit its mineral resources. Although the United States actively negotiates new markets, it has reduced its financial support and commitment to R&D which has traditionally been a key to its successes.

Despite a drastic decrease in R&D funding in the United States, it still invests more than Canada, Brazil, or South Africa in this enterprise because of the size of its GDP. Further, R&D has decreased in all four countries at the industrial level. Many corporations indicate that investor insistence on quarterly improvements in the bottom-line threatens continued advancement and productivity enhancements. South Africa is struggling, yet still invests in R&D. South African researchers have many international patents, but unfortunately its industrial base is too weak to manufacture many products. Brazil has obtained external funding for its R&D programs and hopes to improve its competitiveness in the world economy. Canada closely links R&D to industrial productivity. It seeks to decrease product development time and uses rapid testing and evaluation programs. The United States stands alone in its thinking that support for industrial R&D is "corporate welfare" and inappropriate in today's economy.

There has been a fundamental shift in thinking concerning the strategic and advanced materials industry in the United States. Historically, our concerns, policies, and programs were directed at items needed in times of a national emergency and whose sources of supply were potentially at risk. The end of the Cold War and the increased globalization of national economies has inspired a broader perspective on strategic and advanced materials. The new perspective recognizes that national security encompasses planning for the general welfare of a society and includes economic and political considerations in addition to traditional military requirements.

This broader perspective on the industry and national security was evident in each of the countries included in this project. However, each country is in a different state of economic and political development, which supports our conclusion that "strategic" is a matter of perspective subject to changes over time. The new millennium will present additional changes and challenges and perhaps redefine the parameters used to discuss "strategic materials" in each nation.

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