CHAPTER 4

Security of Supply

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Import dependence—i.e., the proportion of demand supplied by foreign sources–is not the same as import vulnerability. The stability and reliability of foreign sources of supply, plus their number and diversity, are major factors in gauging whether or not this Nation is vulnerable to disruptions in the supply of a given imported material.

The preponderance of U.S. minerals imports comes from reliable sources—allies and close neighbors. Canada is this country's leading provider of nonfuel minerals, accounting for one-third of the total value of U.S. minerals imports. Of the 34 minerals shown in chapter 2 (fig. 2-1), Canada is the largest supplier of 12, including iron, nickel, zinc, tungsten, selenium, cadmium, asbestos, and potash. Australia is by far the United States' biggest source of rutile ore for making titanium (one of the essential metals for airplane parts and engines) and is a significant supplier of alumina and cadmium, Mexico is a dominant or major supplier of a dozen minerals, including strontium, fluorspar, natural graphite, silver, cadmium, and zinc; and Brazil sells the United States large amounts of manganese. Venezuela is a major provider of rich iron ore.

For a few specific minerals, however, the United States is highly dependent on a limited number of sources that could prove unstable. It may fairly be said that vulnerability of supply for some of these materials has increased over the past 30 years. Suppliers that were once colonial dependencies of Western European countries and reliable hosts to international mining companies are now struggling new nations. Many of them are experiencing difficulties in running their own nationalized minerals industries, and some are quite vulnerable to civil disorder and local wars.

Supplies even from sources regarded as reliable can be interrupted. Such was the case in 1969, when a months-long strike of the International Nickel Co. in Ontario sent nickel prices soaring and users scrambling for supplies. In addition, the security of imports from a friendly trading partner like Australia may be called into question because the supply lines are so long. Nor is domestic production proof against interruption of supply. For example, molybdenum was in short supply, here and abroad, from 1974 to 1979, even though the United States is the world's largest producer and exporter of this mineral. The shortage came about because of a world depression in copper production, of which molybdenum is often a byproduct, and because the large new Henderson mine in Colorado was not yet in operation. Moreover, in 1979, after the Henderson mine was producing, a 9-month strike at Canada's Endako mine kept world production of molybdenum flat. That year, spot market prices shot up to triple the mining companies' contract price.

It should be noted that the decline of the American steel industry may be said to increase the vulnerability of the entire U.S. economy, and to make the Nation less self-sufficient in defense. This troubling problem goes to the heart of U.S. economic strength and international competitiveness, and it is receiving sustained attention from analysts and policymakers. However, it involves many issues that are outside the scope of this report. Readers interested in these issues are referred to a prior OTA assessment, *Technology and Steel Industry Competitiveness.*[1]

Altogether, security of minerals supply hinges on a broad variety of factors. One concern, very much to the fore in the early 1970s but less so now, is the depletion of world resources in the face of escalating demand. An impermanent but recurring difficulty for many minerals is boom-and-bust cycles, with surges of demand coming from the most volatile parts of the

[1]Office of Technology Assessment, Technology and Steel Industry Competitiveness, OTA-M-122 (Washington, DC: US. Government Printing Office, June 1980).

economy during the time when users of the minerals are experiencing tight supplies, shortages, and high prices. In the bust side of the cycle, minerals investments in everything from exploration to modernization may decline precipitously, and some mines and plants that are closed down may never reopen.

Recently, concerns about security of supply have centered around the possibility of a cartel gaining control of critically needed minerals, of a Soviet-inspired squeeze on minerals from central and southern Africa, or of unplanned, unpredictable civil disturbances or local wars.

Factors That Affect Security of Supply

Depletion of World Resources

The Earth's resources are, of course, finite, But the minerals that underpin industrial society seem to be in no immediate danger of "running out" in the physical sense, at least for the next 30 to 50 years. Technology has continually extended both reserves—the identified inventory that can be mined profitably under present economic and technical conditions—and the larger body of known or potential resources, Table 4-1 shows the changes in proven world reserves of 13 minerals over 30 years. Most of them increased by at least 100 percent, and several by more than tenfold, even while world demand shot upward, especially in Germany and Japan.

The reason for the continued growth in reserves of the world's minerals is that the means of discovering them, mining them, and processing them have steadily improved. For example, through technological advances, many lower quality ores are now just as usable as the richer ones were before them. An important instance is chromium, where the distinction between the metallurgical grade of chromite ore, with its higher chromium content, and the lower chemical grade has lost most of its significance just in the last 10 years, Thanks to a steelmaking advance (called the argon-oxygen-decarburization or AOD process), high-carbon ferrochromium (made with the chemical grade of chromite ore) can be used in place of low-carbon ferrochromium (made with the metallurgical grade) in the production of stainless steel.

Table 4-1 .—World Reserves of Selected Materials, 1950 and 1981 (tonnes unless otherwise stated)

Material	1950	1981	1981/1950
Bauxite	1.4×10^{9}	2.2×10^{10}	16
Chromite[a]	1.0×10^{8}	3.4×10^{9}	34
Cobalt	7.9×10^{5}	3.1×10^{6}	4
Copper	1.0×10^{8}	5.1×10^{8}	5
Iron	1.9×10^{10}	2.7×10^{11}	14
Lead	4.0×10^{7}	1.7×10^{8}	4
Manganese	5.0×10^{8}	4.9×10^{9}	10
Molybdenum	4.0×10^{6}	9.8×10^{6}	2
Nickel	1.4×10^{7}	5.4×10^{7}	4
Platinum group[b]	2.5×10^{7}	1.2×10^{9}	48
Tin	6.0×10^{6}	1.0×10^{7}	2
Tungsten	2.4×10^{6}	2.9×10^{6}	1
Zinc	7.0×10^{7}	2.4×10^{8}	3

[a]Chromium ore
[b]Troy ounces

SOURCES For all 1950 figures except platinum group, John E Tilton, *The Future of Nonfuel Minerals* (Washington, DC Brookings Institution, 1977), p 10 For 1981 figures and 1950 figures for platinum group, U S Department of the Interiot, Bureau of Mines

Another point about physical depletion is that nonfuel minerals, unlike fuels, are generally not consumed with use, Many can be recycled. In some instances, recycling may not be economical because the mineral ingredients in finished products are widely scattered, degraded, or inconveniently combined with other materials. Yet recycling is already an important source of supply for many minerals and could become more so with advances in technology.

How long technology can extend the life of the Earth's resources is, of course, a serious question. Just because it has done so satisfactorily in the past is no guarantee that it will in the future, especially when world population is growing at a staggering pace and soaring demands for resources may follow. Minerals economists generally argue that depletion would make itself felt as a persistent long-term rise in materials costs rather than an abrupt physical running out of stocks.[2] This expectation may be too optimistic. According to one geophysical theory, most metals have a "mineralogical barrier" beyond which the energy needed to release them from the rocks in which they are bound leaps 100 to 1,000 times. The barrier may be reached for all "geochemically scarce" metals—which is to say, all but five—within a century.[3]

The Earth's crust contains just 12 "geochemically abundant" elements, which account for over 99 percent of the mass. Five of these elements are metals: aluminum, iron, magnesium, titanium, and manganese, A steadily increasing amount of energy will be needed to produce even these metals from progressively leaner ores. But for all the other metals, a mineralogical barrier may exist, usually at ore concentrations of about one-tenth to one-hundredth of 1 percent, past which the metal is no longer concentrated in an ore body. Instead, it is dispersed as atoms, isomorphically replacing atoms of the abundant elements in common rocks. Once the mineralogical barrier is reached, the energy needed to release the scarce metals will be so great, and the prices so high, that according to the theory, new supplies of these metals will no longer be produced. According to this theory, a "Second Iron Age" will begin when "it will be simply cheaper to substitute iron and aluminum and put up with penalties, such as lower efficiencies in machines, that we do not now countenance."[4]

Analysts of the "cornucopian" persuasion concede that minerals depletion is in fact occurring, but they do not regard the loss as crucial.[5] The ultimate raw material, they say, is energy. Assuming that world population stabilizes, decent standards of living can be sustained indefinitely "provided man finds an inexhaustible nonpolluting source of energy."[6] They envision a new "Age of Substitutability," in which society would be based largely on glass, plastic, wood, cement, and the "inexhaustible" minerals: iron, aluminum, and magnesium. Whether societies have the capacity and foresight to plan a smooth transition from the present age of fossil fuels and materials abundance to the Age of Substitutability is a harder question. But, from the cornucopian point of view, there are no technical bars in the way so long as energy is available.

Demand Surges

Temporary shortages and price spikes for materials in response to peaks of demand have sometimes been interpreted as signs of resource depletion, Two major studies of materials policy were started, in fact, at a time of demand surge and materials shortages, one in the early 1950s during the Korean war, and another in 1973-74, when all the world's industrial countries were riding a wave of prosperity together. In both cases, the shortages proved short-lived. With a downturn in business activity, minerals industries found themselves with excess capacity, as they typically do after a boom is over.

Copper is an example.[7] Like many minerals, it is used in construction, transportation, capital equipment, and consumer durables, all of which react in exaggerated form to the peaks and valleys of economic activity. In 1973 and early 1974, with the economies of the United States, Japan, and Western Europe on a simultaneous upswing, there were serious copper shortages, aggravated by attempts of industrial users to build up inventories for security of supply, Within 2 years, the situation reversed.

[2]See, for example, Hans H, Landsberg and John E. Tilton, with Ruth B. Haas, "Nonfuel Minerals, " in *Current Issues in Natural Resource Policy*, Paul R. Portney with Ruth B, Haas (eds.) (Baltimore: The Johns Hopkins University Press, 1982), pp. 83-84.

[3]For a succinct statement of the theory, see 13 ria n J. Skinner, "A Second Iron Age Ahead?" American Scientist, May-June 1976, pp. 258-69.

[4]1 bid., p. 267.

5H, E. Goeller and Alvin M. Weinberg, "The Age of Substitutabil ity, " Science, Feb. 20, 1976, p. 688.

[6]Ibid., p. 688.

'Copper is not generally regarded as a strategic material today because the United States is a large producer, and supplies are currently more than ample. The copper industry does clearly ill ustrate the cyclical nature of minerals production, whether of strategic minerals or less critical ones. In genera], throughout this chapter, minerals that may not be strategic are used for illustrative purposes.

Prices slumped. Copper mines and smelters in the United States, the world's largest producer, were shut down. As industry revived in 1976-77, copper followed. With the recession of 1982, copper once more hit bottom, with prices dropping 30 percent in 2 years and mines closing throughout the American West. At the end of 1982, all of Anaconda's* mines and smelters in Montana were closed down or scheduled for closing. The huge Phelps Dodge open pit mine in Morenci, AZ, was shut down for several months in 1982—the first such closing due to a business slump since the Great Depression.[9]

Instability in the minerals industries is an old story, but some forces in recent years may be making it worse. One detailed study of fluctuations of industrial production in the United States, Japan, and several European countries concluded that the ups and downs of business cycles are now more pronounced than they were in the 1950s and 1960s, and that they are also more synchronized among the world's industrialized nations.[10] Other recent evidence suggests that stocks of copper held by U.S. industry are smaller than they were 20 or 30 years ago, and are not being used to counter swings in the business cycle as they once were, *l The same may be true of other minerals. Another possible factor: U.S. copper mines and smelters seem to have suffered more than a proportionate share of the loss in times of low world demand in recent years, because nationalized mines in some developing countries have been kept open to save jobs and precious foreign exchange even when prices did not cover the costs of production.

Related to the surges and drastic drops in demand that are typical of minerals industries is lagging investment in mines and processing facilities. Inadequate investment while prices are low and facilities idle sows the seeds of future shortages. To be sure, such shortages tend to correct themselves, because the high prices they bring induce the needed investment. But lead times for opening new mines, processing plants, and support facilities are from 2 to 7 years, and meanwhile, industries dependent on the minerals may suffer hardship and dislocations for several years.

Cartels

The success of the Organization of Petroleum Exporting Countries (OPEC) cartel convinced many people that producers of other raw materials—bauxite, chromium, copper, phosphates, and perhaps tungsten—would get together to seize control of their markets. So far, it has not happened. One of the classic conditions for monopoly control does exist for quite a few nonfuel minerals; that is, a limited number of suppliers. In addition, some minerals are essential for certain industries with, at least for the present, no very good substitutes, Often, these same minerals account for a very small share of total production costs. These two factors make for inelasticity of demand and favor the success of cartel control of production and prices, at least in the short run.

There are several reasons why these conditions have not been enough to create a mineral cartel like the oil cartel. As noted earlier, the total costs of U.S. nonfuel minerals imports, compared with oil imports, are small. Also, most nonfuel minerals are far less bulky than oil and therefore much easier to store. Minerals-using industries generally keep a stock on hand, and the U.S. Government (although not European or Japanese governments) has a 1- to 3-year reserve of many critical materials to meet national defense needs in an emergency,

Significantly, markets for most nonfuel minerals have been soft since mid-1974. And for many producer countries (e.g., Zaire, Zambia) minerals exports are the mainstay of the economy. Considering the state of the market, the existence of government and private stocks, the existence of substitutes for many materials, the potential for development of substitutes for

'3 Now owned by The Atlantic Richfield Co,

[9]"Arco Unit to End Copper Mining in Butte, Mont." Wall Street Journal, Jan. 10, 1983; Jay Mathews, "U.S. Copper Industry, Beset by High Costs, Low Prices, Losing Out to Foreign Producers," Washington Post, June 22, 1982,

[10]David Chien, "Business Cycles and Instability in Metal Markets," Materials and Society 5(3), 1981, pp. 257-265.

[11]Timothy J. Grubb, "Metal Inventories, Speculation, and Stability in the U.S. Copper Industry, " Materials and *Society* 5(3), 1981, pp. 267-288,

others, and the threat of new, alternate suppliers to any cartel, these producers could not risk supply stoppages. Most importantly, producer countries as diverse in ideology and goals as Zimbabwe, South Africa, and the Soviet Union might find it difficult indeed to cooperate in an OPEC-like organization that sets production controls and prices.

Producers of copper and bauxite did take steps to restrict supply and raise prices in 1974 and 1975. The copper effort, undertaken by members of the International Council of Copper Exporting Countries (CIPEC) was a failure, The CIPEC agreement to reduce copper exports by 15 percent had no effect on prices, Copper exporters thus turned to urging price stabilization agreements, which require the consent of purchasing countries. These efforts, made through the United Nations Conference on Trade and Development, also failed.

More successful was Jamaica's imposition of sharply higher taxes on bauxite. U.S. aluminum producers tolerated the higher price resulting from the tax because they had no alternative supplier as convenient as nearby Jamaica, and the cost of bauxite is a small fraction of the cost of finished aluminum. Nonetheless, during the aluminum recession of 1974-76, Jamaican output of bauxite dropped 30 percent, while bauxite production expanded in Australia, Guinea, and Brazil, none of which had imposed high taxes.

Because producer countries in the developing world had little success in the 1970s in creating minerals cartels does not guarantee that cartels will never succeed, Arguing against success is the distinct lack of common goals among producing countries and the deterrence exerted by stockpiles and substitutes. Arguing for it, in the short run at least, is the fact that a few important minerals are produced in a very few countries, It is worth keeping in mind that most minerals cartels in the past have fallen apart because consumers conserved or found substitutes, other suppliers got into production, and cartel members were tempted to cheat, raising output or lowering prices in the attempt to maintain their own income or foreign exchange. OPEC itself has been under severe strain for several years as a result of these factors.

Another point to consider is that monopolistic control of the market for economic purposes does not necessarily imply shortages or price leaps. Monopolies are certainly not unknown in minerals history. Past examples include Canada's Inco, formerly preeminent in world nickel production, and the Union Miniere of Belgium for cobalt in the days before Zaire's independence. In these instances, monopoly control resulted in rather reliable levels of production and prices that remained stable, although prices probably were higher than they would have been under competitive conditions.

Political Embargoes and the Resource War

As fears of cartel control over nonfuel minerals have faded somewhat, a new fear has grown that the supply of critical materials may be choked off for political reasons. Governments, including that of the United States, restrict both imports and exports to serve political goals. From 1966 to the end of 1971, the United States cooperated with United Nations' sanctions against the former British colony of Rhodesia, refusing to buy Rhodesian chrome because the colony resisted greater participation by blacks in the government. The United States has also prohibited nickel and other imports from Cuba since the 1960s.

Now, some analysts believe that the Soviet Union is carrying out a grand, long-term strategy to gain control of both Mideastern oil and African minerals, and to threaten the West with the loss of these critical materials. They believe that the Soviet invasion of Afghanistan, Soviet influence and the presence of Cuban troops in Angola and other African nations, and the buildup of the Soviet navy are all pieces of the strategy.[12] In their view, "state domi-

[12] Some publications expressing this view are Council on Economics and National Security, Strategic Minerals: A Resource Crisis (Washington, DC: 1981); and World Affairs Council of Pittsburgh, The Resource War in 3-D–Dependency, *Diplomacy, Defense* (Pittsburgh: 1980).

nance," rather than commercial ownership, of mineral resources in Third World countries gives the Soviet Union access to these minerals through political agreement, backed up by Soviet military power.[13] Figure 4-1 shows the mineral-rich part of Africa which has prompted the greatest concern about possible Soviet control of resources.

A variation of the resource war argument is that the traditional Soviet self-sufficiency in minerals is crumbling, and that the Soviet Union plans to rely on political and military domination of Africa rather than on costly economic competition with Western nations to get the resources it needs, Proponents of this idea point to Soviet and Eastern bloc purchases, beginning in 1978, of chromium, cobalt, manganese, tantalum, titanium, and vanadium, together with halts or large cutbacks in exports of platinum, gold, and titanium.[14]

Other observers of this situation find the picture of a full-scale resource war unpersuasive.[15] While not discounting "the desire and ability of the Soviet Union to create mischief for the United States and its allies,"[16] they see little evidence so far that Soviet activities in Africa are part of a grand design to grab minerals for themselves and deny them to the West. If the Soviet Union wanted to mount a direct challenge to the Weston resources, these observers say, it would be far more likely to choose the Mideast than southern Africa. The Mideast is nearby and has the oil that is the West's lifeblood.

The actual behavior of African nations with Marxist governments and strong ties to the Soviet Union so far has not resulted in efforts to disrupt minerals supply to the West. All of them maintain economic relations with the West. They are keenly aware of their need for income and foreign exchange from minerals exports. Angola, for example, even with its thousands of Cuban troops, protects Gulf Oil facilities and encourages further foreign investment. Likewise, Zimbabwe is trying to expand its minerals exports, and Mozambique has growing American investment. One contributor to a series of scholarly papers on the Soviet Union and the resource war, prepared for the School of Advanced International Studies of the Johns Hopkins University, said:

> The vocabulary of the resource war, when addressing Southern Africa, mentions possible Soviet desires; often it neglects to examine Soviet abilities to realize their desires , . . Today, despite sizable military aid for the region from Moscow, probably all of the states harbor a healthy distrust of Soviet tactics and methods . . . Along with Soviet economic and political failings, [the region's] growing dependency upon Western economic institutions should preclude southern African states from becoming Soviet clients .[17]

This analyst believes the danger from Soviet influence will be greatest if South Africa continues its support of insurgent groups in neighboring black African states, including non-Marxist Zambia as well as Angola and Mozambique. The danger is that, to repel the insurgents, these nations might become increasingly dependent on Soviet military aid and might then be forced into a client-state relationship.[18]

Several observers report that they see little evidence of rapidly increasing Soviet dependence on imports of strategic materials. They believe that the recent Soviet buying forays for some minerals and the cessation of the sale of

[13]William Casey, Director, Central Intelligence Agency, Speech to U.S. Chamber of Commerce, Apr. 28, 1981, reprinted in *Congressional* Record, June 23, 1981, S6779.

[14]Daniel I. Fine, "Mineral Resource and Dependency Crisis: Soviet Union and United States" in World Affairs Council of Pittsburgh, The Resource War in 3-D, cited in note 12. For a more moderate view of increasing Soviet dependency on minerals imports, with no conclusions drawn as to the consequences for a "resource war, " see Daniel S. Papp, "Soviet Non-Fuel Mineral Resources: Surplus or Scarcity?" paper prepared for the School of Advanced International Studies (SAIS), The Johns Hopkins University, May 1981.

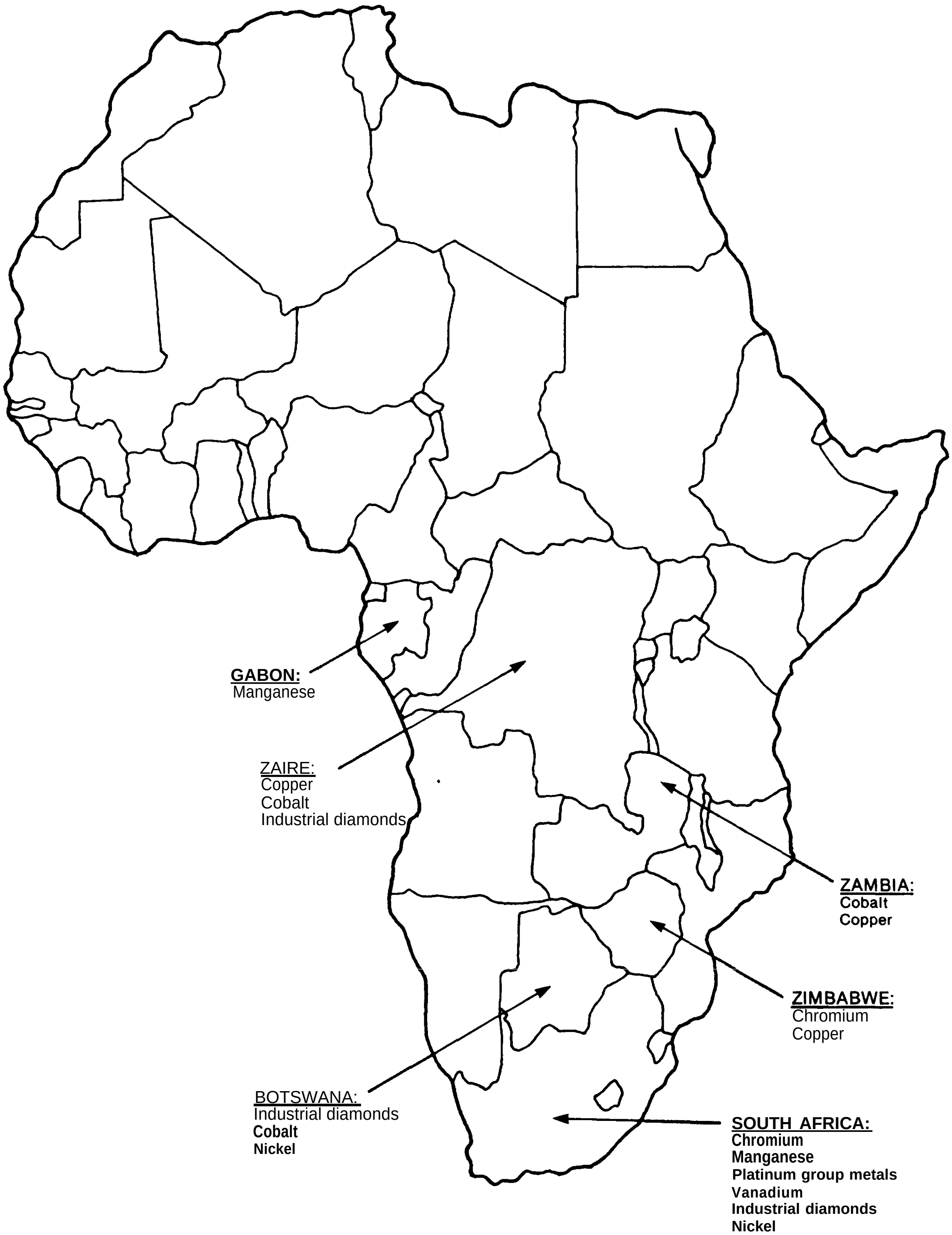
[15]See for example, Hans H. Landsberg, et al., "Nonfuel Minerals, " cited in note 2; and Robert Legvold, "The Strategic Implications of the Soviet Union's Nonfuel Minerals Policy"; Herbert Howe, "The Soviet Union and Southern Africa: A Patron-Client Relationship?" Michael Moodie, "The Soviet Navy: A Weapon in the 'Resource War'?" Robert E. Osgood, "The Security Implications of Dependence on Foreign Nonfuel Minerals, " papers prepared for the SAIS, cited in note 14.

[16]Hans H. Landsberg, "Minerals in the Eighties: Issues and Policies, An Exploratory Essay," paper prepared for the Oak Ridge National Laboratory, Oak Ridge, TN, 1982.

[17]Herbert Howe, "The Soviet Union and Southern Africa, " cited in note 15, pp. 2, 5.

[18]Ibid., pp. 17-19.

Figure 4-1 .—Selected Mineral Resources of Central and Southern Africa



SOURCE Office of Technology Assessment, based on U S Department of the Inter! or, Bureau of Mines data others signify "the consequences of poor Soviet planning, shoddy maintenance of facilities, and low production efficiency, " not an "emerging minerals shortage that could lend a common rationale to these actions."[19]

Indeed, as the quality of Soviet ores declines, and as new minerals exploration moves north and east into the forbidding Siberian environment, Soviet leaders may gradually abandon self-sufficiency as a top priority goal and may look to the outside world for cheaper, more convenient supplies of some minerals. But this does not necessarily imply that they will resort to strong-arm methods or a resource war to get those supplies.

One Soviet specialist asks: "Even were the Soviet Union shortly forced to import 5 to 10 percent of its lead, zinc, or titanium needs, what in that circumstance would begin to justify the risks of plundering Western sources of supply?"[20] Instead, he suggests, Soviet leaders wishing to buy a greater share of minerals abroad would use the conservative commercial approach they already use in foreign trade, possibly relying heavily on barter arrangements, or on development aid in which they are repaid in minerals.[21]

In sum, this school of thought holds that Soviet actions affecting the price and availability of African minerals is a matter of seizing opportunities rather than carrying out a strategic plan. They do agree, however, that the Soviet Union will go on trying to gain political power and influence in Africa by exploiting tribal conflicts, strong anticolonial feelings, and the opposition of black majorities to the rule of white minorities. Furthermore, they agree that mineral imports to this country and its allies from the richly endowed but troubled regions of central and southern Africa are definitely vulnerable.

[19]Landsberg, "Minerals in the Eighties, " cited in note 16. See also, William R. Severin, "Soviet Non-Fuel Minerals: Recent Trends and Prospects, " prepared for the SAIS cited in note 14, and Legvold, cited in note 15.

[20]Legvold, cited in note 15, p. 17.

[21]Ibid., pp. 18-21

Civil Disturbances, Local Wars, Internal Troubles

Civil strife, insurrections, difficulties of management, and breakdowns in mine production have, in the past, threatened the security of minerals supply from Africa. In many people's judgment, these are the kind of events most likely to cause interruptions of minerals imports in the foreseeable future.

The supply of Zairian cobalt, never actually cut off, has been threatened by insurrection and civil war in central and southern Africa. Angola's Benguela railway was the major route between central Africa's copper and cobalt mines and the rest of the world until the civil war shut it down in 1975. Zaire and Zambia had to scramble to find other exit routes for their minerals, including through South Africa, and are still relying on these less satisfactory routes, If the Angolan railway had shut down at a time of strong demand for minerals, the interruption might well have driven up prices and disrupted markets, In fact, the 1978 invasion of Zaire's Shaba province, with a brief occupation by the insurgents of the mines and processing facilities, had more serious consequences for the world cobalt market, as described later in this chapter.

In the future, the state of domestic peace and stability in central and southern African nations such as Zaire, Zambia, Zimbabwe, and Gabon, will strongly affect minerals production and export. Nor is South Africa exempt from the possibility of trouble. It is unknown how long South Africa can resist pressure for change and a possibly difficult transition to a new form of government with black participation. Even now, with white minority rule still firmly in place, the potential for disruption exists, as shown by the 1980 bombing of SASOL, South Africa's synthetic oil project.

A general war would, of course, be more profoundly disruptive than any of the circumstances described here. This report does not explicitly consider the contingency of general war. However, as a part of preparedness, the U.S. Government's stockpile goals are set with a 3-year conventional war in mind. Advanced technologies that reduce import vulnerability—the main focus of this report—are as valuable to the national interest in wartime as they are protective of U.S. economy and national defense in peace, but will not obviate the need to fulfill stockpile goals as a means to assure adequate supplies in the event of war.

Materials Supply Interruptions Since World War II

In the years since World War II, supplies of several critical materials have actually been cut off quite abruptly on a few occasions. It is instructive to look at the reasons why the cutoffs occurred, how the economy and defense industries coped with shortages, and how the imbalance of supply and demand was eventually righted.

Soviet Embargo of Manganese and Chromium, 1949

When the Soviet Union blockaded Berlin in 1948, cutting the city's land links with the West, the United States clamped down on exports of industrial goods to the Soviet Union. Among the goods embargoed were machinery, tools, trucks, and scientific instruments. In retaliation, the Soviet Union cut off shipments to the United States of raw materials critically needed by U.S. industry, mainly manganese, and chromium.[22]

The loss could have been serious. The Soviets at that time were supplying one-third of U.S. manganese consumption and one-quarter of U.S. chromium. Soviet exports of manganese ore to the United States dropped from 427,229 tons in 1948 to 81,459 in 1949, and their chromium ore exports dropped from 393,966 tons to 107,131 tons, In both cases, much of the ore was shipped early in the year, Within a few months of the embargo, however, the United States had made up the loss with supplies from other countries.

For manganese, substitute supplies came mainly from the Gold Coast (now Ghana), India, and the Union of South Africa. These substitute supplies came from the expansion of already producing mines. Enough capacity of this kind was available so that U.S. imports of manganese in 1949 actually increased 23 percent over 1948, despite the embargo,

Actual use of manganese dropped in 1949, a recession year, but demand remained strong because industries added 45 percent to their inventories, probably as insurance against any possible shortages from the embargo. In fact, manganese prices rose about 15 percent in 1949 (compared with 8 percent the year before) despite the recession. At the same time, the recession probably softened any additional damage the embargo might have caused.

The U.S. Government, together with industry, swung into action to encourage the opening of more manganese mines outside the Soviet Union. India got steel from the United States to improve her rail system for transporting ore, Canada and the United States sent ore rail cars to South Africa, and the Gold Coast's railway and port equipment were improved. With the help of loans from U.S. banks and the World Bank, South Africa improved railways to mines and improved harbors for shipping ore. India got a World Bank loan to build an electric power project in the Damodar Valley, where manganese and other minerals were produced.[23]

The answer to the Soviet embargo of chromium was the same as for manganese: alternate suppliers, Turkey and the Philippines increased their chromium ore exports to the United States, and the Union of South Africa

[22] Contemporary accounts of the Soviet cutoff of manganese and chromium include Bureau of Mines' publications; Business Week, Sept. 10, 1949, p. 125; and U.S. News and World Report, Dec. 16, 1949, p. 26.

[23] The President's Materials Policy Commission, *Resources for Freedom* (Washington, DC: U.S. Government Printing Office, 1952), vol. 1, p. 74,

remained a major supplier. At the same time, because of the recession, U.S. chromium consumption fell by nearly one-quarter. Chromium imports dropped as well, prices fell, and industries added 20 percent to their inventories,

In the aftermath, the United States continued to diversify its suppliers of manganese and today buys none from the Soviet Union. The principal suppliers of manganese ore to the United States are South Africa, Gabon, Brazil, Australia, and Mexico. These countries are all large producers of manganese, and important suppliers in the world free market. While manganese ore producers are today quite diverse, the Soviet Union and South Africa together hold the great bulk of the world's reserves (known deposits, commercially minable) and of its identified (but subeconomic) resources.

As for chromium, U.S. imports from the Soviet Union resumed in the 1960s and for a time the Soviets were among the principal U.S. suppliers. That story is told next.

U.S. Embargo on Imports of Rhodesian Chromium, 1966-72

The British colony of Southern Rhodesia (now Zimbabwe) unilaterally declared its independence in November 1965, setting a course of continued white minority rule. The next year, the United Nations (U. N.) passed a resolution prohibiting member nations from buying any of a dozen export commodities from Rhodesia. On the embargoed list was chromium ore.

Before the ban, Rhodesia was one of the big four suppliers of chromium ore to the United States, second to South Africa and ahead of the Philippines and the Soviet Union.[24] Together, these four countries contributed five-sixths of chromium ore imported by the United States, Rhodesia and the Soviet Union each supplied about 35 percent of this country's imports of high-grade metallurgical ore, and South Africa supplied 17 percent. At that time, the metallurgical grade of chromium ore was essential for making stainless steel. (In the last decade, as mentioned above, technological advances have blurred the distinction between the metallurgical and chemical grades of chromium ore in stainless steel production.)

Photo credit" George C Coakley, US. Bureau of Mines

An aerial tramway is one link of the transportation system that carries manganese ore from mines in Gabon to deepwater ports on the West Coast of Africa

When the United States complied with the U.N. ban on buying Rhodesian chromium, the Nation could have felt a real shock. Nothing so dramatic happened. First, the shock was cushioned by large sales from the U.S. Government stockpile. A long-range plan to rid the government stockpile of 1.9 million tons of "excess" metallurgical grade chromium ore had already been authorized before the man-

[24] Contemporary accounts of the Rhodesian chromium embargo include Bureau of Mines' reports and Business Week, Nov. 27, 1971, p. 23.

datory ban on Rhodesian chromium took effect. In late 1966 and 1967, industry contracted to buy 666,000 tons of this stockpiled ore for future delivery. Deliveries of high-grade ore from the stockpile amounted to 66,237 tons in 1966 and 62,980 tons in 1967, These quantities compare with Rhodesian imports of 144,000 tons of metallurgical grade ore in 1966, before the embargo took effect. Large amounts of lower grade chromium ore were also available from the stockpile, but found no industry takers.

Other factors also eased the effects of the ban on Rhodesian imports. Chromium-using industries had built up their stocks during 1966, when storm warnings from Rhodesia were apparent. Furthermore, deliveries of Rhodesian ore already purchased tailed off gradually over 1967,

At the same time, U.S. imports of metallurgical-grade chromium ore from the Soviet Union—and a year or two later from Turkey—began to increase, So did prices. For its exceptionally high-grade ore, the Soviet Union repeatedly raised prices, from around $32 per ton in 1966 to about $70 per ton in 1971, The price of Turkish high-grade ore rose comparably. Steelmaker throughout the industrialized world were competing for the more limited supplies of metallurgical-grade chromium ore available on the world market, and the suppliers took full advantage.

Nonetheless, it appeared that the ban on Rhodesian ore was being evaded. News accounts in 1971 reported that Rhodesian mines were going full blast and that chromium ore from Rhodesia was finding ways out despite the U.N. sanctions. France, Japan, and Switzerland, in particular, were accused of buying the Rhodesian high-grade ore under the guise of shipments from South Africa and Mozambique and of paying lower prices than for Russian and Turkish ore. There were suggestions, though no certain confirmation, that the Soviets were buying Rhodesian ore and reselling it at premium prices.

Members of Congress and the steel industry angrily protested that the embargo was forcing American steelmaker to pay higher prices for chromium than their European and Japanese competitors had to pay, Another theme in the protest was that the sanctions against Rhodesia had caused the United States to become dangerously dependent on Soviet chromium. Imports of Soviet metallurgical-grade ore had risen from 35 percent of total imports of that grade to 58 percent in 1970. (For total imports of chromium ore, of all grades, the Soviet share amounted to 29 percent in 1970, up from 16 percent before the embargo.)

The national defense argument was perhaps less telling than the economic one, because the U.S. Government still held large stockpiles of chromium ore, including the metallurgical grade, Moreover, a number of new suppliers had entered the market as chromium prices rose. Iran and Pakistan, as well as Turkey, became important alternate suppliers to the United States. Other countries raised production too. South Africa became the world's second largest chromium producer after the Soviet Union; and the Philippines, Turkey, Albania, India, Finland, and the Malagasy Republic (now Madagascar) all gained importance in the world market.

In November 1971, Congress passed legislation removing the President's authority to ban the import of strategic or critical materials from a non-Communist country. This ended U.S. participation in the U.N. sanction. During the next year, prices of Soviet and Turkish ore dropped 15 percent, rising only gradually with inflation over the next few years. The position of the Soviet Union as a chromium supplier to the United States rapidly declined, from 40 percent of chromium ore imports in 1972 (the peak year) to 12 percent in 1981. But the reasons were more complex than simply the end of sanctions against Rhodesia. Changes in the steelmaking industry were probably at least as important.

As technology advanced through adoption of the argon-oxygen-decarburization (AOD) process, making it possible to use the chemical grade of chromium ore for making stainless steel, the Soviet high-grade ores were no longer at a premium. By 1981, metallurgical-grade ores amounted to only 17 percent of chromium ore imports to the United States, compared to 50 percent or more 10 years earlier. Another change is that U.S. imports of chromium ore are giving way to imports of ferrochromium, just as ferromanganese is displacing manganese ore. South Africa led in changing its exports to the United States from chromium ore to ferrochromium alloys. Also, all of recent U.S. imports of chromium from Zimbabwe have been in the form of ferrochromium. As U.S. demand for raw chromium ore declined—particularly for the high-grade ore that was a Russian specialty—the Soviet Union no longer commanded preferential buying by American purchasers.

Today, South Africa is the United States' dominant supplier, contributing 55 to 60 percent of all U.S. chromium imports (including alloys as well as ore). The Soviet portion (of alloys plus ore) was 8 percent in 1981, with the Philippines supplying a like amount. Other substantial suppliers are Yugoslavia, Zimbabwe, Finland, Turkey, and Brazil.

Canadian Nickel Strike, 1969

Strikes in Canada's nickel mines in 1969 had a brief but jolting effect on nickel-using industries in the United States and Great Britain. Unlike the politically inspired embargoes described above, the 4-month strike at Canadian nickel mines caused actual shortages and acute price hikes. Yet military and essential civilian production were never interrupted in the United States, which was then at war in Vietnam. At the height of the shortage, scrap nickel was the main substitute for Canadian supplies, supplemented by larger nickel imports from Norway and the Soviet Union and ferronickel from New Caledonia (a French Territory in the Pacific) and Greece. A month after the strike was over, a large release of nickel from the government's stockpile helped refill the pipelines, while Canadian production geared up again. Within a year, prices and supplies were back to normal.[25]

The reasons for the acute effects of the cutoff of Canadian nickel supply were twofold: first, Canada's commanding position as a producer and exporter of nickel, especially to the United States; and second, tight supplies of nickel worldwide before the strike. In 1968 Canada supplied half the nickel for the non-Communist world, and was overwhelmingly the largest supplier of U.S. nickel imports, contributing over 90 percent. Imports were then 90 percent or more of U.S. nickel consumption. In addition, world demand for nickel had grown steadily from 1966 through 1969, while supplies lagged behind. The industrialized countries, increasingly prosperous, were demanding more nickel for stainless steel, alloys for jet engines and space hardware, long-life batteries, and dozens of uses requiring hard, strong, corrosion- and heat-resistant materials. Furthermore, the United States increased its nickel demands to satisfy military needs, In several countries, especially New Caledonia and Australia, mining companies were digging new mines and building new processing plants, but world production was only beginning to rise. There was practically no slack.

The big International Nickel Co. (Inco) mines in the Sudbury district of Ontario were struck in July 1969, and a month later strikes closed the mines of Canada's second largest producer, Falconbridge Nickel Mines Ltd. Immediately, prices on the dealer market (as opposed to producer prices charged by the mining companies] soared, rising from Inco's producer price of $1.03 per pound to $7 and even $9 per pound.

Nonessential industrial users without a ready substitute for nickel suffered real hardship. In particular, small electroplating companies using nickel for trim had to scramble for ma-

[25]Contemporary accounts of the nickel shortage include Bureau of Mines' reports; Business Week, Oct. 25, 1969, pp. 42-44; Anthony F. W. Liversidge, "The Beguiling New Economics of Nickel," Fortune, Mar. 1970, pp. 100ff.

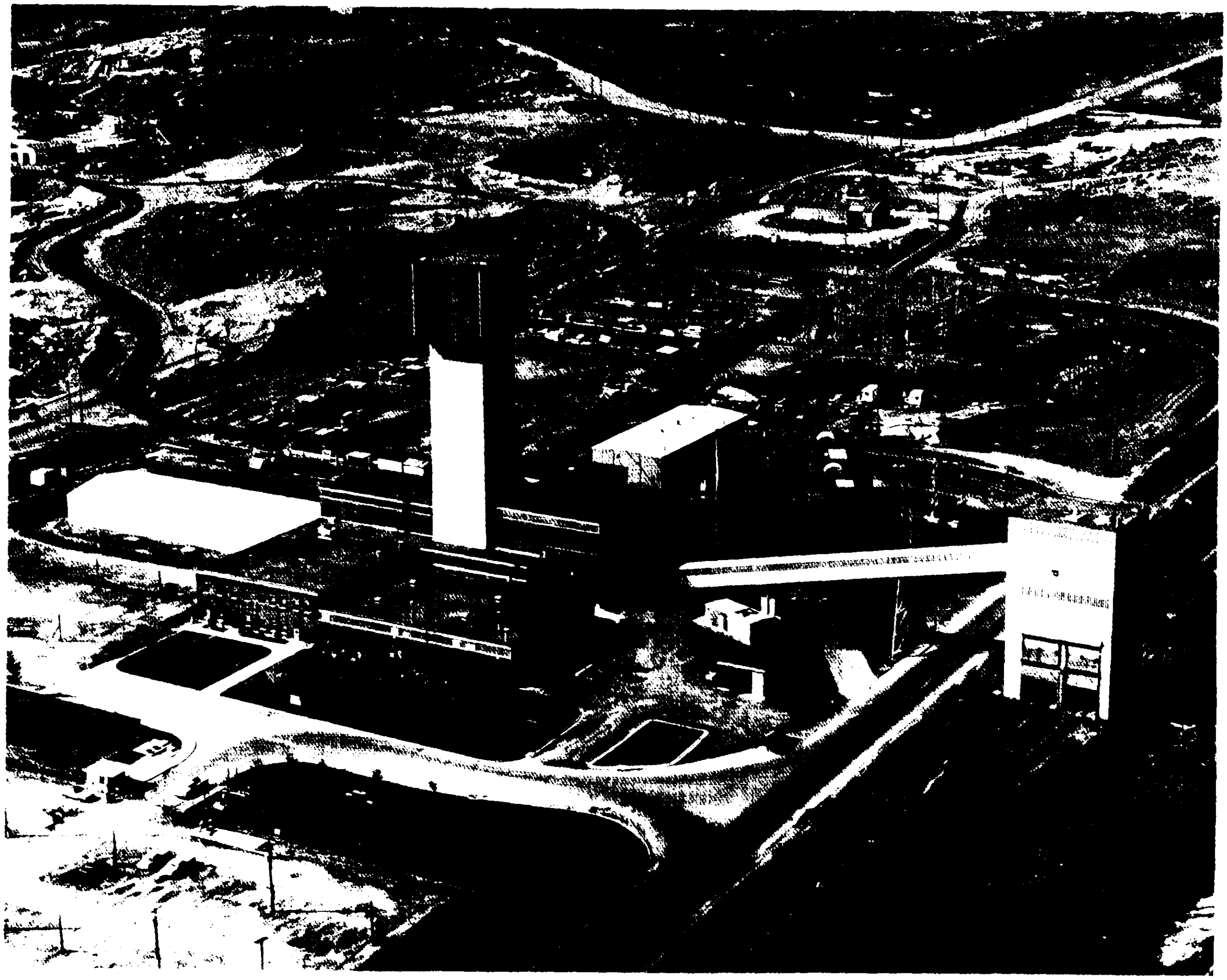


Photo credit: Inco, Ltd.

Entrance to the south mine at Copper Cliff in the Sudbury district, Ontario, Canada. Cobalt and platinum group metals are produced as byproducts of copper and nickel production

terial and pay the high prices or stop producing. Cobalt is an adequate substitute for nickel in electroplating, but usually sells at twice the price. During the shortage it was hard to find because most cobalt was sold by producers under contract to their regular customers.

Nickel-using industries that were able to use substitutes did so. For example, phosphor bronze was used in place of 12 percent nickel for electric powerplant hardware, and steelmakers offered chrome-manganese stainless steel instead of nickel-bearing stainless steel, The manganese stainless steel technology was already on the shelf. Steelmaker had developed it in response to fears of nickel shortages that arose in World War II and the Korean War; another motive was to have a substitute on hand in case nickel prices rose prohibitively. The shift to high-manganese stainless steel did not last past the nickel shortage, partly because nickel stainless steel has some superior properties (greater corrosion resistance) and partly because, at the time, the process of making high-manganese stainless steel was exacting and hard to control.[26]

The British, also 90 percent dependent on Canada for nickel, suffered shortages at least as severe as those in the United States. Looking back in 1982, spokesmen for the British Institute of Geological Sciences called the 1969 nickel shortage "perhaps the gravest metal crisis in the United Kingdom since the Second World War."[27] British steelmaker, like their American counterparts, offered customers a variety of steels in place of nickel steel.

Use of scrap nickel jumped 64 percent in the United States during 1969. Of the 23,300-ton drop from the previous year in Canadian imports, recycled nickel made up more than 9,000 tons. Everyone scrounged for scrap. Even new nickel products lying idle in inventories, such as pipes and fittings, were sometimes melted down for reuse. Some desperate electroplates collected ferronickel scrap and swapped it for pure nickel, trading with foundries which had assured allocations from producers. z*

As Canada's production slid nearly 20 percent from its 1968 level, several countries stepped up their nickel production, with New Caledonia, Australia, the Soviet Union, South Africa, and Rhodesia the leaders. The main substitute suppliers for the United States were Norway, which sold us 1,700 tons of nickel processed from ore obtained earlier from Canada, and the Soviet Union, which continued its expansion of nickel mining and increased exports to the United States by 700 tons. The Soviets also supplied additional nickel to hard-pressed Britain. The Soviets were reported to be the source of three-quarters of the high-priced dealer market nickel sold during the shortage.

The blow to the United States from the drop in Canadian imports was also softened by a large increase in ferronickel imports (from about 9,500 to 15,700 tons). Most of this came from Greece and New Caledonia. New Caledonia had a growing nickel minerals industry based on laterite ores.

Altogether, with additional imports from other countries and with the rapid rise in recycling, consumption of nickel in the United States dropped only 5 percent from 1960 to 1969, down from 173,700 tons to 165,400. However, it must be remembered that supplies had been tight since 1966. A better indication of the degree of shortage might be the U.S. consumption of primary and scrap nickel in 1970, which was 182,500 tons.

Throughout the shortage, defense industries continued to get nickel supplies. Three years before the strike, with nickel already in short supply, the government ordered the three principal U.S. nickel importers to set-aside 25 percent of their shipments for defense-related orders. The set-aside was continued after the strike, with the proviso that defense industries must use these supplies for current production, not for hoarding in inventories. Also, the government embargoed nickel exports. Most importantly, President Nixon directed the release of 10,000 tons of nickel from the government stockpile at the end of 1969. The strikes were over in November, but by this time the nickel supply pipeline was depleted, Without the stockpile release, shortages might have continued for several months.

By the end of January 1970, U.S. civilian as well as defense industries had all the nickel they needed. In fact, with rapidly rising production in several countries, nickel shortages disappeared entirely in 1970. Dealer market prices plunged from over $6 per pound at the first of the year to $1.33, the same as the producer price, at the end.

A lasting effect of the 4-year period of tight supplies in the late 1960s was to encourage

[26]To eliminate nickel completely in high-manganese stainless steel, nitrogen must be added as an alloying element. With the technology in use in 1969, it was difficult to add controlled amounts of nitrogen, Today, the argon-oxygen-decarburization (AOD) process is used almost universally in stainless steelmaking, and with this process it is easy to add controlled amounts of nitrogen.

[27]Institute of Geological Sciences, Strategic Minerals, memorandum submitted to the Parliament, House of Lords, Select Committee on the European Communities (Subcommittee F), Feb. 18, 1982.

[28]Liversidge, op. cit., p. 100.

more nickel production and greatly expand the number of suppliers. In the classic mode of the minerals industries, demand for nickel dropped off in the late 1970s, and some of the new capacity lay idle. Nearly half of Canada's mining capacity was unused in 1978, and New Caledonia, another big producer, had only about 60 percent of its mines in production.

The world's reserves and identified resources of nickel are not nearly so concentrated as those of chromium and manganese. Some of the Pacific islands (New Caledonia, parts of Indonesia) appear to be very well endowed, and there are also large deposits remaining in North America, the Soviet Union, Cuba, and Australia. Thus, the present diversity of producers can be expected to last for many years.

The Cobalt Panic, 1978-79

During the cobalt "shortage" of 1978-79, there was never any real interruption of supply. On the contrary, production in Zaire and Zambia—by far the largest cobalt producers for the world market—rose 43 percent during 1978 and 12 percent in 1979.[29] But the combination of rapidly rising world demand and fears of a supply cutoff, triggered by a rebel invasion of Zaire's mining country, set off a wave of buying that sent cobalt prices through the roof. Cobalt users turned to cheaper substitutes and recycling wherever they could, relieving some of the pressure. By 1982, with worldwide recession, cobalt prices plunged below the 1978 price.

[29] Unless otherwise noted, data on cobalt production, consumption, uses, recycling, and prices in this section are drawn from Charles River Associates, Inc., *Effects of the 1978 Katangese Rebellion on the World Cobalt Market*, final report to the Office of Technology Assessment, December 1982. The data in the Charles River Associates' report are largely based on Bureau of Mines' figures, but with some adjustments. The account of events in Zaire and Zambia from 1975 on and of the cobalt panic of 1978 is also largely drawn from the Charles River Associates' report. Other sources were Bureau of Mines' publications, officials of the Amax Mining Co., and Patti S. Litman, "The Impact of Minerals Scarcity on Technological Innovation: Cobalt, A Case Study," an unpublished M.S. thesis presented to the Sever Institute of Technology, Washington University, St. Louis, MO, 1981.

Cobalt is a specialty metal, produced in small quantities (only about 27,650 tons worldwide in 1982),[30] but has a number of specialized uses for which it is highly suited, or even irreplaceable, at current levels of technology. Cobalt is critical for making certain high-strength, heat-resistant superalloy used in jet engines, and has highly desirable properties as a material for permanent magnets, wear-resistant tools, and catalysts for refining oil and making petrochemicals.

The threat of interruption of world cobalt supply surfaced in 1975 when the civil war in Angola shut down that country's Benguela railway. The Angolan railway had been the major artery for transporting copper, cobalt, and other minerals out of central Africa to the industrialized world. Central African cobalt is pivotal. In a typical year, Zaire accounts for 60 percent of cobalt production in the non-Communist world; Zambia, usually the second largest free world producer, contributes 10 to 15 percent. Thus, if cobalt cannot get out of Zaire and Zambia, world supply is in trouble. This situation of extreme world dependence on central African cobalt is aggravated by the fact that cobalt is a byproduct of mining for other higher volume minerals, mainly copper and nickel. In case of a supply cutoff in central Africa, it might be uneconomical in the short run, at least, for producers in other parts of the world to expand cobalt mining as such.

Because the Angolan railway shutdown of 1975 occurred during a world business recession, with demand low and industry stocks fairly high, Zaire and Zambia were able to find alternate routes for shipping metals from their mines without causing immediate distress. As of mid-1984, the Benguela railway was still closed because of guerrilla attacks (related to civil war in neighboring Angola and Namibia), and the makeshift exit routes were still being used. They are not very dependable. One alternate route to the port of Beira in Mozambique was closed when Mozambique shut its border to what was then white-ruled Rhodesia. (Now that Zimbabwe has a largely black, elected gov-

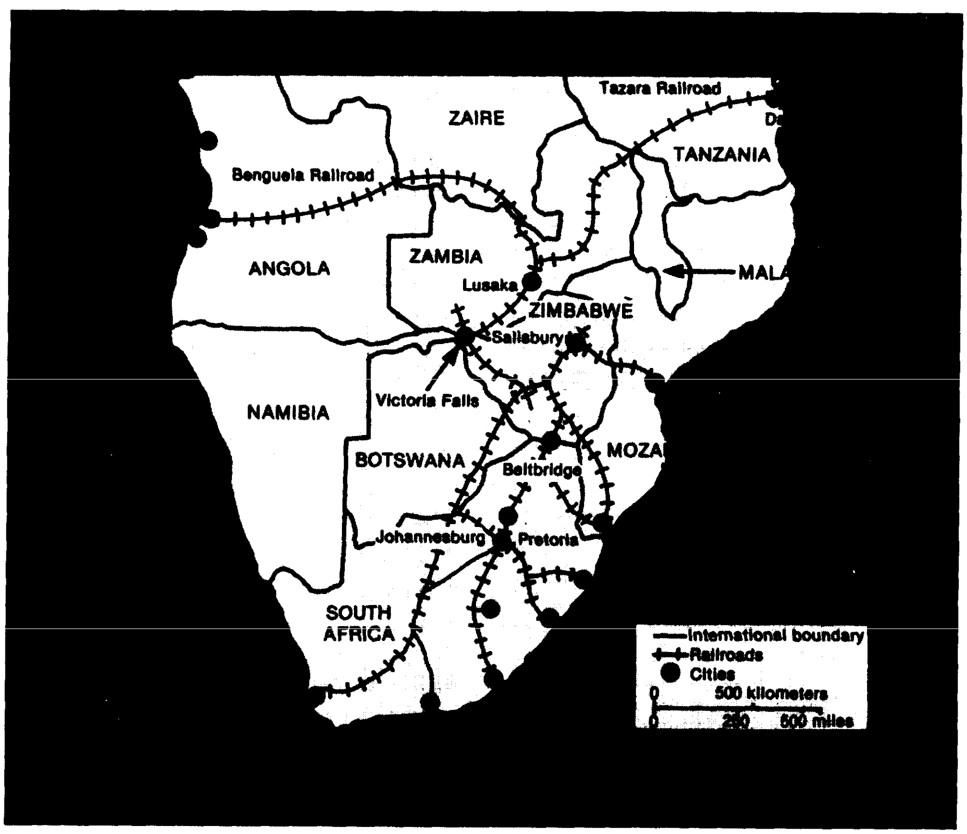
[30] The figure cited is from Bureau of Mines' data.

ernment, negotiations may reopen this route, although it too has been subjected to guerrilla attacks.) Meanwhile Zaire and Zambia ship their minerals out through the inadequate, backed-up port of Dares Salaam in Tanzania, or take a long, expensive route through Zambia, Zimbabwe, and South Africa. Zaire uses its own western port of Matadi at the mouth of the Zaire River for some copper and cobalt shipments, but getting there requires arduous transshipment by rail and river, and the river is not always navigable. Figure 4-2 shows the routes and location of ports.

With economic recovery in 1976 and 1977, U.S. and world demand for cobalt rose moderately, but not enough to cause real pressure on prices. In fact, Zaire was stockpiling cobalt hydroxide, an intermediate material produced in the processing of copper, to avoid building up unsalable inventories of cobalt. In 1977, a brief invasion of Zaire by insurgents based in neighboring Angola caused some concern for cobalt supply because Zaire's copper mines, from which cobalt is a byproduct, are in the southern Shaba province where the invasion took place. The rebels were emigres who had fled Zaire after losing a bid in the *1960s* to create an independent state of Katanga in Shaba province. The invaders were quickly routed. The incident had no effect on cobalt production or prices,

In *1978,* the situation was different. With world business activity on the upswing, and the market for new jet planes particularly strong, demand for cobalt began to heat up rapidly. Unable to expand production as fast as demand was climbing, Zaire announced in April *1978* an allocation scheme by which cus-

Figure 4-2.—Transportation Routes for Minerals in Central and Southern Africa



SOURCE: U.S. Department of the Interior, Bureau of Mines, Mineral *Perspective: Zimbabwe, 1981* tomers would be limited to 70 percent of their purchases of the previous year.

Aggravating the tight world supply was a recent turnabout in U.S. policy for stockpiling cobalt. For 8 years, until 1976, the U.S. Government sold 6 million to 9 million pounds of cobalt each year from its strategic stockpile because holdings in the stockpile were far above what was then the official goal of 11 million pounds. During the years of the stockpile sales, these sales amounted to as much as one-half of U.S. cobalt consumption and 10 percent of consumption in the non-Communist world.

In 1976, after the Angola civil war cut the Benguelan railway, U.S. stockpile sales of cobalt came to a halt. With cobalt holdings then down to about 40 million pounds, the government set a new stockpile goal of 85 million pounds. Overnight, the United States went from being a major supplier of the world's cobalt to a potential major purchaser. Zaire, Zambia, and other cobalt-producing countries were unprepared for the change and had not geared up to higher production levels. But it was not until demand suddenly boomed in 1978 that the loss of U.S. stockpile sales began to pinch.

Shortly after Zaire announced its allocation scheme, insurgents from Angola reinvaded Shaba province. This time they succeeded in taking the mining headquarters town of Kolwezi, but after 2 weeks they were once again driven out. The only damage done to mining facilities was the flooding of one mine. But the publicity surrounding the invasion, the reported killing of 130 foreign workers, and the subsequent flight of several hundred skilled mineworkers and professionals raised the alarm about continued availability of cobalt. Around the world, industries tried to stock up, buying all the cobalt they could find.

Prices skyrocketed from $6.85 per pound (the producer price) in February to $47.50 per pound (dealer market spot price) in October. The producer price reached $25 per pound in early 1979. With this kind of demand and at these prices, Zambia airlifted its cobalt out, and Zaire also sent some out by air.

The typically slow response by the minerals industries to a surge in demand was aggravated in the case of cobalt because it is usually a byproduct, Nonetheless, producers responded to the cobalt price spike, as shown in table 4-2. Zaire raised output by producing from its stockpiles of cobalt hydroxide. Zambia opened a new refinery that was already under construction, improved cobalt yields, and pushed ahead with plans for new mines and refineries, Zaire and Zambia accounted for most of the added cobalt production in 1978 and 1979, but small increases occurred elsewhere. Two Canadian nickel companies added capacity to their cobalt refineries, and others made plans to recover cobalt from nickel slag. Recently opened nickel-cobalt mines in Australia and the Philippines raised their output as they solved technical problems and responded to demand.

The more remarkable response to high prices and tight supplies came from the industries that consume cobalt. A switch to substitutes or recycled materials swept some industries. By 1980, use of cobalt in the United States was estimated to be 19 percent below what it would have been without the price rise.[31] Demand for cobalt continued to drop in 1981, partly because of the weak economy and high interest rates. Consumption in 1981 was 11.7 million pounds—41 percent below the 1978 high of 20 million pounds. According to another informed estimate, 1981 consumption would probably have been 13 million to 15 million pounds if there had never been a "shortage."[32] Figure 4-3 depicts this estimate of the effect of the price rise in U.S. cobalt demand.

Where effective substitutes were ready on the shelf, the decline in cobalt use was steep. As table 4-3 shows, cobalt use in permanent magnets dropped by one-half in 3 years. Probably four-fifths of this reduction was due to the price spike. 's Before the shortage, permanent mag-

[31]Congressional Budget Office, *Cobalt: Policy Options for a Strategic Mineral* (Washington, IX: U.S. Government Printing Office, 1982), p. x.

[32]Charles River Associates, Inc., op. cit., p.1-6.

[33]Ibid., p. 3-I 2.

Table 4-2.—Mine Production of Cobalt n the Non-Communist World (tonnes)

	Australia	Botswana	Canada	Finland	Morocco	New Caledonia	Philippines	Zaire	Zambia	Zimbabwe	Total
1972	NA	—	1,520	1,270	1,602	NA	41	13,112	3,345	—	24,835
1973	NA	6	1,517	1,270	1,422	NA	41	15,052	4,300	—	29,418
1974	NA	33	1,564	1,270	1,627	NA	30	17,632	2,379	—	30,885
1975	NA	81	1,354	1,402	1,961	NA	117	13,638	1,843	—	20,396
1976	544	132	1,356	1,278	934	82	492	10,686	2,175	—	17,679
1977	1,000	163	1,485	1,227	1,015	109	1,084	10,215	1,704	—	18,002
1978	1,350	261	1,234	1,212	1,134	150	1,191	13,299	3,741	18	23,590
1979	1,500	294	1,640	1,065	961	210	1,370	14,996	4,280	210	26,526
1980	1,600	226	1,603	1,035	838	180	1,331	15,500	4,400	120	26,833
1981[e]	1,600	250	2,270	1,035	752	140	1,090	15,500	4,500	80	27,217

NOTES: Data reported for Australia and New Caledonia in 1975 are inconsistent with data for later years, so are not presented here.
Data for South Africa are not available.

SOURCE: Charles River Associates, Inc., *Effects of the 1978 Katangese Rebellion on the World Cobalt Market*, report prepared for the Office of Technology Assessment, December 1982.

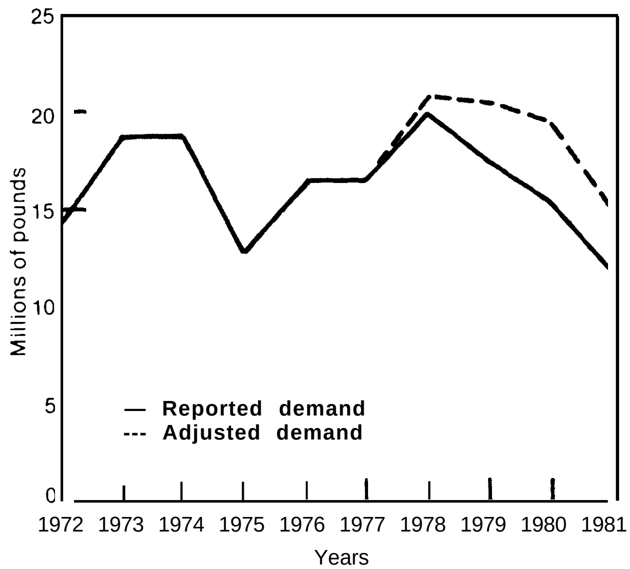
Table 4-3.—U.S. Consumption of Cobalt by Use (million pounds)

Year	Superalloys	Magnets	Cutting and wear-resistance	Welding and hardfacing	Tool steels	Other metallurgical	Catalysts	Salts and driers	Other	Total
1970	2.32	2.37	1.40	0.18	0.53	1.78	0.40	2.62	0.36	13.37
1971	1.98	2.28	1.23	0.25	0.32	1.25	0.47	2.74	0.44	12.50
1972	3.01	3.44	1.27	0.20	0.36	1.59	0.70	2.69	0.54	14.13
1973	3.28	4.30	2.51	0.39	0.52	1.85	1.15	3.57	0.64	18.74
1974	4.09	3.46	2.58	0.42	0.69	1.72	1.38	3.64	0.53	18.86
1975	2.26	2.03	1.40	0.48	0.29	1.31	1.11	2.87	0.47	12.79
1976	2.78	3.53	1.59	0.52	0.22	1.74	1.45	3.99	0.33	16.48
1977	3.71	3.48	1.43	0.42	0.31	1.36	1.29	3.78	0.30	16.58
1978	4.30	3.77	1.84	0.73	0.38	1.36	1.62	5.40	0.32	19.99
1979	5.28	3.27	2.12	0.44	0.41	1.03	1.88	1.79[a]	1.18[a]	17.40[a]
1980	6.29	2.27	1.34	0.62	0.32	0.52	1.66	1.41[a]	0.90[a]	15.32[a]
1981	4.20	1.69	1.08	0.49	0.17	0.43	1.28	1.44[a]	0.90[a]	11.68[a]

[a]The definitions of and reporting practices for the chemical categories changed in 1979. As a result, the chemical end use and total consumption data are not comparable with those for earlier years.

SOURCE: Charles River Associates, Inc., *Effects of the 1978 Katangese Rebellion on the World Cobalt Market*, report prepared for the Office of Technology Assessment, December 1982.

Figure 4-3.— Estimated Price Effects on U.S. Cobalt Demand



SOURCE Charles River Associates, Inc., *Effects of the 1978 Katangese Rebellion on the World Cobalt Market,* report prepared for the Off Ice of Technology Assessment December 1982

nets for such items as television, radio, and phonograph loudspeakers, telephone receivers and ringers, electrical meters, and automobile speedometers were an important use of cobalt, accounting for 20 percent of U.S. consumption. By the end of 1979, ceramic magnets had replaced 70 percent of cobalt-bearing Alnico magnets in loudspeakers. Moreover, the Bell system announced in 1979 that it was changing to alloys with lower cobalt content for telephone equipment, with savings of 100,000 pounds of cobalt per year. Much of the change in material for magnets is probably irreversible. Ferrite (ceramic) magnets are cheaper than cobalt, and now that the redesigning and retooling for the change has been done, there is little reason to change back.

On the other hand, demand for cobalt for superalloys in jet engines did not decline at all. Despite the high prices, superalloy demand continued to rise for 2 years until dampened by the recession in 1981. The boom in aerospace had led the 1978 surge in demand for cobalt, and jet engine manufacturers led the scramble for supplies when fears of a shortage rose. These manufacturers could do little in the short run to substitute other materials for cobalt superalloys in gas turbines for jet engines. Only after the most exacting, expensive qualification program can new alloys be used in jet engines. In some cases, however, different alloys had already been tested, and were adopted. For stationary gas turbines (e.g., for electrical power and pumping engines) the requirements are not so stringent, and some manufacturers were able to use other alloys for turbine parts. These substitutions, adopted over 3 years, probably saved about 10 percent of the cobalt that would otherwise have been used for superalloy, and the changes were probably permanent.[34]

Another leading use of cobalt in the United States is for hardfacing material, which, welded to a base material, provides a layer resistant to corrosion and wear (e. g., in engine valves, chainsaws, and earth-moving equipment). Some users of cobalt for hardfacing switched to nickel alloys. In Europe, where cobalt is used much more extensively in tool steels than it is here, users changed to cobalt-free tool steels. Consumption of cobalt for driers of inks and paints dropped 10 to 30 percent as users switched to manganese and zirconium as partial substitutes for cobalt. Substitutions for cobalt as a binder for carbide cutting materials were not very successful, but recent technological advances had made recycling more feasible, and these users did recycle. No replacements were immediately available in the short run for cobalt catalysts, although nickel-molybdenum catalysts may eventually displace some cobalt consumption for catalysts in the future.[35]

Recycling rose dramatically during the cobalt shortage. Everyone in the superalloy pipeline, from alloy producer to gas turbine manufacturer, began to recycle cobalt. This meant carefully segregating scrap by alloy specification, sending it back to the alloy melter and reusing it in the same grade. Possibly 10 to 25 percent of cobalt used in superalloys was recycled in this fashion. At the same time, methods for recycling all the materials in cemented

[34] Ibid., pp. 1-4 and 3-10.
[35] Ibid., p. 1-6.

carbide cutting materials (including cobalt) had just been brought to a state of economic feasibility. Methods widely adopted in 1978-79 continue to be used. It is estimated that most "new" carbide scrap (recovered from fabricators) is now recycled, and more old scrap (recovered from used products) is reused.[36]

Altogether, according to Bureau of Mines' data, recycling of cobalt increased 100 percent in the year 1978, and quickly rose from 4 percent of consumption in 1977 to nearly 11 percent in 1980, before tapering off to the 1982 level of about 8 percent. These figures understate the real extent of recycling, because they are limited to scrap that is purchased, and not all recycling is reported.

The U.S. Government never released cobalt from its stockpile throughout the period of high prices and tight supplies, since defense and essential civilian industries were getting what they needed and the stockpile, by law, can be used only to aid these industries during a national emergency. Cobalt-using industries added to their stocks during the 1978 panic and began drawing them down the next year.

[36] Ibid., pp. 3-14 to 3-16.

The cobalt bubble burst in 1981. World production, spurred by high prices, continued to rise for the third year in a row in 1980. But with the 1981 recession, world cobalt demand fell drastically; in the United States, consumption dropped 24 percent. The producer price, pegged at $25 per pound in January 1981, was cut to $12.50 per pound in early 1982. Meanwhile, Zaire had contracted to sell the U.S. Government 5.2 million pounds of cobalt, for replenishment of the stockpile, at $15 per pound. Sixteen other producers had vied with Zaire to supply the government's stockpile purchases. By the end of 1982, the dealer market price sank below $5 per pound—considerably below the price in 1978 when the boom began. Cobalt prices stayed in the $5 to $6 per pound level until early 1984, when the producer price was increased to $11 to $12 per pound.

A modicum of diversity had entered the market between 1978 and 1982. A number of suppliers with new or expanded operations now stand ready to compete with Zaire. The bulk of world cobalt reserves are still in Zaire and Zambia, but Cuba, the Soviet Union, the Philippines, New Caledonia, and Australia all hold important reserves that are currently known and economic to mine. The United States also has substantial resources that are not now profitable to mine without a production subsidy.

The Effects of Supply interruptions

These accounts of the few instances when U.S. imports of critically needed materials have actually been interrupted or threatened are interesting in their variety. The causes of interruption were different in each case, and the coping reactions, both by industry and by government, were varied enough to illustrate a wide gamut of responses to abrupt deprivation of supply.

The Soviet cutoff of manganese and chromium exports in 1949 was a Cold War political action, a response to the U.S. clampdown on export of manufactured goods, which in turn was a response to the Soviet blockade of Berlin. The Rhodesian chromium embargo in 1966, also political, was imposed by the United States in conformance with a United Nations resolution. The nickel strike of 1969 shut down supplies from the quintessentially "safe" foreign source—Canada—at a time when world nickel supplies had already been straightened for 3 years and Canada was then almost the sole U.S. supplier. The cobalt shortage of 1978-79 was a superheated case of a world surge in demand, combined with the abrupt removal of an important source of world supply (sales from the U.S. stockpile), which was aggravated by fears of insurrection and collapse of Zaire's mines (which never happened).

The response in the first two cases was, essentially, to find other foreign sources of supply, After the 1949 Soviet embargo, the U.S. Government actively sought alternate suppliers, offering loans for mine development, sending rail cars and providing steel for improved transportation. With the Rhodesian chromium embargo of 1966, the government sold excess chromium from the national stockpile, but otherwise took little active part, leaving industry to find alternate suppliers. That industry was able to do so quite readily, with little evidence of shortage, was due to several factors besides the stockpile sales: The Soviets promptly volunteered to serve as alternate suppliers of chromium to the United States (despite the Vietnam war which they opposed) and the United States was willing, for a time, to buy from them. Prices rose, drawing other suppliers like Turkey and the Philippines into production. The rapid adoption of the argon-oxygen-decarburization (AOD) process in stainless steel production allowed the substitution of South African chromium ore for Rhodesian ore. Finally, the Rhodesian embargo leaked, If France, Japan, Switzerland, and others had not bought what was probably Rhodesian chromium from South Africa and Mozambique, the alternate suppliers might have been hard put to provide the whole industrialized world with chromium.

The acute shortage of nickel that followed the Canadian strikes necessitated changed behavior from U.S. nickel users, They substituted other materials where they could, for example, replacing nickel stainless steel with chrome-manganese stainless steel (a technology that already existed). Users turned to nickel recycled from scrap, and they paid high prices for "gray market" nickel—once more supplied largely by the Soviets, despite the continuing Vietnam war. (In both the Rhodesian chromium and Canadian nickel episodes, it will be noted the Soviets behaved much more like enterprising capitalists than like ideological resource warriors.) An important factor in stopping the acute nickel shortage was the U.S. Government's release of a large quantity of nickel from the stockpile. The government had also responded to 3 years of tight nickel supplies by allocating what was needed to military users, and the set-asides were continued during the acute shortage.

As for the cobalt "shortage," users turned very quickly to substitutions and recycling, Under the spur of high prices, nonessential uses made way for essential, Government allocation was not needed to reserve cobalt for superalloys for military jet engines. Superalloy producers and users paid high prices and they recycled, while use of cobalt in magnets dropped by half. Ceramic magnets, for which the technology was ready, were substituted.

In all four cases, a long-lasting effect of the supply interruption was that new producers entered the market, and supply became more diversified. In the case of manganese, the U.S. Government and the World Bank deliberately encouraged new producers. In the other cases, shortages, rising prices, and eager buyers provided enough market incentive to draw new sources into production, Some substitutions (ceramic magnets) and some recycling (carbide cutting materials) adopted during the shortages appear to be permanent.

Another conclusion is worth noting: There is no one single answer to import vulnerability. In the episodes described above, multiple responses—some by government and some by industry—helped avoid a crisis or end shortages. On the government's part, there were active assistance to alternative suppliers, stockpile sales, and allocations to defense needs. On the private side, there were substitutions of materials (based on previous research and development [R&D]), recycling (also based in part on previous R&D), and a search for new sources of supply. In some cases, government and private actions were not so helpful—in fact, they were contributing causes, not solutions to the problems. The obvious example is the government's abrupt halt to sales of cobalt from the stockpile, and industry's panic buying of cobalt after the invasion of Zaire's Shaba province.

One response to import vulnerability that has rarely been used, except when begun in wartime, is government subsidies to high-cost domestic minerals producers. During the Korean war, which began just a year after the 1949 Soviet embargo of chromium and manganese, the government subsidized U.S. production of a number of minerals, including the two embargoed by the Soviets and cobalt. The last of the subsidies expired in the early 1960s. No one seriously suggested reviving subsidies for domestic producers of chromium in the late 1960s, when U.S. imports of Soviet chromium were once again rising following the Rhodesian embargo. The reason was the low-quality and limited supplies of domestic chromium ore and the high cost of producing it. Then, as now, even the best deposits of U.S. chromium would probably have cost two to three times as much as chromium mined abroad, with less favorable U.S. deposits still more costly.[37]

[37]Information provided by John Morgan, Bureau of Mines, U.S. Department of the Interior. See also C.C. Hawley & Associates, Inc., subcontractor to Charles River Associates, Strategic Mineral Markets and Alaska *Development* Potentials, Policy Analysis Paper No. 82-12, prepared for the State of Alaska, Office of the Governor, Division of Policy Development and Planning (Juneau: 1982), vol. II, p. 1. This study estimated that the world chromium price would have to rise sixfold to stimulate production from known deposits in Alaska.

During the cobalt panic, subsidies for U.S. cobalt production were considered by Congress.[38] U.S. cobalt resources are considerably better than chromium resources, though they are still subeconomic. At congressional hearings in 1981, representatives of firms owning the most promising domestic sites estimated that cobalt prices ranging from $20 to $25 per pound would be needed to stimulate domestic production through government purchase contracts. Before any subsidies were decided on, the cobalt bubble had burst. By the end of *1982,* the world cobalt price of $6 per pound (or less) was far below the estimated cost of producing U.S. cobalt. World prices have subsequently risen again (to $11 to $12 per pound in 1984), and one company has revised downward its estimate of the price needed for it to produce cobalt to about $16 per pound. Further discussion of subsidies for U.S. minerals production, in the context of broader materials policy, appears in the following section, as well as in chapters 5 and 8.

[38]U.S. Congress, Senate Committee on Banking, Housing, and Urban Affairs, Hearing on the Defense Production Act and the Domestic Production of Cobalt, 97th Cong., 1st sess., Oct. 26, 1981 (Washington, DC: U.S. Government Printing Office, 1982); Congressional Budget Office, Cobalt: Policy Options *for* a *Strategic Mineral,* cited in note 31.

Materials Policy

Over the past three decades, as episodes of tight supplies and high prices have come and gone, concern about a national materials policy has risen and ebbed. Three major commission studies, many other scientific and policy studies, three Federal laws stating materials policy, and several other relevant laws have addressed the question of how to assure a reliable supply, at reasonably stable prices, of the materials needed for this Nation's economy and defense,

All of the commissions recommended that the Nation seek materials wherever they may be found, at the lowest cost consistent with national security and the welfare of friendly nations. A policy of self-sufficiency was considered and rejected, most emphatically by the Paley Commission in 1952, and again quite explicitly by the Commission on Supplies and Shortages in 1976.

On the whole, the commissions' counsel in favor of interdependence has been heeded. The United States has, by and large, adhered to the "least cost" principle for materials supply for 35 years, The government has not only tolerated, but encouraged, US. consumption of minerals produced abroad. With low-cost loans, tax credits for taxes paid to foreign countries, and insurance against expropriation, it has helped U, S.-based firms to open mines in foreign countries, such as Australia, Brazil, and Peru. It has usually resisted proposals to protect the domestic mining industry by import quotas or other restrictions on trade and has subsidized domestic mining only rather briefly,

For security of supply, U.S. policy has been to rely mainly on stockpiles rather than on permanent subsidies of domestic production—again, a course which was urged by the commission reports. The first Federal law authorizing stockpiling of critical materials goes back to 1939, but actual accumulation of stocks was put aside during World War II and began in earnest during the Korean war. Large-scale purchases continued through the 1950s. Despite changes back and forth since then in stockpile policy, the Nation still has substantial amounts of many critical materials stored away.

Another recurring recommendation in the past three decades of studies, reports, and laws on materials policy has been to establish a focal point in the Federal Government for making comprehensive materials policy. This advice has been difficult to follow. One reason may be that materials shortages have been quite fleeting, and supplies are usually available when needed. Another is that materials policy is connected with other important policies—foreign, defense, taxation, environment, energy—which it is part of but does not dominate. Moreover, it is difficult to establish an overall "materials" or "nonfuel minerals" policy when the materials it is meant to cover are so numerous and so different from one another in the needs they meet, in critical importance, in availability of substitutes, and in the diversity and security of supply,

With the rising level of concern over U.S. import vulnerability, Congress (in *1980* and again in *1984)* called on the Executive Office of the President to develop a coordinated materials policy, Questions of interdependence, self-sufficiency, and stockpile policy are also being reexamined. The following sections briefly survey the findings of the three major commissions on materials policy in the past *30* years and outline the main features of government policy and congressional actions on materials during the period.

Self-Sufficiency v. Interdependence

Many of those who believe that self-sufficiency is desirable subscribe to a broad-scale remedy of materials independence. They favor intensive exploration of most of the federally owned public lands, including wilderness, for minerals; tax breaks and government subsidies to encourage U.S. mining and minerals processing; and relaxation of strip mine controls, mine health and safety regulations, and clean air and water standards, which they blame for putting U.S. mining industries at a disadvantage vis-à-vis foreign competitors. On the other hand, critics of minerals independence say that an effort to replace imports with high-priced domestic minerals would raise the cost of finished goods, escalating prices at home, and making it harder for American products such as steel and autos to compete with foreign goods.

Despite the low quality of some U.S. mineral resources, the Nation could probably achieve significant domestic production in most minerals if it were willing to pay a high enough price, Part of the price might be greater environmental degradation and higher energy use, as well as higher dollar costs. Another cost might be a greater degree of government management of the minerals market and strains with European and Japanese allies, whose import dependence for 36 important nonfuel materials is considerably greater than that of the United States.

U.S. import dependence is often compared unfavorably with the Soviet Union's high degree of self-sufficiency in minerals, The Soviet Union has long followed a deliberate policy of supplying its own resource needs and, when forced to rely on foreign sources, has imported mainly from allies and neighbors. The result

[39]The Office of Technology Assessment analyzed some aspects of the U.S. steel industry in its 1980 report, *Technology and Steel Industry* Competitiveness, OTA-M-122 [Washington, DC: U.S. Government Printing Office, June 1980].

is that the Soviets are net importers of only 11 of 35 important nonfuel minerals, and for only four—bauxite and alumina, barium, fluorine, and cobalt—is import dependence as high as 40 to 60 percent.

If the United States opts for a policy of minerals self-sufficiency instead of the traditional one of interdependence in a world free market, such a policy could require the United States to isolate itself from that market. Unless the government imposed export controls to keep domestic supplies inside the United States, U.S. trading partners could bid up the price and buy "U. S." minerals in times of shortages. In times of minerals abundance and low world prices, either U.S. mines would have to be subsidized or import controls imposed (like the pre-1973 oil import quotas) or both. In all these cases, economic and political stresses can be foreseen,

Commission Studies

President's Materials Policy Commission (Paley Commission)

The President's Materials Policy Commission, named for its chairman, William S. Paley, was established by President Truman in January 1951 during the early months of the Korean war. It was a time when a precipitate rise in military demands, added to an expanding post-World War II civilian economy, had caused tight supplies and shortages. The realization had dawned that materials usage worldwide was on an upward spiral. Reflecting a sense of crisis about the continued supply of enough materials to sustain the Nation's military security, civilian welfare, and economic growth, President Truman said in his charge to the Commission:

> By wise planning and determined action we can meet our essential needs . . . We cannot allow shortages of materials to jeopardize our national security nor to become a bottleneck to our economic expansion.[40]

The Commission's report, *Resources for Freedom,* published in June 1952, was colored with the same tone of strenuous response to a serious challenge. The Commission set for itself this question: "Has the United States the material means to sustain its civilization?" Al It noted that the United States had already outgrown its resource base and had become a "raw materials deficit" Nation. At the core of the materials problem it put "growth of demand"—growth not only in the United States but also among the free world allies and in the former colonies seeking to industrialize rather than export raw materials.

To assure the material basis for security and growth the Paley Commission saw interdependence as the best answer. "The United States must reject self-sufficiency as a policy, " the Commission said, "and instead adopt the policy of the lowest cost acquisition of materials wherever secure supplies may be found: self-sufficiency, when closely viewed, amounts to a self-imposed blockade. . . "[42]

The Commission emphasized policies that would encourage investment by American business in mineral development in foreign countries and would remove barriers to trade. It also urged U.S. loans and technical assistance, in addition to international help, for indigenous investment in mining, especially in poor countries. Besides these policies to promote "least cost" production worldwide, the Commission also stressed the value of greater efficiency of use, substitution of more abundant materials for scarce ones, and the expansion of domestic supplies by "pushing back the technological, physical, and economic boundaries that presently limit supply."[43]

Even to protect national security, the Commission regarded a quest for self-sufficiency as "fallacious and dangerous. " For many materials, the Commission said, "self-sufficiency is either physically impossible or would cost so much . . . that it would make economic nonsense."[44] Instead, the Commission suggested a range of policies to raise the Nation's pre-

[40] The President's Materials Policy Commission, op. cit., p. IV.

[41] Ibid., pp. 1, 6, and passim.
[42] Ibid., p. 3.
[43] Ibid., p. 8.
[44] Ibid., p. 157.

paredness against a possible cutoff of materials critical to the Nation's defense.

To assure supply, the Commission strongly urged stockpiling, Also, it recommended several measures to prepare emergency sources of production, including: setting aside "in-the-ground" domestic reserves of key minerals, especially limited or low-grade deposits; developing and maintaining ready-for-use technology to produce low-grade deposits; and preparing processing facilities and transportation for the in-the-ground reserve. On the demand side, the Commission recommended the design of military products to use abundant rather than scarce materials, and the preparation of "stand-by" designs for use in extremity, substituting available materials for scarce ones that would otherwise be preferred. As

The Paley Commission report noted the lack of a coordinating body for materials policy, and suggested that the National Security Resources Board, in the Executive Office of the President, undertake the role.[46] However, the Board was soon abolished by Congress as fears of "running out" of material, which had prompted the establishment of the Paley Commission, died down. No other body was given the policy coordination task.

Indeed, after a brief burst of public attention, the Commission's report fell into obscurity. True, the interdependence policy strongly urged by the Commission has generally guided the government's actions since then. One administration after another has followed the Commission's advice in such matters as negotiation of treaties to support freer trade and provision of government insurance for private businesses investing in resource development abroad. But for the most part, the detailed recommendations of the Commission's report were ignored. One of the very few concrete responses by anyone was the creation of a non-government institution to monitor materials supply and demand—Resources for the Future, which is largely funded by the Ford Foundation.

[45]Ibid., ch. 27-30.
[46]Ibid., p. 171,

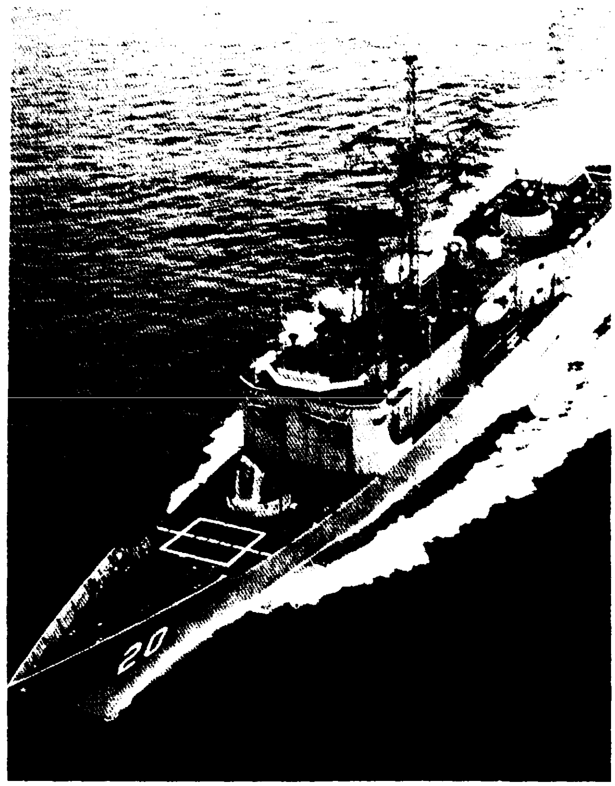


Photo credit U S Navy

One mission of U.S. Navy frigates such as the USS Antrim (FFG-20) is to protect the flow of strategic materials to the United States

The reasons for the report's neglect are not hard to find. First, the party in power changed; President Eisenhower won the 1952 election, and the Republicans took control of Congress for the first time in 20 years. More important, wartime shortages of materials turned to glut with the end of the Korean war. When President Eisenhower appointed a Cabinet committee in 1954 to examine minerals policy, the question was not how to assure enough supply, but how to help rescue the ailing domestic mining industries, (As discussed below, the Eisenhower Administration's response was to guarantee purchases of minerals for an expanded strategic stockpile,)

National Commission on Materials Policy

For most of the 1950s and 1960s, adequacy of materials supply was a quiescent issue, despite some bottlenecks and shortages as Vietnam war needs expanded. Supplies of minerals rose comfortably with demand, and real prices generally remained stable or fell throughout most of the period. Production of aluminum rose enormously (over fourfold) relieving pressure on other structural and electricity-conducting materials, and petrochemical-based plastics replaced a number of the conventional metals.

Toward the end of the 1960s, Congress and the public began to look at materials issues in a new perspective—i. e., in relation to conservation of resources and environmental quality. In 1970, Congress created a new materials policy commission as a direct outgrowth of its work on recycling of materials and recovery of energy from waste. Former Senator J. Caleb Boggs was a sparkplug of the renewed congressional interest in materials policy and its connections with energy and the environment. A series of biennial National Materials Policy Conferences was begun in 1970 at his request, and he introduced the legislation creating a new materials commission.[47]

The background of the commission's formation was this: While considering an innovative Federal law on solid waste (The Resource Recovery Act of 1969), the Senate Committee on Public Works asked for a study on a national policy for handling materials, from extraction to disposal. The ad hoc committee doing the study recommended a fresh look at materials problems as a whole and a new national commission.[48] The next year, Congress amended the Resource Recovery Act, incorporating in it the National Materials Policy Act of 1970 and creating the National Commission on Materials Policy (NCMP) with this objective:[49]

> . . . to enhance environmental quality and conserve materials by developing a national materials policy to utilize present resources and technology more efficiently, and to anticipate the future materials requirements of the Nation and the world, and to make recommendations on the supply, use, recovery and disposal of materials.

The Commission's report, Material Needs and the Environment Today and Tomorrow, issued in 1973, recommended striking a balance between the need to produce goods and the need to protect the environment. In particular, it urged that environmental costs be included in reckoning the costs and benefits of materials production. While calling for "orderly" development of resources, the Commission also strongly urged conservation through recycling and greater efficiency of use. To carry out these policies, the NCMP made 198 detailed recommendations in *10* major areas.[50]

The "traditional U.S. economic policy" of buying materials at least price was reaffirmed by this Commission, The policy was given credit for providing reasonably priced goods to consumers and keeping U.S. goods competitive in world markets. However, the Commission qualified its support of the least-cost interdependence policy to a degree, It argued that some U.S. minerals industries might need a limited amount of protection from competition with "subsidized" foreign producers.[51]

As for national security, the Commission recommended that where problems of supply are foreseen, the United States should foster domestic production, diversify sources of supply, develop special relations with reliable foreign sources, increase the dependence of supplying countries upon continuing U.S. goodwill, and find substitute materials.[52] The Commission gave little attention to stockpiling, possibly because the imported material of greatest concern at the time was oil, and stockpiling oil is far more expensive and cumbersome than stor-

[47] In response to a request by Senator Boggs, the late Dr. Franklin P. Huddle, Senior Specialist with the Congressional Research Service of the Library of Congress, organized a series of biennial National Materials Policy Conferences. The conferences, under the auspices of The Engineering Foundation, were held at New England College, Hemiker, NH. They are widely known as "the Henniker Conferences. "

[48] U .s. Congress, Senate Committee on Public Works, Toward a National Materials Policy, committee print, 91st Cong., 1st sess.

[49] Title II of the Resource Recovery Act of 1970 (Public Law 91-152), entitled the National Materials Policy Act of 1970, sec. 202.

[50] National Commission on Materials Policy, *Materials* Needs and *the* Environment Today and *Tomorrow* (Washington, DC: U.S. Government Printing Office, 1973), pp. 1-4, 1-5, and ch. 6,

[51] Ibid., pp. 9-8 through 9-10.

[52] Ibid., p, 9-26,

ing most nonfuel minerals, (The NCMP's charge included energy; it defined materials as all natural resources intended for use by industry, except for food.)

Like the Paley Commission 20 years earlier, the NCMP urged that a high-level government body oversee Federal materials policy. It proposed a Cabinet-level agency—possibly a new Department of Natural Resources—to plan and execute comprehensive policy for materials, energy, and the environment. [53]

While the Department of Natural Resources was not created, the report of the NCMP received considerably more official attention than its predecessor had. At the time the report came out, interest in materials issues had quickened. A world economic boom was on the upswing, and some shortages of materials had begun to appear. The Club of Rome's widely read report *The Limits to Growth* (published in *1972),*[54] suggested that world demand for materials, increasing exponentially, would outrun the planet's finite supplies, leading to a devastating collapse of world economies in the 21st century. In this atmosphere, interest in the Commission's report ran high.

The Commission's report was the springboard for hearings before the Senate Subcommittee on Minerals, Materials, and Fuels,[55] and materials issues were the subject of other congressional hearings and reports;[56] the Office of Technology Assessment added a program to assess materials issues. Other congressional agencies—the General Accounting Office and the Congressional Research Service—undertook studies on materials issues.[57] The National Academy of Sciences issued numerous reports commenting on and related to the NCMP report.[58] Finally, a most concrete result was the hearings and work done by the Senate Committee on Public Works on resource recovery and recycling,[59] which eventually led to passage of the Resource Conservation and Recovery Act of 1976.

National Commission on Supplies and Shortages

When the National Commission on Materials Policy issued its report in mid-1973, OPEC was a name known only to specialists. Oil prices had just begun to rise as a result of cartel control. Within a year, OPEC had not only quadrupled prices, but for a time had denied its members' oil to the United States and The Netherlands. In addition, the world economic boom, by then 2 years old, had created shortages of many industrial materials. Prices of commodities from rubber and oil to scrap steel and copper bounded upward, and industries had real difficulty in getting the aluminum, copper, chemicals, petrochemicals, steel, and paper that they needed. The influence of *The Limits of Growth,* with its projections of world resource exhaustion and economic collapse, was at its height, To some people, the shortages of 1973-74 seemed early indications of just such a collapse.

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[53] Ibid., p. 1-8 and ch. 11.

[54] Donella H, Meadows, et al., *The Limits to Growth* [New York: Universe Books, 1972).

[55] U.S. Congress, Senate, Committee on Interior and Insular Affairs, Subcommittee on Minerals, Materials and Fuels, Hearings, Oct. 30, 31, and Nov. 1, 1973, committee print.

[56] See, for example, U.S. Congress, Senate, Committee on Public Works, Resource Conservation, Resource Recovery, and *Solid* Waste *Disposal,* committee print, 1973.

[57] See, for example, the reports of the biennial Henniker conferences, which were organized by the Congressional Research Service, and U.S. Congress, House of Representatives, Committee on Science and Astronautics, Industrial Materials: Technological Problems and Issues *for* Congress, committee print, 1972, prepared by Dr. Franklin P. Huddle of the Congressional Research Service. The General Accounting Office undertook studies that led to such reports as Federal Materials Research and *Development:* Modern *izing* Institutions *and Management* (Washington, DC: U.S. Government Printing Office, 1975). The Office of Technology Assessment Materials Program undertook a broad range of studies too numerous to cite.

[58] Reports produced by the National Academy of Sciences and affiliated organizations included: National Academy of Sciences/ National Academy of Engineering, *National Minerals Policy*, Proceedings of a Joint Meeting, Oct. 25-26, 1973 (Washington, DC: The Academy, 1975); National Academy of Sciences, Man, Materials, and the Environment, report of the Study Committee on Environmental Aspects of a National Materials Policy (Washington, DC: The Academy, 1973); National Academy of Sciences, Committee on the Survey of Materials Science and Engineering, Materials and Man's Needs (Washington, DC: The Academy, 1974); National Academy of Sciences, Committee on Mineral Resources and the Environment (COMRATE), Mineral Resources and the Environment [Washington, DC: The Academy, 1975).

[59] U.S, Congress, Senate Committee on Public Works, Hearings, June 11-13, July 9-11, 15-18, 1974, committee print.

In this crisis atmosphere, national attention again fastened on the adequacy of material supplies. While two House committees were preparing reports on the subject—one on America's resource needs and import dependence and the other on world resource "scarcities"[60] –former Senators Mike Mansfield and Hugh Scott formed a joint Executive Congressional Leadership group to discuss threatened shortages of natural resources, raw materials, and agricultural commodities. Out of this group emerged legislation (an amendment to the Defense Production Act of 1950, in September 1974) creating the National Commission on Supplies and Shortages.

The Commission was instructed to look at four principal issues: the possibility of resource exhaustion, the consequences of the Nation's growing dependence on imported materials, the ability of the free market to deal with shortages, and the adequacy of government mechanisms for handling materials problems.

The Commission's report, Government and the Nation's Resources, issued in 1976, concluded that the country's ability to meet its material needs was in no imminent danger.[61] It said that:

- resource exhaustion was not a serious threat to economic growth for the next quarter century "and probably for generations thereafter";
- U.S. dependence on imported materials other than oil was growing only gradually and manageably;
- cartel control of nonfuel minerals was unlikely and embargoes directed against the United States "only remotely conceivable, " and that neither was any real threat to the American economy; and
- the widespread severe shortages of 1973-74 were a temporary phenomenon due to the world surge in demand, to lagging investment in materials industries for a few years before the boom, and to a "shortage mentality" that led to panic buying and hoarding of materials by industries in many countries.

These conclusions added up to strong, continued support for the principle of free trade and interdependence.[62]

The Commission stated that it found no instances of import dependence that would justify the costs and rigidities of placing restrictions on imports. Instead, to cope with interruptions of supply that might result from civil disorders in producing regions or, possibly, from price-gouging by producers, the Commission recommended stockpiling as "the universal antidote."[63] The Commission supported a strictly limited use of the strategic stockpile for economic purposes during a sudden disruption of supply of critical materials to keep the civilian economy as well as defense industries on an even keel. However, the Commission said, stocks should not be sold simply to influence prices in the absence of a supply disruption (as the Johnson Administration had done in the 1960s—see the discussion below). [64]

Underlying many of the Commission's conclusions was confidence in the ability of market forces to bring forth adequate materials for the world's economies and to right imbalances within a reasonable time. Many of the recommendations amounted to "hands off" the market. For example, in its consideration of recycling, the Commission suggested the removal of depletion allowances for minerals, which favor virgin ore over recycled materials-but no subsidies for recycling either. es In a similar vein, the Commission was cautious about recommending government funding for R&D for alternative supplies, conservation, and substitute materials. Recognizing that government

[60] U.S. Congress, House of Representatives, Ad Hoc Committee on the Domestic and International Monetary Effect of Energy and Other Natural Resource Pricing, Meeting America's Resource Needs, a report to the Committee on Banking and Currency (Washington, DC: U.S. Government Printing Office, 1974); U.S. Congress, House of Representatives, Committee on Foreign Affairs, *Global* Commodity Scarcities in an Interdependent World (Washington, DC: U.S. Government Printing Office, 1974].

[61] National Commission on Supplies and Shortages, *Government* and the Nation's Resources (Washington, DC: U.S. Government Printing Office, *1976).*

[62] Ibid., pp. x-xii, chs. 2, 3, and 4, especially pp. 22-23 and 38-39.

[63] Ibid., p. 39.

841 bid., ch. 7.

[65] Ibid., p. 166.

does have a role to play [especially in basic research), the Commission suggested that more knowledge is needed of what motivates industry to commit R&D funds before government rushes in to fill the breach.[66]

The Commission recognized political obstacles to private investments in the world's minerals, such as the threat of expropriation, but called attention to existing measures to lessen the obstacles—measures such as government insurance for foreign investment, international disputes settlement and investment codes, and World Bank investments in developing countries. The Commission also expressed confidence "that private investors and Governments will find ways to adjust to political and economic realities."[67]

The Commission noted that complicated problems, like the rapid growth of world population, the unequal distribution of world resources, and the sometimes unexpected and unwanted byproducts of technological advance might require an increasing degree of government sophistication and management. It found room for improvements in the adequacy of the U.S. Government institutions to deal with materials issues. It also proposed practical changes in data collection and analysis and suggested the creation of a small, high-level corps of professionals to monitor specific industries and economic sectors and to develop a comprehensive picture of how government policies combine to affect basic industry and the national interest. However, the Commission recommended against seeking a "coordinated materials policy" as an end in itself, because materials policy affects and is affected by many other policies on matters of equal or greater importance.[68]

By *1976,* when the Commission published its report, the materials shortages that were so worrisome at the time of its creation had disappeared. Minerals activity had slid from the peak of high prices and tight supplies of the first half of 1974 to the trough of a world business recession, following the OPEC oil price hike.

Under the circumstances, the Commission's more astringent suggestions for "hands off the market (e.g., removal of the percentage depletion allowance for new minerals) were coolly received. In fact, there was some sentiment in Congress (especially among members from the western mining States) for much more active government support of the now-depressed and always volatile domestic mining industry than anything suggested by the noninterventionist report of this Commission, Some were also dissatisfied with the limited backing the Commission had given to the idea of "comprehensive" or "coordinated" materials policy.[69] Altogether, the report got little official response. Changes in the Commerce Department's economic analysis toward stronger analysis by the industrial sector was perhaps the principal result.

Once again, a Commission report on materials coincided with a change of the party in power, Within a month of President Carter's taking office, former Representative James Santini and *42* other members of the House of Representatives wrote to the President expressing concern that the Nation's policies were adversely affecting nonfuel minerals production, asking for a "balanced" national minerals policy, and proposing a special minerals advisor in the Executive Office of the President. In December of that year, the President ordered a government review of nonfuel minerals policy. The results, as noted below, were minimal; the policy review was never completed. At the end of the Carter presidency, demands by the industry and interested members of Congress for a "national minerals policy, " support for the minerals industry, and a special minerals advisor to the President were stronger than ever.

As the brief history outlined here suggests, Commission reports on materials policy and government actions have not always meshed. This is perhaps predictable, given the cyclical nature of the minerals industry. When commis-

[66]Ibid., pp. 182-184.
[67]1 bid., p. 46.
[68]Ibid., chs. 5 and 6.

[69]For this point of view, see U.S. Congress, House of Representatives, Committee on Interior and Insular Affairs, Subcommittee on Mines and Mining, U.S. Minerals Vulnerability: National *Policy* Implications, committee print, 96th Cong., 2d sess.

sions are formed, one set of problems may be dominant (e.g., shortages and high prices); but economic conditions may be quite different a year or two later when the report is issued, so that the problems may look quite different (e.g., idle domestic capacity, inadequate investment, "unfair" foreign competition). Also worth noting is that commissions may be rather insulated from political concerns, while the government that responds to them is not.

Thus, it is not too surprising that of the hundreds of detailed recommendations made by the three major materials commissions, Congress and the various administrations of the past three decades have specifically adopted only a few. By and large, both the executive branch and the Congress have steered a course —from tax laws to international trade treaties— that is consistent with the interdependence policy recommended by the commissions. But there have been exceptions. And in general, congressional and other government actions have followed their own agendas, rather than responding directly to commission recommendations. Thus, government actions on materials issues over the past *30* years are discussed separately from the story of the commissions reports.

Congressional Actions and Government Policies

Two strands in materials policy, besides the general support for free world trade, have won consistent backing from Congress over a number of years. One is the building of a strategic stockpile, a policy that is now nearly 45 years old. The other is high-level government oversight of a "comprehensive" materials policy, an idea at least as old as the Paley Commission, but insistently put forward by Congress since about *1970.*

A program that promoted and subsidized domestic minerals industries—an exception to the least-cost, interdependence policy—began during the Korean war and was actively pursued for a few years thereafter. The program died out in the *1960s,* but the law that authorized it, the Defense Production Act of *1950,* remained on the books and interest in the program has been revived as a means to reduce import dependency. TO Congress has repeatedly extended the law, most recently in *1984.* Production subsidies for cobalt were considered in deliberations about this extension, but are considered unlikely in fiscal years *1985* and *1986.* (See chs. 5 and *8* for further discussion.)

Stockpiling and Subsidies

Stockpiling originated in 1939, when, on the eve of world war, Congress passed the Strategic Materials Act, The Act authorized the government to list materials essential for industry and defense and to buy them for a strategic stockpile. Wartime needs soon overwhelmed the stockpiling program. The postwar Strategic and Critical Materials Stock Piling Act of *1946* restated the goal of preparing for an emergency by building stockpiles, and by *1950* some *$1.6* billion worth of stocks had been acquired. This was less than halfway to the objective then in effect of $4.1 billion. With the outbreak of war in *1950,* Congress provided funds for further major additions to the stockpile.

The Korean war prompted the passage of the Defense Production Act of **1950.** Besides authorizing government priorities and allocations of materials, the Act provided financial assistance for expanding domestic productive capacity, including facilities to produce critical nonfuel minerals. During and after the Korean war, purchase agreements, floor prices, and loans or loan guarantees under the Act promoted a doubling of U.S. aluminum production, a **25-**percent increase in U.S. copper mining, and a fourfold expansion of tungsten mining. Assistance under the Act also encouraged the startup of U.S. nickel mining and titanium processing and fostered domestic production of other minerals, including manganese, cobalt, and chromium. The gross outlay of the government for these programs was *$8.4* billion; with the payback of loans, the ultimate direct cost has been estimated as **$900** million.[71]

[70] Certain parts of the law that were tailored specifically to wartime needs (authorization for price, wage, and credit controls and for settlement of labor disputes) lapsed in 1951.

[71] U.S. Congress, Senate Committee on Banking, Housing, and Urban Affairs, *Defense* Production *Act* Extension *of 1981,* report to accompany S.1135 (Washington, DC: U.S. Government Printing Office, 1981), p. 3.

With the end of the war, many of the minerals supported by government programs were being produced in greater quantities and at higher prices than the civilian economy could absorb. Purchases for the strategic stockpile drained off some of the excess. The Eisenhower Administration continued to build stockpiles throughout most of the 1950s, partly to bolster mining industries the government itself had created, but also because President Eisenhower strongly believed in stockpiles as insurance. [72]

Government support proved to be a mixed blessing for some mining industries. Companies drawn into production by the combination of subsidized loans, purchase agreements, and large stockpile purchases were left stranded when stockpiles became filled, government purchases ceased, and subsidies were withdrawn. Tungsten mining in particular was on a roller coaster .[73]

A vital constituent for many superalloy and a widely used material for cutting tools, tungsten was selected as a critical material to be stockpiled, with a goal of 146 million pounds set in 1950, By 1955, government financial assistance, combined with stockpile purchases at high prices, had drawn more than 700 U.S. mines (mostly small ones) into operation. The government stopped stockpile buying of tungsten in 1957, after stocks had swollen to 210 million pounds-enough for 6 years consumption by the entire Western World, or 10 years of U.S. consumption.

In 1958, the Eisenhower Administration reduced the requirement for stockpiled materials from the amount needed to sustain the Nation for a 5-year war to enough for 3 years. Three-quarters of the tungsten holding was thereupon declared excess. In 1962 the Government began to sell tungsten stocks. Prices tumbled by two-thirds, and all but 2 of the 700 domestic mines ceased operations, Not until the late 1970s did the domestic tungsten industry resume growth.

In the 1960s, during the Kennedy and Johnson years, the government sold a number of commodities from the stockpile that were now in excess of the 3-year requirement—often using the sales as part of a strategy to control inflation or reduce budget deficits. In 1973, the Nixon Administration further reduced the stockpile requirements, from 3 years' sustenance to one, with the result that still greater quantities of stockpiled material were now officially declared excess,

At this point, Congress balked. The House Subcommittee on Seapower and Strategic Critical Materials questioned the new policy, threatened to block sales of stockpiled materials, and demanded a thorough study of stockpile policy. The Ford Administration complied, conducting an interagency review under the White House National Security Council. In 1976 the Administration announced a new stockpile policy based on planning to support defense and essential civilian needs for the first 3 years of a national emergency of indefinite duration. A few months after taking office, President Carter reaffirmed the Ford policy.

In 1979 Congress took stock. At this point, 40 years after the stockpile was established, the publicly owned stockpile was large but out of balance. The inventory was valued at $10.5 billion, of which $4.9 billion (or 47 percent) was excess to goals based on the 3-year requirement. But needs for acquisition amounted to $12.9 billion–more than the value of stocks on hand, "

Dissatisfied with the fluctuations in stockpile policy over the 40 years, Congress now wrote more explicit policy guidance and stockpile requirements into law. In the Strategic and Critical Materials Stock Piling Revision Act of 1979, Congress stated that the purpose of stockpiles is for the defense of the United States, not to control commodity prices. It also wrote into

[72]Franklin P. Huddle, "The Evolving National Policy for Materials, " Science 191, p. 655 (Feb. 20, 1976); also, A. E. Eckes, Jr., The United States and *the Global Struggle for* Minerals (Austin: University of Texas Press, 1979), p. 215.

[73]Most of the material that follows on the tungsten industry from 1950 to 1970 is drawn from Konrad J. A. Kundig, "The Tungsten Market–From Chaos to Stability," *Journal* of Metals, May 1981, pp. 42-47.

[74]Information on stockpile holdings was provided by the Federal Emergency Management Agency,

law that stockpiles should be sufficient to sustain the country's military, industrial, and essential civilian needs for at least 3 years, and that goals based on this requirement cannot be changed without prior notice to Congress. Finally, Congress set up a stockpile transaction fund, so that the proceeds from the sale of excess materials can be used to buy materials that are needed, rather than going back into the general Treasury funds.

A "National Materials Policy"

Meanwhile, at the end of the 1960s, Congress also turned its attention to the question of a broad Federal responsibility for materials policy, acting initially in the area of minerals policy. The Mining and Minerals Policy Act of 1970 was inspired by the National Environmental Policy Act of 1969, and was intended to provide similar guidance and goals in its own area.[75]

The Act declared it the national policy to foster and encourage: 1) the development of economically sound and stable domestic mining, minerals, and minerals reclamation industries; 2) the orderly and economic development of domestic mineral resources, reserves, and reclamation of minerals to help satisfy industrial, security, and environmental needs; 3) mining, mineral, and metallurgical research, including use and recycling of scrap; and 4) the study and development of methods for disposal, control, and reclamation of mineral waste products and mined land to lessen adverse impacts. The Secretary of the Interior was put in charge of advancing national minerals policy, as set forth in the law. He was required to report each year on the state of the domestic mining and minerals industry, and to recommend any laws needed to carry out the national policy. Beyond that, the law called for no specific actions.

[75] House Subcommittee on Minerals and Mining, U.S. *Minerals* Vulnerability, pp. 18-18. See the Committee's comparison of environmental laws with the Mining and Materials Policy Act of 1970, which it viewed as the victim of neglect by the executive branch.

Few identifiable actions were undertaken in response to the act. The Bureau of Mines used the language of the law to support funding requests for research in recycling and safe disposal of mine wastes, but no remarkable changes in funding priorities resulted. The Secretary of the Interior's first two annual reports (in 1972 and 1973) viewed with alarm problems of the U.S. minerals industry and the increasing U.S. import dependence on fuel and nonfuel minerals, but made few recommendations for changes in the law to carry out a national minerals policy. (One of the few changes recommended was to amend the antitrust laws to allow joint ventures for mineral research.) Later annual reports took a less alarmist view of the rising import dependence for fuel and nonfuel minerals, most of which was actually due to oil imports. The 1975 report, for example, said that problems arise from increasing imports "only when foreign sources become unreliable. " Especially in 1978 and 1979, the document failed to advocate the strong government support of the domestic minerals industry that sponsors of the law had evidently envisioned.

By the mid-1970s strong supporters of the mining industry in Congress had become concerned about what they saw as continuing neglect of national minerals policy by the executive branch. Displeased with the rather laissez-faire conclusions of the Commission on Supplies and Shortages, they urged the new Carter Administration to undertake a fresh review of national nonfuels mineral policy, President Carter responded in December 1977, appointing Secretary of the Interior Cecil B. Andrus chairman of an interdepartmental policy review committee.

The nonfuel minerals policy review gave even less satisfaction to advocates of a "national minerals policy." The review ultimately foundered, going no further than a partial draft report in 1979.[76] It had suffered a fate common for interdepartmental task force efforts—con-

[76] U. S. Department of the Interior, "Report on the Issues Identified in the Nonfuel Minerals Policy Review, " draft for public review and comment, August 1979.

signment to lower rungs of the bureaucratic ladder and a watering down of controversial issues, In hearings held around the country on draft portions of the report, the document was criticized by all sides—industry, environmental groups, and consumer organizations.

A number of congressional and industry critics criticized the document on national security grounds. They linked together the issues of import dependence, the health of the domestic minerals industries, the Nation's need for strategic materials, and the threat of a "resource war."[77]

Aside from mining and minerals, Congress had yet to declare a statutory national materials policy. The Paley Commission, in 1952, had spoken of "a national materials policy for the United States" with an overall objective of insuring "an adequate and dependable flow of materials at the lowest cost consistent with national security and with the welfare of friendly nations. " But the difficulties entailed in translating such recommendations into meaningful policy were formidable—given the diverse role that materials play in all aspects of society. When Congress, in 1970, enacted a National Materials Policy Act, it was for the purpose of developing such a policy (through Commission recommendations) rather than articulating one.

Nonetheless, throughout the 1970s, materials advocates both inside and outside the Congress had been laying the groundwork for a materials policy that would encompass a broad range of concerns—yet not be so broad as to be all inclusive. Some material policy concerns that were prominent in the early part of the decade became themselves the subject of separate legislation, thus making the task of what to emphasize in an overall national materials policy more manageable. Solid waste disposal—a dominant materials policy issue in the early 1970s—was perhaps the most conspicuous example. It still attracted considerable attention, but with enactment of the Resource Conservation and Recovery Act of 1976 its earlier prominence in the hierarchy of material policy concerns began to decline. Other concerns, such as import vulnerability, and the competitiveness of basic U.S. industry, had moved to the forefront.

Meanwhile, the House Committee on Science and Technology was working on legislation which emphasized the role of research and development in resolving material problems. Since the early 1970s, the Committee had become increasingly involved with the issue, releasing a series of background reports and holding hearings on various legislative proposals which had a science and technology component in implementing materials policy.

By the 95th Congress, these legislative concepts had begun to crystallize, so that one member of the committee could speak, in mid-1977, of acting in "concert with other committees of both Houses" to begin "to establish an orderly, effective national materials policy."[78] Several members of the committee had introduced bills which, while differing in detail, had themes in common.[79] First, the bills proposed a statutory materials policy. Second, implementation of the policy would be achieved through focusing Federal materials R&D activities. Third, they emphasized the need for greater involvement of the Executive Office of the President (through the Office of Science and Technology Policy (OSTP) or a new organization in the EOP) in materials decisionmaking.

None of these bills passed the 95th Congress, but the hearing process helped to further refine the basic legislative concepts and build a greater degree of consensus about components of national materials policy legislation. While expressing agreement with the overall objective of these bills, the Carter Administration was

[77]U.S. Congress, House of Representatives, Committee on Interior and Insular Affairs, Subcommittee on Mining and Minerals, Hearings, Oct. 18, 1979 (Washington, DC: U.S. Government Printing Office, 1979), statement of Representative James D. Santini, Chairman. See also the testimony of E. F. Andrews, Vice-President, Allegheny Ludlum Industries, Inc.

[78]U.S. Congress, House Committee on Science and Technology Subcommittee on Science, Research and Technology, Hearings on a National Policy for Materials; Research and Resources, 95th Cong., 1st & 2d sess., June 29, July 13, 14, 1977; Feb. 28, Mar. 1, 2, and 6, 1978 [Washington, DC: U.S. Government Printing Office, 1978], pp. 1-2.

[79]Material policy bills introduced in the 95th Congress included H.R. 10859, H.R. 11203, and H.R. 13025.

not convinced that new legislation was necessary. OSTP, it said, already had the authority to achieve those goals, and moreover its nonfuel mineral policy review, and other initiatives in areas of basic innovation and improved coordination of R&D would provide the needed direction for Federal policy without additional legislation.

The Administration's position became less persuasive in the 96th Congress, when its draft nonfuel mineral policy review came under considerable congressional criticism. With the reverberations of the cobalt price spike still shaking U.S. industry, the issue of import dependency was very much on the minds of legislators. Sponsors of materials legislation in the House saw an emphasis on science and technology as an important step toward reducing import vulnerability. At the end of 1979, the House, by a 398 to 8 vote, passed H.R. 2743, called the Materials Policy, Research and Development Act. The bill, originally introduced by Representative Don Fuqua, Chairman of the House Science and Technology Committee, reflected many of the basic concepts considered by the Committee in the 95th Congress—including a broad-based material policy, to be implemented through an improved executive branch decisionmaking process in regard to R&D activities.

After it was sent to the Senate, the House bill's basic framework was maintained, but its scope was enlarged as the bill moved through two Committees (Commerce, Science, and Transportation; and Energy and Natural Resources) to the Senate floor. New provisions were added which placed greater emphasis on materials import vulnerability, and the Departments of Defense, Commerce, and Interior were given important supporting roles in identifying vulnerability problems. In general, the Senate bill placed greater emphasis on minerals—thus bringing together in one piece of legislation the sometimes disparate concerns of the materials and minerals communities.

The bill was signed by President Carter on October 21, 1980, in the closing days of the 96th Congress.[80] The National Materials and Minerals Policy, Research and Development Act of 1980 (Public Law 96-479) 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 resource production, energy use, a healthy environment, natural resources conservation, and social needs.[81]

The law spelled out a number of activities in furtherance of this national materials policy, to be undertaken by the President, his Executive Office, and various departments. It directed the President to submit a plan to Congress that would assure: policy analysis and decisionmaking on materials in the Executive Office of the President; interagency coordination of material policy at the Cabinet level; continuing long-range analysis of the use and supply of materials to meet national needs; and continuing consultation with the private sector on Federal material programs.

The law designated the Office of Science and Technology Policy, in the Executive Office of the President, to coordinate Federal materials R&D, emphasizing R&D to meet long-range material needs through annual assessments. Responsibility for several specific tasks was placed in various departments: Commerce, to do case studies of material needs (the aerospace industry was selected for the first study and the steel industry the next); Defense, to assess material needs critical to national security; and Interior, to improve the assessment of international minerals and to make better minerals data and analysis available for decisions on Federal land use, and to report on its activities in these areas,

[80] For legislative history of Public Law 96-479, see House Report 96-272, Nov. 29, 1979 (House Science and Technology Committee); Senate Report 96-897, Aug. 13, 1980 (Senate Commerce, Science and Transportation Committee); Senate Report 96-937, Sept. 12, 1980 (Senate Energy and National Resources Committee; House debate and passage, Congressional Record, Dec. 4, 1979; Oct. 2, 1980; Senate debate and passage, Congressional Record, Oct. 1, 1980.

[81] Public Law 96-479, sec. 3.

In April 1982, President Reagan submitted the plan called for by the Act.[82] Dominating the plan was its emphasis on opening more of the federally owned public lands to minerals prospecting and development in order to "achieve a proper balance between wilderness and mineral needs of the American people, " Another major theme was renewed and improved stockpiling. The President took credit for the first major stockpile acquisitions in 20 years—purchases of cobalt and acquisition of Jamaican bauxite by purchase, barter of agricultural products, and swap of excess stockpile materials. The President's report promised a thorough review of the quality of stockpiled materials, some of which are decades old.

Despite efforts by Congress to assure high-level coordination of national materials policy, the plan offered little that was new in this regard. National materials policy, it said, would be coordinated through the Cabinet Council on Natural Resources and Environment (as it had been since the early days of the Reagan Administration). No budget for a coordinated materials program was presented (even though the law requires one); the Cabinet Council needs only a "minimum administrative staff, " said the report. For coordination of government-sponsored R&D, the plan proposed to resurrect the interagency Committee on Materials (COMAT). COMAT had been disbanded in the early days of the Carter Administration, then resurrected before Carter left office, and then was again disbanded in the early days of the Reagan Administration.

The President's report had little discussion of the potential for smoothing materials supply problems by developing advanced technologies for more efficient use of materials, recycling, or substitution of abundant materials for scarce ones—themes emphasized in the 1980 Act and its legislative history. While the Administration actually proposed to fund strategic materials R&D at a fairly high level, the President's plan offered few specifics, stating that "favorable tax incentives" in the 1981 tax law would stimulate private R&D of essential materials activity. Any government-financed R&D, the report said, "will concentrate on high-risk, high potential payoff projects with the best chance for wide generic application to materials problems and increased productivity. " The exception to this policy was mission-specific projects of the Department of Defense.

Although the President's plan was seen by many as an important first step, its lack of emphasis on materials issues other than those associated with mining and the public lands, as well as the choice of the Cabinet Council on Natural Resources and the Environment to coordinate policy, drew strong criticism from the House Committee on Science and Technology, By mid-August 1982, the Committee had reported a bill—the proposed Critical Materials Act of 1982—to establish a Council on Critical Materials "under and reporting to" the Executive Office of the President. "It is no accident, " the Committee report said, "that the Cabinet Council on Natural Resources and Environment, headed by the Secretary of Interior, placed primary emphasis on minerals, mining and related public land policies with almost no attention to basic material processing, conservation, substitution, or new materials development."[83] Only an entity within the Executive Office of the President, the Committee report reasoned, would be able to transcend "normal interagency competitiveness and provide the necessary balance in materials policy considerations." The Administration disagreed, arguing that a new layer of bureaucracy would impede—rather than enhance—materials and mineral policy coordination,

Although the hill did not pass in the 97th Congress, the House Science and Technology Committee continued the push for a critical materials council in the 98th Congress. Its Subcommittee on Transportation, Aviation, and Materials held hearings in May and June of 1983, focusing on implementation of the 1980 Materials Act.[84] Administration witnesses,

[82] *National Materials and Minerals Program Plan* and *Report to Congress*, submitted hy President Reagan, Apr. 5, 1982.

[83] House Report 97-761, Part 1, Aug. 18, 1982, p. 9.

[84] U.S. congress, House Committee on Science and Technology, Subcommittee on Transportation, Aviation, and Materials, Hearings on Material Research and Development Policy, 98th Cong. 1st sess., May 17, 18, 19; June 24, 1983 (Washington, DC: U.S. Government Printing Office, 1984),

while supporting the need for effective coordination, maintained that the Cabinet Council on Natural Resources and Environment and COMAT would fulfill this need. However, the U.S. General Accounting Office, which had been asked by full Committee Chairman Fuqua to monitor implementation of the 1980 Act, identified several areas in which additional attention would be needed to meet the goals of the 1980 Act, including more effective coordination.[85] While its final report was not released until March 1984,[86] GAO's preliminary findings (as reflected in its testimony) supported the contention of those who held that implementation of the 1980 Act was not adequate.

GAO pointed out that the Cabinet Council on Natural Resources and the Environment did not include all agencies with important materials responsibilities, such as the Department of Defense and the Federal Emergency Management Agency, which coordinates stockpile planning. COMAT, assigned R&D coordination by the President's plan, had apparently not been involved in determining the need for a major new materials research initiative proposed in the President's budget for fiscal year 1984. The Act called on OSTP to prepare and annually revise an assessment of national material needs related to scientific and technological changes over the next 5 years; while no date was specified for the initial assessment, none had been prepared. Finally GAO noted that the 1980 law did not require the administration to periodically revise and resubmit to Congress its overall materials program plan. Hence, the President's material plan would not necessarily be revised. (Key findings from the GAO report are summarized in box 4-A.)

Another issue taken up at the hearings concerned the potential role of advanced materials in U.S. industrial competitiveness, and in easing import vulnerability. In 1981, Japan had announced a 10-year program giving considerable prominence to advanced ceramics and other "high technology" materials in its industrial goals. Concern had been mounting that U.S. primacy in advanced materials research was in danger of being supplanted as these materials increasingly found commercial application.

By late October 1983, the subcommittee had reported a measure (H. R. 4186) to the full Science and Technology Committee which called for the establishment of a national critical materials council and for increased emphasis on advanced materials R&D. When a Senate-passed arctic research measure that had been endorsed by the Administration was referred to the Committee, it emerged from mark-up with a new Title II, the National Critical Materials Act of 1983, The measure was signed into law by President Reagan on July 31, 1984.

The National Critical Materials Act (Title II of Public Law 98-373) has three major components. First, it establishes a National Critical Materials Council in the Executive Office of the President, to advise the President on materials policy, and define responsibilities and coordinate critical materials policies among Federal agencies. The Council, to be composed of three presidentially appointed members who will need Senate confirmation if they do not already serve in a Senate-confirmed office, is to prepare a report on critical materials inventories, and projected use, including a long-range assessment of prospective critical materials problems.

Second, it calls for the establishment of a national Federal program for advanced materials research and technology, with the Council assuming key responsibilities for overseeing and collaborating with other agencies on the program. The Council is directed to establish a national Federal program plan for advanced materials R&D, and to review authorization and budget requests of all Federal agencies to ensure close coordination with policies determined by the Council. The Office of Management and Budget, in turn, is to consider Federal agency authorization requests in the materials area as an "integrated, coherent, multiagency request" to be reviewed with the

[85] Ibid., p. 23.

[86] U.S. General Accounting Office, *Implementation of the National Minerals and Materials Policy Needs Better Coordination and Focus*, GAO—RCED-84-63 (Gaithersburg, MD; Mar. 20, 1984).

Council for adherence to the Federal materials program plan then in effect.

Third, the law seeks to promote innovation and improved productivity in basic and advanced materials industries. The Council is to evaluate possible use of centers for industrial technology, authorized by the Stevenson-Wydler Technology Innovation Act of *1980* (Public Law 96-480), as a means to encourage such innovation. It is also called on to establish an "effective mechanism" for efficient and timely dissemination of materials property data.

The Range of Solutions

Thirty years of debate have drawn attention to a very wide range of political responses to materials supply problems. The promise of advanced technologies, both in expanding supply and in promoting more efficient, more flexible use of materials, has received considerably less attention. That is the purpose of this report. Chapters 5, 6, and 7 present in detail the principal subjects of this report—supply alternatives, conservation, and substitution. Chapter 8 discusses policy issues and options related to these subjects.

Box 4-A.-GAO Evaluation of Executive Branch Implementation of the National Materials and Mineral Policy, Research and Development Act of 1980

Soon after passage of the National Materials and Minerals Policy, Research and Development Act of 1980, the U.S. General Accounting Office (GAO) was asked to monitor and review the Administration's implementation of the Act by the Chairman of the House Science and Technology Committee. GAO's final report, issued in April 1984, draws the following conclusions:

- The President assigned overall responsibility for coordination of materials policy to the Cabinet Council on Natural Resources and Environment, but the council has not provided the "continuous decision and policy coordination required" by the Act. The Cabinet Council is restricted to Cabinet members; therefore, representatives from the Federal Emergency Management Agency (FEMA), which oversees stockpile policy, and the Environmental Protection Agency (EPA), which regulates the activities of mining and mineral processing industries, are not included. The Council cannot completely address minerals and materials issues with this lack of membership. In fact, several material-related decisions have been made by independent agencies or individuals with little or no coordination with the Council or sister agencies.
- The President's program plan focused on one of the three policy goals included in the Act—national security. However, almost no attention was given to the Act's other two policy goals-economic well-being and industrial production, except to address domestic minerals extraction problems. No consideration was given to the long-term implications of the decline in domestic minerals processing capacity for the U.S. economy and industrial base.
- The Act required the Office of Science and Technology Policy (OSTP) to prepare an assessment of national materials needs related to scientific and technological changes over the next 5 years and to revise such assessment on an annual basis. The Act, however, did not specify a reporting date, Agency officials told GAO that they consider this a low-priority task, and have not prepared the report.
- The Department of Defense was to prepare a report assessing critical materials needs related to national security and to identify steps to meet these needs. This report was to be made available to Congress on October 21, 1981. According to officials in the Defense Department, the report had been sent to the Cabinet Council on Material Resources and Environment in time for it to be used in the preparation of the President's material plan in April 1982. However, the report was still under review within the Administration as of February 1984, and had not been sent to Congress.
- Similarly, the Department of the Interior did not submit a report due to Congress on October 21, 1981, until November 10, 1983. The report was submitted only after the Chairman of a House subcommittee indicated that "legislative action" would be pursued if the report were not submitted. (The Interior report summarizes actions to improve the capacity of the Bureau of Mines to assess international mineral supplies, to increase the level of mining and metallurgical research by the Bureau in critical and strategic minerals, and to improve the availability of mineral data for Federal land use decisionmaking.)
- The only Federal agency to comply consistently with the Act's requirements is the Department of Commerce. (Commerce has completed two materials case studies on critical materials requirements of the steel industry and of the aerospace industry; a third dealing with domestic minerals industries is in progress.)

GAO concluded that the Executive Office should develop an expanded program plan which takes into account Congress' three policy goals of national security, economic well-being, and industrial production. Specific recommendations were:

- The plan should clearly define the terms "strategic" and "critical" to focus attention on those mineral and material markets where the United States is most vulnerable to price increases or supply disruptions and should develop a plan to measure the magnitude of the potential problem in a given market. The benefits and costs of various alternatives such as stockpiling, expanding domestic productive capacity and supply, and developing substitutes should be weighed in this long-term plan which should be geared towards specific minerals or materials.
- The program plan should reach beyond the goal of national security and include issues affecting the law's goals of economic well-being and industrial production, which are now being addressed in an uncoordinated fashion by the Departments of Interior, Commerce, Defense, and others.
- The program plan should address the future role of high technology materials R&D. This alternative should be developed within the report that OSTP is required to prepare under the 1980 Act, and the recommended redirection resulting from COMAT's inventory of Federal material R&D programs.

GAO offered the opportunity for the various agencies to comment on their conclusions and recommendations. The agency responses are as follows:

- The Department of the Interior disagreed on the need to develop an approach to measure U.S. minerals and materials vulnerability. Interior felt it was not necessary to quantify the magnitude or degree of vulnerability in a given nonfuel minerals or materials market.
- The Department of Defense agreed with GAO that the report assessing critical national security materials needs and the steps necessary to meet those needs required by the Act should be made available to Congress. Defense was in agreement with the Department of the Interior regarding measuring U.S. vulnerability.
- The Office of Science and Technology Policy did not comment on the GAO proposal that it prepare the assessment of national materials needs related to scientific and technical changes over the next 5 years as required by the Act. Interior, however, stated that the administration intended that COMAT would constitute the primary means through which OSTP would carry out the Act's reporting requirements. In the opinion of GAO, neither the program plan or COMAT's activities to date assess national materials needs related to scientific and technological changes over the next 5 years; therefore, this requirement has not been met.

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