TABLE 1. U.S. NET IMPORT RELIANCE FOR STRATEGIC AND CRITICAL NONFUEL MINERALS, 1979 TO 1981 (In percents) a/

Mineral	1979	1980	1981
Antimony	53	48	51
Asbestos	83	78	80
Bauxite and Alumina	93	94	94
Beryllium	-- b/	-- b/	-- b/
Bismuth	-- b/	-- b/	-- b/
Cadmium	64	55	63
Chromium	90	91	90
Cobalt	94	93	91
Columbium	100	100	100
Copper	12	14	5
Diamonds--Industrial	100	100	100
Fluorspar	86	87	85
Graphite	-- b/	100	100
Iodine	-- b/	-- b/	-- b/
Lead	4	-- c/	10
Manganese	98	98	98
Mercury	59	26	39
Micasheet	100	100	100
Nickel	69	73	72
Platinum-Group	89	88	85
Quartz Crystals	-- d/	-- d/	-- d/
Rutile (Titanium)	-- b/	-- b/	-- b/
Silicon	13	8	20
Tantalum	96	90	91
Thorium	-- d/	-- d/	-- d/
Tin	80	79	80
Tungsten	58	53	52
Vanadium	28	17	42
Zinc	63	60	67

SOURCE: U.S. Interior Department, Bureau of Mines, Mineral Commodity Summaries, 1982, for 23 minerals and CBO rough estimates derived from the Bureau of Mines partial data for six.

a. Net import reliance is defined as net imports adjusted for changes in inventories as a percent of apparent consumption.

b. Data withheld to maintain confidentiality of limited producers or users.

c. Net export.

d. Not available.

showing the proportion of apparent U.S. consumption that was met by net imports in 1979, 1980, and 1981. The three years illustrate various levels of economic activity. On the whole, 1979 was a year of relatively high economic activity, while 1980 was a poor year for the U.S. economy, and 1981 was a year of global recession.

Of the 29 strategic and critical minerals, U.S. dependence on imports exceeds 90 percent for ten and is between 50 and 90 percent for 13. 3/ The six for which U.S. import reliance is less than 50 percent are beryllium, copper, lead, mercury, silicon, and vanadium. The data in Table 1 do not include the metal contained in U.S. foreign trade in finished products. Were it possible to calculate the metal content in these products, measured import reliance might be higher. Moreover, U.S. reliance on imported supplies of some minerals has grown over the past two decades as richer U.S. deposits have been depleted, environmental restrictions have been implemented, and industrial output has increased to meet growing demand. Most of the increase in reliance occurred in the 1960s; the percentages have not changed much since 1970. While the United States was a net exporter of copper, iron and steel, and vanadium in 1960, it is now a net importer. Dependence on imported bauxite and alumina increased from 74 percent in 1960 to 94 percent in 1981 and on imported cobalt from 66 percent to 91 percent, respectively. Dependence has also increased for zinc, cadmium, tungsten, and titanium. For most other minerals, the percentages have remained essentially stable over the two decades.

Obviously the U.S. economy, including defense and other industrial production, would be severely crippled if all imports of all these materials were cut off. But not only has such a contingency never occurred (even in wartime) but the probability of such an event in the future is extremely low. Minerals supplies would be only one of a host of problems faced by the United States if all foreign trade were brought to a sudden halt. The more probable contingency for which U.S. minerals policy should provide is a sharp reduction, if not a complete termination, of imports of one or more of these essential minerals.

THE NATIONAL DEFENSE STOCKPILE

The National Defense Stockpile is the cornerstone of U.S. minerals policy. It contains 93 commodities, 80 are of mineral origin and the

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3. Based on the import reliance percentages calculated by the Bureau of Mines for 23 minerals as shown on Table 1, plus CBO rough estimates for the remaining six minerals derived from partial data reported by the Bureau of Mines.

remainder are agricultural products, such as quinine and opium. Stockpile goals have been set for 64 of the 80 mineral commodities. These 64 commodities represent 34 different minerals, most of which are divided into different grades and stages of processing for which separate stockpile goals are established. One mineral may be stockpiled in the form of ore, processed metal, an alloy with other metals, or some combination of these. For example, both chromite ore and several grades of ferrochrome (chromium alloy) are stockpiled.

Of the 34 minerals included in the National Defense Stockpile, five--talc, silver, sapphire and ruby, molybdenum, and jewel bearings--are excluded from the import dependent listing in Table 1 for various reasons. For three of the mineral groups--silver, sapphire and ruby, and molybdenum--the stockpile goals have been reduced to zero. 4/ Of the remaining 31 minerals with goals above zero, the United States is a net importer of 30; it is a net exporter of talc. The fifth item excluded from the Table 1 listing--jewel bearings--is a synthetic product assembled in the United States from imported substances. The list of 31 stockpiled minerals is presented in the Appendix. For 14 out of the 31 minerals, strategic stockpile inventories at the end of the first quarter of 1982 were in excess of the established goals, although in several cases inventories were below goals for particular subcategories of the mineral.

Evolution of the Stockpile

While the authority for the National Defense Stockpile is now found in the Strategic and Critical Materials Stockpiling Revision Act of 1979, its origins go back to before World War II. In 1939, the Strategic Materials Act authorized the government to determine the quality and quantities of strategic and critical materials that should be stockpiled. In 1946, the Strategic and Critical Materials Stockpiling Act confirmed the Congress' commitment to assured adequate supplies of materials in the event of a military emergency. The act was motivated, however, as much by concern for the drop in mineral prices that would occur if materials stocks held at the conclusion of the war were sold.

The Korean War led to another period of materials shortages and again focused attention on minerals vulnerability. The Defense Production Act of 1950 allowed the government to subsidize production of a number of minerals, such as cobalt. The materials stockpile was also augmented under the

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4. Significant publicly owned inventories exist for silver and sapphire and ruby, despite the zero goal. No inventory exists for molybdenum.

act. In 1951, the President's Materials Policy Commission (known as the Paley Commission) endorsed a policy of supplying the economy with minerals bought "at the least cost possible for equivalent values," thus rejecting a policy of minerals self-sufficiency. While the commission recommended that a stockpile be maintained for strategic minerals to meet U.S. requirements during a military emergency, it sanctioned reliance on lower-cost foreign sources for economic purposes. Ever since, this principle has been the basis of U.S. minerals policy.

In 1979, the Congress passed the Strategic and Critical Materials Stockpiling Revisions Act. The major purpose of the legislation was to update and revise the defense stockpile program, particularly setting a three-year military contingency as the criterion for establishing stockpile goals. (Over the previous two decades, stockpile requirements had been successively reduced by the Executive Branch from five to three to one year's demand associated with a military contingency.) In addition, the act specified that the stockpile was to be managed for defense purposes and not to control or influence commodity prices. It also consolidated inventories collected under all previous legislation into one National Defense Stockpile. 5/

The National Materials and Minerals Policy, Research, and Development Act of 1980 mandated the development of a national minerals policy, and was largely concerned with improving materials information and analysis and policy coordination within the Executive Branch. Pursuant to this act, President Reagan sent the Congress his National Materials and Minerals Program Plan in April 1982. Apart from providing increased availability of public lands for research and development and placing greater emphasis on both government and private research and development, it contained no new policy directions.

Current Stockpile Status

The value of materials now held in the defense stockpile is estimated at $11 billion at current market prices. Of this total, however, $4 billion represents the value of minerals held in excess of official stockpile goals. The value of the stockpile would be about $18 billion if all stockpile goals

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5. Inventories had been built under the previous Strategic Materials Acts, the Commodity Credit Corporation Charter Act of 1949, and the Trade Development Assistance Act of 1954. This last act authorized either bartering of agricultural products for minerals or the use of revenues from surplus food sales for minerals purchases.

were met. Thus, if materials in excess of stockpile targets were sold at current market values, completing the stockpile would require $7 billion in new appropriations.

Recent Budgetary Treatment. The Congress authorizes both purchases for and sales from the stockpile, and appropriates funds for purchases as well. The General Services Administration, which conducts stockpile transactions on behalf of the Federal Emergency Management Agency (FEMA), is directed to carry out these transactions with minimal effect on minerals markets. Thus, purchases do not necessarily occur in the year their funds are appropriated, and revenues are often carried over. For example, the Congress appropriated $57.6 million in fiscal year 1982 for purchases, $120 million in fiscal year 1983, and $120 million has been requested for fiscal year 1984. Actual purchases of $44 million occurred in fiscal year 1982 and an estimated $156.2 million will occur in fiscal year 1983. 6/ Recent purchases have included cobalt, metallurgical bauxite, and small quantities of refractory bauxite and tantalum, among other materials.

Sales from the stockpile--predominantly of surplus tin, industrial diamonds, and tungsten--totaled $178 million in fiscal year 1982 and $197 million in fiscal year 1983. Requested fiscal year 1984 sales are estimated at $314 million, including the sale of $100 million worth of surplus silver. The sale of surplus silver had been planned earlier, but was suspended in the Department of Defense Appropriation Act of 1982 pending further study.

Relation to a National Defense Emergency

The defense stockpile is intended by law to assure the availability of minerals needed for the national defense. Its stated purpose is to meet the military, industrial, and essential civilian needs of the United States during a national emergency. A national emergency is defined as mobilization for the national defense and use of the stockpile is now expressly forbidden for economic or budgetary purposes. Thus, the stockpile is designed to operate primarily during a period of international hostilities. The law further provides that the quantities in the stockpile should be sufficient for a period of not less than three years of mobilization needs.

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6. Appropriated funds are placed in a special Stockpile Transaction Fund used to finance minerals purchases. Receipts from minerals sales are also placed in this fund, but must be reappropriated for new acquisitions.

The stockpile goals are established by the Federal Emergency Management Agency through an elaborate interagency process that involves simulation of wartime minerals requirements as well as domestic primary and secondary production under conditions of national mobilization. Emergency scenarios are postulated, but their character is obviously sensitive for both national security and foreign policy reasons and they are not publicly available. Nevertheless, the published strategic stockpile goals shed some light on the kinds of contingencies that must have been assumed.

A strategic stockpile of minerals and metals could hardly be relevant to a nuclear war involving an attack on the United States. A global conventional war must be postulated, during which the enemy would be capable of interdicting all foreign mineral supplies. Such interdiction could be the result of enemy occupation of the mineral producing areas, or an enemy alliance with the governments of those areas, or the capture of sea lanes to the United States.

Under these circumstances, U.S. vulnerability to the loss of Canadian and Mexican supplies would presumably rank rather low. Dependence on Canada and Mexico for selected minerals is shown in Table 2. While future governments of these countries might conceivably wish to distance themselves from a particular global conflict in which the United States was involved, neither could risk U.S. retaliation for wartime embargoes they might impose on exports of strategic and critical materials to the United States. Large stockpile goals have been established for copper and lead, though the United States is a net importer of less than 15 percent of its consumption of these basic metals and obtains a fourth to a third of its gross imports of copper and over two-thirds of its imports of lead from Canada and Mexico. The goals for tungsten, cadmium, fluorspar, nickel, and zinc also appear to be high relative to recent U.S. net imports and the high degree of reliance on Canadian and Mexican supplies. A modest stockpile goal has been set for asbestos, though Canada supplies virtually all of U.S. imports. Both Canada and Mexico have sufficient resources to increase production of the materials listed in Table 2 to meet U.S. needs during an emergency.

The stockpile goals for bauxite are equal to about three years of imports from Jamaica and Surinam, currently the source of half of U.S. bauxite imports. Storage problems deter the establishment of a goal for alumina, of which three-fourths of U.S. imports are derived from Australia and virtually all the rest from Jamaica and Surinam. Canada supplies three-fifths of U.S. gross imports of aluminum metal, using Caribbean bauxite as its raw material. The stockpile goal for aluminium metal is nearly equal to average annual gross imports, although the United States has been a net exporter of this metal over the past three years.

TABLE 2. SELECTED STRATEGIC STOCKPILE GOALS, NET U.S. IMPORTS, AND CANADIAN-MEXICAN SHARE OF U.S. IMPORTS (In short tons)

Mineral	Stockpile Goals a/	U.S. Net Imports, 1979-81 Average	Canadian-Mexican Share of U.S. Imports, 1981 (In percents)
Asbestos	20,000	389,000	97
Cadmium	11,700,000	2,824	49
Copper	1,000,000	229,000	31
Fluorspar	3,100,010	1,122,000	62
Graphite	29,000	57,000	61
Lead	1,100,000	-- b/	69
Nickel	200,000	161,987	56 c/
Silicon	29,000	81,000	28
Tungsten	50,666,000	5,094	30
Zinc	1,425,000	678,700	61

SOURCE: U.S. Bureau of Mines, Minerals Yearbook, 1981.

a. Stockpile goals as of March 31, 1982.

b. Net exports.

c. Includes 10 percent of U. S. imports that comes from Norway, which manufactures nickel from matte imported from Canada.

Other stockpile goals concern a variety of minerals whose military and economic importance is substantial, but which are imported in relatively small tonnage from a variety of sources in Latin America and Asia. Except for tin and rutile (titanium), net imports in each case are less than 20 thousand tons a year from all sources, though the gross tonnage of imported ore may be larger in some cases. A 20-thousand-ton shipment would be half or less the capacity of a single bulk freighter, assuming that secure shipping was available. If the sources of supply were not under enemy control, U.S. needs under conditions of emergency might well be met by air transport.

The rest of the stockpile goals consist of metals of African origin--chromium, industrial diamonds, platinum-group metals, and manganese--imported primarily from the Union of South Africa, Zimbabwe, Zaire, and Gabon. Cobalt is imported from Zaire and Zambia. These sources pose greater vulnerability risks.

The strategic stockpile goals thus appear to provide generous insurance against national defense contingencies (such as a three-year cessation of minerals trade) whose probability of occurrence is low. On the other hand, a loss of supplies of these minerals under some circumstances would be extremely damaging. But many of these circumstances would not involve a defense emergency. Rather, they would reflect political or logistical conditions, such as those already experienced in oil and cobalt.

Relation to Political and Economic Events

An interruption or curtailment of U.S. supplies of one or more critical materials arising from political or economic events is far more likely than a national defense emergency. The 1973 and 1979 oil shocks, the ongoing Iraq-Iran War, and the interruption of Zaire's cobalt supplies in 1978, all suggest that some interruption of mineral supplies may occur again. While such disruptions are unlikely to affect U.S. national security or economic well-being to the same extent as those arising out of a national defense emergency, they may be more likely and could cause significant economic damage for a limited period of time. For such contingencies, the U.S. government does very little to provide insurance. The defense stockpile is not intended for such emergencies, nor does the government make any other provisions.

The causes of such disruptions could be actions by foreign governments intended to disrupt U.S. supplies for political purposes or to raise prices, localized political or military actions that incidentally disrupt supplies, or abrupt demand surges in excess of existing worldwide production capacity. But users of imported materials generally regard such events as normal business risks, much as they would strikes or natural disasters affecting their domestic sources of supply. They try to keep well-informed about the likelihood of such events affecting a major foreign supplier. Many have sophisticated contingency plans for a supply interruption and most maintain inventories at a level intended to provide time to arrange for alternative supplies or substitute materials. In the case of cobalt, such private inventories proved quite adequate in 1978 when the importer (who had a near monopoly of U.S. supplies of the primary metal) put his customers on a 70 percent allocation. Free market prices rose, but only limited supplies were purchased at the higher prices. Thanks to private inventories, no production line dependent on cobalt was shut down, nor was production of military or industrial equipment incorporating cobalt curtailed.

Despite this salutary experience, a policy that depends on the private sector to provide for possible acts by foreign governments or political groups that could threaten U.S. industrial production and employment may be questioned. When interest rates are high, company profits are poor, and raw material prices are stable or declining, private companies are under considerable internal pressure to reduce inventories and accept greater risks of supply interruptions. Private company acceptance of greater risks under such circumstances may be less acceptable in terms of the national economic interest.

The minerals of concern to the U.S. economy are essentially the same as those for which strategic stockpile targets have been established. The peacetime problem is mitigated considerably by the possibility of turning to alternative sources of supply in the event of a political, economic, or military contingency affecting one supplier. The single exception would be formation of a cartel in which most of the major suppliers participated.

Persistent attempts to establish such cartels over the past decade have not been successful, however. Such a cartel would have both to control a large proportion of world production and to forgo the benefits accruing to noncartel suppliers who could expand their production and sales under cover of the cartel's restrictive umbrella. The cartel members would also have to accept the further invasion of their markets by new producers, recyclers, and producers of substitute materials. Still, two-thirds of every mineral (except tantalum) for which strategic stockpile goals have been established originate in only three or four foreign countries. Indeed, it is the absence of diversified sources of supply that is at the root of U.S. vulnerability to minerals supply shortages that could arise from political, economic, or localized military events.

The Committee on Natural Resources of the International Economic Policy Association is composed of representatives of major companies that are important users of imported minerals. It recently identified only nine nonfuel minerals as warranting major concern: chromium, cobalt, columbium, fluorspar, manganese, the platinum group, tantalum, titanium, and tungsten. 7/

As a part of a Nonfuel Minerals Policy Review ordered by the President in late 1977, Resources for the Future was commissioned to study seven of the major minerals identified as potential problems in the course of

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7. T.W. Stanley, A National Risk Management Approach to American Raw Materials Vulnerabilities (Washington, D.C.: International Economic Policy Association, 1982).

the preliminary work of the cabinet-level committee charged with the review. The study foresaw long-term supply problems only for aluminum and lead, largely because of cutbacks in plans to expand capacity for bauxite, alumina, aluminum, and lead refining. 8/ As for short-term contingencies, it judged the probability of shortages up to 20 percent of usual consumption to be moderate to high for cobalt, chromite, ferrochromium, ferromanganese, alumina, aluminum, copper, and lead. The study reported that it was unlikely that either zinc or manganese ore would be in short supply for more than a few months because of any imaginable short-term contingency. Cobalt, chromium, and ferromanganese gave concern because of potential disruptions in southern Africa; aluminum because of possible disruption in Guinea and the Caribbean; and copper and lead because of possible surges in demand in the event of a simultaneous economic boom in the industrialized world.

U.S. vulnerability is, in one sense, greater in the case of political or economic contingencies than in the event of a global war. Peacetime disagreements with various mineral producer governments over political or economic interests could conceivably lead to a reduction in their shipments of raw materials to the United States. In wartime, however, the threat of vigorous U.S. retaliation would be much more credible, and damaging behavior on the part of foreign suppliers much less probable.

Reliance on southern African supplies remains a significant, if not primary, concern. The stability of the government of Zaire has been a continuing problem. Its copper-cobalt producing province has been subject to two invasions in recent years that met considerable local support. The ability of the South African government to maintain peaceful domestic conditions is questionable, and the antagonism of its neighbors to its apartheid policy has strengthened with the passage of time. The U.S. government may one day be compelled, for political reasons, to participate in an embargo on all imports from South Africa. Thus, a stockpile might eventually be useful as a buffer against an interruption of southern African supplies, but never be needed for use during a military mobilization in the United States. Unless the Congress were to pass new legislation, however, the current stockpile would be unavailable to ameliorate the loss of minerals supplies from the first type of disruption.

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8. Resources for the Future, Major Mineral Supply Problems (Washington, D.C.: National Technical Information Service, 1979).

CHAPTER III. ANALYSIS OF SELECTED STRATEGIC MATERIALS

A mineral is strategic and critical if it is both imported and essential to industrial production--especially defense production. But, high import dependence does not necessarily mean high risk; risk is a function of the relative stability of sources, the political orientation of these sources, and the nature of alternative sources that could be used during a supply disruption. Risk also depends on the criticality of the mineral's applications.

This chapter examines four strategic minerals that are most frequently listed as problem "minerals" from the foregoing perspectives. The four minerals chosen for review are cobalt, chromium, manganese, and the platinum group. Cobalt is not only an important ingredient of the "superalloys" necessary for jet engines, but is also essential for the manufacture of high-speed machine tool bits and permanent magnets used in precision electronics. Chromium is necessary for the manufacture of stainless steel. Manganese is essential in steelmaking. Platinum has important applications in the manufacture of automobile pollution-control devices and of electrical and electronic goods, as well as in petroleum refining and in petrochemicals.

Another characteristic that all four of these minerals share is that the bulk of their supply comes from sub-Saharan Africa. The United States produces few or no supplies. The principal African sources--Zaire and South Africa--are vulnerable at least to terrorism and at worst to takeover by unfriendly forces. Zaire's Shaba province, where most of the cobalt is mined, has been attacked twice in the past decade by rebels based in neighboring Angola--once with some interruption of the cobalt supply--and further incursions are threatened. The Transvaal district of South Africa, where most of the chromium, platinum, and manganese originates, is within striking range by African National Congress rebels operating out of Zimbabwe and other neighboring countries and enclaves, besides being subject to domestic racial strife. The principal alternative sources of chromium are Zimbabwe, whose reliability is far from assured, and the Soviet Union. The Soviet Union is the major alternative source for platinum. For manganese, the most important alternative U.S. supplier is Gabon.

All four minerals also share in the phenomenon that U.S. vulnerability is substantially mitigated by the availability of both supply and consumption alternatives. Both the nature of the risk and the character of the alternatives differ considerably in their details from commodity to commodity, however. Accordingly, individual consideration is essential.

CHROMIUM

The United States used 504,000 tons of chromium in 1981. Around 90 percent of this consumption was met by imports, at a cost of $264 million. Chromium arrives in the United States in two important forms: as ore (chromite) and as processed (refined) ferroalloy (mostly ferrochromium). Imports have shifted to the latter form, as South African and Zimbabwean processing plants have progressively taken markets away from U.S. ferroalloy makers. For example, while in 1970 nearly 95 percent arrived as ore, in 1981 imports were equally divided between ore and ferroalloy.

Chromite is mined in three principal varieties. The first, with high aluminum content, is useful for making refractories (exceptionally heat-resistant furnaces). A second has high chromium content and is used to make low-carbon ferrochromium. The third has a relatively higher iron content and is useful both for chemical applications (including liquors for chromium plating) and to produce high-carbon ferrochromium. A decade ago this third variety was considered "low grade" and hardly qualified as metallurgical ore, but it is now the predominant--and cheapest--one used for ferrochromium manufacture. South Africa's growing predominance as both a chromite and a ferrochromium supplier is due primarily to concentrated reserves of this cheaper type of ore, along with transportation, energy, and labor economies.

Supplementary U.S. tariff protection had been in force since 1978 on low-cost, high-carbon ferrochromium, but was allowed to expire in November 1982, whereupon its price immediately fell, though not to pretariff levels. In permitting the expiration, the Administration rejected a petition of the Ferroalloy Producers Association for continued protection.

Uses

About 45 percent of the chromium consumed in the United States is used to make stainless steel, typically from ferrochromium. Roughly another 15 percent goes into other alloy steels. Chromium enhances resistance to corrosion and oxidization, especially at high temperatures, and may also be used to increase hardness (important in some military applications, such as high-speed engines). Chromium's use in nonferrous alloys is only about 2 or 3 percent of total consumption, but it is critical since such alloys are mainly used to meet exacting requirements for jet engines and other high-temperature applications. Generally, the more critical the chromium application, the higher the total value of the final product and the lower the sensitivity of chromium demand to price, since chromium is only a small part of overall cost.

Chemical uses of chromium, which rely on direct utilization of chemical-grade ore, account for about 20 percent of total consumption. This classification includes one method to produce pure chromium metal, chromium plate, and chemicals for leather tanning, pigments, and many other uses. The balance of chromium demand results from the refractory use of chromite, which requires an ore that comes mostly from the Philippines rather than South Africa. This is a stagnant, if not diminishing, application since a large part is used in open-hearth steelmaking--an obsolescent method in a declining U.S. industry.

Sources of Supply

Except for a small quantity of ore mined and exported in 1976, there has been no domestic mining of chromite since 1961, when the last Defense Production Act contract was phased out. About 10 percent of U.S. chromium supply is provided by recycling (essentially of chromium contained in stainless steel); the remaining 90 percent is obtained from imports. Imports increasingly are in the form of ferrochromium; this form now constitutes 40 to 50 percent of the overall import total and more than half of total chromium use in metallurgy.

Table 3 summarizes the sources of U.S. chromium supply in 1981. At present, all chromite is imported. The small amount of refractory-grade chromite not supplied by the Philippines originates in South Africa. South Africa supplies the major part of metallurgical-use chromite, but substantial quantities are also imported from the USSR, Finland, Madagascar, and Turkey. Zimbabwe (formerly Rhodesia) used to be an important ore supplier--surreptitiously, during the days of the UN trade embargo against Rhodesia. It has apparently ceased shipping ores directly, and now processes them into ferrochromium.

Between 1978 and 1981, South Africa was the source of about 70 percent of U.S. imports of ferrochromium. Zimbabwe and Brazil are growing in relative importance as suppliers, eclipsing formerly second-place Yugoslavia. Turkey is also a contributor, along with a new and possibly growing entrant, the People's Republic of China.

TABLE 3. SOURCES OF U.S. CHROMIUM IMPORTS FOR 1981 a/

Country	Percent of Chromite Imports	Percent of Ferrochromium Imports
South Africa	57.3	56.4
Zimbabwe	--	16.7
Philippines	14.1	0.6
Yugoslavia	--	12.4
Brazil	--	4.5
USSR	13.0	--
Finland	6.5	--
Turkey	5.4	2.1
Other	3.7	7.3

SOURCE: U. S. Bureau of Mines, Minerals Yearbook, 1981.

a. Percents based on chromium content.

Nature of the Risks

While there is a wide spectrum of opinion regarding the risk of instability in South Africa because of its racial policies, the consensus seems to be that it is growing. As a consequence, isolated acts of violence and sabotage could interfere for limited periods with some of the export flow of both chromite and ferrochrome. At some later date, a protracted struggle could throttle more of the flow for longer periods. Under almost any plausible outcome, however, full flow of both ferroalloy and ore could be expected to resume once the conflict was settled. A United Nations-adopted embargo against South Africa is also possible, but at the moment it seems unlikely that the United States would cooperate in such an action.

In peacetime, a reasonable summary of the South African supply risk for the next decade includes an outside chance that nearly all of it could be interrupted for as much as a year or more. A more likely scenario is short-term interruption--a matter of months--of a minor portion of the supply as a result of strikes or sabotage against producing facilities, power supplies, or rail export connections. Another risk is the possible deliberate interruption by South Africa of the outward rail movement of Zimbabwean ferrochrome, which is now shipped either through South African or a Mozambican rail line whose interdiction could be engineered by South Africa. Within the present political context, however, an extended concurrent interruption of both the South African and the Zimbabwean chromium supplies seems remote.

The relatively minor flow of chromium from the Soviet Union is subject to obvious risk even short of a national emergency. Commercial rather than political reasons appear to explain fluctuations in U.S. imports from that source over the past two decades, however. The supply of Brazilian chromium could be preempted in the future by the needs of that country's own industry, but that eventuality would develop gradually. Finally, the potential for instability in the Philippines suggests a degree of insecurity about the U.S. supply of refractory grade chromite. This kind of chromite is becoming progressively less critical, however.

A major East-West conflict would entail the additional risks of military occupation of Southern Africa, political alienation of the United States from black African producers, or interruption of sea traffic. For the most part, the sea lanes in question would merit priority military protection for reasons going well beyond the need for chromium. The United States would also have more important reasons than chromium supply protection to resist any attempt at territorial takeover.

Apart from the risks of physical interruption, the very large share of ferrochromium supplied by South Africa to the free world suggests the future possibility of oligopolistic pricing actions. Only a strong and prolonged worldwide economic recovery, however, would make such price manipulation feasible.

Supply Alternatives

A number of available supply alternatives could be called upon to counter almost any chromium supply contingency. It might not take much more than a year to replace all of the South African supply, if an interruption from that source were perceived to be long lasting.

The most immediate crunch would occur in the supply of ferrochromium. Existing inventories, both those in private hands and those in the national stockpile, contain much more chromite than ferrochromium. Private stocks of chromite have been running at eight to nine months of consumption. Ferrochromium stocks in the hands of both producers and consumers have been closer to three months of consumption. The real bottleneck, therefore, would be furnace capacity to convert ore into ferrochromium. Not only is there little available alternative U.S. furnace capacity suitable for rapid conversion to ferrochrome production, but the United States also lacks the capacity to manufacture new furnaces. These are imported from European sources. Once the rather substantial slack in existing Japanese and European capacity is taken up, Brazil would probably be the next most important alternative for ferrochrome furnace capacity.

Wartime vulnerability would be reduced through a program recently announced by the General Services Administration to upgrade part of the national strategic stock of chromite into ferrochromium. That program is also intended to replace the expired tariff protection by providing business for the U.S. ferrochromium industry.

A continuing major contingency in southern Africa could result in a shortage of chromite itself. To replace this shortfall, the flow of chromite from Brazil, Turkey, Finland, Madagascar, and a dozen other places could be expanded. Depending upon the circumstances and the price, additional supplies might also be forthcoming from the Soviet Union. The Philippines could be called upon for metallurgical as well as refractory ore.

At higher prices or with some subsidy, the Stillwater complex in Montana could be activated fairly quickly to produce domestic chromite, as could beach sand mining in Oregon. Research by the Bureau of Mines suggests, however, that the required break-even price for these operations is higher than probable market prices, even under circumstances of severe chromite shortfall. 1/

Consumption Alternatives

Considerable scope exists for chromium conservation and substitution. Much of the demand for stainless steel can be satisfied with less chromium content. Equivalent anticorrosion qualities can be attained--though at higher cost--by increasing the content of nickel. Equivalent or near-equivalent heat-resistance qualities can be achieved--again usually at higher cost--by the use of such alternative alloying elements as nickel, cobalt, columbium, or molybdenum. Aluminum, copper, glass, titanium, and plastics can substitute for stainless steel in many applications. Finally, the total supply of chromium available for stainless steel production can be increased by more intensive recycling.

Conclusions

The risks of a shortfall in chromium supply are significant. The most critical--though certainly not the most probable--would involve a denial of

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1. U.S. Bureau of Mines, unpublished paper (November 1981).

southern African supplies during a major military conflict. If the current national stockpile were completely upgraded into ferrochromium, it would be equal to four to five years of normal peacetime consumption. This would seem more than ample to meet all critical needs. It would certainly be ample if its mandated stockpile goal was filled (again substituting ferrochromium for most of the ore).

Cost is a major drawback to upgrading. Fulfilling the chromite goal would only cost an additional $700,000 to $900,000. Upgrading just the present chemical and metallurgical chromite inventory, including below specification material, to ferrochromium would cost around $500 million.

Either in wartime or in a major peacetime contingency--especially one occuring during a time of general economic recovery--an interruption in chromium supply could simply result in substantial price rises. Price increases would probably accompany any other problems that might arise. The many opportunities for chromium conservation, substitution of alternative materials, and alternative chromite production would serve to place a ceiling on upward price pressures, however. Moreover, chromium prices per se would not contribute significantly to general price inflation. Expenditures on chromium account for only a small portion of the final cost of most metallurgical end products. For example, a recent study for the Bureau of Mines estimates that doubling the price of domestic ferrochrome would raise the price of stainless steel by only 6 percent. 2/

COBALT 3/

The United States used some 13 million pounds of cobalt in 1981, of which 92 percent was imported, at a cost of $261 million. Of the four strategic metals examined in this chapter, cobalt is the only one within recent history to have been subjected to a significant supply disruption. After the second of two invasions of Zaire's Shaba (Katanga) province by Katangan dissidents operating out of Angola, the official (producer) price of cobalt rose from about $7 per pound in May 1978 to $25 per pound by February 1979. Spot prices went as high as $50. The price rise was exacerbated by an already tight market. In April 1978 (prior to the invasion) the Zairian distributor in the United States announced that it would limit its

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2. F.E. Katak, T.B. King and J.P. Clark, "Domestic Production of Stainless Steel Mill Products: Cost and Supply Analysis," Materials and Society, vol. vi:2 (1982).

3. For additional information, see Congressional Budget Office, Cobalt: Policy Options for a Strategic Mineral (September 1982).

customers to only 70 percent of their preceding year's supplies. Retrospectively, it was learned that very little hiatus occurred in actual Zairian output. Though the rail link through Angola to the sea was effectively cut off, it was perfectly feasible to ship cobalt by air. By the end of 1981, the official price of cobalt had sunk back to $17, and by early 1982 to $12.50. On the spot market, the metal was selling at $4 per pound before the end of 1982.

Such price gyrations are a consequence of the high degree of concentration of the Western world's cobalt supply in Shaba province. Lack of confidence in the stability of the Zairian government is widespread and its ability to cope with revolutionary challenges is suspect. Foreign forces were called upon to help quell the May 1978 invasion. Price volatility was also a consequence of a worldwide economic boom in 1977-1978 and a subsequent recession.

Uses

Significant changes took place in cobalt consumption as the result of the 1978-1979 price runup. Examples include substitution of ceramics and organic composites for cobalt as well as the use of cobalt-free alloys, even in such critical applications as engine blades and vanes. Use of cobalt for permanent magnets--such as those used in radios--has declined from about a third of total U.S. consumption to about one-sixth. The reasons are twofold. First, the source of U.S. electronics supplies has shifted substantially from the United States to Japan. Second, when cobalt prices zoomed, the electronics industry realized that consumer electronic goods could be adequately served by ceramic magnets.

Cobalt consumption has declined in a variety of uses. The use of cobalt in chemical form, as a drier and pigment in paints, is price sensitive. Most of the decline in this use occurred prior to the mid-1970s with the decreased use of oil-based paints. Technological change has been the principal factor behind declining cobalt use in glass and ceramics. In general, the nonmetallic (chemical-compound) uses of cobalt have dropped from about 30 percent of total consumption prior to the mid-1970s to about 20 percent in more recent years. This change has taken place despite a growing use of cobalt compounds as catalysts, especially in petroleum refining and petrochemical manufacture.

An important use of cobalt--as the "cement" in cemented carbide cutting tools--has declined quite abruptly in the last few years, from more than 15 percent to less than 10 percent of the total. The reason is essentially the economic recession and lower oil prices, with their effects on the machine-tool and mining and drilling industries. The 1978-1979 cobalt price rises also had lasting effects on cobalt conservation in such applications, as well as increasing routine recycling, although cutting tools still require some cobalt content.

Conservation has been least employed in the metal's use in high-temperature alloys, mostly for gas turbine engines, especially in jet airplanes. In 1982, this use accounted for some 37 percent of total consumption--well beyond both the proportion and the absolute amounts of the mid-1970s. Cobalt is important in imparting high-temperature strength and its cost is very low relative to the total cost of an engine.

Sources of Supply

Sources of cobalt imports for 1981 are summarized in Table 4. It should be noted that Norway, Japan, and Belgium are exporters of refined metals rather than ore. Zaire's Shaba province supplies about 60 percent of the free world's cobalt, where it is produced as a by-product of copper mining and processing. Neighboring Zambia, whose cobalt capacity is increasing, is the next largest world supplier. Thus, two-thirds of the Western supply originates in central Africa. With or without the excuse of domestic instability, Zaire is in a position to lead or abet an upward price spiral whenever the industrial world is at a high level of economic activity. When world industrial activity is weak, cobalt supplies typically decline,

TABLE 4. SOURCES OF U.S. COBALT IMPORTS FOR 1981

Country	Percent of Imports a/
Zaire	26.8
Canada	11.8
Norway	10.5
Japan	10.4
Zambia	9.7
Finland	7.7
Belgium-Luxembourg	6.0
Other	17.0

SOURCE: U. S. Bureau of Mines, Minerals Yearbook, 1981.

a. Percents based on cobalt content.

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since nearly all cobalt output is a by-product of copper or nickel, whose demands are procyclical. Demand for cobalt usually declines as well. But even during recessions, Zaire and Zambia may maintain high levels of copper and cobalt output in order to avoid increasing domestic unemployment and to maintain the flow of foreign exchange. Under these conditions, continued high production would depress prices for both minerals.

Most of the supply of cobalt follows a roundabout route from mines to industrial consumers. Historically, most of the refining or re-refining of Zaire's cobalt took place in Belgium. Only since 1975 have any U.S. facilities existed for refining primary cobalt. Plants for recovery of the nearly 10 percent of cobalt supply that comes from recycled scrap have been in existence longer. Traditionally, Zairian cobalt was marketed either through Belgian channels or with Belgian advice and assistance (Union Miniere or its affiliates). Increasingly, however, the Zairian government is taking marketing into its own hands.

Given the lack of U.S. refining facilities, the great bulk of U.S. imports of cobalt arrives already in metallic form (including scrap). The sole domestic primary refinery operates on nickel-cobalt or copper-cobalt matte--obtained from Botswana, South Africa, New Caledonia, and Australia. A recently established U.S. re-refiner imports metallic (cathode) cobalt from Zaire and processes it into extra-fine powder. It is owned by the Belgian Company Union Miniere affiliate and will replace Belgian production. In addition, plans have been announced for construction of a U.S. plant for recycling the now significant amount of cobalt used as catalysts in petroleum processing.

Nature of the Risks

The high proportion of U.S. cobalt supply that comes directly or indirectly from a small area in central Africa suggests high vulnerability to supply disruption. The peacetime risk can easily be overestimated, however. One source of reassurance is the decline in the Zairian share of the U.S. market and the continuing growth of the Zambian portion. Peacetime contingencies that might concurrently interrupt production in both countries appear to be improbable, since sources of political tension are very different in each of these countries. Also, it is hard to conceive of a regime in either country that could long afford to forego copper exports to the West and with them the cobalt produced as a by-product. If land transportation facilities were shut down, cobalt metal could be shifted by air at a supportable cost. A more stringent contingency would involve interruption of power supplies to cobalt refineries in these countries.