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IMPORTS OF MINERALS FROM SOUTH AFRICA BY THE UNITED STATES AND THE OECD COUNTRIES

PREPARED FOR THE
SUBCOMMITTEE ON AFRICAN AFFAIRS
OF THE
COMMITTEE ON FOREIGN RELATIONS
UNITED STATES SENATE

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(II)

MEMORANDUM FROM THE CHAIRMAN

Although the United States is blessed with a wealth of natural resources, all of these resources are not available in equally abundant quantities. Furthermore, there are simply many materials for which we do not possess significant reserves. Thus, for better or worse, we have come to depend upon foreign countries to supply many of the resources which sustain our technological society. Viewing the 1973 Arab oil embargo as the archtypical example, many observers see U.S. dependence upon the raw materials of other nations as inherently unsettling. I do not disagree. The logical course for the United States is to lessen our reliance upon overseas sources of critical and strategic materials, by identifying domestic reserves, promoting recycling, and expanding the national stockpiles. However, at the same time we must assess the world materials situation and our relationships with other countries with an inquiring eye. This report, prepared by the Congressional Research Service for the Subcommittee on African Affairs of the Senate Foreign Relations Committee, is an important document in that regard. As Senator McGovern has noted in his letter of transmittal, this report challenges many of the current assumptions about U.S. reliance upon mineral imports from the nation of South Africa. Consequently, it is a valuable contribution to the ongoing debate over the effects of American nonfuel minerals policies on foreign affairs, and it should be carefully read by all who are interested in this topic.

FRANK CHURCH.

LETTER OF SUBMITTAL

CONGRESSIONAL RESEARCH SERVICE,
THE LIBRARY OF CONGRESS,
Washington, D.C., November 28, 1979.

Hon. GEORGE MCGOVERN,
*Chairman, Subcommittee on African Affairs, Committee on Foreign
Relations, U.S. Senate, Washington, D.C.*

DEAR MR. CHAIRMAN: I am pleased to submit to you the study of United States and OECD mineral imports from South Africa prepared by the Congressional Research Service at your request. As the United States moves into the 1980's, it is clear that the issue of access to sources of raw materials will be an important one. I therefore hope that you will find this report both timely and useful.

The report is the product of a cooperative effort, extending over many months, between the Foreign Affairs and National Defense Division and the Senior Specialists Division of CRS. The study was extensively revised and updated during the fall of 1979 by Raymond W. Copson, Analyst in International Relations, Foreign Affairs and National Defense Division; Jane Powers, Research Assistant in the Senior Specialists Division; and Allen F. Agnew, Senior Specialist in Environmental Policy (Mining and Mineral Resources). The initial study was written in 1978 by William N. Raiford, Analyst in African Affairs, Foreign Affairs and National Defense Division; Barbara J. Bascle, Research Assistant in the Senior Specialists Division; and Allen F. Agnew. The final typescript was prepared by Theresa E. Varela.

Sincerely,

GILBERT GUDE, *Director.*

LETTER OF INTENT

TO THE HONORABLE SECRETARY OF THE
NAVY

SIR,

I have the honor to acknowledge the receipt of your letter of the 10th inst. in relation to the proposed purchase of the vessel "Albatross" for the service of the Navy. I am pleased to inform you that the Board of Navy Commissioners has approved the purchase of the vessel, and that the same may be purchased for the sum of \$100,000.

The vessel "Albatross" is a fine vessel, and is well adapted for the service of the Navy. It is a vessel of the class of vessels known as "Albatross" class, and is a vessel of the class of vessels known as "Albatross" class. It is a vessel of the class of vessels known as "Albatross" class, and is a vessel of the class of vessels known as "Albatross" class.

I am, Sir, very respectfully,
Your obedient servant,
J. M. Smith

Very respectfully,
J. M. Smith

LETTER OF TRANSMITTAL

U.S. SENATE,
COMMITTEE ON FOREIGN RELATIONS,
Washington, D.C., August 18, 1980.

Hon. FRANK CHURCH,
U.S. Senate,
Washington, D.C.

DEAR SENATOR CHURCH: In recent years, the Subcommittee on African Affairs has focused attention on the relationship between the United States and South Africa. Among our principal concerns is the extent to which the United States and its allies are dependent on South Africa for mineral resources.

In an effort to stimulate public discussion and provide an authoritative analysis of this important topic, some time ago the Subcommittee on Africa requested the Congressional Research Service of the Library of Congress to conduct a study of mineral imports from South Africa and to assess the impact on the United States and other OECD countries of a possible cutoff of supplies. This report, prepared by several analysts, is the result. The Subcommittee hopes that this report will be helpful to Congress, the Executive Branch, and the general public. It provides information which challenges much of the current thinking on this issue, making an important contribution to the continuing debate on United States-South African relations and U.S. nonfuel minerals policy in general.

I wish to express my appreciation to the authors of this study and to the Congressional Research Service for providing this important public service.

With best wishes, I am
Sincerely,

GEORGE MCGOVERN.

Enclosure.

PREFACE *

Recent events in the Middle East have underscored as never before the vital dependence of the United States on overseas supplies of critical raw materials. While the world's attention is focused on oil and the potential threats to national security interests in the Persian Gulf, there is a growing realization that the United States may also be vulnerable to interruptions in the supply of strategic nonfuel minerals found in other geographical areas.

As recently as 6 years ago, the United States was rather sanguine about this problem. A special task force created by President Nixon in 1974 concluded that there were ample resources to meet the world's needs for nearly every mineral well beyond the year 2000.¹ In no other part of the world but the Middle East, the panel believed, was there comparable political interest and economic strength to pose a threat similar to that caused by the 1973 oil embargo.

As we enter the 1980's, that complacency has been bitterly shattered. Astronomical price hikes in critical commodities, political instability in producer countries, accelerated demands for a new international economic order, Third World anti-Americanism, and Soviet aggression in a non-aligned country have deepened America's insecurities.

In these rapidly changing circumstances, some analysts are beginning to ask whether there are parallels between oil and nonfuel strategic minerals, whether the Soviet Union has embarked upon a policy of resource denial to the West, and whether the United States and other OECD countries have the capacity to sustain their industrial economies and maintain an adequate defense if these materials suddenly become scarce.

These concerns spark new urgency when considering the situation in southern Africa, a region undergoing enormous political transformations. The most important raw materials supplier in the region is South Africa, the world's fourth largest producer of nonfuel minerals, several of which have vital industrial and military applications. Four of these are especially important to the industrial democracies: chromium, manganese, vanadium and the platinum-group metals.² The Soviet Union and South Africa together dominate world production of these resources and have the largest proportion of the world's reserves. Without South Africa, it is widely believed, the West would have no alternative but to depend upon the Soviet Union for these critical materials.

*Prepared by Pauline H. Baker, Senate Foreign Relations Committee staff.

¹ *Special Report: Critical Imported Materials*, Council on International Economic Policy, December 1974. Also see *Need to Develop a National Non-fuel Mineral Policy*, GAO report to the Congress, July 2, 1976.

² Other countries in southern Africa are also rich in minerals (Zambia has copper, cobalt and zinc; Zaire has copper, cobalt and diamonds; Angola has oil and diamonds; Zimbabwe has chrome; Namibia has copper uranium, and diamonds; Botswana has copper and diamonds). Concerns have been raised about access to these resources. However, these countries are beyond the scope of this study.

Many observers have therefore concluded that the United States cannot do without South Africa. "What oil is to Iran, a half-dozen strategic metals are to Southern Africa," *Barron's* recently concluded. The availability of these materials has begun to worry the Western World because "they are essential not only to steel making but also to the manufacture of military equipment and aircraft. A shortage of essential minerals would obviously disrupt industry of all sorts."³

Senator Strom Thurmond noted that "that portion of Africa known as the plateau of southern Africa, stretching from South Africa's Transvaal Province northward through Rhodesia and into Angola and Zaire, has been called the Persian Gulf of Minerals, and South Africa its 'Saudi Arabia'."⁴ Congressman David Marriott warned that "our nation is facing a resource crisis potentially more devastating than any that could arise from a shortage of petroleum. If the Soviet Union in their efforts in southern Africa would team up with those nations in southern Africa we could well have the entire Western World shut down in approximately six months."⁵ A spokesman for the United States metals industry, Mr. E. F. Andrews, Vice President of Allegheny Ludlum Industries, Inc., was more blunt: "we would have to revert 40-50 years in our standard of living and technology if deprived of the minerals and metals of South and Southern Africa. Without these strategic metals, all production of steel, aircraft, missiles, tanks, naval vessels, automobiles and weapons of all kinds would cease."⁶

For obvious reasons, the South African Government actively promotes its role as a minerals supplier to the West. In his 1980 New Year's message, Prime Minister P. W. Botha said "naturally we are disappointed that Western nations who are dependent on our mineral resources, who have an interest in our stability and are fully informed on our strategic importance, are apparently not prepared to stand up and be counted in defense of what is of decisive importance to the free world in southern Africa."⁷ Several South African officials have visited the United States in the past few months stressing the interdependence of the two countries.⁸ In an official document produced by the South African Minerals Bureau, South Africa was described as "the dominant supplier of many of the so-called strategic minerals [in contrast to] the Soviet Union, the other major producer, which in many cases either consumes most of its own production, or exports essentially to Comecon countries. There are of course exceptions like chrome ore but reported lack of reserves in the Soviet Union will have an effect on future, medium term, supply. Particularly to the West."⁹

* * * * *

In order to assess the validity of these claims, the Subcommittee on African Affairs of the Senate Foreign Relations Committee commissioned this report by the Congressional Research Service of the

³ *Barron's*, February 5, 1979.

⁴ *Congressional Record*, September 5, 1979.

⁵ *Ibid.*, October 18, 1979.

⁶ *ACSA Foundation Newsletter*, December 1979-January 1980.

⁷ *Foreign Broadcasting Information Service*, January 2, 1980.

⁸ *The Star*, December 1, 1979.

⁹ *World Mineral Supply Situation 1975 vs 1977: The Role of South Africa*, a confidential internal report of the South African Minerals Bureau, unclassified extracts from which were made available to the Senate Africa Subcommittee by the South African Embassy in Washington, D.C.

Library of Congress. The purpose of the report is threefold: (1) to examine the actual dependence of the United States and other OECD countries on South African strategic minerals, (2) to analyze the likely impact on these countries if they should experience supply interruptions, and (3) to assess the circumstances under which a cutoff in mineral supplies may occur.

The key conclusion of this report, contrary to conventional wisdom, is that South African minerals are of significant, but not critical, importance to the West:

It is fortunate that in the case of each of the critical minerals imported from South Africa, means are available for dealing with an interruption without depending on the Soviet Union as an alternative supplier. These means may be costly, and they cannot in all cases be implemented without disruption. But, in general, the disruptions can be minimized if preparations for a possible cut-off in South African supplies are made in advance.

Advance preparations suggested include stockpiling, conservation, process changes, alternative technologies, use of functionally acceptable substitutes where possible, providing incentives to encourage design changes, recycling, and exploiting untapped reserves. For example, abundant manganese deposits on the seabed have not been developed, partly due to the failure to reach an international agreement on exploitation. Known platinum deposits in Montana are potentially significant, although still classified today as "hypothetical." According to a South African geologist, the Montana reserves could seriously compete with South African production, providing the United States with all its platinum needs.¹⁰ Moreover, much of the global consumption of platinum is for jewelry, a nonessential purpose, easing adaptation to an interruption of supply.

As the authors of this report point out, "the major immediate impact of disruptions in the supply of South African minerals on the United States would be indirect, taking the form of higher inflation rates and economic disruptions resulting from the direct impact on production in other OECD nations."

The report also reviews possible conditions under which South African supplies might be cut off. Because its main source of foreign exchange comes from the sale of minerals and because it relies heavily on foreign trade and investment, a decision by South Africa to withhold minerals is highly unlikely and would probably be made only after extreme provocation. Economic sanctions could conceivably be imposed by the United Nations against South Africa, with the support of the United States. Such an embargo would probably be limited in scope and enforcement would be problematic. Revolutionary violence remains a continuing possibility, but its likelihood cannot be forecast with any precision.

* * * * *

In sum, it does not appear that the West faces an imminent threat of interruption of South African mineral supplies. More importantly, such an interruption would not spell disaster; the entire Western World

¹⁰ Dr. D. L. Buchanan, "Platinum Group Metal Production from the Bushveld Complex and its Relationship to World Markets," cited in *The Star*, December 15, 1979.

would not be shut down in six months and we would not be forced to revert 40-50 years in our standard of living, should we have to do without South African minerals.

However, a sense of realism about this issue does not justify an attitude of equanimity. Many observers will argue that under current patterns of production and consumption, South Africa still exercises considerable leverage on the West and that our foreign policy should be shaped in recognition of our vulnerability. Others are properly concerned about the higher inflation rates, economic disruptions and relatively weaker position of other OECD countries in the face of a cutoff of supplies. In addition, as a recent review of Federal policies related to nonfuel minerals reported, "current nonfuel mineral policymaking is generally ad hoc and often conducted without adequate coordination among all appropriate policymakers. Capabilities for supply and demand data and analysis, early warning (forecasting), and environmental impact information to support nonfuel mineral policymaking are often deficient or nonexistent."¹¹

For all of these reasons, the United States should heed the underlying recommendation of this report—make advance preparations for a possible cutoff in South African supplies to minimize disruptions. A comprehensive nonfuel minerals policy, formulated in cooperation with our allies, should be a national priority. Failure to take prompt action will risk repeating in southern Africa the same mistakes we have made in the Middle East.

¹¹ "Report on the Issues Identified in the Nonfuel Minerals Policy Review," Draft, August 1979.

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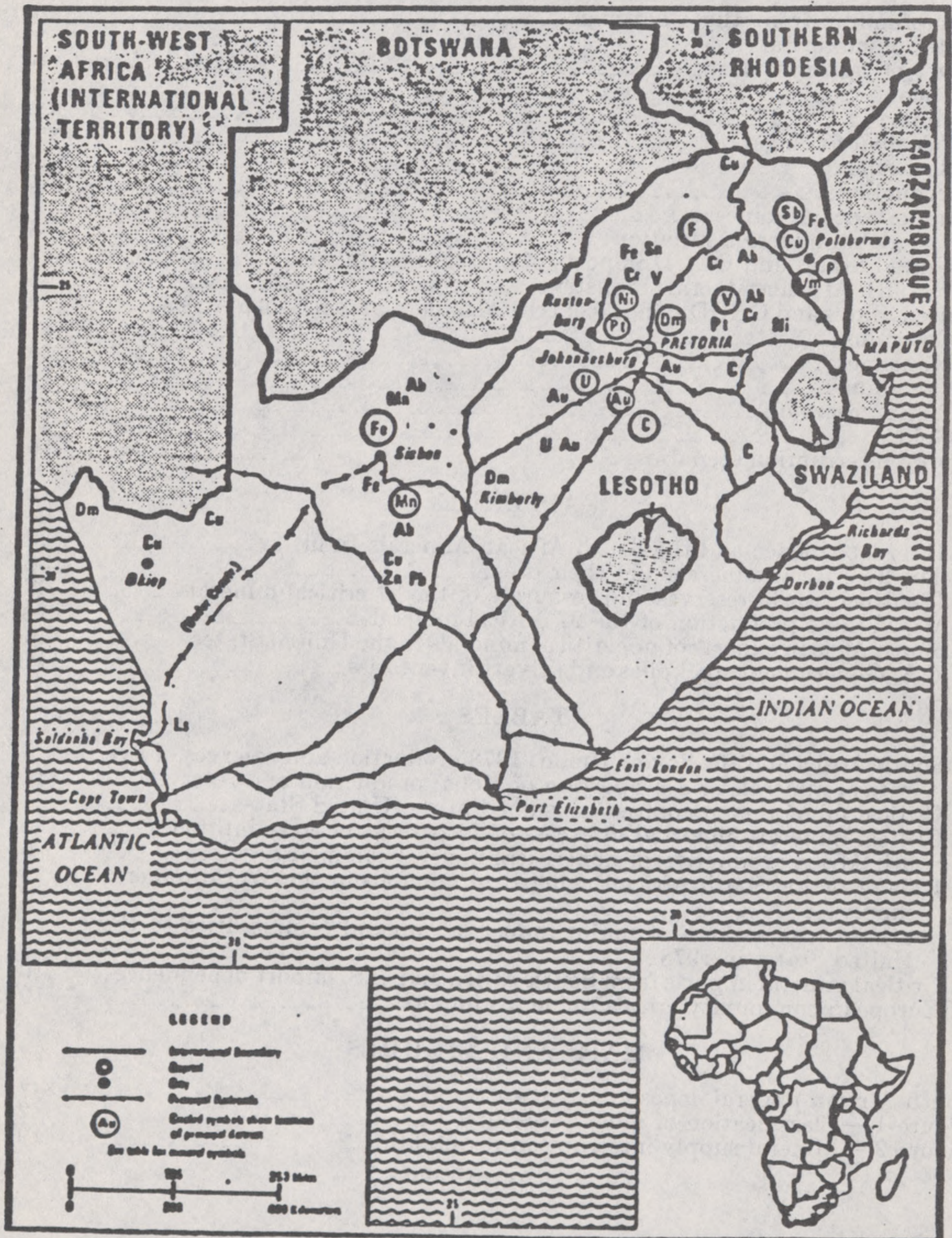
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SOUTH AFRICAN MINERAL DEPOSITS
Area: 1.2 Million Sq. Kms. Population: 25 Million



Sb—Antimony.	Cu—Copper.	Fe—Iron.	Pt—Platinum-group.
Ab—Asbestos.	Dm—Diamond.	Mn—Manganese.	U—Uranium.
Cr—Chromite ore.	F—Fluorspar.	Ni—Nickel.	V—Vanadium.
C—Coal.	Au—Gold.	P—Phosphate.	Vm—Vermiculite.

Source: U.S. Bureau of Mines, "Mineral Industries of Africa," 1976, p. 84.

SUMMARY

South Africa possesses major reserves of many of the world's mineral commodities and is the fourth largest producer of nonfuel minerals. Substantial quantities of South African minerals are exported to the United States and to other OECD countries,¹ and several of these minerals have vital industrial and military applications. Because of the importance of these applications, and because there is a possibility that mineral supplies from South Africa will be interrupted, this study of South African minerals has been undertaken.

PRINCIPAL FINDINGS

1. South African supplies of chromium, manganese, vanadium, and the platinum group metals are of significant importance to the United States and other OECD countries.

2. In general, the United States has stockpiles that are more nearly adequate than are those of other OECD countries, and would thus suffer less immediate impact on productive capability than would some European countries and Japan.

3. The major immediate impact of disruptions in the supply of South African minerals on the United States would be indirect, taking the form of higher inflation rates and economic disruptions resulting from the direct impact on production in other OECD nations.

4. In the short term of 3 to 5 years, U.S. stockpiles, the capacity for technological innovation, and the ability to reduce consumption for non-essential purposes would enable U.S. industry to obtain adequate quantities of these minerals or acceptable substitutes—albeit in the context of higher world market prices—in the wake of interruptions in the supply of South African minerals.

5. For chromium and manganese, the medium term of 5 to 10 years after an interruption would be critical as industry moved to adapt to new technologies, secondary recovery, and new supply sources. If these adaptations were not successful, serious medium-term dislocations in the production of stainless and other hardened steels could result. Over the long term, there is no alternative to reliance on chromium imports from southern Africa. However, a new source of supply has opened up in Zimbabwe since the independence of that country in 1980.

6. An interruption in the supply of platinum-group metals would be unlikely to pose a serious problem because of the possibility of adopting alternative technologies for automobile emission control and because prospects for efficient secondary recovery seem good.

7. An interruption in the supply of gold from South Africa would not result in direct industrial damage, but it could lead to monetary instability and contribute to global inflation.

¹ The Organization for Economic Cooperation and Development, made up of developed countries, includes the United States together with Australia, Austria, Belgium, Canada, Denmark, Federal Republic of Germany, Finland, France, Greece, Iceland, Irish Republic, Italy, Japan, Luxembourg, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, and the United Kingdom.

8. South Africa's economic health is heavily dependent on trade with the United States and other OECD countries and on the investment it receives from them. Because of this interdependence, a South African decision to deny minerals to the OECD countries is highly unlikely and would probably be made only after extreme provocation.

9. Economic sanctions might be imposed against South Africa for a number of reasons, including new incidents of racial violence in South Africa; the acquisition of nuclear weapons by South Africa; South African intervention in Zimbabwe or Angola; or a South African refusal to grant independence to Namibia. Such sanctions could take the form of a trade embargo that would interrupt mineral supplies. Although the United States has the power to veto mandatory sanctions at the U.N. Security Council, moral and diplomatic considerations might persuade it to support sanctions proposals.

10. Revolutionary violence within South Africa is a continuing possibility and one which could at least temporarily endanger mineral supplies.

11. Although various mineral supply interruption scenarios can be imagined—involving both the current and/or successor regimes in South Africa—a long-lasting and complete cutoff of South African minerals seems the least likely possibility.

BACKGROUND

South Africa produces four minerals that are of particular importance to the industries of the United States and the other OECD countries: chromium, manganese, vanadium, and the platinum-group metals. In addition, gold, which is also exported by South Africa, is a critical mineral in the global economy because of its continuing importance as a store of value. South Africa and the Soviet Union dominate world production of these minerals and have the largest part of the world's reserves (table 1). Since the Soviet Union is not an acceptable alternative long-term supplier of critical minerals, there is added reason for concern over possible interruptions in South African supplies.

TABLE 1.—SOUTH AFRICA AND THE SOVIET UNION: 1978 PRODUCTION AND RESERVES OF 5 CRITICAL MINERALS AS A PROPORTION OF GLOBAL PRODUCTION AND RESERVES¹

[In percent]

	South Africa	Soviet Union	Total
Reserves:			
Chromium.....	68	<1	² 69
Manganese.....	37	³ 50	87
Vanadium.....	19	74	93
Platinum-group metals.....	73	25	98
Gold.....	48	⁴ 22	70
Production:			
Chromium.....	34	⁴ 32	66
Manganese.....	23	³ 43	66
Vanadium.....	39	31	70
Platinum-group metals.....	46	47	93
Gold.....	58	⁴ 21	79

¹ Source: U.S. Bureau of Mines. Mineral Commodity Summaries, 1979 [Washington, 1979].

² An additional 30 percent of global chromium reserves are held in Zimbabwe.

³ The manganese data are for the "Central Market Economies" as a group, reflecting the Bureau of Mines reporting procedure. According to the Bureau, "the U.S.S.R. and the Republic of South Africa account for more than 80 percent of the world identified resources."

⁴ Data are for the Central Market Economies as a group, again reflecting the Bureau of Mines reporting procedure.

Chromium is essential in the production of stainless steel and of other hardened and specialty steels. As far as is known, the United States has only small, primarily low-grade chromium resources, and it produces virtually no chromium at the present time. South Africa is the principal supplier of imported chromium, and the Soviet Union is another major source. But U.S. short-term and medium-term reliance on imported supplies is offset by its ability to eliminate non-essential uses, by the availability of stockpiles and inventories, and by new technological capabilities.

Over the long term, design changes and process improvements—as yet unknown or undeveloped—would be needed before all of the chromium in stainless steel could be replaced. Moreover, some 20 percent of the chromium used in wrought and cast steel, as well as the chromium used in tool steel and some other limited applications, may be irreplaceable. For these applications, alternative sources of supply in the Philippines, Turkey, and perhaps Zimbabwe might be used together with conservation and recycling. A doubling or tripling of chromium prices might also bring U.S. reserves back into production.

Manganese is also used in the production of steel, including stainless and tool steels. In most of its principal steel-making applications, there are no known substitutes for manganese at the present time. All manganese consumed in the United States is imported, either in the form of ore, of which South Africa supplies 9 percent, or of ferromanganese, with South Africa directly supplying 30 percent. Half or more of the ferromanganese imported by the United States may actually originate in South Africa, before it is processed in other countries.

Although the United States has only low-grade, uneconomic manganese ores, higher grade reserves are found in a number of countries and on the sea floor. Brazil, Gabon, and Australia are major suppliers of manganese ore, and the United States has a significant stockpile of this metal. Consequently, the United States would be capable of offsetting an interruption in the supply of South African manganese.

Vanadium is used as an addition to iron and steels, and is particularly important in the production of high-strength steels in applications where weight reduction is a consideration. Vanadium is also used to produce titanium alloys with important applications in the defense sector.

While South Africa supplies more than half of the vanadium imported by the United States, and although South Africa has more than 70 percent of the known vanadium reserves in the non-Communist world, the United States itself has large reserves of this metal. In addition, vanadium is available from several foreign sources, and from U.S. stockpiles of vanadium. Thus adaptations could be made to an interruption in supplies from South Africa.

Platinum-group metals are used as catalysts in automobile emission control systems, petroleum refining, and the chemical industry. In addition, platinum, like gold, is sometimes held as a store of value. The United States produces very little platinum, and South Africa is the leading supplier of imported platinum. The U.S.S.R. is the second-most important supplier. South Africa and the U.S.S.R. hold 98 percent of the world's known platinum-group reserves.

Despite South Africa's dominance in the platinum field, adaptations to an interruption in supply seem possible. The enhancement of secondary-recovery techniques holds out the possibility of recapturing most

of the platinum used for catalytic purposes. New or existing technology could eliminate the use of platinum in auto emission-control devices. Moreover, the United States has some low-grade, subeconomic platinum resources that might be called into production in the event of a platinum shortage.

Gold is used primarily in jewelry and the arts, although 27 percent of the gold consumed in the United States is used in industry, primarily in the electronics industry. South Africa accounts for over 70 percent of gold production in the non-Communist world, and holds more than 60 percent of the non-Communist world's reserves, but the OECD countries have ample gold in stockpiles or in reserves for meeting industrial needs.

The use of gold as a store of value, however, holds open the possibility of international monetary instability if South African supplies were cut. Even the prospect of an interruption could reduce new investment by prompting private investors and speculators to tie up large amounts of capital in gold holdings, lead to sudden international capital shifts as buyers sought gold, and contribute to inflation by damaging the value of paper currencies. Speculation in platinum and in gem diamonds, produced in South Africa and Namibia, as well as in gold, could also be anticipated.

Gold-price increases might be countered by sales from the reserve stocks held by the U.S. Treasury, although the decision to make such sales could be politically difficult. New investment might be stimulated by reducing interest rates, although this step could add to the inflation caused by rising gold prices. In sum, the loss of South African gold might lead to a period of instability in international capital markets and contribute to global inflation.

INTRODUCTION

IMPORTANCE OF MINERALS

A high standard of living in the United States, as in any industrialized nation, is based upon the utilization of mineral resources. Twenty-seven minerals have been identified by the U.S. Geological Survey as critical to an industrial civilization.¹ These 27 include 11 major iron related or ferrous metals, 10 nonferrous metals, and 6 fossil or nuclear fuels. Table 2 provides basic data on U.S. consumption of the 27 critical minerals and of 3 critical metal alloys. The table which appears as appendix 2 in this report briefly summarizes the major uses of these critical minerals. Substitution is possible in some applications, though often with an accompanying loss in end-product quality or a higher price, but for many important uses no substitutes are presently available.

TABLE 2.—CRITICAL MINERAL COMMODITIES CONSUMED IN THE UNITED STATES ¹

Mineral commodity	Domestic apparent consumption ² (in short tons unless other- wise noted)	Net import reliance ³ as a percent of apparent consumption in 1978 ⁴	Major foreign sources (1974-77)
Ferrous metals:			
Chromium.....	590, 000	92	South Africa, U.S.S.R., Philippines, Turkey. ⁵
Cobalt.....	9, 433	97	Zaire, Belgium Luxembourg, Finland, Zambia.
Columbium.....	2, 850	100	Brazil, Thailand, Canada.
Iron ore.....	126, 400, 000	29	Canada, Venezuela, Brazil, Liberia.
Manganese.....	1, 415, 000	98	Brazil, Gabon, Australia, South Africa.
Molybdenum.....	33, 000	Net exporter	Canada, Chile.
Nickel.....	232, 600	77	Canada, Norway, New Caledonia, Dominican Republic.
Silicon.....	647, 000	18	Norway, Canada, France, Yugoslavia.
Tantalum.....	830	97	Thailand, Canada, Malaysia, Brazil.
Tungsten.....	10, 250	50	Canada, Bolivia, Peru, Thailand.
Vanadium.....	7, 213	27	South Africa, Chile, U.S.S.R.
Nonferrous and precious metals:			
Aluminum (bauxite).....	5, 973, 000	10	Canada.
Copper.....	2, 480, 000	93	Jamaica, Guinea, Surinam.
Gold.....	⁶ 5, 400, 000	19	Canada, Peru, Chile, Zambia.
Lead.....	1, 490, 000	54	Canada, Switzerland (mostly South African in origin), U.S.S.R.
Magnesium.....	⁷ 1, 001, 000	11	Canada, Mexico, Peru, Australia.
Platinum group ⁸	⁸ 2, 318, 000	Net exporter	Canada, Italy, Netherlands, Norway, Greece, Ireland.
Silver.....	⁶ 135, 000, 000	91	South Africa, U.S.S.R., United Kingdom.
Tin.....	65, 700	41	Canada, Mexico, Peru, United Kingdom.
Titanium ⁹	1, 017, 000	81	Malaysia, Bolivia, Thailand, Indonesia.
Zinc.....	1, 260, 000	W	Japan, U.S.S.R., United Kingdom.
		62	Canada, Mexico, Honduras, Australia, Peru, Belgium-Luxembourg.

See footnotes at end of table.

¹ Pratt, Walden P. and Donald A. Brobst. Mineral Resources: Potentials and Problems. U.S. Geological Survey, circular 698. Washington, U.S. Government Printing Office [1974] p. 3.

TABLE 2.—CRITICAL MINERAL COMMODITIES CONSUMED IN THE UNITED STATES¹—Continued

Mineral commodity	Domestic apparent consumption ² during 1978 (in short tons unless otherwise noted)	Net import reliance ³ as a percent of apparent consumption in 1978 ⁴	Major foreign sources (1974-77)
Fuels: ¹⁰			
Coal (bituminous and lignite)	618,089,000	<1	South Africa, Poland, Canada.
Natural gas (including liquefied natural gas)	¹¹ 19,390	5	Canada, Venezuela, Algeria.
Petroleum (including crude oil and refined petroleum products)	¹² 18,822	43	Saudi Arabia, Nigeria, Libya, Venezuela, Algeria.
Thorium	⁴ 130	NA	Malaysia, Thailand.
Uranium	⁴ 13,000	⁴ 5	Canada.
Processed mineral commodity: ¹³			
Ferrochromium	¹⁴ 480,000	NA	South Africa, Zimbabwe, Japan.
Ferrovandium	NA	Net exporter	Norway, West Germany.
Ferromanganese	¹⁴ 900,000	NA	France, South Africa, Japan.

¹ Adapted from U.S. Bureau of Mines, Mineral Commodity Summaries, 1979, and other sources.

² Apparent consumption—U.S. primary plus secondary production, plus net import reliance. Petroleum and natural gas include industry stock changes.

³ Net import reliance—Imports minus exports, plus adjustment for government and industry stock changes (except for petroleum and natural gas).

⁴ Estimated. Speech by John H. Patterson, Director, Division of Resource Assessment Operations, U.S. Department of Energy, March 12, 1979.

⁵ Major foreign sources are for chromite ore.

⁶ Data in troy ounces.

⁷ Reported consumption for magnesium plus apparent consumption for magnesium compounds.

⁸ Platinum group includes platinum, palladium, iridium, osmium, rhodium, and ruthenium.

⁹ Includes ilmenite and rutile consumption.

¹⁰ U.S. Department of Energy Monthly Energy Review, June 1979.

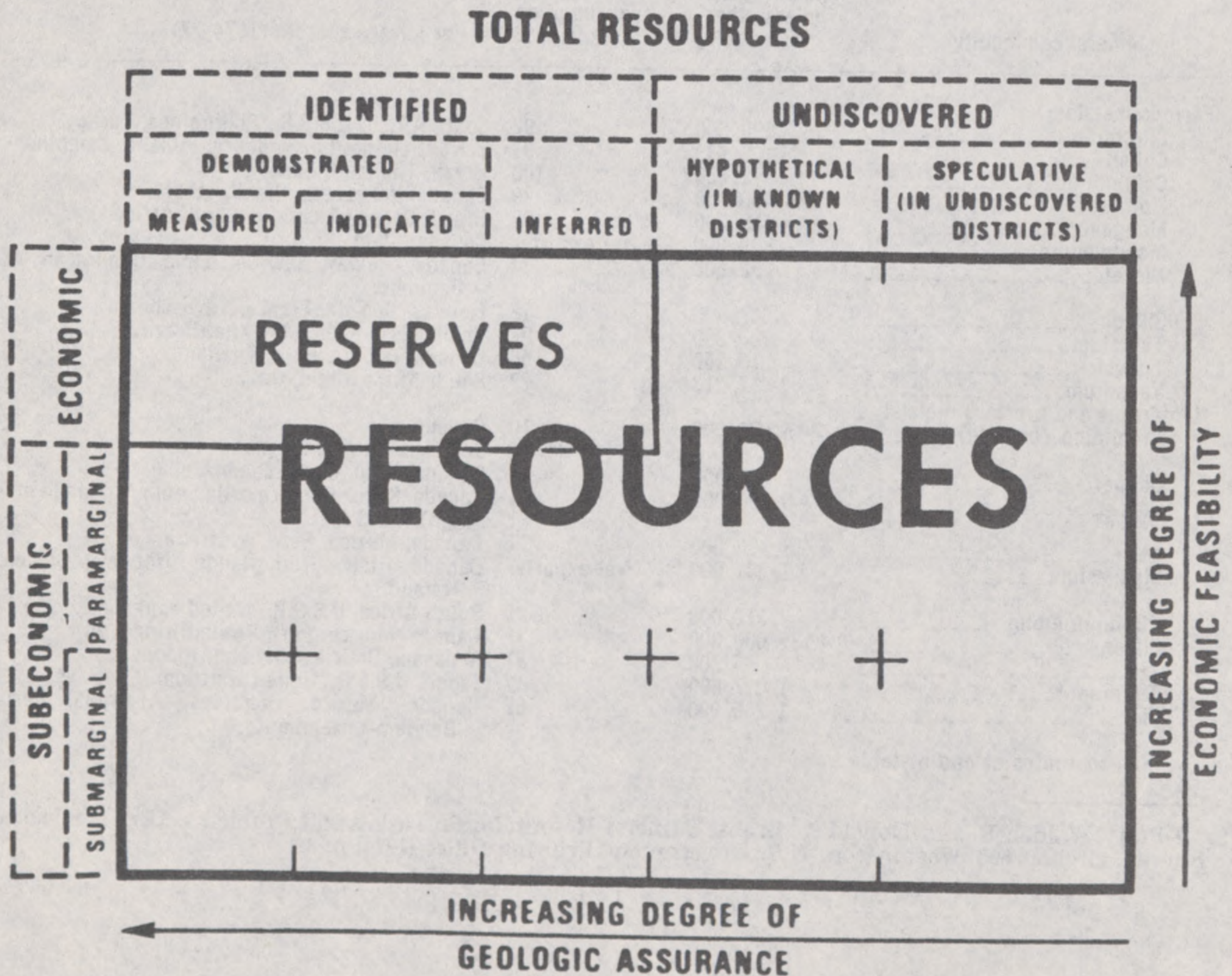
¹¹ Data in billion cubic feet.

¹² Data in thousands of barrels per day. Data for refined petroleum products and crude oil.

¹³ These processed mineral commodities are a significant part of U.S. consumption and are, therefore, included.

¹⁴ Reported consumption.

FIGURE 1



Classification of mineral resources.

Reserves.—Identified resources from which a usable mineral or energy commodity can be economically and legally extracted at the time of determination.

Identified-subeconomic resources.—Materials that are not reserves, but that may become reserves as a result of changes in economic and legal conditions.

Hypothetical resources.—Undiscovered materials that may reasonably be expected to exist in a known mining district under known geological conditions.

Speculative resources.—Undiscovered materials that may occur either in known types of deposits in a favorable geological setting where no discoveries have yet been made, or in as-yet-unknown types of deposits that have not been recognized.

Adapted from.—U.S. Geological Survey, Bulletin 1450A, Washington, U.S. Government Printing Office [1976], p. A-2.

THE GLOBAL MINERALS SITUATION

For an understanding of the global minerals situation, it is important to distinguish mineral *resources* from mineral *reserves*. Reserves are immediately available deposits that can be profitably extracted with existing technology. Resources include reserves, together with subeconomic identified resources that cannot now be profitably extracted, and probable but as yet undiscovered deposits. With price increases or the development of new technologies for mining and processing, resources may become profitably extractable. Figure 1 shows this classification of mineral resources, as originally suggested by McKelvey in 1972 and subsequently accepted for formal use by the U.S. Geological Survey and the U.S. Bureau of Mines.²

Appendix 3 shows world reserves and resources separately, by country, of the 27 critical industrial minerals. In general, several countries appear to be rather well endowed with reserves, including the United States, the Soviet Union, Canada, Australia, Brazil, China, South Africa, India, and Zaire. The United States is completely without reserves of only four minerals: manganese, columbium, cobalt, and tantalum. The OECD countries as a group possess at least some reserves of all 27 commodities, and the same is true of the Soviet bloc.

World production of the 27 critical minerals is shown in appendix 4. In 1978, the United States was not producing chromite ore, and of course it was not producing the four minerals of which it has no reserves. Production of some other minerals was small. Taken together, the OECD countries were producing all 27 minerals, as was the Soviet bloc.

The prominence of South Africa in appendix 3 and appendix 4 is remarkable. South Africa has reserves of 11 of the 27 critical minerals, and it is a significant producer of chromite ore, manganese, vanadium, copper, gold, the platinum group metals, coal, and uranium.

UNITED STATES AND OECD IMPORTS OF CRITICAL MINERALS

Although the United States is well-endowed in most minerals, it imports each of the 27 critical industrial minerals. The amounts imported are as low as .5 percent of consumption for coal but the United States imports 50 percent or more of consumption of 10 critical minerals and of two critical metal alloys. Several critical mineral commodities are imported in amounts of 75 percent or more of consumption: chromite ore and ferrochromium, cobalt, columbium,

² U.S. Bureau of Mines and U.S. Geological Survey. Coal Resource Classification System of the U.S. Bureau of Mines and the U.S. Geological Survey. U.S. Geological Survey Bulletin 1450B. Washington, U.S. Government Printing Office [1976], 7 p.

nickel, manganese and ferromanganese, tantalum, platinum group metals, and tin (table 3). The minerals importation position is not dissimilar for most OECD nations.

The fact that critical minerals are imported, however, does not necessarily dictate that the importing nations are dangerously vulnerable to supply interruptions. There are a number of ways of preparing for and dealing with supply interruptions that can reduce vulnerability, including the creation and use of government stockpiles and private inventories; the use of alternative foreign suppliers; the introduction of design changes to reduce critical minerals consumption; recycling; substitution; and the elimination of non-essential uses. In the short run, drawing down stockpiles and inventories together with the elimination of non-essential uses could quickly reduce import dependence. In the medium and long term, alternate suppliers can be found, and the other strategies, which may require some research and development, can be implemented.

TABLE 3.—CRITICAL MINERALS IMPORTED IN EXCESS OF 74 PERCENT OF CONSUMPTION¹

[In short tons unless otherwise noted]

Mineral commodity: Major sources (percent of total imports) 1974-77	Total U.S. reported consumption during 1978	U.S. stockpile ²	Possible alternative import sources ³
Chromite ore: South Africa (35), U.S.S.R. (18), Philippines (16), Turkey (13), other (18).	1, 000, 000	2, 591, 000	Zimbabwe, India, Madagascar, Brazil, Iran.
Cobalt: Zaire (42), Belgium-Luxembourg (23), Zambia (7), Finland (6), other (22).	9, 000	20, 402	Australia, New Caledonia, Philippines, Cuba, Canada, Botswana, Morocco.
Columbium: Brazil (73), Thailand (8), Canada (8), other (11).	1, 600	489	Zaire, Malaysia, U.S.S.R., Nigeria.
Manganese: Gabon (36), Brazil (33), Australia (13), South Africa (9), other (9).	1, 350, 000	2, 815, 000	U.S.S.R., Bulgaria, Rumania, Hungary, Zaire, Morocco, Ghana, Chile, People's Republic of China, Mexico, Thailand.
Tantalum: Thailand (36), Canada (16), Malaysia (9), Brazil (4), other (35).	950	815	Zaire, Nigeria, Mozambique, U.S.S.R.
Platinum group: ⁴ South Africa (42), U.S.S.R. (26), United Kingdom (17), other (15).	2, 100, 000	1, 725, 000	Zimbabwe, Colombia.
Tin: ⁵ Malaysia (49), Bolivia (16), Thailand (14), Indonesia (9), other (12).	70, 231	225, 282	Brazil, Argentina, Nigeria, Zaire, U.S.S.R., People's Republic of China, Burma, Mexico.
Nickel: Canada (58), Norway (7), New Caledonia (7), Dominica Republic (7), other (21).	183, 500	-----	Cuba, U.S.S.R., Australia, Indonesia.

¹ Adapted from: U.S. Bureau of Mines, Mineral Commodity Summaries, 1979, and other sources.

² Includes ore, metal, concentrate, powder, etc., of stockpile grade as of Nov. 30, 1978, unless otherwise specified. Figures do not include ferro-products.

³ Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 667, 1975 Bicentennial ed., 1259 p.

⁴ Data in troy ounces.

⁵ Primary and secondary.

In the United States, the capability for short-term adjustment to supply interruptions is enhanced by the existence of a Government stockpile of critical materials. Congress has mandated that this stockpile should contain a 3-year supply of each critical material,³

³ Strategic and Critical Materials Stock Piling Act of 1979 (Public Law 96-41), enacted into law on July 30, 1979.

and although the stockpile is presently below goal in several mineral categories, meeting the 3-year requirement would significantly reduce U.S. short-term vulnerability to supply interruptions.

Most of the other OECD countries have no stockpiles of critical minerals, although stockpile proposals are under discussion in several member states. France launched a stockpile program in 1975, but neither the identity nor the quantity of the minerals it is holding is publicly known. The Federal Republic of Germany announced in June 1979 that it would begin building a stockpile containing a 1-year supply of critical materials.

THE SOUTH AFRICAN MINERALS INDUSTRY

South Africa is the world's fourth largest nonfuel minerals producer, and its mineral economy is a significant factor in the mineral economy of the world. In addition to its importance in critical industrial minerals, South Africa produces numerous noncritical mineral commodities, as shown in table 4. Fifteen of these 31 noncritical commodities are exported, and five of them—antimony, asbestos, diamond, fluorspar, and vermiculite—are major export commodities for South Africa. South Africa has 10 percent or more of world reserves of each of these five commodities except antimony (table 5), in addition to very large reserves of asbestos and fluorspar. South Africa's output of antimony, diamond, and vermiculite is greater than 20 percent of total world production (table 5).

TABLE 4.—SOUTH AFRICAN PRODUCTION OF NONCRITICAL MINERAL COMMODITIES

	Exported	Major export
Metals:		
Antimony, concentrate.....	×	×
Beryllium, beryl concentrate.....		
Zirconium, concentrate.....	×	
Nonmetals:		
Asbestos.....	×	×
Barite.....		
Cement, hydraulic.....		
Clays (bentonite, fire clay, flint clay, fuller's earth, kaolin).....	×	
Corundum.....		
Diamond (gem and industrial).....	×	×
Diatomite.....		
Feldspar.....	×	
Fertilizer materials, crude, natural phosphate rock.....	×	
Fluorspar.....	×	×
Gem stones (semiprecious emeralds and tiger's eye).....	×	
Graphite.....		
Gypsum.....		
Kyanite and related minerals (andalusite and sillimanite).....	×	
Lime.....	×	
Lithium minerals.....		
Mica.....	×	
Pigment (ochers and oxides, natural minerals).....		
Salt.....		
Silcrete.....		
Stone, sand, and gravel.....	×	
Sulfur, elemental byproduct.....		
Talc and related minerals (pyrophyllite).....	×	
Vermiculite.....	×	×
Minerals fuels and related materials:		
Carbon black.....		
Coke.....		

¹ Stone, dimension.

Adapted from: U.S. Bureau of Mines, Minerals Yearbook, vol. III, area reports, international [Washington, 1977], pp. 791-815.

TABLE 5.—ROLE OF MAJOR SOUTH AFRICAN NONCRITICAL MINERALS IN THE WORLD MINERAL SUPPLY

[In percent]

Commodity	Estimated share of production exported ¹	Share of world output during 1978 ²	Share of world reserves in 1978 ²
Antimony.....	98	13	7
Asbestos.....	96	7	6
Diamonds (industrial).....	90	15	7
Fluorspar.....	64	8	26
Vermiculite.....	95	35	39

¹ Adapted from: U.S. Bureau of Mines, Mineral Industries of Africa [Washington, 1976], p. 85.² Calculated on the basis of data appearing in U.S. Bureau of Mines Mineral Commodity Summaries, 1979.

South Africa's minerals industry is the prime factor on which the country's economic prosperity is based. The value of its mineral production was approximately \$7.5 billion in 1978,¹ or about 18 percent of the South Africa's GDP (Gross Domestic Product). Minerals exports are critical foreign-exchange earners, with gold the leading profitmaker. Of \$11.6 billion in foreign exchange earned by exports in 1978, \$4.5 billion or 38 percent was attributable to gold bullion and gold coin.² With gold prices at times exceeding \$400 per ounce in 1979—more than double the 1978 average price of \$192.50³—it is clear that South Africa will record additional billions from gold sales in 1979. Other major mineral-export earners were manganese, nickel, vanadium, copper, diamonds, the platinum-group metals, asbestos, coal, and uranium. Principal mineral-export destinations were the United States, Western Europe, and Japan.

Shipment of mineral commodities is largely by rail to domestic consumers or to the country's major ports, Port Elizabeth and Durban, as well as to the port of Maputo in Mozambique. Two new port facilities, Richards Bay and Saldanha Bay (see map), have also begun operations. The two new ports handle mainly iron, manganese, chromite, and coal shipments, and will allow a threefold increase in export volume. Development of largescale ore-loading facilities is also planned at Saint Croix, near Port Elizabeth.

The South African mining industry is one of the most highly developed and successful in the world. Technologically, South Africa has developed more expertise in deep underground mining than any other nation. The South African mining industry holds every major speed record for shaft sinking, and has contributed greatly to the science of rock mechanics and the prediction of rockbursts using analog and digital computer programs. South Africa has given attention to the problems of mine health and safety, and has pioneered in the development of compensation for mine-related respiratory diseases. South Africa's knowledge and control of respiratory diseases among miners is believed to be unmatched in the world.⁴

¹ Republic of South Africa. Department of Statistics. Short Term Economic Indicators. March 1979: 7, 27.² Ibid.: 17.³ Mineral Commodity Summaries, 1979. p. 62.⁴ Engineering and Mining Journal, V. 173, November 1972: 102; and *ibid.*, V. 179, March 1978: 248.

South African policy officially encourages private enterprise in mining, and the mining industry is largely privately held.⁵ The government is, however, deeply involved in the mining industry as a regulatory agency, and it actively promotes mining through tax incentives and other concessions. The State itself has entered into the large scale mining and processing of ferrous metals, coal, and phosphate rock.⁶ The government-owned South African Coal, Oil, and Gas Corporation, Ltd. (SASOL) produces oil from coal, and another government corporation, the South African Iron and Steel Industrial Corporation (IsCOR) dominates the steel industry. Government corporations also operate the railways and harbors and produce electricity—activities which are essential to mining operations.

Government involvement in the gold industry is an important producer of revenue for the treasury. Mining companies must obtain government leases for the right to mine, and the gold marketing is carried out—and closely controlled—by the South African Reserve Bank. The government may grant tax holidays to new mines, but mining profits are later taxed at progressive rates that can be quite high for the more profitable operations.⁷ In September 1979, it was estimated that increased gold prices during the year had brought in some \$320 million in additional tax revenue,⁸ and this revenue has allowed the government to declare a state pension bonus, increased child allowances, and other subsidies and benefits.⁹

In 1978, the South African mining industry employed about 663,000 workers. An extremely tight labor market exists, partly because of the objections of white miners to the promotion of blacks into skilled and semiskilled positions and partly because the low wages that have historically been paid to black miners have made it difficult to recruit labor on the South African market.¹⁰

Mining companies, however, encouraged by rising gold prices, have granted substantial recent wage increases which have attracted more South African black labor and made the industry less dependent on impoverished immigrants from Malawi, Mozambique, and other neighboring countries. In 1979, it was reported that 54 percent of black miners were from South Africa, up from 24 percent 5 years before.¹¹

⁵ U.S. Bureau of Mines. *The Mineral Industries of Africa*. Washington, U.S. Government Printing Office [1976] pp. 85-86.

⁶ *Ibid.*

⁷ Grant, James. *New Lease on Life: Like its Mines, South Africa Continues to Prosper*. *Barron's*, March 12, 1979: 5.

⁸ South African Government Printer. *South African Digest*, Week Ended September 28, 1979: 20.

⁹ *Ibid.*, Week Ended September 21, 1979: 1.

¹⁰ A number of mining companies stated in their 1977 annual reports that a shortage of labor resulted in production shortfalls. *Financial Times*, March 17, 1978.

¹¹ Leger, Richard. *Gold Price Surge Bolsters Economy, Generates Euphoria in South Africa*. *Wall Street Journal*, July 19, 1979.

U.S. AND OECD IMPORTS OF CRITICAL MINERALS FROM SOUTH AFRICA

The United States imports 7 of the 27 critical minerals and 2 key alloys from South Africa: Chromium, both as chromite ore and ferrochromium; manganese and ferromanganese; vanadium; copper; gold; the platinum group metals; and coal (table 6). Copper and coal imports, however, make up only a small part of U.S. consumption. Because of this, and because ample supplies of these two materials are available to the United States and the other OECD countries from other sources, neither receives further discussion in this report. Table 7 reports imports from South Africa as a proportion of U.S. consumption.

TABLE 6.—SOUTH AFRICAN EXPORTS OF MAJOR INDUSTRIAL MINERAL COMMODITIES TO THE UNITED STATES IN 1978¹

[In short tons, unless otherwise noted]

Mineral commodity	U.S. reported consumption during 1978	U.S. mine production during 1978	Total during 1978	U.S. imports
				Sources (percent of total, 1974-77)
Ferrous metals:				
Chromite.....	1, 000, 000	(2)	1, 000, 000	South Africa (35), U.S.S.R. (18), Philippines (16), Turkey (13), other (18).
Manganese ore.....	1, 350, 000	(2)	600, 000	Gabon (36), Brazil (33), Australia (13), South Africa (9), other (9).
Vanadium ³	⁴ 6, 300	5, 250	2, 300	South Africa (56), Chile (25), U.S.S.R. (9), other (10).
Nonferrous metals:				
Copper.....	⁵ 2, 350, 000	1, 485, 000	⁶ 620, 000	Canada (28), Chile (21), Peru (13), Zambia (10), South Africa (3), other (25).
Gold ⁷	4. 84	0. 97	4. 68	Canada (44), U.S.S.R. (17), Switzerland (mostly South African origin) (16), other (23).
Platinum group ^{8,9}	2, 100, 000	5, 000	2, 700, 000	South Africa (42), U.S.S.R. (26), United Kingdom (42), other (15).
Fuels: Coal, bituminous and Lignite ¹⁰	618, 089, 000	653, 800, 000	¹¹ 3, 403, 105	Poland (34), South Africa (32), Australia (30), Canada (2), ¹¹ other (2).
Processed mineral commodities:¹²				
Ferrochromium ¹³	480, 000		300, 000	South Africa (38), Zimbabwe (23), Japan (15), other (24).
Ferromanganese ¹⁴	900, 000		675, 000	France (32), South Africa (30), Japan (14) other (24).

¹ Estimated.

² None.

³ Data in short tons of contained vanadium.

⁴ Consumption of intermediate vanadium products.

⁵ Consumption of refined copper.

⁶ Total imports of refined and unmanufactured copper.

⁷ Data in million troy ounces.

⁸ Platinum group includes platinum, palladium, iridium, osmium, rhodium, and ruthenium.

⁹ Data in troy ounces.

¹⁰ Source: U.S. Department of Energy, Monthly Energy Review, June 1979, p. 56.

¹¹ Bureau of the Census, personal communication, Aug. 27, 1979.

¹² These processed mineral commodities are a significant part of total consumption and are, therefore, included in the table, even though they are not mined.

¹³ Ferrochromium is typically from 36 to 70 percent chromium content while chromite ore typically ranges from 22 to 38 percent manganese content.

¹⁴ Ferromanganese typically ranges from 74 to 95 percent manganese content while manganese ore typically ranges from 35 to 54 percent manganese content.

Adapted from: U.S. Bureau of Mines, Commodity Data Summaries, 1979, p. 190, and other sources.

TABLE 7.—CRITICAL MINERAL IMPORTS FROM SOUTH AFRICA AND U.S. IMPORT DEPENDENCE

Mineral	1974-77 average	
	Total imports as percent of apparent consumption	Imports from South Africa as percent of total imports
Chromium.....	90	
Chromite.....		35
Ferrochromium.....		38
Manganese.....	98	
Ore.....		9
Ferromanganese.....		30
Vanadium (contained vanadium).....	36	56
Platinum-group metals.....	88	42
Gold.....	59	¹ 16

¹ Refers to imports from Switzerland, which are reported to be mostly of South African origin.

Adapted from U.S. Bureau of Mines, Mineral Commodity Summaries, 1979.

Several OECD countries, including France and Britain, import uranium from South Africa and Namibia, but global resources of this element are large. Of greater concern for these countries, as for the United States, are imports of chromium, manganese, vanadium, and the platinum-group metals, each of which has important industrial and defense-related applications. Imports of gold are also a matter of concern because of the continuing role of this metal as a store of value. OECD data on critical minerals imports from South Africa are not available, but the imports of the European Community are given in table 8. Japan, which depends on imports for all of its chromite ore,¹ took 52 percent of its imports of this commodity from South Africa in 1978,² in addition to 71 percent of imported ferrochromium. Thirty percent of Japan's imported manganese came from South Africa, as did large amounts of the platinum-group metals.

TABLE 8.—EUROPEAN COMMUNITY¹ CRITICAL MINERALS IMPORTS²

Mineral or alloy	Net im- ports, 1977 ³ (1,000 met- ric tons)	Import de- pendence ⁴ (percent)	South African share of imports (percent)	Soviet share of imports (percent)
Chromite ore.....	1,111	100	49	11
Ferrochrome.....	274	(⁵)	44	4
Manganese.....	2,288	100	41	<1
Ferromanganese.....	508	(⁵)	8	1
Platinum-group metal and alloys, unworked.....	0.051	100	⁶ 18	24
Gold:				
Unworked.....	1.034	(⁵)	57	1
Coin.....	0.075	(⁵)	44	17

¹ The members of the European Community are Belgium, Denmark, Federal Republic of Germany, France, Irish Republic, Italy, Luxembourg, the Netherlands, and the United Kingdom.

² Vanadium data are not available. Over 90 percent of European imports of vanadium, however, are believed to come from Australia and Norway.

³ European Communities, statistical office, analytical tables of Foreign Trade, 1977, Luxembourg, European Communities (1978).

⁴ Crowson, Phillip, British Foreign Policy to 1985: Nonfuel Minerals and Foreign Policy, London, Royal Institute of International Affairs (1977).

⁵ Not available.

⁶ This figure represents direct imports from South Africa. Additional platinum that originated in South Africa is re-exported from the United Kingdom and other countries.

¹ Crowson, Phillip. British Foreign Policy to 1985. Non-fuel Minerals and Foreign Policy. London, Royal Institute of International Affairs [1977], Annex A.

² Japan Tariff Association. Japan Exports and Imports, December 1978.

As noted above, only the United States and France among the major Western industrial powers are currently stockpiling critical materials,³ although the Federal Republic of Germany announced in June 1979 that it would begin to build a stockpile of its own. The reluctance many governments have shown toward stockpiles enhances the vulnerability of the OECD countries to an interruption in mineral supplies from South Africa. Even if the United States were able to protect its own industry against the effects of an interruption in South African supplies, its economy might still be damaged indirectly if the economies of its major trading partners in the OECD suffered. This stockpile problem is one that might be rather easily dealt with if the U.S. partners in the OECD were willing to take the necessary action. According to a 1977 estimate, the European Community could stockpile a 1-year strategic stockpile of chromium, manganese, vanadium, and their ferroalloys, together with the platinum-group metals, for \$870 million plus storage costs,⁴ or less than one-tenth of 1 percent of GNP.

Another source of worry is that the Soviet Union is a major producer of each of the critical materials imported from South Africa and holds a significant portion of the world's reserves in each case. The largest deposits of chromium outside southern Africa are in the Soviet Union, and that country has three-fourths of known vanadium reserves as well as large reserves of manganese, the platinum-group metals, and gold. Thus an interruption in the supply of critical minerals from South Africa would raise the prospect of dependence on the Soviet Union—a prospect most OECD members would wish to avoid.

It is fortunate that in the case of each of the critical minerals imported from South Africa, means are available for dealing with an interruption without depending on the Soviet Union as an alternative supplier. These means may be costly, and they cannot in all cases be implemented without disruption. But in general, the disruptions can be minimized if preparations for a possible cutoff in South African supplies are made in advance.

CHROMIUM

The United States, as far as is known, has only small, primarily low-grade, subeconomic chromium resources, and it imports virtually all of the chromium it consumes. Chromium imports are in the form of chromite ore, which must be processed before use, and of ferrochromium, which has been processed abroad and is ready for use in the metals industry.

Chromium plays a critical role in industry. Its principal use is in the manufacture of stainless steel, a material that is vitally important in the defense, aerospace, power-generation, and transportation industries where high-strength, corrosion-resistant materials are needed. In addition, chromium is used to increase the hardness of wrought and cast steel; in the manufacture of tool steel; and in lining refractory vessels used in the steel industry. Chromium also has a number of applications in the chemical industry, where among other purposes it is used in leather tanning and in wood preservatives.

³ For the data on U.S. stockpiles and private inventories of critical minerals imported from South Africa see appendix 6.

⁴ Crowson, *British Foreign Policy to 1985*, Annex B.

South Africa is the principal supplier of chromium to the United States, providing 35 percent of U.S. chromite imports from 1974 through 1977, and 38 percent of ferrochromium imports over the same period.⁵ Imports of chromium from South Africa are increasing rapidly, and in 1978 South Africa supplied 48 percent of chromite imports and 78 percent of imported ferrochromium.⁶ These increases result in part from the 1977 termination of imports of chromium from Zimbabwe, which had been permitted under the Byrd Amendment to the Fiscal Year 1972 Armed Forces Appropriation Authorization (Public Law 92-156).⁷

But increased importation of chromium from South Africa also results from South Africa's policy of encouraging local processing of raw materials. A program of incentives launched in 1975 offered low-cost loans, tax concessions, and other benefits intended to step up local processing. Taking advantage of these incentives, together with lower labor costs and the savings which result from shipping processed material rather than ore, Union Carbide has completed a \$50-million ferrochromium processing facility in South Africa that is able to undersell U.S. producers in the U.S. market.⁸ President Carter has given U.S. processors some relief from South African competition by granting a small tariff increase,⁹ but the effects of this increase—much less than U.S. processors sought—are not yet known.

Over the long-term, the United States and the other OECD countries have no alternative to reliance on chromium from two countries in southern Africa—South Africa and Zimbabwe. Together, they hold over 99 percent of known chromium resources, amounting to nearly 25 billion tons of ore in South Africa and 10 billion in Zimbabwe—amounts that would meet global demand for centuries.¹⁰ If these resources were unavailable, chromium resources in the rest of the world would be exhausted in 21 years at 1975 rates of consumption¹¹—a possibility that has led a committee of the U.S. National Materials Advisory Board (NMAB) to conclude that the United States is strategically more vulnerable to a long-term chromium embargo than to the embargo of any other natural resource including petroleum.¹²

Despite this long-term dependence on southern African sources, an interruption in supply from South Africa need not be disastrous. As will be seen in the final section of this report, none of the plausible scenarios that might lead to an interruption would be likely to last for a period of time approaching 21 years; nor would it necessarily be the case that chromium supplies from Zimbabwe and South Africa would be interrupted at the same time. Moreover, technical means are available for achieving major reductions in chromium consumption even though consumption cannot be eliminated entirely.

⁵ U.S. Department of the Interior. Bureau of Mines. Mineral Commodity Summaries, 1979. p. 35.

⁶ Calculated on the basis of data provided by the U.S. Bureau of Mines.

⁷ This Act became law on November 17, 1971.

⁸ "The Ferrochromium Caper." *Forbes*, v. 122, Sept. 18, 1978: 116.

⁹ U.S. Congress. House of Representatives. Import Relief Action, High-Carbon Ferrochrome. Communication from the President of the United States. January 15, 1979. Washington, U.S. Government Printing Office, 1979. (96th Congress, 1st session. House Doc. No. 96-28).

¹⁰ Mineral Commodity Summaries, 1979: 35.

¹¹ U.S. National Academy of Sciences. National Materials Advisory Board. Contingency Plans for Chromium Utilization. Washington, U.S. National Academy of Sciences [1978] p. 37.

¹² *Ibid.*, p. 16.

According to the NMAB report cited above, an immediate reduction of 31 percent in chromium consumption is possible using functionally acceptable substitutes currently available.¹³ If a reasonably well-funded and well-staffed investigation¹⁴ were undertaken, chromium consumption could be reduced by 35 percent from current levels within 5 years and by 64 percent within 5 to 10 years. After 10 years, however, only an additional 1-percent reduction in chromium consumption would be possible. The NMAB report notes that a crash program supported by Government and industry might be able to reduce chromium consumption at a faster rate than this schedule suggests.¹⁵

Examining particular industries, the NMAB committee found that 60 percent of the chromium used in stainless steel could probably be replaced without unacceptable performance degradation,¹⁶ while all but 20 percent of the chromium in wrought and cast steels could be replaced.¹⁷ Chromium used in tool steels appears irreplaceable, however, and practical substitutes for most chromium applications in the chemical industry do not seem likely to be developed. Thus the United States would have a continuing need after 10 years for about 404 million pounds of chromium per year, or about 35 percent of present consumption.

These NMAB estimates suggest that if U.S. imports of chromium from South Africa were running at their 1974-77 levels of 35 percent for chromite and 38 percent for ferrochromium, adjustment to an interruption in supplies from South Africa need not cause severe dislocations. The U.S. stockpile now contains about a 2½-year supply of chromium, and this, combined with reliance on alternative sources of supply in Turkey and the Philippines, and the measures for an immediate 35 percent reduction in consumption proposed by the NMAB, should make it a relatively simple matter to adjust to a cut-off in South African supplies.

With the higher levels of imports from South Africa that are now emerging, an interruption in supplies could have a more serious immediate impact. Even so, after an initial jolt, an adjustment should be possible. In addition to the use of the stockpile and alternative suppliers, U.S. resources might be brought into production as prices rise.

For the OECD countries lacking chromium resources and stockpiles, the disruptions following an interruption in supplies from South Africa might be more severe. But presumably they too would be able to implement conservation measures and turn to alternative suppliers to last out the emergency. It should be noted that if Zimbabwean chromium were available after an interruption in supplies from South Africa occurred, the emergency would not be great.

In any event, it would seem highly advisable for the United States, perhaps in cooperation with its OECD partners, to begin implementation of the NMAB recommendations on chromium. These include appointing a high-level design team to develop industrial processes consuming less chromium than is now the case and offering incentives

¹³ Calculated on the basis of data appearing in *ibid.*, p. 9.

¹⁴ *Ibid.*

¹⁵ *Ibid.*, p. 9.

¹⁶ *Ibid.*, p. 10.

¹⁷ *Ibid.*, p. 11.

to encourage design changes and recycling. Preventive action taken now could minimize damage to vital chromium-consuming industries in the future.

Summary.—Although there seems to be no long-term alternative to reliance on chromium imports from South Africa and Zimbabwe, stockpiles, conservation, process changes, and other adaptations could permit an adjustment to short- and medium-term interruptions.

MANGANESE

Manganese is an essential element in the production of nearly all steels, in which it is a desulfuring, hardening, and conditioning agent, and there are no satisfactory substitutes in these applications at the present time. By far the largest part of the manganese consumed in the United States goes to the steel industry, but manganese is also used in the manufacture of dry-cell batteries and in other chemical applications.

The United States has no manganese resources that can be exploited economically and is almost totally dependent on foreign sources of supply. The Republic of South Africa and the Soviet bloc countries hold over 30 percent of world reserves, and in 1978 they accounted for two-thirds of world mine production. South Africa itself has 36 percent of known reserves and 75 percent of known resources in the non-communist world.¹⁸

Manganese is imported both as manganese ore and as ferromanganese, which has already been processed. South Africa is a minor supplier of manganese ore, providing 9 percent of U.S. imports from 1974 through 1977, but it supplied 30 percent of ferromanganese imports over the same period.¹⁹ Half or more of the ferromanganese imported by the United States may originate in South Africa, however, before it is processed in other countries.

Despite the importance of South Africa as a supplier of manganese, the United States and the OECD countries need not suffer severe dislocations following an interruption in South African supplies. Gabon, Brazil, and Australia are major suppliers of manganese to the United States, and each of these countries, in addition to India, has substantial manganese reserves. Of even greater potential significance are the manganese deposits in metal-bearing nodules on the seabed. The obstacles to exploiting these resources are partly legal—an international agreement on deep seabed mining has not yet been reached—and partly technical. Nonetheless, in the event of a manganese-supply crisis these seabed resources could possibly be developed fairly quickly, particularly if Government incentives were provided for a development program in advance of any cutoff.

The U.S. stockpile of manganese is currently in a deficit position, containing about a 1.8-year supply of manganese ore and an 8-month supply of ferromanganese.²⁰ But the Government also holds some manganese ore which is below stockpile grade, and there are additional stocks in private hands. Meeting the 3-year stockpile goal in manganese would significantly reduce the dislocations likely to result from a loss of South African manganese supplies. In addition, as in the case of

¹⁸ Mineral Commodity Summaries, 1979, p. 95.

¹⁹ Ibid., p. 94.

²⁰ Calculated on the basis of data appearing in Mineral Commodity Summaries, 1979, p. 95.

chromium, a research and development effort directed toward reducing manganese consumption and encouraging recycling would be well-advised, as would an acceleration of seabed mining programs.

Summary.—The exploitation of seabed resources, turning to alternative suppliers, and possible design changes should permit an adaptation to an interruption in manganese supplies from South Africa. That adaptation would be eased by an increase in the manganese stockpile.

VANADIUM

Vanadium is used as an alloy in the iron and steel industry, and is particularly useful in producing high strength, lightweight steels. It is also used to produce vanadium-aluminum alloys which are in turn incorporated in titanium-based alloys. As an alloy, vanadium finds its way into jet engines, airframes, and pipelines, and it has a number of other applications in the transportation, construction, and defense fields.

The United States produces 73 percent of the vanadium it consumes and imports the remainder. South Africa supplied more than half of this imported vanadium from 1974 through 1977, with most of the rest coming from Chile and the Soviet Union. South Africa and the Soviet Union possess about 93 percent of global vanadium reserves, with South Africa holding over 70 percent of reserves among non-communist countries. South Africa is the world's most important producer, annually accounting for 39 percent of global production.²¹

But despite the importance of South Africa in vanadium production, an interruption in supplies would not be critical because of the large vanadium reserves held by the United States and other countries. U.S. reserves in deposits now being worked are equal to more than 20 years' consumption at current rates.²² Resources in the United States are vast, amounting to nearly 10 million tons—an ample supply when measured against a projected 1990 consumption of 10,300 tons.²³ Large deposits of vanadium also exist in Australia, Canada, China, and Japan, and there are smaller resources in several black African countries and Scandinavia.

At the present time, the U.S. vanadium stockpile is in deficit, but this is not likely to cause a major problem in view of the reserves that are available. Columbium, molybdenum, and other metals can be used as substitutes for vanadium in some applications.

Summary.—Vanadium reserves and resources in the United States and other countries would minimize the impact of an interruption in supplies from South Africa.

PLATINUM-GROUP

The platinum-group metals—platinum, palladium, rhodium, ruthenium, iridium, and osmium—commonly occur in the same deposits and are mined together. Platinum-group metals are used as catalysts, or substances that promote chemical reactions without themselves being altered. Seventy percent of platinum-group consumption in the United

²¹ Mineral Commodity Summaries, 1979, p. 177.

²² U.S. National Academy of Sciences. National Materials Advisory Board. Vanadium Supply and Demand Outlook. Washington, National Academy of Sciences [1978] p. 14.

²³ Ibid p. 2.

States is for catalytic purposes in automobile emission-control systems, petroleum refining, and chemical processing.²⁴ The balance of consumption is used in dental supplies, glass and ceramics, and electronic and electrical equipment.²⁵

The United States imports all but a tiny fraction of the platinum it consumes, and South Africa is the leading supplier, providing 42 percent of imports directly.²⁶ Additional platinum from South Africa enters the United States from the United Kingdom after processing. The Soviet Union is the second most important supplier, accounting for 26 percent of imports.

U.S. resources of platinum are potentially significant, but they are classified today only as hypothetical,²⁷ meaning that they are poorly known and that there is no assurance of development. The great bulk of the world's known reserves, some 73 percent, are in South Africa, while 25 percent are in the Soviet Union. Canada, the United States, and Colombia together have only 1.3 percent.

The ability of the United States and the other OECD countries to deal with an interruption in platinum shipments from South Africa arises from the potential for reducing consumption and for recycling. Japanese demand for platinum is typically 40 percent of world demand, but more than 70 percent of Japanese consumption goes for jewelry. In other words, 28 percent of global production is for a non-essential purpose in Japan alone.²⁸

In the United States, which itself consumes nearly one-third of global platinum production,²⁹ much of the platinum used is involved in the automotive pollution control program. Thirty-seven percent of platinum consumption goes directly to the automotive industry for emission-control devices.³⁰ Yet alternative technologies for controlling emissions, including the stratified charge ignition system, already exist, and others, notably the computer-controlled ignition system, are under development.

Platinum also contributes to automotive pollution control through the petroleum industry where it is used in platinum catalyzed reforming—a method of refining that increases gasoline octane ratings without lead anti-knock compounds. The development of lean-burn engines capable of using low octane gasoline, and the possible substitution of non-platinum catalysts, could eliminate this use of platinum.

The demand for newly mined platinum can also be offset by the secondary recovery of platinum from scrap. The potential for recycling is great because, when used as catalysts, the platinum-group metals are not consumed. As noted above, 70 percent of platinum consumption in the United States is for catalytic purposes, and it is estimated that from 70 to 80 percent of the platinum catalysts now scrapped are salvageable.

The U.S. stockpile of platinum contains less than a 1-year supply at present rates of consumption. Enlarging the stockpile to a 3 year

²⁴ U.S. Department of Commerce. Personal communication.

²⁵ Mineral Commodity Summaries, 1979, p. 116.

²⁶ 1974 through 1977. Ibid.

²⁷ U.S. Department of the Interior. Bureau of Mines. Mineral Facts and Problems, 1975 edition. Washington, U.S. Government Printing Office [1976] p. 839.

²⁸ Engineering and Mining Journal, v. 179, March 1978: 183.

²⁹ Calculated on the basis of data in Mineral Commodity Summaries, 1979, pp. 116 and 117.

³⁰ Ibid., 116.

supply level could ease the adjustment to any interruption in South African supplies.

Summary.—Recycling, conservation, and the development of alternative technologies in the automotive and petroleum industries would permit adaptation to an interruption in platinum-group supplies from South Africa. Adaptation could be facilitated by a conscious policy of increasing stockpiles prior to any cutoff.

GOLD

An interruption in the supply of gold from South Africa would probably not have any significant direct effect on industry because of the potential for reducing nonessential uses, recycling, turning to substitutes, and drawing down the U.S. Treasury stockpile. Some 56 percent of the gold used in the United States each year is for jewelry or for other artistic purposes³¹ which could easily be eliminated. Sixteen percent of gold consumption goes into dental applications for which substitutes are available.

Only 27 percent of the gold consumed in the United States, or about 1.5 million troy ounces, is for industrial purposes,³² primarily in the electronics industry where base metals clad with gold alloys are increasingly being substituted for pure gold. U.S. production of gold is approximately .97 million troy ounces, but reserves total 100 times that quantity or 110 million ounces. In addition, the U.S. Treasury stockpile contains 275 million ounces. Thus there is no doubt that the United States could easily meet its own industrial demand for gold and assist other OECD countries in meeting their industrial needs.

Nonetheless, the continuing importance of gold as a store of value means that an interruption in South African supplies could have disruptive economic effects on the United States and other OECD countries. South Africa produces 58 percent of the world's gold, or 71 percent of the gold produced in non-communist countries. It has about half of world resources, and an additional 15 percent is found in the Soviet Union.³³ Consequently, any interruption in South African mineral supplies, or even the rumor of interruption, would inevitably lead to an increase in the price of gold. In addition, increases in the prices of gem diamonds and of the platinum-group minerals, both of which are produced in South Africa and are also used to store value, could be anticipated.

The size of the potential gold price increase and its effects on the global economy are difficult to assess, because of the importance of psychological considerations in such a situation. It is possible that a panic mentality would set in and drive gold prices higher than strictly rational considerations would justify. The relevant rational considerations include the following: U.S. Treasury stockpiles of gold are equivalent to 12 years of South African production and could be used to combat drastic price increases; any interruption in South African supplies would likely be of limited duration, holding out the prospect of a fall in gold prices when South African supplies returned to the

³¹ Mineral Commodity Summaries, 1979, p. 62.

³² Ibid.

³³ Mineral Commodity Summaries, 1979, p. 63.

market; and finally, higher gold prices could lead to increased production in the United States, Canada, and other countries with gold reserves and resources, further restraining prices.

If, despite these considerations, a drastic increase in gold prices should occur, large sudden capital shifts could be anticipated as buyers sold other assets to buy gold. These capital shifts might be made by governments as well as by corporate and private investors. The IMF abolished the official selling price for gold on April 1, 1978, ending a long process of demonetization designed to free the world's currencies from dependence on gold as a reserve. Nonetheless, a number of European central banks, together with the governments of several oil exporting countries, continue to purchase gold as a reserve, evidently regarding it as the only secure store of value.³⁴ These purchasers could be expected to join private and corporate purchasers in a quest for gold, promoting some instability in world capital markets as assets were shifted into the precious metal. Some depressing effect on economic activity could also be expected as large amounts of capital were tied up in nonproductive assets.

Although an interruption in South African supplies of gold could, as a result of these effects, create an atmosphere of economic crisis, the means of dealing with such a crisis appear to be at hand. Sales from the U.S. stockpile can indeed have a calming effect, although experience has shown that regular monthly sales can excite speculation and drive up the price of gold. By announcing a recent sale only one week in advance, the U.S. Department of the Treasury precipitated a \$17 drop in the price of gold futures.

To counter the depressive effects of a gold-price run-up, new investment might be spurred if central banks were to lower interest rates and if the International Monetary Fund acted to increase international liquidity by issuing new Special Drawing Rights (SDR's). (Such steps would, however, have some inflationary effects.) Over the medium term of 3 to 5 years, as gold prices rose, gold production could be expected to increase in the United States—which has 13 percent of global resources—and in other non-communist countries with gold reserves amounting to 20 percent of the world total.³⁵

Summary.—Gold sales from reserves, an expansion in gold output capability, and the manipulation of interest rates and the money supply could be used to counter the economic dislocations resulting from an interruption in gold supplies from South Africa.

³⁴ Business Week, June 4, 1979: 76.

³⁵ In the short term, higher gold prices may mean a decrease in gold output because producers will process low-grade, previously uneconomic ores to take advantage of the price situation. This shift to lower-grade ores reduces the output of refined gold because the ore "throughput" capability remains the same. One mining company in the United States was recently reported to be processing 11 tons of low-grade ore to extract one ounce of gold (New York Times, November 1, 1979.) If gold prices remain high, producers can be expected to invest in expanded throughput capacity, increasing output in the medium term.

SUPPLY INTERRUPTION SCENARIOS

The impact of an interruption in mineral supplies from South Africa would be affected by the scope of the interruption and its duration. An interruption of the broadest possible scope would mean the complete cutoff of all South African minerals exports to all countries, but, as will be seen, such an interruption seems the least likely possibility. Interruptions of lesser scope can easily be imagined, and these interruptions would have lesser impacts. A trade embargo imposed from the outside against South Africa, for example, might not be effectively enforced, so that some South African minerals would reach the outside world. Alternatively, if South Africa were itself to embargo minerals exports, it might decide to spare certain countries or to prohibit exports of only some minerals and not others, again reducing the impact of the interruption. Supply interruptions from South Africa could also vary in time, and an interruption of short duration, other things being equal, would be less disruptive than one of long duration.

The general interruption possibilities are outlined in figure 2. The worst possible situation for the OECD countries is that represented by outcome (d), where the interruption is both long in duration and complete in scope. It will be argued in the paragraphs which follow that this outcome, while possible, is not very likely to occur. Outcomes (a) and (c), both of which are brief in duration, can be dealt with by the use of stockpiles and reserves if proper preparations have been made beforehand. Outcome (b), in which the interruption is long-lasting but partial might be handled by technical innovations, design, changes, and other long-term strategies requiring research and development.

FIGURE 2.—Mineral supply interruption possibilities.

		<u>Duration</u>	
		<u>Brief</u>	<u>Long</u>
<u>Scope</u>	<u>Partial</u>	a	b
	<u>Complete</u>	c	d

At the present time, there are three plausible scenarios which might lead to an interruption in mineral supplies from South Africa: (1) The imposition of a trade embargo against South Africa by foreign

nations; (2) the imposition of an embargo on minerals exports by South Africa in reaction to international criticism or sanctions imposed by the international community; and (3) protests, demonstrations, and other revolutionary activity damaging mineral production and exports in South Africa.

One danger which seems unlikely, unless there is a substantially greater deterioration in the international environment, is possible Soviet naval interdiction of shipping lanes from South Africa. Armed Soviet interference with United States or allied commerce on the high seas would be a grave provocation and presumably will continue to be deterred by broader considerations that deter direct Soviet aggression against the United States.

Economic sanctions could be imposed against South Africa for a number of reasons, including new outbreaks of racial violence and acts of oppression within South Africa; armed South African intervention in Angola, Zimbabwe, or other states in the region; a South African nuclear weapon test; or a continuing South African refusal to withdraw from Namibia. Sanctions could take a number of forms, including a prohibition on investment in South Africa or a ban on petroleum shipments to that country, but they might also include a trade embargo that would interrupt South African mineral exports.

The United States and the other OECD countries need not participate in an embargo,¹ and if a proposal for a mandatory embargo were made at the U.N. Security Council, the United States, Britain, or France could exercise its veto power. Nonetheless, if the South African actions provoking the sanctions proposal were sufficiently objectionable, the major Western powers might well decide to give the proposal their support. These countries did, after all, vote in favor of a mandatory arms embargo against South Africa in November 1977,² in the wake of the 1976 Soweto uprising, the death of anti-apartheid leader Steve Biko while in police custody, and the subsequent crackdown in South Africa on black organizations and dissidents. Even if a mandatory embargo were not imposed, one or more of the OECD countries might decide out of moral or political considerations to participate in a voluntary embargo imposed by the U.N. General Assembly, where sentiment in favor of sanctions has been strong for many years. It is also possible that the United States or other OECD countries might act individually to impose a trade embargo. Certainly there would be domestic political support for such a move in the United States if a crisis comparable to that which followed the Biko death were to occur in South Africa.

If a trade embargo were imposed against South Africa, it is possible that it would be only partial in scope. The scope of a voluntary embargo might well be limited because participation would probably not be universal. Left to choose their own course, many governments might decide that their trade with South Africa, including the importation of critical minerals, was more important than support for voluntary sanctions. Even in the event of a mandatory trade embargo it is

¹ At the present time, U.S. participation in an embargo on the importation of strategic and critical minerals would not be permitted under the "Byrd Amendment" to the Armed Forces Appropriation Authorization of 1971 (Public Law 92-156), which became law on November 17, 1971. The application of this amendment to participation in sanctions against Zimbabwe was ended in 1977 (Public Law 95-12) by an amendment to section 5 of the United Nations Participation Act (Public Law 79-264), but the Byrd Amendment remains in force.

² U.N. Security Council Resolution 418 of November 4, 1977. On October 31, however, the United States, Britain, and France vetoed stronger resolutions banning investment and taking other punitive measures.

possible that enforcement would not be completely effective and that, as happened in the case of the sanctions against Zimbabwe, some governments and private corporations would find ways of evading the restrictions. It should be noted, however, that while evasion might reduce the impact of an embargo in the industrialized nations, it could also enable South Africa to defy the sanction without suffering crippling economic damage. Consequently, an ineffective embargo, as happened in the case of the embargo against Zimbabwe, might remain in force for many years.

An embargo might also be limited in scope by design. For example, it could be written to apply only to gold on the grounds that gold is an important foreign exchange earner for South Africa but not a critical industrial commodity for the importing nations. It is possible, however, as noted below, that South Africa might retaliate against such an embargo by cutting off other minerals exports. Another way of limiting an embargo's scope would be an exemption for Bophutatswana, one of the nominally independent black homelands within South Africa, where much of South Africa's platinum is produced. South Africa could, of course, prevent Bophutatswana from exporting platinum, apart from the small amount that might be smuggled into neighboring Botswana, if it wished to do so. On the other hand, South Africa might allow exports to continue as a source of foreign exchange for the South African corporations that operate the mines. Exempting Bophutatswana from the embargo, however, would be opposed by many countries for just this reason. Moreover, exemption would constitute a form of recognition of the territory's independence, and thereby imply acceptance of the homelands, the cornerstone of the policy of apartheid.

A second minerals interruption scenario could take the form of a South African decision to embargo its own minerals exports—a decision that could be taken to punish the OECD nations and other countries for their criticism of South Africa or for the sanctions they might impose. In this way, partial sanctions, imposing an oil embargo against South Africa, for example, or restricting investment, could lead to an interruption in mineral imports from South Africa, even if these imports were not directly prohibited or only partially banned. South Africa could also impose an embargo on mineral shipments as a demonstration of its importance to the Western nations—a demonstration designed to force these countries to adopt a more conciliatory attitude toward South Africa.

A self-imposed embargo, while potentially very costly for South Africa, could lead to a more complete interruption than would internationally imposed sanctions because it would be enforced within South Africa by the South African authorities. Seeking to inflict maximum punishment on its critics, South Africa might prohibit platinum exports from Bophutatswana and deny Zimbabwe access to South African railways and ports,³ giving the embargo its broadest possible scope.

It is possible, however, that South Africa might impose only a selective embargo against those countries that had been most hostile to it, and in such a case the global economic impact of the interruption would be reduced. If the embargo were designed primarily as a demonstration, South Africa might make it a brief one, intended to have

³ Zimbabwe might nonetheless be in a position to turn to alternative export routes through Mozambique and Zambia.

only shock value, or it might restrict its application to only one or two minerals. Any of these options would reduce the scope of the embargo.

Even if enacted in anger, the embargo might be brief in duration because South African minerals exports are so critical to the South African economy. As noted in section II, the South African minerals industry is an essential contributor to the country's GNP and to its foreign exchange holdings. Thus, if minerals exports were cut off, the damage would be swift and potentially destabilizing for the South African Government itself.

In any case, the importance of minerals exports to the South African economy strongly suggests that a South African decision to embargo minerals exports is highly unlikely and would be taken only after the most extreme provocation. That the risks of such an action are recognized in South Africa was shown in a recent study by the South African Foreign Affairs Association, which concluded that "any attempts to place an embargo on the export of minerals and their processed products from South Africa would have a disastrous effect on South Africa's balance of payments and indeed on the whole economy."⁴

Finally, it is conceivable that revolutionary violence in South Africa could disrupt mineral exports. Outbreaks of revolutionary violence would create a highly volatile situation within South Africa, and this means that the scope and duration of the resulting instability cannot be forecast. Hence the impact of revolutionary violence on mineral exports cannot be assessed at the present time. It may be that revolutionary outbreaks would first occur among black South African mineworkers, and if this were the case, mineral exports would be affected immediately. The same would be true if revolutionary activities began to occur among railway and dockworkers. If revolutionary activities were accompanied by guerrilla infiltration from the north, South African reprisals and pre-emptive attacks in Zimbabwe, Namibia, Zambia and other countries could disrupt mineral shipments from the entire southern African region. On the other hand, it is possible that important productive regions would remain largely unaffected by violence for long periods, or that there might be periods of calm affecting the entire country during which full-scale production and export could be resumed. What the attitude of a post-revolutionary government in South Africa might be toward mineral exports to the United States and to other OECD countries is a cause for concern, but it can hardly be predicted on the basis of currently available information.

⁴ van Rensburg, W. C. J. and D. A. Pretorius. *South Africa's Strategic Minerals—Pieces on a Continental Chessboard*. Edited by Helen Glenn. Valiant Publishers, Johannesburg [1977], p. 116.

APPENDIX 1

INTERDEPENDENCE AND THE SOUTH AFRICAN MINERALS INDUSTRY

(By William N. Raiford)

A. THE MINING AND FINANCE HOUSES OF SOUTH AFRICA

Corporate concentration characterizes the mining industry throughout the world; the high risk involved in exploration, enormous infrastructure requirements, the volatility of price, and the capital-intensive nature of the industry require concentration of resources sufficient to carry out major ventures as well as the ability to overcome the impact of unprofitable enterprises. This concentration is equally evident in South Africa, the world's fourth largest nonfuels mineral producer, where a small number of "mining and finance houses" dominate the industry. This small group is, in itself, profoundly interrelated through equity holdings of one company in another and through associations such as the Chamber of Mines which promote the interests of the industry through common-use programs in research, training, safety, and marketing.

Two mining and finance houses dominate the South African minerals industry. Anglo-American Corporation of South Africa, Limited is the major mining and finance house in the world in the production and sale of gold and gem diamonds and with General Mining and Finance Corporation, Limited is predominant in the production of other minerals in South Africa. These two mining and finance houses, along with Anglo-Transvaal Consolidated Investment Company, Limited, Gold Fields of South Africa, Limited, and Johannesburg Consolidated Investment Company, are the five major such houses. Along with Barlow Rand Limited and South African Manganese Amcor Corporation, a mining company and a major ferro-alloy producer,¹ they account for almost all of South Africa's mineral and ferro-alloy production.

The name Anglo-American runs throughout the corporate mining structure of South Africa like a seam of exceptionally rich ore. Formed in 1917 with British, American, and South African capital, it produced in 1976 29 percent of the world's gold and 15 percent of its copper. Anglo-American also produced in 1976 37 and 33 percent, respectively, of South Africa's uranium and coal. Though these products are not the focus of this paper, they suggest the concentration of wealth and control of resources and products upon which the companies' operations are based. Anglo-American owns 41 percent of Johannesburg

¹ These companies are hereinafter referred to, in the order in which they appear above, as Anglo-American, General Mining, Anglovaal, GSFA, JCI, Barlow Rand, and SAMANCOR.

Consolidated Investments Company² which has major interests in platinum-group metals and 11 percent of GFSA, two of the five major South Africa mining and finance houses. The Chairman of Anglo-American is Harry F. Oppenheimer, an industrial leader of the English-speaking South African community and a political activist whose progressive and liberal views are not always appreciated by the Afrikaner-controlled government.

General Mining and Finance, Limited, the second largest mining house, is controlled and managed by Afrikaners, which some assert gives it greater influence with the Government than any other house. General Mining subsidiaries produce 35 percent of South Africa's platinum and chrome ore; 50 percent of it is electrolytic manganese and substantial percentages of other major minerals, including gold, uranium and coal. General Mining purchased a 50.1 percent interest in Union Corp. in 1976, the latter also being among the largest mining and finance houses in South Africa. It also owns 22 percent of Anglovaal which has major holdings in chrome, manganese, and antimony. General Mining is also backed by the resources of Anton Rupert, one of the wealthiest of Afrikaners with interests in many parts of South African industry and commerce.³

Barlow Rand, Limited, through its wholly owned subsidiary, Rand Mines, Limited, which it purchased in 1971, is a major chromium producer through its 70 percent interest in Transvaal Consolidated Land and Exploration Company, Limited. SAMANCOR is an owner of chromite and manganese mines and produced approximately 32 percent of South Africa's ferroalloys in 1976. SAMANCOR is "expected to rapidly become South Africa's pacesetter and principal exporter of . . . ferrochrome . . . ferromanganese . . . ferrosilicon, . . . ferrovanadium."⁴

Although this brief array of names does not completely delineate the complex web of ownership and control in the South African mining industry, the following generalizations may be made:

(a) Two mining and finance houses (Anglo-American and General Mining) dominate the industry through their own activities and through equity holdings in other major mining and finance houses.

(b) All of the major houses are, in fact, interrelated though Anglo-American and General Mining, each of which has interests in the other as well as in Charter Consolidated, Limited, a British corporation. A Charter Consolidated subsidiary also supplies financial and administrative services to Anglo-American and Barlow Rand.

(c) The South African Government, as discussed in section II of this report, is deeply involved in the mining industry through leasing arrangements, mining regulations and taxation, gold marketing, and ownership of some production facilities together with the railways and harbors and the electrical industry. Consequently, it would appear that with respect to the mining industry the South African Government is tied to the mining and finance houses in a web of ownership and control that constitutes a virtual "South African, Incorporated."

² Anglo-American, together with another member of its group, De Beers, own 50 percent of JCI. The total assets of Anglo-American are estimated to be between \$5.5 and \$6.0 billion. (United States Department of Commerce Staff, Personal Communication, 1978). The assets of Anglo-American (\$1.733 billion), Debeers (\$1.98 billion), and JCI (\$580 million) totaled \$4.3 billion in 1978. General Mining and Finance (\$1.47 billion) and its principal equity holder, Federal Mynbou Beperle (\$1.48 billion) have assets which total \$2.95 billion. The assets of Barlow Rand in early 1978 are \$1.342 billion and of Anglovaal \$531 million. These are substantial enterprises by global standards. The SA Giants League. Supplement to Financial Mail, April 21, 1978. p. 74.

³ Dumphries, Malcolm. *Minings New Horizons*. Management, September 1977. p. 63.

⁴ U.S. Department of State, Airgram A-25, 1977. p. 9.

(d) British corporations have considerable equity in South Africa's minerals industry—Consolidated Gold Field's stake in GFSA, Charter Consolidated's holdings in Anglo-American and General Mining and Lonhro's equity in Western Platinum being of greatest prominence.

B. UNITED STATES CORPORATE INVESTMENT IN SOUTH AFRICAN MINING

Relatively few United States corporations have investments in the mining or ferro-alloy production of the minerals which are the focus of this paper. U.S. corporations have an estimated \$150 million investment in South African mining⁵ and an estimated \$120 million investment in smelting operations.⁶ The total, \$270 million, represents less than 2 percent of the estimated \$15 billion investment, both domestic and foreign, in South African mining and smelting operations.⁷

Despite the few corporations that invest, and the relatively small amount of what would appear to be their total South African investment in relation to their total assets, that investment may represent: one, a substantial sum of money, and two, access to a mineral supply which is critically important to the individual company. For example, Union Carbide's 49 percent investment in the \$48 million Tubatse Ferrochrome plant represents a \$24 million investment out of its current assets (1977) of over \$3 billion; that plant also supplies Union Carbide with all of its ferro-chromium imports.⁸

Union Carbide, in addition to its Tubatse Ferrochrome holdings, owns Ucar Chrome and Ucar Minerals, South African subsidiaries which mine chrome and vanadium, respectively. Union Carbide is, of course, a major purchaser of both products; it markets both ferrovanadium and ferrochrome in the United States; and its subsidiaries market chromium and vanadium products in Japan and Europe.

United States Steel has a minority interest in the Rustenburg Platinum Mines and the Zeerust Chrome Mines; is a 10-percent owner of Associated Manganese Mines of South Africa, Limited; and is a 30-percent owner of Ferroalloys, Limited a producer of ferromanganese.

Newmont Mining Corporation has an 11.8-percent interest (\$23 million)⁹ in Highveld Steel and Vanadium which mines vanadium and produces ferrovanadium. Its subsidiary, Foote Mineral Co., is an importer of ferroalloys. Newmont also has much larger investments in South African copper mines.

⁵ U.S. Congress. House. International Relations Committee. Resource Development in South Africa and United States Policy, Hearings, 94th Congress, 2nd Session. May 29, June 8 and 9, 1976. Washington, U.S. Government Printing Office, 1976. p. 22.

⁶ The \$120 million estimated is derived by (1) subtracting the \$150 million figure from the \$229 million which the Department of Commerce reported as being the U.S. investment in South African mining and smelting in 1974, and (2) adding another \$40 million in view of the fact that Union Carbide, Allegheny Ludlum, and Newmont Mining have interests in corporations which have initiated or expanded smelting operations since 1974. (\$229 - 150 + 41 = \$120).

⁷ Beyond this, United States investors have found the purchase of stocks with interests in South African mining companies attractive. Two United States groups reported to be investors are the Ludwig Group, which has some equity in General Mining, and the Onival Group, which has a 10 percent interest in SAMANCOR. (State Airgram A-10. p. 7.) Daniel Karl Ludwig is the chairman of National Bulk Carriers, an advisor on U.S. maritime policies, and a member of the Military Preparedness Advisory Board of the Department of Defense. His holdings are estimated to be at least \$27 million (Richard Rolfe. Rupert Moves In. Financial Mail. Nov. 28, 1975. pp. 863-4). U.S. investors also hold an estimated \$1.65 billion in South African gold stocks.

⁸ Union Carbide informant.

⁹ Myers, Desaux, III, Robert Hecht, and David Swift. United States Business and South Africa: The Withdrawal Issue. Special Report 1977-D. Washington, Investor Responsibility Research Center (November 1977), p. 4.

Allegheny Ludlum has a minority interest (less than 20 percent) in JCI's Consolidated Metallurgical Industries, a producer of ferrochromium. In addition to importing ferroalloys, it has a trading arm, Almet, which sells South African ferroalloys to other United States producers of stainless steel.

Owens-Illinois is a 20 percent (\$11.5 million)¹⁰ owner of Anglovaal which has major interests in chromite, manganese, and antimony mines, as well as interests in ferroalloy production.

Engelhart Minerals and Chemicals Co. does not appear to have direct investments in South African mining, but it is 30-percent owned Anglo-American which gives it a very large direct interest. In addition, it is a major purchaser of platinum and a leading researcher in the use of platinum-group metals. Engelhart, or companies which it controls, market ferrochromium and platinum-group metals throughout the world.

U.S. corporations which have a major interest, although not direct investment, in the four South African minerals groups previously discussed are the following sales agents: International Minerals and Chemicals Corp., which has special ties with the Lavino South African chrome mines; Le Nickel, a subsidiary of a French firm, which is the United States sales agent for SAMANCOR; and J. Aron and Company, one of the more important sellers of platinum and other South African metals. The users of these products would include most United States industrial corporations, and in particular the producers of stainless steels and the automobile manufacturers.

The pattern of distribution from mining company to United States manufacturers is partially determined by ownership—as in the case of Union Carbide and United States Steel—and is partially determined by long-term contract, particularly with respect to platinum-group metals producers, the automobile manufacturers such as Ford and General Motors, and Engelhart Minerals and Chemicals whose research and manufacturing is important to them. The sales agents buy and sell to all participants in the market, including the consumers mentioned above, who have their own ties to South African producers.

Other U.S. corporations which have substantial investments in South African minerals include Phelps-Dodge—lead, copper, zinc, and fluorspar; Chemetron Corp.—a 50-percent owner of Antimony Products, a producer of crude antimony oxides; Amax—with a major interest in copper mines as well as owning 10.49 percent of Newmont Mining Corp.; and Kennecott Corp., and Gulf and Western, Inc.—with a 26.2-percent and 13.1-percent ownership, respectively, in the \$290 million Richards Bay Mining and Smelting Complex.¹¹

C. NON-UNITED STATES FOREIGN CORPORATE INTERESTS IN SOUTH AFRICAN MINING

A brief list of the major multinational companies with interests in South African mining would include: *Great Britain*—Rio-Tinto-Zinc and Lonhro; *West Germany*—Metallgesellschaft and Bayer A. G. Leverkusen; *France*—Le Nickel; and *Canada*—International Nickel,

¹⁰ Ibid., p. 46.

¹¹ Carr, Jonathan. West Germany Limits its Exports to South Africa. Financial Times. Dec. 1, 1977. Thus, the value of the Gulf and Western holding would be approximately \$29 million and that of Kennecott approximately \$58 million. The Gulf and Western interest is held indirectly through New Jersey Zinc Company, which it owns. Kennecott Corporation owns two-thirds and New Jersey Zinc one-third of Quebec Iron and Titanium Corporation, which directly holds the 39.3 percent interest in the Richards Bay Project.

Inco, Noranda, and Falconbridge. The Scandinavian countries are important users of South African minerals in the manufacture and export of ferroalloys. Of these countries, the interests of Great Britain are by far the greatest. Britain's direct investment in South Africa is now estimated at \$5.25 billion, or three times that of the United States, and is just over 50 percent of total foreign direct investment in South Africa. British investment in South African mining would be much less than the \$5.25 billion, but is, nevertheless, substantial. Its capital was a principal instrument in the development of the South African mining industry in the late 19th century. Today, the annual reports of the South African mining and finance houses regularly appear in the *Financial Times*, and British journals carry reports on the South African mining industry. British industry is not only a major utilizer of South African minerals, but it also transships substantial amounts of platinum to the United States: from 1974-1977, Britain supplied 17 percent of the platinum-group imports, most of which originated in South Africa.¹²

D. PRODUCERS AND SELLERS: BY INDUSTRY¹³

Chromium.—60 percent of South African chromite is produced by General Mining and Barlow Rand, with the former accounting for 35 percent of production and the latter 25 percent. SAMANCOR has become an important producer with its recent acquisition of the Ruighoek Chrome Mine from Union Carbide, and Anglovaal has interests associated with General Mining as well as its own production.

Chromite is increasingly exported in the form of ferrochrome. Major South African manufacturers of ferrochrome are JCI's Consolidated Metallurgical Industries in which Showa Denko KK of Japan, British Steel Corporation, and Allegheny Ludlum of the United States, have interests; SAMANCOR's Metalloys, Limited and Ferrometals, Limited; Tubatse Ferrochrome, Limited which is 51-percent owned by General Mining and 49 percent by Union Carbide of the United States; and two subsidiaries of Barlow Rand's Middleburg Steel and Alloys.

Chromium and ferro-alloy producers tend to market their product in the United States through sales agents, some of whom appear to be primary buyers for a particular firm. Tubatse Ferrochrome is the sole foreign source of ferrochrome for Union Carbide which also sells to other users in the United States and through Ucore, Limited to the European market. International Minerals and Chemicals Corp., a sales agent supplied primarily by Lavino South African, sells to virtually all the producers of stainless steel in the United States. Almet, the trading arm subsidiary of Allegheny Ludlum, and Le Nickel, the United States sales agent for SAMANCOR, are primarily supplied by Consolidated Metallurgical Industries and SAMANCOR, respectively, and sell to all stainless steel producers. Phillip Brothers Division of Engelhart Minerals and Chemical Co. is the sales agent for ferrochrome producers in the United States and Japan, and Engelhard Ore and Base Metal Co. is the sales agent in Europe.

¹² Mineral Commodity Summaries, 1979, p. 116.

¹³ The basic sources for this section are The Financial Times 1976 Mining International Yearbook, the Republic of South African Minerals Bureau Preliminary Report No. 6.76, and industry informants.

TABLE A1, 1.—SOUTH AFRICAN MINE OWNERS AND U.S. SALES AGENTS, CHROMIUM¹

Chromite mines	Owners	Percent Equity in owners	Percent Ferroproducers ²	U.S. sales agent
Groothoek	General Mining	64	62.8	Union Carbide, Ucore Ltd. (Europe).
Zwarkop	Anglovaal		20.0	
Montrose			22.0	
Kroondal				
Millsell, Henry Gould, Win- terveld T.C.L.	Transvaal Consolidated Land & Exploration.		59.0	Phillip Brothers (subsidiary of Engel- hart sells to United States and Japan).
Grasvally	Cromore Ltd.	100	100.0	Le Nickel.
Ruighoek	Bathlako Mining	100		
Zeerust	Anglovaal		20.0	Anglovaal Plant held through Associated Manganese.
	U.S. Steel	(³)	22.0	International Minerals & Chemicals Corp.
Jugdlust	Ucar Chrome	100		
Grootboom	Lavino South African	100		
Rustenburg	Minex	100		
Marico	Vereeniging Refractories Ltd.			
Waterkloof Ntuane	Metallurgy			

¹ Sources: Skinner, Walter R. Mining International Yearbook, 1976, London, Financial Times (1976). Also Republic of South Africa, Mineral Bureau, Preliminary Report no. 6.76: Ferrous and nonferrous mines and work in South Africa [Pretoria, 1976]. Industry informants were also helpful.

² It would appear that the ferroproducers and sales agents and mineowners have primary links as represented across this table, but this should not strictly exclude the Tubatse plant, for example, from processing ferrochrome from other mines.

³ Minority interest.

Manganese.—SAMANCOR produces approximately 65 percent of South Africa's manganese products and an Anglovaal controlled company produces much of the remainder. Both SAMANCOR and Anglovaal are vertically integrated and are major producers of ferro-manganese. Anglovaal's ferro-manganese producer, Ferroalloys, Limited, is 30 percent owned by United States Steel. Le Nickel is the United States sales agent for SAMANCOR's ferro-manganese producers.

Vanadium.—Three South African companies produce over 50 percent of the western world's vanadium requirements and one company, Highveld Steel and Vanadium, accounts for over 80 percent of South African production. Highveld is owned by eight companies, including a number related to Anglo-American which controls the company. SAMANCOR and General Mining also have interests in Highveld. Foreign ownership is represented by Charter Consolidated, Limited of Britain, and Newmont Mining Co. of the United States which has an 11.9-percent interest.

The second major producer is Ucar Minerals, a subsidiary of Union Carbide South Africa which is, in turn, owned by its U.S. parent. Union Carbide is a major utilizer of Ucar's product and also acts as a selling agent to other United States corporations.

Transvaal Alloys is owned by West Germany's Otavi mining group, with most of its exports going to West Germany's Vereinigte Aluminum Werke and Japan's Taiyo Koko.

Platinum.—There are three platinum producing companies in South Africa. Rustenburg Platinum Mines, which accounts for over 50 percent of South Africa's productive capacity, is managed by JCI. JCI and Gold Fields of South Africa, as well as the parent companies of each, Anglo American and Consolidated Gold Fields (United Kingdom), all have substantial interests in the company. Rustenburg Platinum recently purchased Atok Platinum Mines, a small producer owned by Anglovaal and United States Steel; the latter apparently retains a small equity in the company. Rustenburg platinum is refined by Matthey Rustenburg Refiners (United Kingdom) at subsidiaries in South Africa and the United Kingdom. Johnson Matthey and Co. is the sole sales agent for Rustenburg with a subsidiary, Matthey Bishop, handling U.S. sales. Rustenburg Platinum has long-term sales contracts with Ford Motor Co. and has traditionally sold to Engelhard Minerals and Chemical Co. in the United States.

Impala Platinum, in which General Mining has a majority interest, has approximately one-third of South Africa's platinum producing capability. Its sales are handled by Impala subsidiaries in the United States and Europe and by other sales agents. Impala Platinum has a long-term contract with General Motors to supply 300,000 troy ounces of platinum and 120,000 troy ounces of palladium per year through 1983; this amounts to over one-half of Impala's yearly production.

Western Platinum has about 20 percent of South Africa's productive capacity. It is managed and 50 percent owned by Lonrho (United Kingdom), with over half of the remaining equity held by Falconbridge Nickel of Canada. Falconbridge Nikkelverk (Norway) does much of the refining of the company's product and marketing is done by Falconbridge Nickel Mines of Toronto, Canada.

TABLE A1, 2.—SOUTH AFRICAN MINE OWNERS AND U.S. SALES AGENTS, MANGANESE¹

Managanese producers	Owners	Percent	Ferroproducers	U.S. sales agent
Manganese Iron Mining- Associated Managanese Mines of S.A.	SAMANCOR Anglovaal Anglo-American United States Steel	45.0 11.5 10.0	Metalloys Ltd. Ferroalloys Ltd. (Anglovaal has majority interest through Associated Managanese; United States Steel has 30 percent.)	Le Nickel.
Rand London Manganese- Marble Lime & Assoc. Industries Ltd.	Rand London Corp.		Emcor (Electrolytic Metal Corp. owned by General Mining).	
Delta Manganese	Delta Metal Co. (United Kingdom)		Delta Metal Co.	Alcan Trading (Montreal-based, sells to United States, Canada, Europe).
Consolidated African Mines				
Roodepan Manganese Corp.				
National Manganese Mines				
Western Transvaal Manganese				
Middelplaats Mine ²	Anglo-American			

¹ Sources: Skinner, Walter R. Mining International Yearbook, 1976, London, Financial Times (1976). Also Republic of South Africa, Mineral Bureau, Preliminary, Report No. 6.76: Ferrous and nonferrous mines and work in South Africa (Pretoria, 1976). Industry informants were also helpful.

² Scheduled to begin production in 1979.

TABLE A1, 3.—SOUTH AFRICAN MINEOWNERS AND U.S. SALES AGENTS, VANADIUM ¹

Vanadium producers	Owners	Percent	Equity in owners	Percent	Ferroproducers
Highveld Steel & Vanadium	Anglo-American, African & European Investment Co., Ltd.		Anglo-American	100.0	Highveld Steel & Vanadium.
	Charter Consolidated Ltd.		General Mining, Anglo-American		
	Union Corp.		General Mining, Anglo-American	50.1	
	South African Townships, Mining & Finance				
	Newmont Mining (United States)		Amax	10.5	
Ucar Minerals	Union Carbide	100			
Transvaal Alloys	Otavi Mining Co., Vereinigte Aluminium Werke		Otavi Minen-und Eisenbach Gesellschaft	100.0	

¹ Sources: Skinner, Walter R. Mining International Yearbook 1976, London, Financial Times (1976). Also Republic of South Africa, Mineral Bureau, Preliminary Report No. 6.76: Ferrous and nonferrous mine and work in South Africa [Pretoria, 1976]. Industry informants were also helpful.

TABLE A1, 4.—SOUTH AFRICAN MINEOWNERS AND U.S. SALES AGENTS, PLATINUM¹

Platinum producers	Owners	Percent Equity in owners	Percent Refiners	U.S. sales agents
Rustenburg Platinum Mines Ltd.	Polgeitersrust Platinum Mines	32.9 JCI and subsidiaries, British Amalgamated Investments.	27.5 Matthey Rustenburg Refiners (in United Kingdom and South Africa).	Johnson Matthey & Co. (Worldwide). Matthey Bishop (U.S. subsidiary).
	Union Platinum Mining Co.	37.3 Gold Fields Anglo-American (through African and European Investment Co.).		
	Watervaal (Rustenburg) Platinum Mining Co.	29.8 Consolidated Gold Fields (United Kingdom).	100.0	
Atok Platinum Mine (recently acquired by Rustenburg).	Anglovaal, United States Steel			
Impala Platinum Ltd.	Union Corp.		50.1	Impala Sales Platinum Sales (subsidiaries of Impala Platinum).
	Union Corp. Investments			Phillips Brothers (subsidiary of Englehard).
	Bishopsgate Platinum Ltd. and subsidiaries, Industrial Section.	21.6 Hambros Bank Ltd., Union Corp. 5.0	35.6	J. Aron & Co. Nickel Mines (Toronto Canada).
Western Platinum Ltd.	National Selection Industrial Nickel Co. of Canada (Inc.) Lonrho Ltd. (United Kingdom) Falconbridge Nickel (Canada) Superior Oil.	5.0 10.0 50.0		
				Falconbridge Nikkelverk (Norway)

¹ Sources: Skinner, Walter R. Mining International Yearbook, 1976, London, Financial Times (1976). Also Republic of South Africa, Mineral Bureau, Preliminary Report No. 6.76: Ferrous and non-ferrous mines and work in South Africa [Pretoria, 1976]. Industry informants were also helpful.

SUMMARY

The corporate structure of the South African minerals industry reflects a high degree of integration, both horizontal and vertical. Horizontal integration is exhibited in the shared ownership of one corporation in another within the five major mining and finance houses in South Africa—in some cases through direct ownership and in other cases through joint ownership in mining companies. Another form of horizontal integration may be said to exist with respect to the minerals focused on in this paper—the major mining and finance houses have interests in most of these minerals.

Vertical integration is reflected in the interests held by the mining and finance houses in mines, ferro-alloy producers, and platinum refiners. There appears to be only a limited degree of captive interests held by foreign owners and consumers in the United States, Great Britain, and Germany and, in no case, would their ownership appear to dominate the industry in the minerals discussed. In fact, it would appear that South Africans control their own minerals industry through both ownership and management. There is, however, significant British equity represented in the case of one of the major houses, Gold Fields, whose 49 percent owner (Consolidated Goldfields) does set broad policy.

It appears that the word “interdependent” best characterizes the relationships between the companies and countries involved in the South African minerals and processing industries. Any action that would severely disrupt the flow of the minerals to the United States and its OECD partners would severely disrupt their platinum-group and chrome-related industries, and cause significant financial harm to the major corporations involved in those industries. However, any denial of South African capability to trade with the United States and its OECD partners, who almost exclusively represent the export market, would be disastrous to South Africa’s mining and finance houses.

APPENDIX 2

THE 27 CRITICAL MINERALS AND THEIR USES

Major uses and characteristics

<i>Mineral</i>	<i>Ferrous metals</i>
Chromium-----	An alloying element in steel and iron (especially resistant to corrosion and oxidation). Used in the production of stainless steel, nickel-chromium heating elements, pigments, catalysts, refractories, in the plating of metals, and in leather processing.
Cobalt-----	Vital alloying element in the aerospace and electrical product industries (imparts essential qualities of heat resistance, high strength, wear resistance, and superior magnetic properties). Major uses include cutting tools, jet engine parts, electrical devices, permanent magnets, catalysts, pigments and dryers for paints and allied products.
Columbium-----	Principally an alloying element in the manufacture of specialty steels and superalloys. Potential use in nuclear and aerospace applications and in superconductors of electricity at cryogenic temperatures.
Iron-----	Used in the production of iron and steel products for the following major end-use categories: Transportation, construction, machinery, cans and containers, oil and gas industries, appliances, and equipment.
Manganese-----	Principal uses in the production of steel, aluminum, cast iron, and in dry cell batteries and certain chemicals.
Molybdenum-----	Used in the manufacture of steels, iron castings, and alloys, and as a refractory metal in the nuclear and space age metals. Becoming increasingly important in the chemical industry.
Nickel-----	Important alloy which adds strength and corrosion resistance over a wide range of temperatures; vital to the iron, steel, and aerospace industries.
Silicon-----	Dissolves readily in most molten metal; used for deoxidizing and as a strengthening alloy in the production of iron, steel, and nonferrous metals.
Tantalum-----	A refractory metal with unique electrical, chemical and physical properties applicable for end uses in electronic components, transportation, metal-working machinery, chemical equipment, and nuclear reactor components.
Tungsten-----	Unique, high-temperature properties make it extremely important for end uses in carbides, ferroalloys, and metals.
Vanadium-----	An alloy in steels and nonferrous metals, especially important for jet engines and airframes.

THE 27 CRITICAL MINERALS AND THEIR USES—Con.

Major uses and characteristics

<i>Mineral</i>	<i>Nonferrous metals</i>
Aluminum-----	Used in the automotive, marine, rail, recreational, motor-scooter, and air-cushion vehicle industries; electrical and communications equipment; containers and other packaging; appliances; agricultural and other special industrial machinery; and in steel and aluminum chemicals.
Copper-----	Important for electrical applications in motors, generators, power distribution, systems, industrial controls, communications equipment, and house wiring. Also important in the production of roofing, plumbing, decorative items, heat exchangers, shell casings, instruments, household utensils, jewelry, and coinage.
Gold-----	Used as a metal or metal alloy in jewelry, transistor connections, computers, aerospace industry, dentistry, glass, and coinage. Store of value.
Lead-----	Used as a metal or metal alloy in storage batteries; construction material such as roofing, piping, and caulking; in structures for protection against X-rays or radiation; sporting ammunition; solder; and in the communication industry in cables and batteries. Used in chemicals, paints, glass, porcelain enamel, ceramic glazes, oxidizing agents, explosive detonators, and insecticides, and as a stabilizer in plastics.
Magnesium-----	Its compounds are used in basic refractories, cement, rayon, fertilizer, insulation, metal, rubber, fluxes, uranium processing, paper processing, medicines, neoprene compounds and other chemicals, pigments and paints, glass, ink, ceramics, sugar refining, dyes, and explosives. Magnesium metal is used in aluminum alloys, and magnesium alloys in the production of aircraft and missiles, machinery, chemical products, tools, and consumer products. Used as a reducing agent for producing titanium, zirconium, hafnium, uranium, and beryllium. •
Platinum group-----	Used as a catalyst in the chemical, petroleum-refining, and automotive industries. Used as a corrosion-resistant material in the chemical, electrical, glass, and dental-medical industries.
Silver-----	Used in photographic equipment, silverware, electrical and electronic equipment, appliances, jewelry, and coinage.
Tin-----	Used in metal containers, tanks, boxes, closures, kitchen utensils, solder, engine bearings; as a plating agent to prevent corrosion; as an alloy of solder, bronze, and brass; in electrical and electronic machinery and equipment, jewelry, dental amalgams, and pewter. Also becoming important in chemicals for plating baths, as a reducing agent, and as a perfume and soap stabilizer, in the production of polyurethane to strengthen glass bottles; and as a toothpaste additive.

THE 27 CRITICAL MINERALS AND THEIR USES—Con.

Major uses and characteristics

<i>Mineral</i>	<i>Nonferrous metals</i>
Titanium-----	Major use is in the manufacture of pigments for surface coatings where it imparts whiteness, opacity, and brightness to paints and provides a pigment with a refractive index that also makes it suitable for varnish and lacquers. Used in making titanium sponge, welding-rod coatings, carbide, and in ceramic and glass formulations.
Zinc-----	Used as a galvanizing agent in construction materials such as roofing, pipes, guttering, siding, door and window frames; brass fittings such as faucets, valves, traps and pump bodies, and in the transportation industry for galvanized steel sheet, die-cast alloys, and brass. Also an important trace element in animal nutrition and a plant nutrient in agriculture. Zinc oxide is used in chemicals in photocopying paper; and in the manufacture of rubber, paint, textiles, and lubricants.
	<i>Fuels</i>
Bituminous coal and lignite.	Indispensable as a fuel for the production of electric power, iron, and steel; essential for space heating and general manufacturing used in the production of chemical raw materials as a byproduct of coal carbonization such products as toluene, benzene, tar derivatives, and fertilizers.
Natural gas-----	Primarily a fuel resource, although gaseous hydrocarbon compounds such as ethane, propane, and butane are used for petrochemical feedstocks.
Petroleum, shale oil-----	End uses include the manufacturing of food products, paper products, chemicals, nonmetallic products. A fuel for households, commercial enterprises, electric utilities, and especially transportation vehicles.
Thorium-----	Metallic thorium and thorium oxide are used in radiation detectors, electric discharge tubes, computers, and incandescent gas mantles. Used in magnesium-base alloys, and certain high-strength corrosion-resistant metals. Consumed as a fuel for nuclear reactors.
Uranium-----	Major use is as a fuel for nuclear power plants. Also used as an alloy in military equipment such as artillery shells and missiles, and as an alloy in metals for shielding from X-ray and gamma radiation. Also used as a colorant in glass and ceramics and in steel and nonferrous metallurgy. Also used as a target in X-ray tubes, in electrodes in ultraviolet light sources, and in resistors in incandescent lamps.

GLOSSARY OF TERMS

Alloy—A substance having metallic properties and being composed of two or more chemical elements of which at least one is an elemental metal.

Catalyst—A substance capable of changing the rate of a reaction without itself undergoing any net change.

Coal carbonization—The process of decomposing coal into solid, liquid, and gaseous products by heating in a reducing atmosphere.

Cryogenics—The production and maintenance of very low temperatures, and the study of phenomena at these temperatures.

Carbides—A cemented or compacted mixture of powdered carbon and heavy metals forming a hard material used in metal-cutting tools.

Ferroalloy—Any alloy containing iron, usually in major amounts.

Ferrous—Iron-bearing or iron-related.

Fluxes—A substance used to promote the fusing of minerals or metals.

Nonferrous—Containing no iron and not used in iron alloys.

Refractory—A material of high melting point.

Adapted from U.S. Bureau of Mines, "Mineral Facts and Problems," USBM Bulletin 667, 1976, 1259 p.

APPENDIX 3

IDENTIFIED WORLD RESERVES AND RESOURCES OF THE 27 CRITICAL MINERALS

[In short tons, unless otherwise noted]

	United States	OECD ¹	Republic of South Africa	Africa	Soviet Bloc ²	South America	Other countries	Total
Chromite ore reserves--	50, 000	16,750,000 (Finland, ³ Greece, Turkey, and United States).	1,156,000,000	616,000,000 (Zimbabwe), 5,600,000 (Madagascar.)	23,100,000 (U.S.S.R.).	6,800,000 (Brazil)-----	7,800,000 (India), 5,280,000 (Philippines), 1,700,000 (Iran), 380,000 (Cuba).	1, 866, 000, 000
Chromite ore, other ⁴ ---	6, 100, 000	20,300,000 (Greece, United States, Finland, Turkey, and Canada).	2,256,000,000	616,000,000 (Zimbabwe), 5,600,000 (Madagascar).	24,200,000 (U.S.S.R.).	5,750,000 (Brazil)-----	11,000,000 (Greenland), 6,700,000 (India), 2,760,000 (Philippines), 1,100,000 (Cuba), 1,100,000 (Iran).	2, 965, 000, 000
Cobalt reserves-----		107,000 (Australia, Canada, and Finland).		668,000 (Zaire, Zambia, Botswana, and Morocco).	230,000 (U.S.S.R.).		300,000 (New Caledonia); 210,000 (Philippines); 120,000 (Cuba).	1, 650, 000
Cobalt, other-----	842, 000	1,360,000 (United States, Australia, Canada, and Finland).		515,000 (Zambia, Zaire, Botswana, and Morocco).	20,000 (U.S.S.R.).		1,036,000 (Cuba); 125,000 (New Caledonia); 15,000 (Philippines).	3, 050, 000
Columbium ⁵ reserves-----		900,000 (Canada).		1,130,000 (Zaire, Uganda, and Nigeria).	750,000 (U.S.S.R.).	9,000,000 (Brazil)-----		11, 880, 000
Columbium, ⁵ other-----	160, 000	525,000 (Canada and United States).		790,000 (Kenya and others).	2,750,000 (U.S.S.R.).	50,000 (Brazil)-----		4, 265, 000
Iron ⁶ reserves-----	4, 000, 000, 000	30,600,000,000 (Canada, Australia, United States, France, and Sweden).	1,200,000,000	2,100,000,000 (Liberia and others).	31 000,000,000 (U.S.S.R.).	19,400,000,000 (Brazil, Venezuela, and others).	6,200,000,000 (India), 3,100,000,000 (People's Republic of China).	99, 800, 000, 000
Iron, ⁵ other-----	14, 000, 000, 000	43,000,000,000 (Canada, United States, Australia, France, and Sweden).	1,800,000,000	2,900,000,000 (Liberia and others).	26,000,000,000 (U.S.S.R.).	31,500,000,000 (Brazil, Venezuela, and others).	4,000,000,000 (People's Republic of China), 2,500,000,000 (India).	115, 200, 000, 000
Manganese ⁷ reserves-----		161,180,000 (Australia, Japan, and Greece).	900,000,000	104,500,000 (Gabon, Zaire, Morocco, and Ghana).	755,100,000 (U.S.S.R., Bulgaria, Romania, and Hungary).	44,150,000 (Brazil and Chile).	28,000,000 (India); 17,000,000 (People's Republic of China); 2,200,000 (Mexico); 1,300,000 (Thailand).	2, 000, 000, 000

Manganese, ⁷ other-----	73, 600, 000	106,100,000 (United States, Canada, and Australia).	780,000,000-----	22,600,000 (Ghana, Upper Volta, Ivory Coast, and Zaire).	600,000,000 (U.S.S.R.).	31,000,000 (Brazil and Bolivia).	17,000,000 (People's Republic of China); 12,600,000 (Mexico); 12,000,000 (India).	1, 600, 000, 000
Molybdenum reserves--	3, 265, 000	3,275,000 (United States, Japan, and Australia).	-----	-----	1,005,000 (U.S.S.R. and Bulgaria).	1,025,000 (Chile and Peru).	250,000 (People's Republic of China); 50,000 (Mexico).	6, 600, 000
Molybdenum, other-----	14, 300, 000	18,440,000 (United States, Canada, Japan, and Australia).	-----	50,000 (Morocco and others).	2,145,000 (U.S.S.R., Yugoslavia, Bulgaria, and others).	2,525,000 (Chile, Peru, and others).	450,000 (Mexico); 250,000 (People's Republic of China).	24, 950, 000
Nickel reserves-----	200, 000	15,400,000 (Canada, Australia, and United States).	-----	2,300,000-----	8,100,000 (U.S.S.R.).	1,100,000 (Colombia and Brazil).	15,000,000 (New Caledonia); 7,800,000 (Indonesia); 5,400,000 (Philippines); 3,400,000 (Cuba); 1,100,000 (Dominican Republic); 300,000 (Guatemala).	60, 000, 000
Nickel, other-----	14, 900, 000	29,700,000 (United States, Canada, and Australia).	-----	6,700,000-----	13, 200,000 (U.S.S.R.).	4,600,000 (Brazil, Venezuela, and Colombia).	31,300,000 (New Caledonia); 14,200,000 (Cuba); 6,600,000 (Indonesia); 5,800,000 (Philippines); 900,000 (Guatemala and Puerto Rico); 100,000 (Dominican Republic).	114, 000, 000
Silicon: Reserves in major producing countries are ample in relation to demand. Quantitative estimates are not available.								
Tantalum ⁸ reserves-----	-----	6,100 (Canada and Australia).	-----	50,200 (Zaire, Nigeria, Mozambique, and others).	5,000 (U.S.S.R. and others).	3,800 (Brazil and others).	5,000 (Thailand) 4,000 (Malaysia).	74, 500
Tantalum, ⁸ other-----	1, 700	1,700 (United States).	-----	4,300 (Mozambique).	200,750 (U.S.S.R.).	-----	-----	213, 500
Tungsten ⁹ reserves-----	119, 000	409,500 (Canada, United States, Australia, Portugal, Japan, France, and New Zealand).	-----	11,500 (Zimbabwe, Rwanda, Namibia, Zaire, and others).	175,000 (U.S.S.R.).	65,000 (Bolivia, Brazil, and others).	1,050,000 (People's Republic of China); 125,000 (North Korea); 50,500 (Republic of Korea); 35,000 (Burma); 20,000 (Thailand); 16,000 (Malaysia); 1,000 (Mexico).	1, 960, 000
Tungsten, ⁹ other-----	360, 000	857,500 (United States, Canada, Australia, Portugal, Japan, France, and New Zealand).	-----	15,000 (Zimbabwe, Rwanda, Namibia, Zaire, and others).	350,000 (U.S.S.R.).	142,500 (Bolivia, Brazil, and others).	2,000,000 (People's Republic of China); 150,000 (North Korea); 87,500 (Republic of Korea); 77,500 (Burma); 37,500 (Malaysia); 17,500 (Thailand); 1,000 (Mexico).	3, 745, 000

See footnotes at end of table.

IDENTIFIED WORLD RESERVES AND RESOURCES OF THE 27 CRITICAL MINERALS—Continued

[In short tons, unless otherwise noted]

	United States	OECD ¹	Republic of South Africa	Africa	Soviet Bloc ²	South America	Other countries	Total
Vanadium ¹⁰ reserves--	115, 000	340,000 (Australia, United States, Finland, and Norway).	2,000,000	-----	8,000,000 (U.S.S.R.)--	250,000 (Chile and Venezuela).	100,000 (India)-----	10, 700, 000
Vanadium, ¹⁰ other-----	20,920,000	36,535,000 (United States, Canada, Australia, Sweden, New Zealand, Norway, and Finland).	18,000,000	1,000,000	4,000,000 (U.S.S.R.)--	1,500,000 (Venezuela).	300,000 (India)-----	51, 300, 000
NONFERROUS METALS								
Aluminum ¹¹ reserves--	10, 000, 000	1,180,000,000 (Australia, Greece, and United States).	-----	1,270,000,000 (Guinea, Cameroon, Ghana, Sierra Leone, and others).	130,000,000 (Yugoslavia, Hungary, U.S.S.R., and others).	780,000,000 (Brazil, Surinam, Guyana, and others).	235,000,000 (Jamaica); 90,000,000 (Indonesia); 70,000,000 (India); 30,000,000 (People's Republic of China).	3, 840, 000, 000
Aluminum, ¹² other-----	40, 000, 000	390,000,000 (Australia, Greece, and United States).	-----	540,000,000 (Cameroon, Guinea, Ghana, Sierra Leone, and others).	100,000,000 (U.S.S.R., Yugoslavia, Hungary, and others).	680,000,000 (Brazil, Surinam, Guyana, and others).	240,000,000 (India); 170,000,000 (People's Republic of China); 140,000,000 (Indonesia); 40,000,000 (Jamaica).	2, 470, 000, 000
Copper reserves-----	93, 000, 000	187,000,000 (United States and Canada).	5,280,000 (not significant on world-wide basis).	70,000,000 (Zambia, Zaire, and others).	66,000,000	150,000,000 (Chile, Peru, and others).	-----	503, 000, 000
Copper, ¹² other-----	320, 000, 000	440,000,000 (United States and Canada).	Much less than 1 percent (not significant on world-wide basis).	120,000,000 (Zambia, Zaire, and others).	190,000,000	240,000,000 (Chile, Peru, and others).	-----	1, 950, 000, 000
Gold ¹³ reserves-----	120	185 (United States, Canada, Australia, and Japan).	800	50 (Ghana, Zimbabwe, and others).	200 (U.S.S.R.)-----	21	15 (Philippines); 8 (Mexico).	1, 320
Gold ¹³ , other-----	120	170 (United States, Canada, Australia, and Japan).	200	35 (Zimbabwe, Ghana, and others).	100 (U.S.S.R.)-----	10	15 (Mexico); 10 (Philippines).	580
Lead ¹⁴ reserves-----	59, 000, 000	105,800,000 (United States, Canada, Australia, West Germany, Spain, and Sweden).	-----	5,000,000 (Morocco, Namibia, Algeria, and others).	26,500,000 (U.S.S.R., Bulgaria, Yugoslavia, and Poland).	6,000,000 (Peru, and others).	3,000,000 (People's Republic of China); 2,000,000 (Iran).	165,000, 000

Lead ¹⁴ , other	60,000,000	102,000,000	9,000,000 (Namibia, Algeria, Morocco, and others).	27,500,000 (U.S.S.R., Poland, Bulgaria, and Yugoslavia).	5,000,000 (Mexico); 3,000,000 (People's Republic of China); 2,000,000 (Iran).	2,600,000,000
Magnesium ¹⁵ reserves	10,000,000	32,000,000 (Austria, United States, Greece, and Turkey).	5,000,000	744,000,000 (U.S.S.R., Czechoslovakia, and Yugoslavia).	820,000,000 (People's Republic of China); 490,000,000 (North Korea); 30,000,000 (India).	
Magnesium, ¹² other	5,000,000	20,000,000 (Austria, United States, Greece, and Turkey).	3,000,000	96,000,000	330,000,000 (People's Republic of China); 330,000,000 (North Korea); 20,000,000 (India).	
Platinum group ¹³ reserves.	1	11 (Canada and United States).	NA (Zimbabwe)	150	Less than 1 unit— (Colombia).	561
Platinum group, ¹³ other. ¹⁰	209	219 (United States and Canada).	100 (Zimbabwe)	NA	4 (Colombia)	573-1,253
Silver ¹³ reserves	1,500	2,415 (United States, Canada, Australia, and Japan).	50	1,600 (U.S.S.R.)	630 (Peru and others).	6,000
Silver, ¹³ other ¹²	4,200	6,325 (United States, Canada, Australia, and Japan).	150	5,400 (U.S.S.R.)	1,200 (Peru)	16,630
Tin reserves	47,040	605,920 (United Kingdom, Australia, Portugal, Spain, and France).	789,600 (Nigeria, Zaire, and others).	694,400 (U.S.S.R.)	1,788,640 (Bolivia, Brazil, and Argentina).	11,175,360
Tin, other ¹²	171,360	3,483,200 (United Kingdom, Australia, Portugal, Spain, Canada, United States, and France).	3,306,240 (Zaire, Nigeria, and others).	2,128,000 (U.S.S.R.)	6,173,440 (Brazil, Bolivia, and Argentina).	30,301,600
Titanium ¹⁷ reserves	31,600,000	150,200,000 (Australia, United States, Canada, Norway, New Zealand, and Finland).	1,800,000 (Sierra Leone).	NA (U.S.S.R.)	69,500,000 (Brazil)	375,000,000
Titanium, ¹⁷ other	198,200,000	436,500,000 (United States, Canada, New Zealand, Sweden, Japan, Finland, and France).	49,200,000 (Sierra Leone, Egypt, Western Sahara, and others).	NA (U.S.S.R.)	15,300,000 (Guyana, Argentina, Brazil, and others).	943,800,000

See footnotes at end of table.

IDENTIFIED WORLD RESERVES AND RESOURCES OF THE 27 CRITICAL MINERALS—Continued

[In short tons, unless otherwise noted]

	United States	OECD 1	Republic of South Africa	Africa	Soviet Bloc 2	South America	Other countries	Total
Zinc reserves.....	30,000,000	95,000,000 (Canada, United States, Australia, Ireland, and Japan).	-----	7,000,000 (Zaire, Zambia, and others).	18,100,000 (U.S.S.R., Yugoslavia, Poland).	9,000,000 (Peru, Brazil, and others).	4,300,000 (Mexico); 2,000,000 (India); 1,600,000 (North Korea); 1,200,000 (People's Republic of China).	149,000,000
Zinc, other 18.....	20,000,000	66,000,000 (Canada, United States, Australia, Ireland, and Japan).	-----	8,000,000 (Zaire, Zambia, and others).	18,900,000 (U.S.S.R., Poland, Yugoslavia).	9,000,000 (Brazil, Peru, and others).	3,800,000 (People's Republic of China); 1,700,000 (Mexico); 1,400,000 (North Korea); 1,000,000 (India).	121,000,000
FUELS								
Bituminous coal and lignite reserves. 19	436,700,000,000	455,000,000,000 (United States, West Germany, United Kingdom, Australia, and others).	3,500,000,000	30,000,000	355,900,000,000 (U.S.S.R., Poland, and East Germany).	1,750,000,000 (Colombia, Chile, and Brazil).	60,000,000,000 (People's Republic of China); 2,000,000,000 (India).	888,400,000,000
Coal, 19 other.....	3,530,000,000,000	4,360,000,000,000 (United States, West Germany, Australia, United Kingdom, and Canada).	45,400,000,000	15,959,000,000	6,040,000,000,000 (U.S.S.R., Poland, and East Germany).	43,550,000,000 (Colombia, Chile, and Brazil).	1,150,000,000,000 (People's Republic of China); 89,500,000,000 (India).	11,700,000,000,000
Natural gas, 20 reserves..	237	1,522 (United States, Netherlands, and others).	-----	196	760 (U.S.S.R. and others).	65	595 (Middle East).	2,330

	542-857 32, 700	NA 342, 200	NA 68, 300, See "Other Countries" (OPEC).	NA 103, 400, (U.S.S.R. and others).	See "other coun- tries" (OPEC).	464, 000 (OPEC coun- tries).	NA 658, 700
Natural gas, ²⁰ other							
Petroleum, ²¹ other							
Oil	1, 820, 000	NA 2, 276, 000	NA 100, 000	NA 22, 000 (U.S.S.R.)	NA 800, 000 (Brazil)	NA	NA
Thorium reserves	140, 000	410, 000 (Canada, United States, and Australia).	5, 000	35, 000 (Nigeria and others).	70, 000 (Brazil and others).	200, 000 (India)	3, 260, 000 780, 000
Thorium, ¹² other	160, 000	700, 000 (Canada, United States, and Australia).	15, 000	45, 000 (Nigeria and others).	120, 000 (Brazil and others).	250, 000 (India)	1, 240, 000
Uranium reserves	267, 000	767, 000 (United States, Australia, Portugal, and Spain).	220, 000	74, 000 (Niger, Gabon, Central African Republic).	NA		1, 066, 000
Uranium, others ²²	89, 000	644, 000 (Sweden, Canada, Australia, United States, France, Spain, and Portugal).	70, 000	19, 000 (Niger and others).	17, 000	28, 000 (India)	798, 000

¹ OECD—Organization for Economic Cooperation and Development includes: Australia, Austria, Belgium, Canada, Denmark, Finland, France, West Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom, and United States. U.S. reserves and resources are also listed separately when they are significant.

² Soviet bloc includes: Bulgaria, Czechoslovakia, East Germany, Hungary, Poland, Rumania, U.S.S.R. and Yugoslavia. (While Yugoslavia is an important trading partner of this grouping, this designation does not imply any degree of political affiliation.)

³ Ranked from highest to lowest.

⁴ Includes subeconomic identified resources which may become reserves as a result of changes in economic and legal conditions. (See fig. 1.)

⁵ Short tons of columbium content.

⁶ Short tons of contained iron content.

⁷ Short tons of manganese content.

⁸ Short tons of tantalum content.

⁹ Short tons of tungsten content.

¹⁰ Short tons of vanadium content.

¹¹ Recoverable aluminum equivalent in short tons from bauxite (commercial production of primary aluminum has been based almost entirely on bauxite).

¹² Includes subeconomic identified resources, plus hypothetical and speculative resources. (See fig. 1.)

¹³ Million troy ounce units.

¹⁴ Short tons of lead content.

¹⁵ Short tons of magnesium content.

¹⁶ Includes undiscovered resources in the United States and Africa; resources are also known to exist in Australia, Ethiopia, Finland, and the Philippines, but quantities have not yet been estimated.

¹⁷ Includes both ilmenite and rutile deposits and represents tons of contained titanium.

¹⁸ Includes only inferred reserves and hypothetical economic resources in known districts. (See fig. 1.)

¹⁹ Includes anthracite.

²⁰ Data in trillion cubic feet.

²¹ Data in millions of 42-gallon barrels.

²² Forward costs of \$10 to \$15 per pound U₃O₈.

NA—data not available.

Sources: The data were compiled from a variety of public and private sources in 1976.

APPENDIX 4

WORLD MINE PRODUCTION OF THE 27 CRITICAL MINERALS—FERROUS METALS

[In short tons, unless otherwise noted. Data are for 1978, unless otherwise noted].

<i>Mineral commodity</i>	<i>Mine production</i>	<i>Mineral commodity</i>	<i>Mine production</i>
Chromite ore:		Tantalum—Continued	
South Africa-----	3, 700, 000	Nigeria-----	75
CME ¹ (principally		Australia-----	55
U.S.S.R)-----	3, 500, 000	Mozambique-----	40
OME ² -----	1, 800, 000	Zaire-----	25
Turkey-----	700, 000	Iron:	
Zimbabwe-----	660, 000	Soviet Union-----	269, 000, 000
Philippines-----	600, 000	OME-----	106, 150, 000
Cobalt:		Australia-----	101, 200, 000
Zaire-----	12, 000	Brazil-----	96, 800, 000
New Caledonia-----	4, 600	United States-----	88, 550, 000
CME-----	4, 000	Canada-----	49, 500, 000
Australia-----	3, 800	India-----	46, 200, 000
OME-----	3, 700	Manganese:	
Zambia-----	2, 500	CME-----	10, 700, 000
Morocco-----	2, 000	South Africa-----	5, 800, 000
Philippines-----	1, 200	Gabon-----	2, 100, 000
Columbium:		India-----	2, 000, 000
Brazil-----	9, 300	OME-----	1, 500, 000
Canada-----	2, 050	Brazil-----	1, 200, 000
Nigeria-----	350	Molybdenum:	
OME-----	100	United States-----	66, 000
Zaire-----	25	Chile-----	13, 000
Malaysia-----	22	CME-----	11, 000
CME-----	NA	Peru-----	500
Nickel:		OME-----	350
OME-----	197, 600	Tungsten:	
CME-----	150, 000	CME-----	21, 500
New Caledonia-----	70, 000	OME-----	11, 100
Cuba ^e -----	38, 000	United States-----	3, 600
United States-----	11, 600	Bolivia-----	3, 300
Silicon:		South Korea-----	2, 750
OME-----	990, 000	Australia-----	2, 750
CME-----	700, 000	Thailand-----	2, 500
United States-----	530, 000	Vanadium:	
Norway-----	280, 000	South Africa-----	12, 400
Tantalum:		Soviet Union-----	10, 000
Canada-----	125	United States-----	5, 250
Brazil-----	75	OME-----	3, 425
		Chile-----	950

See footnotes at end of table.

WORLD MINE PRODUCTION OF THE 27 CRITICAL MINERALS—NONFERROUS METALS

[In short tons, unless otherwise noted. Data are for 1978, unless otherwise noted].

Mineral commodity	Mine production	Mineral commodity	Mine production
Aluminum (Bauxite):		Lead:	
Australia-----	29, 150, 000	OME-----	1, 237, 500
OME-----	24, 090, 000	CME-----	1, 232, 000
CME-----	13, 420, 000	United States----	584, 100
Guinea-----	13, 200, 000	Australia-----	407, 000
Jamaica-----	12, 540, 000	Canada-----	396, 000
Copper:		Magnesium (metal and compounds):	
CME-----	1, 660, 000	Japan-----	4, 200, 000
United States----	1, 485, 000	United States----	920, 000
Chile-----	1, 170, 000	Soviet Union-----	71, 000
OME-----	967, 000	OME-----	68, 000
Canada-----	870, 000	Silver ³ :	
Zambia-----	700, 000	OME-----	100. 0
Zaire-----	480, 000	CME-----	70. 0
Peru-----	370, 000	Mexico-----	50. 0
Philippines-----	290, 000	Canada-----	41. 0
South Africa-----	210, 000	United States----	38. 0
Papua New Gui- nea-----	210, 000	Peru-----	35. 0
Gold ³		Tin:	
South Africa-----	22. 90	Malaysia-----	66, 000
CME-----	8. 20	Soviet Union-----	36, 300
OME-----	5. 80	Bolivia-----	33, 000
Canada-----	1. 70	Indonesia-----	28, 600
United States----	. 97	Thailand-----	28, 600
Platinum-group ³ :		People's Republic of China-----	22, 000
Soviet Union-----	3. 0		
South Africa-----	2. 9	Fuels ⁴	
OME-----	. 4		
Titanium (sponge metal):		Coal (bituminous and lignite):	
CME-----	39, 000	CME-----	2, 030, 000, 000
Japan-----	9, 000	OME-----	777, 000, 000
OME-----	2, 400	United States----	685, 000, 000
United States----	(W)	South Africa-----	82, 000, 000
Zinc:		Thorium:	
OME-----	3, 762, 000	Australia-----	300
CME-----	1, 595, 000	India-----	200
Canada-----	1, 408, 000	Malaysia-----	130
		Brazil-----	100
		OME-----	40
Natural gas ⁵ :		United States----	(W)
United States----	19, 900	CME-----	(NA)
OME-----	14, 900		
Soviet Union-----	12, 600	Uranium ⁷ :	
Petroleum ⁶ :		United States----	14, 000
OME-----	8, 550	OME-----	7, 250
Soviet Union-----	4, 000	Canada-----	7, 000
Saudi Arabia-----	3, 400	South Africa-----	4, 000
United States----	2, 987	Namibia-----	1, 500
Iran-----	2, 200		

* Estimated.

(W) Withheld by the Bureau of Mines to avoid disclosing confidential information.

(NA) Not available.

¹ Central Market Economy Nations. These are Albania, Bulgaria, People's Republic of China, Cuba, Czechoslovakia, German Democratic Republic, Hungary, North Korea, Mongolia, Poland, Romania, the Soviet Union, Vietnam, and Yugoslavia.

² Other Market Economy Nations. These are market economy countries not otherwise listed.

³ Data in million troy ounces of metal.

⁴ Data on fuels are for 1977.

⁵ Data is billion cubic feet measured at 14.73 psia at 60 degrees F.

⁶ Data in millions of 42-gallon barrels.

⁷ Uranium concentrate.

Source: Mineral Commodity Summaries, 1978 and 1979.

APPENDIX 5

SOUTH AFRICAN EXPORTS OF NONCRITICAL MINERALS TO THE UNITED STATES

[Data in short tons unless otherwise noted]

Mineral commodity	U.S. apparent consumption (1978)	Import reliance (percent of apparent consumption)	South African imports (percent of total imports) 1974-77
Metals:			
Antimony.....	32,000	48	28
Ores and concentrate.....			48
Oxide.....			<2
Zirconium.....	(1)	(1)	
Nonmetals:			
Asbestos.....	750,000	90	3
Diamond (industrial) ²	33.5	³ 100	28
Kyanite and related materials.....	(1)	(4)	37
Stone.....	1,570,000	0	^{5 6} 3
Vermiculite.....	334,000	(4)	100

¹ Withheld by the Bureau of Mines to avoid disclosing confidential information.² Data in million carats.³ Stones.⁴ Net exporter.⁵ Dimension stone.⁶ Data are for 1973-76.

Source: Mineral commodity summaries, 1978 and 1979.

APPENDIX 6

U.S. GOVERNMENT STOCKPILES AND PRIVATE INVENTORIES

Mineral/alloy	U.S. stockpile (thousand short tons)	Private inventories (thousand short tons)	Equal to years of U.S. consumption
Chromite ore.....	2,591	1,300	6 yr, 5 mo.
Chromium ferroalloys.....	759	¹ 130	2 yr.
Manganese ²	2,856	1,200	3 yr.
Ferromanganese.....	629	¹ 283	1 yr.
Vanadium.....	0.540	4.35	6 mo.
Ferrovandium.....	0	^{1, 3, 4} 1.70	2 mo.
Platinum-group metals (thousand troy ounces).....	1,725	900	1 yr, 4 mo.

¹ Personal comment, Bureau of Mines, Sept. 24, 1979. Preliminary data subject to revision.² Includes all types of manganese with the exception of ferromanganese.³ In short tons.⁴ Contained vanadium.

Adapted from Mineral Commodity Summaries, 1979, and other sources.