RC. 930–A

U.S. GEOLOGICAL SURVEY CIRCULAR 930–A

International Strategic Minerals Inventory Summary Report—Manganese

Major geologic age units

Age				Million years before present
Holocene	QUATERNARY	CENOZOIC		0.1
Pleistocene				2
Pliocene	TERTIARY			5
Miocene				24
Oligocene				38
Eocene				55
Paleocene				63
Late Cretaceous	Cretaceous	MESOZOIC		96
Early Cretaceous				138
Jurassic				205
Triassic				~240
Permian		PALEOZOIC		290
Pennsylvanian	Carboniferous			~330
Mississippian				360
Devonian				410
Silurian				435
Ordovician				500
Cambrian				~570
PRECAMBRIAN	Late Proterozoic	PROTEROZOIC		900
	Middle Proterozoic			1600
	Early Proterozoic			2500
		ARCHEAN		

International Strategic Minerals Inventory Summary Report—Manganese

By John H. DeYoung, Jr., David M. Sutphin, and William F. Cannon

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Prepared as a cooperative effort among earth-science and mineral-resource agencies of Australia, Canada, the Federal Republic of Germany, the Republic of South Africa, and the United States of America

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FOREWORD

Earth-science and mineral-resource agencies from several countries started the International Strategic Minerals Inventory in order to gather cooperatively information about major sources of strategic mineral raw materials. This circular summarizes inventory information about major deposits of manganese, one of the mineral commodities selected for the prototype phase of the inventory.

The report was prepared by John H. DeYoung, Jr., and David M. Sutphin of the U.S. Geological Survey (USGS). Manganese inventory information was compiled by William F. Cannon (chief compiler), USGS; Ian Goldberg, South African Department of Mineral and Energy Affairs (MEA), Minerals Bureau; Erik C. I. Hammerbeck, MEA, Geological Survey; Silvia M. Heinrich, USGS; Ulrich Krauss, Federal Institute for Geosciences and Natural Resources of the Federal Republic of Germany; and C. Roger Pratt, Australian Bureau of Mineral Resources, Geology and Geophysics. Additional contributions to the report were made by A. B. T. Werner and Jan Zwartendyk, Canadian Department of Energy, Mines and Resources (EMR), Mineral Policy Sector; Ian Goldberg; G. A. Gross, EMR, Geological Survey of Canada; and Aldo F. Barsotti, Joseph S. Coffman, and Thomas S. Jones, U.S. Bureau of Mines.

Director

CONTENTS

ILLUSTRATIONS

TABLES

INTERNATIONAL STRATEGIC MINERALS INVENTORY SUMMARY REPORT

MANGANESE

By John H. DeYoung, Jr., David M. Sutphin, and William F. Cannon

ABSTRACT

Major world resources of manganese, a strategic mineral commodity, are described in this summary report of information in the International Strategic Minerals Inventory (ISMI). ISMI is a cooperative data-collection effort of earth-science and mineral-resource agencies in Australia, Canada, the Federal Republic of Germany, the Republic of South Africa, and the United States of America. This report, designed to be of benefit to policy analysts, contains two parts. Part I presents an overview of the resources and potential supply of manganese on the basis of inventory information. Part II contains tables of some of the geologic information and mineral-resource and production data that were collected by ISMI participants.

PART I—OVERVIEW

INTRODUCTION

The reliability of future supplies of so-called strategic minerals is of concern to many nations. This widespread concern has led to duplication of effort in the gathering of information on the world's major sources of strategic mineral materials. With the aim of pooling such information, a cooperative program named International Strategic Minerals Inventory (ISMI) was started in 1981 by officials of the governments of the U.S.A., Canada, and the Federal Republic of Germany. It was subsequently joined by the Republic of South Africa and Australia. The United Kingdom will participate in future ISMI resource studies.

The objective of ISMI reports is to make publicly available, in convenient form, nonproprietary data and characteristics of major deposits of strategic mineral commodities for policy considerations in regard to short-term, medium-term, and long-term world supply. This report provides a summary statement of the data compiled and an overview of the supply aspects of manganese in a format designed to be of benefit to policy analysts.

The term "strategic minerals" is imprecise. It generally refers to mineral ore and derivative products that come largely or entirely from foreign sources, that are difficult to replace, and that are important to a nation's economy, in particular to its defense industry. Usually, the term implies a nation's perception of vulnerability to supply disruptions, and of a need to safeguard its industries from the repercussions of a loss of supplies.

Because a mineral that is strategic to one country may not be strategic to another, no one list of strategic minerals can be prepared. The ISMI Working Group decided to commence with chromium, manganese, nickel, and phosphate.

The information used was the best at hand in various agencies of the participating countries that contributed to the preparation of this report. These agencies were the Bureau of Mines and the Geological Survey of the U.S. Department of the Interior; the Geological Survey and the Mineral Policy Sector of the Canadian Department of Energy, Mines and Resources; the Federal Institute for Geosciences and Natural Resources of the Federal Republic of Germany; the Geological Survey and the Minerals Bureau of the Department of Mineral and Energy Affairs of South Africa; and the Bureau of Mineral Resources, Geology and Geophysics of the Australian Department of Resources and Energy.

Deposits (or districts) are selected for the inventory on the basis of their present or expected future contribution to world supply. Records for all deposits compiled by ISMI participants meet this general "major deposit" criterion and are included in the inventory.[1]

The ISMI record collection and this report on manganese have adopted the international classification system for mineral resources recommended by the United Nations Group of Experts on Definitions and Terminology for Mineral Resources (Schanz, 1980). The terms, definitions, and resource categories of this system were established in 1979 to facilitate international exchange of mineral-resource data; the Group of Experts sought a system that would be compatible with the several systems already in use in several countries. Figure 1 shows the U.N. resource classification used in this report. The term "reserves," which many would consider to be equivalent to r1E or R1E, has been interpreted inconsistently and thus has been deliberately avoided in the U.N. classification. Category R3, undiscovered deposits, is not dealt with in this report.

USES AND SUPPLY ASPECTS

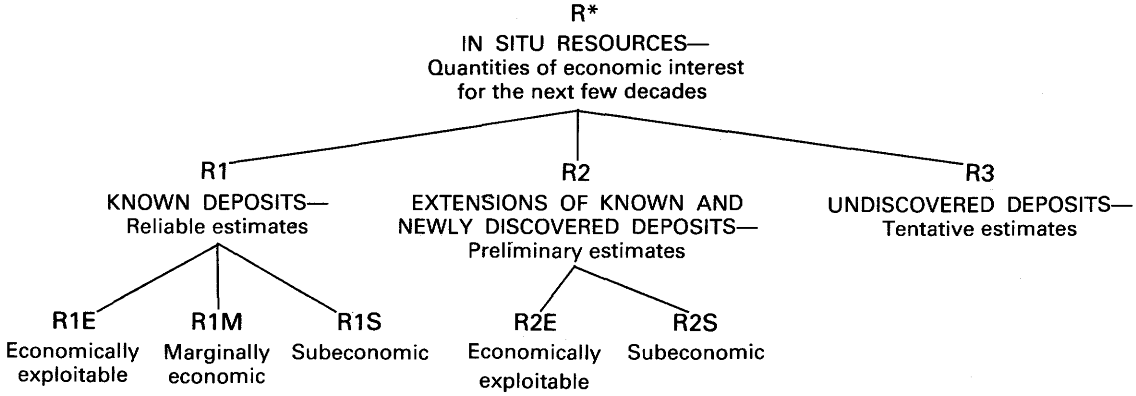
Manganese is essential for the manufacture of steel; about 95 percent of the 8.6 million metric tons of manganese (contained in 24 million metric tons of ore) produced in the world in 1981 was used in steelmaking. Manganese, mostly in the form of ferromanganese or silicomanganese, is used to "scavenge" the unwanted sulfur and oxygen from molten steel in order to reduce the brittleness of the product. Ferromanganese is also added to molten steel to produce manganese alloy steels that are stronger, harder, and more resistant to abrasion than other steels. There are no satisfactory substitutes for manganese in iron and steel production (Jones, 1983a, p. 549). Steel could be made with more expensive alternative materials, but this would increase the cost of steel, reduce the manufacture and use of steel, and would disrupt markets for the alternative materials (National Materials Advisory Board, 1981, p. 65). Other uses, which constitute about 5 percent of manganese consumption, are as an alloying element in several nonferrous metals, as an oxidizer or catalyst in a variety of industrial processes, and as an agent in dry-cell batteries ("battery-grade" ores).

As shown in subsequent sections of this report, manganese resources and production are not uniformly distributed around the world. The geological factors that control the distribution of manganese deposits, coupled with the geographical history of economic development, have required that many industrialized nations import manganese from developing countries. Several aspects of manganese supply are especially noteworthy:

- Direct foreign investment in overseas manganese ore production by several U.S. and western European steel companies after the late 1940's has had a large influence on trade and on new development of manganese resources (Brooks, 1966, p. 24).
- Programs for research, stockpiling, and production incentives have been established in several nations for strategic reasons.
- Plants to convert manganese ore into ferromanganese, which is used in quantity in steelmaking, were initially sited, for technological and economic reasons, near steelmaking facilities in industrialized countries. According to United Nations statistics (United Nations Conference on Trade and Development, 1981, p. 2 of annex), in 1960 the United States accounted for some 29 percent of world ferromanganese output, the United Kingdom plus West Germany for 16 percent, France for 10 percent, Japan for 5 percent, and South Africa for 4 percent.

  The 1970's saw a marked shift in the location of new ferromanganese plants toward countries endowed with both readily available sources of manganese ore and cheap power supplies. For instance, by 1978, the contribution of the United States to world ferromanganese production had dropped to 6 percent and that of the United Kingdom plus West Germany to 7 percent; France had stayed about the same at 9 percent; Japan's contribution had risen to 11 percent and South Africa's to 12 percent; the output of a combination of previously insignificant producers, Australia, Brazil, and Mexico, had come to account for 8 percent of world output. The location of the new ferromanganese production centers near the sources of the ore caused world exports of manganese ore to

[1] No information is provided on deposits that once were significant but whose resources are now considered to have been depleted.



*The capital "R" denotes resources *in situ*; a lower case "r" expresses the corresponding *recoverable* resources for each category and subcategory. Thus, r1E is the recoverable equivalent of R1E. This report deals only with R1 and R2, not with R3.

FIGURE 1.—United Nations resource categories used in this report (modified from Shanz, 1980, p. 313).

decline after the mid-1970's, and those of ferromanganese to rise. The effect of this shift was particularly pronounced in the United States, where, from 1960 to 1980, imports of manganese ore fell from 1,100,000 to 300,000 metric tons of contained manganese, and imports of ferromanganese rose from 84,000 to 430,000 metric tons of contained manganese at the expense of domestic ferromanganese producers (DeHuff and Fratta, 1962, p. 870, 872; DeHuff and Jones, 1981, p. 549, 550).

The trend toward ferromanganese production in ore-producing countries may well continue. Additional ferromanganese production capacity has recently been installed in Mexico. Consideration is being given to a plant that would use ore from a future mine in the Carajas regon in Brazil. Gabon is also considering the production of ferromanganese, possibly in the 1990's.

- The depressed state of metal markets in the early 1980's has discouraged development of new manganese deposits and has caused deferment of expansion of some mining operations.
- Transportation systems must be developed or improved before some identified manganese resources can be produced and marketed. For instance, development of the Azul deposits in Brazil and the Tambao deposit in Upper Volta depends upon the construction of railways. Improved rail and water transportation systems in some areas may also stimulate more thorough exploration, which may lead to the discovery of new resources.
- Production of low-grade ore is maintained by some nations having economic philosophies that place greater emphasis on self-sufficiency and maintenance of a domestic industry than on market forces. For example, some deposits being mined in the Soviet Union have manganese grades as low as 18 to 20 percent, compared to ore of 40 to 50 percent manganese produced in most other countries.
- So-called manganese nodules and crusts on the ocean floor have been proposed as a source of manganese, cobalt, nickel, and copper. Recent reports, such as Antrim and Sebenius (1983), are pessimistic about the possibility that these resources will be developed within the next 20 or 30 years. Nevertheless, if the technological and legal problems of ocean mining can be solved, these resources may provide an economic alternative to manganese resources on land.

DISTRIBUTION OF MANGANESE DEPOSITS AND DISTRICTS

The world map in figure 2 shows the locations of major manganese deposits and districts. Of the four leading steel producers (Soviet Union, U.S.A., Japan, and western Europe), only the Soviet Union has major manganese deposits.

Major manganese deposits in this report are of two general types: marine chemical sediment deposits and secondary enrichment deposits (fig. 2). Deposits of the marine chemical sediment type commonly contain two kinds of extensive layers.

One consists of manganese oxide and the other of manganese carbonate minerals. Both kinds of layers are commonly interbedded with limestone and(or) shale typical of shallow-water depositional environments. Deposits of the secondary enrichment type are composed of manganese oxide and hydroxide minerals. They typically occur in tropical regions where intense weathering has formed manganese-rich surficial accumulations by dissolving other elements from manganiferous protores. For instance, seven of the nine secondary enrichment deposits shown in figure 2 lie between the tropics. Less commonly, the secondary enrichment type of deposit has resulted from the action of hot surface waters; the deposits of Imini, Morocco, and the Postmasburg district of South Africa are examples of this type. There are other manganese deposit types, such as hydrothermal and volcanogenic types on land and deep-sea nodules in the oceans. Deposits of these other types, however, either are not large enough or do not have enough immediate production potential to be included in this inventory.

Figure 3 shows the global distribution of major manganese deposits and indicates the economic class (GNP per capita) of countries where deposits are located.

MANGANESE RESOURCES

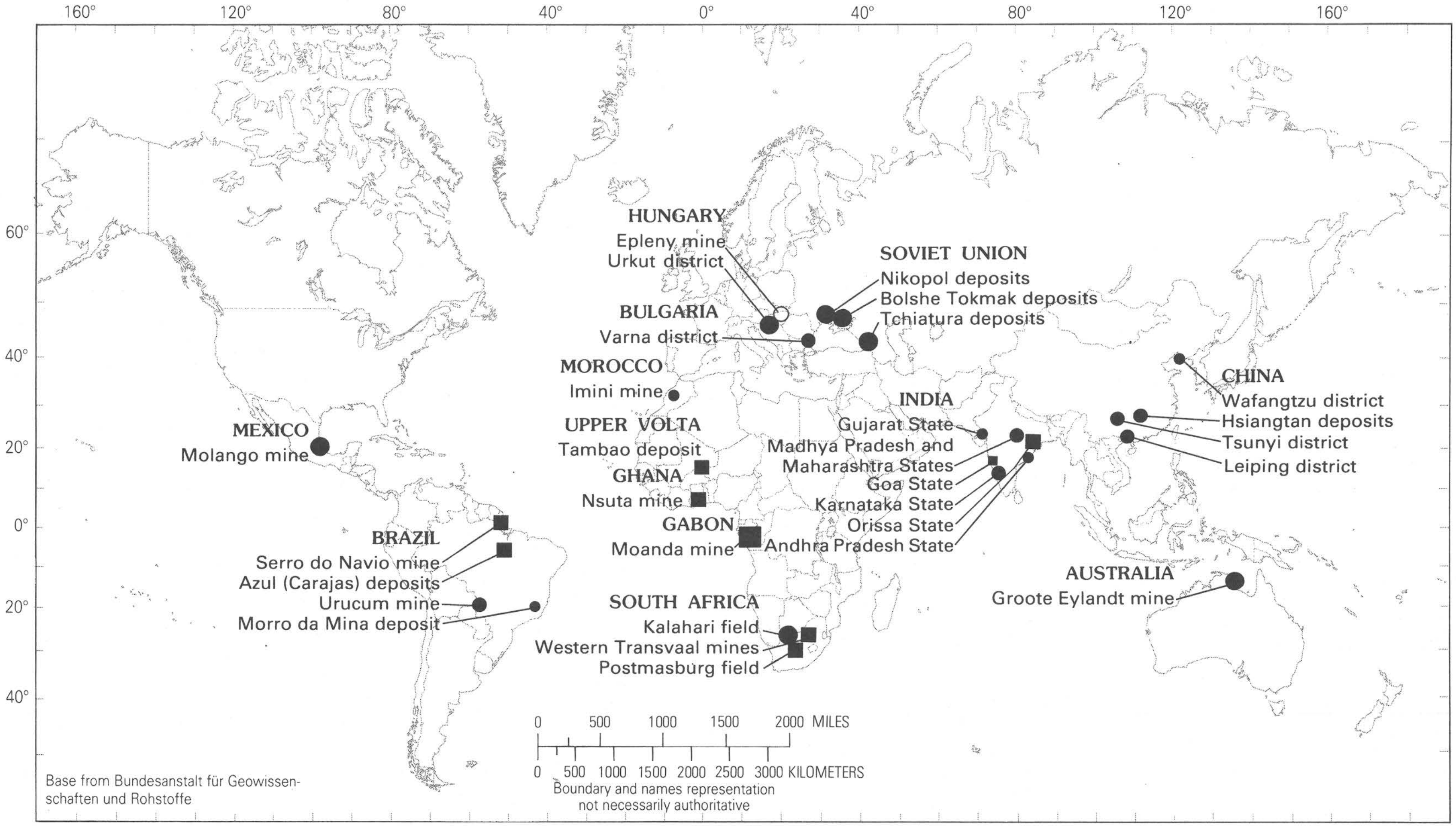
Marine chemical sediment type deposits account for about 70 percent of the number of deposits and districts shown in figure 2. These deposits account for over 97 percent of the identified, economic resources, R1E, (in terms of contained manganese) and for over 95 percent of resources in other categories for major manganese deposits (table 1).[2] Table 1 also shows cumulative production from these deposits; cumulative production has been small compared to resources.

Table 2 shows the distribution of resources (tons of contained manganese) of major manganese deposits among the World Bank country economic classes from figure 3. Low-income and lower middle-income countries have only a small proportion of the total manganese resources of these deposits in spite of having 13 of the 29 deposits and districts. Upper middle-income countries have nine deposits with about 89 percent of R1E resources and 84 percent of resources in other categories; most of these resources are in the Republic of South Africa, Mexico, and Brazil. Deposits in eastern European nonmarket-economy countries (the Soviet Union, Hungary, and Bulgaria) account for most of the other resources from major deposits (6.5 percent of R1E resources and 11 percent of other resource categories). Only one major manganese deposit (Groote Eylandt, Australia) is in an industrial-market-economy country. Table 2 indicates, as discussed earlier, that the location of manganese resources is not coincident with the regions of consumption (steelmaking centers). It is estimated on the basis of data from Roskill Information Services (1981) and Jones (1983b) that about 30 percent of manganese content of ores produced in 1979 was involved in that year's international trade as ore and ferroalloys; the number rises to over 45 percent when only non-Communist nations are considered.

The addition to world manganese resources in major deposits by discovery of new deposits is shown in figure 4. The discovery of manganese ore in the Kalahari, Republic of South Africa, in 1940 resulted in a large increase of resources. The figure shows that the Kalahari discovery and smaller discoveries since the 1940's have resulted in an impressive quantity of manganese resources compared to pre-1940 amounts. Conclusions drawn from this figure should take account (1) of the uncertainty of discovery date due to difficulties in defining "discovery"; (2) of the limited validity of assigning all of a deposit's (or district's) resources to the initial discovery date, as done in figure 4; and (3) of the different standards used to report resource data from different deposits. The latest discovery date shown in table 7 of Part II is 1971 (Azul (Carajas) deposits, Brazil). The absence of subsequent discoveries may reflect reduced exploration rather than a dearth of undiscovered resources. This pattern of discoveries is typical of many mineral commodities.

After the time when a deposit or district is discovered, development and production activities increase the amount of information about the mineral deposit(s), resulting in changes in resource estimates. The Kalahari field provides a good example of the problem of assigning present-day resource estimates for a deposit to the date of its discovery. As noted above, most of the large amount of manganese resources shown in figure 4 as having been "discovered" during the 1940–59 period is accounted for by about 13 billion metric tons of resources (containing about 5 billion metric

[2] Resource estimates for the years given in table 7 of Part II are used to calculate these resource totals in Part I.



EXPLANATION

Geologic Deposit Type

Marine chemical sediment		Secondary enrichment	
Symbol	Resources (metric tons)	Symbol	Resources (metric tons)
● (large)	$>10^8$	■ (large)	$>10^8$
● (medium)	10^7–10^8	■ (medium)	10^7–10^8
● (small)	$<10^7$	■ (small)	$<10^7$
○	Unreported		

FIGURE 2.—Location, deposit type, and estimated resources of major manganese deposits and districts in the world.

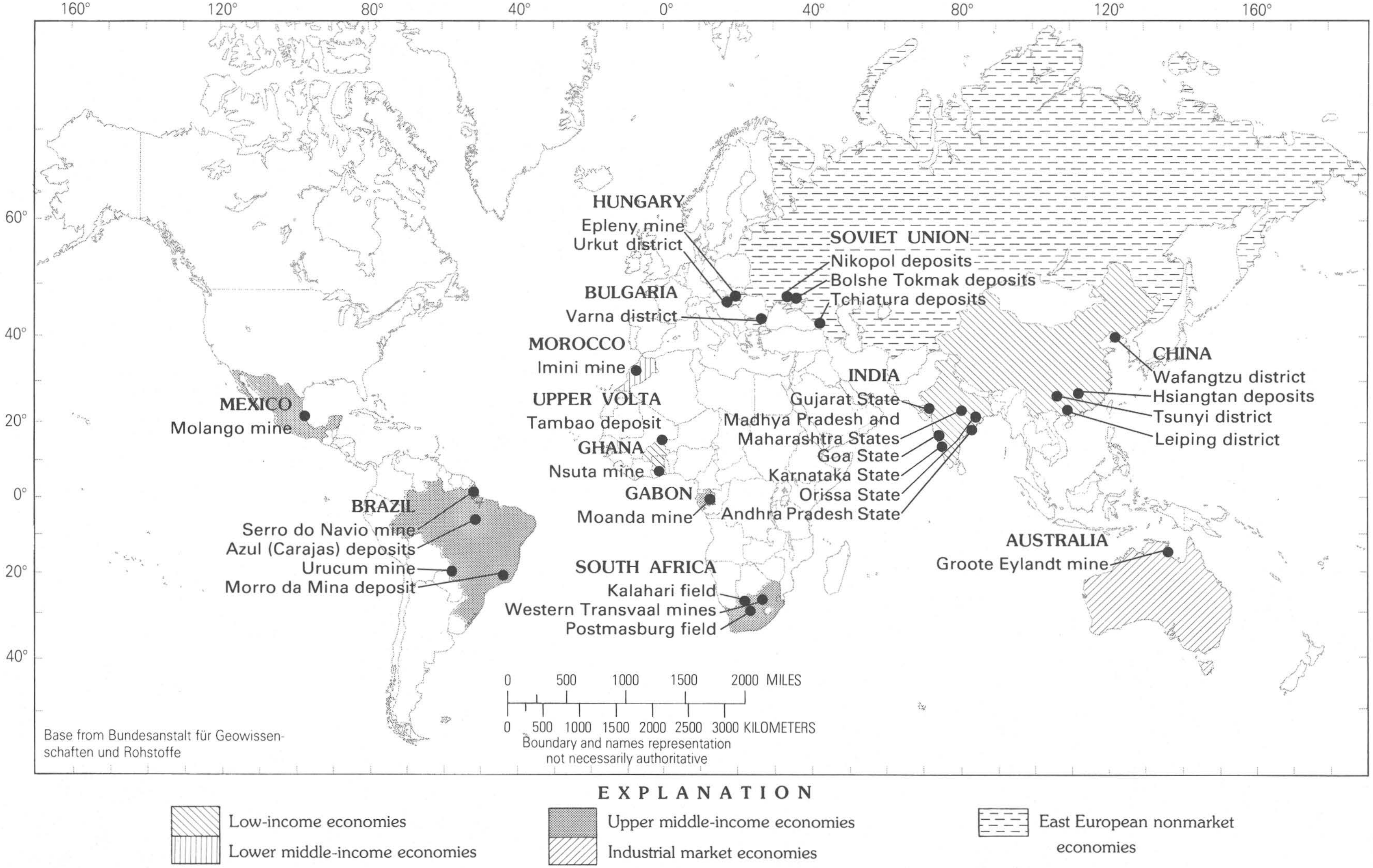


FIGURE 3.—Economic classification of the World Bank (1983, p. 148–149) for countries where major manganese deposits and districts occur. Location names are from the tables in Part II.

TABLE 1.—*Manganese resources in and cumulative production from the world's major deposits and districts, by geologic deposit type and resource category*

[Figures are in million metric tons of manganese metal]

Geologic deposit type[1]	No. of records	Resource category: R1E[2]	Resource category: All other R1 and R2[3]	Cumulative production[4]
Marine chemical sediment	20	3,050	1,940	68
Secondary enrichment	9	77	98	46
Total[5]	29	3,120	2,040	114

[1]Deposit types of the world's major manganese deposits are shown in figure 2.
[2]Reliable estimates from identified deposits with economically exploitable resources (fig. 1).
[3]Includes resources in the R1M, R1S, R2E, and R2S categories (fig. 1).
[4]Reported cumulative production; years for individual mines are listed in table 7 of Part II. This is a minimum estimate of cumulative production because no estimates have been added for those deposits that have no cumulative production data reported in table 7 of Part II. Note that production figures are not comparable to *in situ* resource figures because production only represents the recoverable portion of those resources.
[5]Figures may not add to totals shown due to rounding.

tons of manganese) in the Kalahari field. The size of the Kalahari resources was not understood when serious geological investigations were started about 1940. (The manganese occurrence at Black Rock at the northern edge of the field had been recorded in 1908.) When early prospecting was done near Black Rock in 1950, the estimates of resources (hundreds of millions of tons) were still very small compared to the estimates given in table 7 of Part II. As development and mining operations progressed at the Black Rock mine, the Smartt mine (which opened in 1954), the Hotazel mine (1959), the Mamatwan mine (1964), the Wessels mine (1973), the Middelplaats mine (1979), and others, estimates of the Kalahari field's resources became larger. Over 1 billion metric tons of resources of all classifications were estimated by 1964; that figure increased to over 7 billion metric tons by 1975 and over 13 billion metric tons by 1982. All of these resources have been assigned to the 1940 discovery date in table 7 of Part II and are shown in the 1940–59 period on figure 4 because year-by-year resource estimates for deposits and districts are not consistently available and are not included in ISMI records.

MANGANESE PRODUCTION

The 29 manganese deposits and districts in the International Strategic Minerals Inventory occur in 13 countries; these countries, except Upper Volta, collectively have accounted for most of the world's manganese ore production since 1940 (fig. 5). The data plotted in figure 5 include a small, indeterminable amount of ore from mines that are not in the inventory.

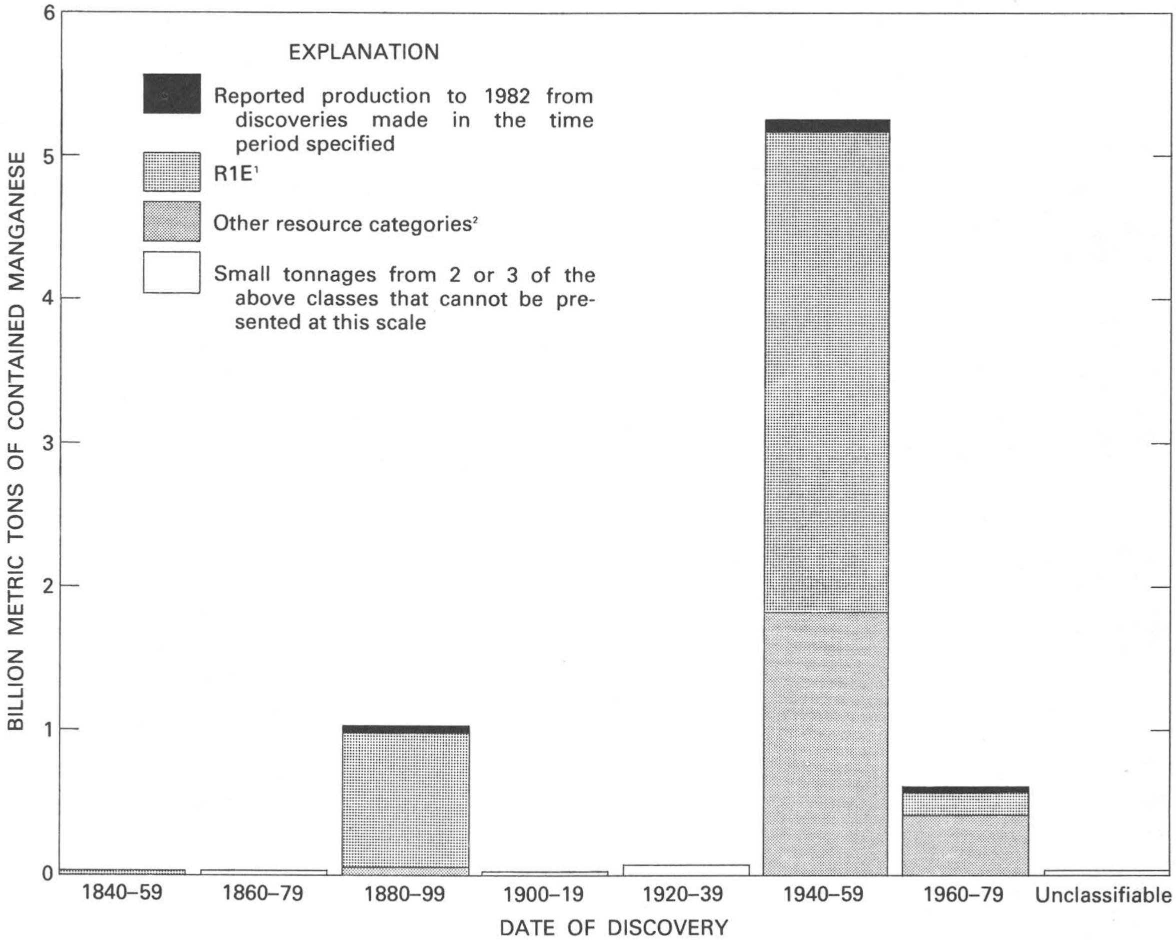
Figure 6 shows the production (in terms of contained manganese) from each of the countries included in the figure 5 totals. Because of increases in production in South Africa, Australia, Brazil, and Gabon for the years shown, the proportion of world manganese production accounted for by the Soviet Union has fallen.

TABLE 2.—*Manganese resources in the world's major deposits and districts, by economic class of country and resource category*

[Figures are in million metric tons of manganese metal]

Economic class[1]	No. of records	Resource category[2]: R1E	Percent	All other R1 and R2	Percent
Low-income	12	20.0	0.6	55.3	2.7
Lower middle-income	1	.46	.01	.23	.01
Upper middle-income	9	2,790	89	1,720	84
Industrial market	1	114	3.7	38.5	1.9
Eastern European nonmarket	6	204	6.5	230	11
Total[3]	29	3,120	100	2,040	100

[1]Based principally on GNP per capita and, in some instances, other distinguishing economic characteristics (World Bank, 1983, p. 148–149). Countries where major manganese deposits or districts occur are, by class: low-income economies—China, Ghana, India, Upper Volta; lower middle-income economies—Morocco; upper middle-income economies—Brazil, Gabon, Mexico, South Africa; industrial market economies—Australia; and eastern European nonmarket economies—Bulgaria, Hungary, Soviet Union. A sixth economic class, high-income oil exporters, is not listed because those countries do not have identified major manganese deposits.
[2]Categories are defined in figure 1.
[3]Figures may not add to totals shown due to rounding.



[1]Reliable estimates from identified deposits with economically exploitable resources (fig. 1)
[2]Includes resources in the R1M, R1S, R2E, and R2S categories (fig. 1)

FIGURE 4.—Manganese resources in the world's major deposits and districts according to their date of discovery. If the year of discovery was not reported, the year of first production was used instead; if neither the year of discovery nor the year of first production was reported, the deposit's resources were considered "unclassifiable." Years of discovery are listed in table 7 of Part II.

Information on 1982 production and on cumulative production from 1940 through 1982 for countries with deposits in the inventory is shown in table 3. These production data have been grouped according to World Bank country economic class in table 4. About 35 percent of 1982 production and 42 percent of cumulative production since 1940 has been from eastern European nonmarket-economy countries (largely the Soviet Union). The second-ranking group of countries in cumulative production, the upper middle-income class (South Africa, Gabon, Brazil, and Mexico), accounts for about 45 percent of 1982 production and 34 percent of production since 1940.

Manganese is produced from surface and underground mining operations. Table 5 shows the distribution of resources by mining method. The Kalahari field contains both surface and underground mines. It constitutes the major part of resources reported for the largest resource entry in this table, the upper middle-income countries.

In studies of industrial market structure, some approaches used to measure market concentration focus directly on observable dimensions, such as number of suppliers. The market concentration ratio, defined as the percentage of total industry sales or output contributed by the largest few firms (Scherer, 1970, p. 50–51), can be adapted as

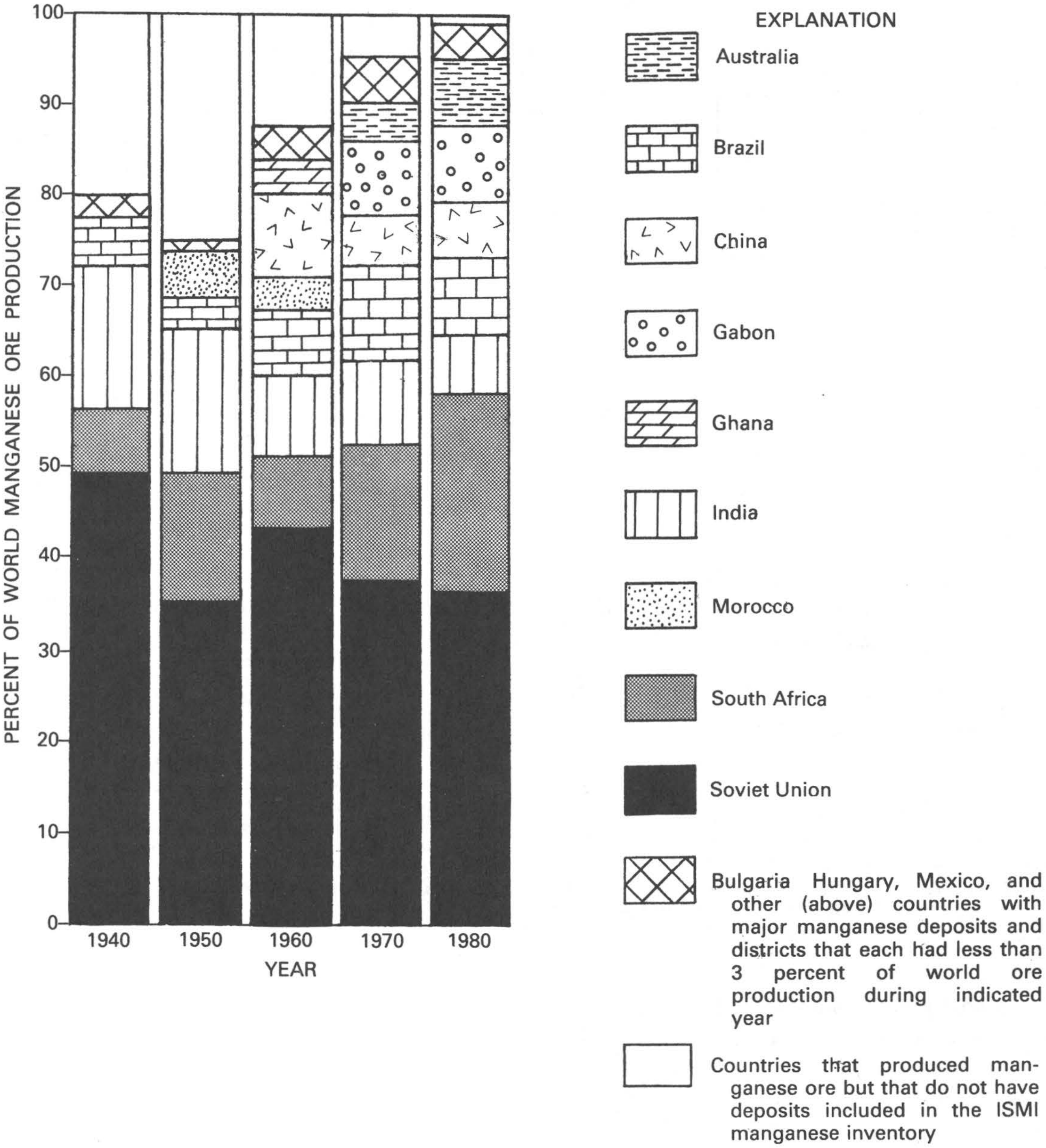


FIGURE 5.—Proportions of total world production of manganese ore accounted for by countries with major deposits and districts in the ISMI manganese inventory; selected years 1940–80. Reported production (U.S. Bureau of Mines, 1943–83) is for those countries listed in table 3.

a measure of a country's control of mineral production. Figure 7 shows the four-country and eight-country concentration ratios for 1913 and 1980 production of several nonfuel mineral commodities. By these measures, manganese ranks high among those mineral commodities controlled by a few producing countries, although this concentration has decreased from 1913 to 1980.

Present and probable future production of manganese from the deposits included in the International Strategic Minerals Inventory is shown on the map in figure 8. Some present major producers (Kalahari, Nikopol, Bolshe Tokmak, Groote Eylandt, Moanda, Molango, and others) will probably continue to be large suppliers through 2020. Decreases in output from certain deposits may be

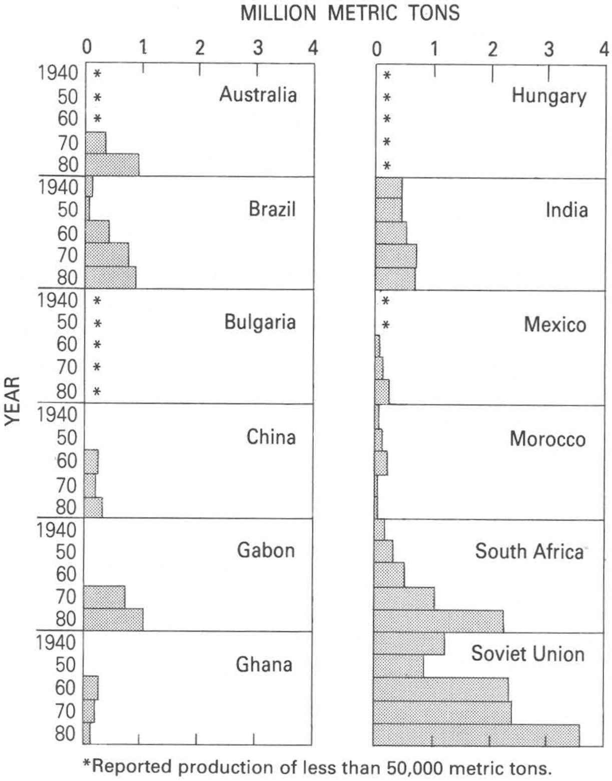


FIGURE 6.—Manganese production (manganese contained in ore and concentrate) in countries with major deposits and districts in the ISMI manganese inventory; selected years 1940–80. Figures are calculated from reported ore production (U.S. Bureau of Mines, 1943–83) and estimated manganese grades for those countries listed in table 3, except Upper Volta which has no production.

compensated for by production from other major deposits such as those in Tambao, Upper Volta, which require development of transportation facilities. The world distribution of manganese production among country economic classes and by country concentration will probably not change much from that of the early 1980's.

CONCLUSIONS

There are no satisfactory economic substitutes for manganese in steel manufacture. As such, industrialized countries not possessing manganese deposits consider the commodity highly strategic to their economic well being and essential to their industrial progress.

Most manganese production and resources are confined to only 29 deposits or districts—a relatively small number for a major commodity. Most industrialized nations have to rely on imports to keep their steel mills operative. In efforts to decrease dependency on imports in the long term, some such countries have resorted to direct investment in overseas production; others have begun investigating recovery from lower grade deposits as well as from manganese nodules on the ocean floor.

TABLE 3.—*Estimated cumulative and annual production of manganese contained in ore and concentrate for each country having a major manganese deposit or district*

[Figures are in thousand metric tons]

Country[1]	Cumulative production 1940–82[2]	Annual production 1982[2]
Soviet Union	92,000 (1)	2,800 (1)
South Africa	35,000 (2)	2,055 (2)
India	23,000 (3)	507 (6)
Brazil	19,000 (4)	637 (4)
Gabon	17,000 (5)	771 (3)
Australia	10,000 (6)	[3]547 (5)
China	9,400 (7)	480 (7)
Ghana	5,600 (8)	53 (9)
Morocco	4,800 (9)	50 (10)
Mexico	3,400 (10)	183 (8)
Hungary	1,100 (11)	31 (11)
Bulgaria	410 (12)	14 (12)

[1]Includes all countries with major deposits and districts in the International Strategic Minerals Inventory except Upper Volta which has no production.
[2]Cumulative production calculated from reported ore production (U.S. Bureau of Mines, 1943-83) and estimated manganese grades; 1982 production calculated from reported ore production (Jones, 1983b, p. 587) and estimated manganese grades. Numbers in parentheses denote production ranking of country.
[3]Australia Bureau of Statistics (1984).

TABLE 4.—*Estimated cumulative and annual production of manganese contained in ore and concentrate by economic class of country*[1]

[Figures are in thousand metric tons]

Economic class[2]	Cumulative production 1940–82[3]	Annual production 1982[3]
Low-income	38,000 (3)	1,000 (1)
Lower middle-income	4,800 (5)	50 (5)
Upper middle-income	74,000 (2)	3,650 (1)
Industrial market	10,000 (4)	[4]547 (4)
Eastern European nonmarket	93,000 (1)	2,800 (2)
Total[5]	220,000	8,100

[1]Includes only countries having major manganese deposits and districts. See table 3.
[2]Based principally on GNP per capita and, in some instances, on other distinguishing economic characteristics (World Bank, 1983, p. 148-149). A sixth economic class, high-income oil exporters, is not listed because those countries do not have identified major manganese deposits.
[3]Reported production from countries in indicated economic class (U.S. Bureau of Mines, 1943-83); 1982 production estimated from ISMI deposit records and U.S. Bureau of Mines data for prior years. Numbers in parentheses denote production ranking of economic class.
[4]Australia Bureau of Statistics (1984).
[5]Figures may not add to totals shown due to rounding.

TABLE 5.—*Manganese resources[1] in the world's major deposits and districts, listed by mining method and economic class of country*

[Figures are in million metric tons of manganese metal]

Economic class[2]	Mining method				
	Surface	Underground	Surface and underground	Not mined	Not reported
Low-income	35	---	24	---	17
Lower middle-income	---	0.69	---	---	---
Upper middle-income	116	27	4,330	25	---
Industrial market	153	---	---	---	---
Eastern European nonmarket	---	49	386	---	---
Total[3]	304	77	4,740	25	17

[1]Includes resources in the R1 and R2 categories.
[2]Based principally on GNP per capita and, in some cases, on other distinguishing economic characteristics (World Bank, 1983, p. 148–149). A sixth economic class, high-income oil exporters, is not listed because those countries do not have identified major manganese deposits.
[3]Figures may not add to totals shown due to rounding.

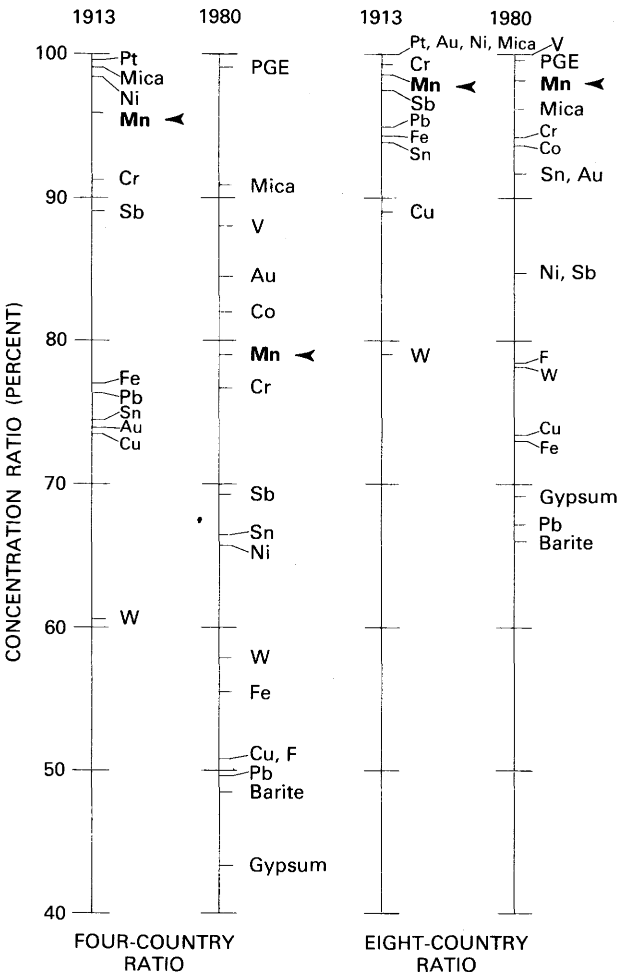


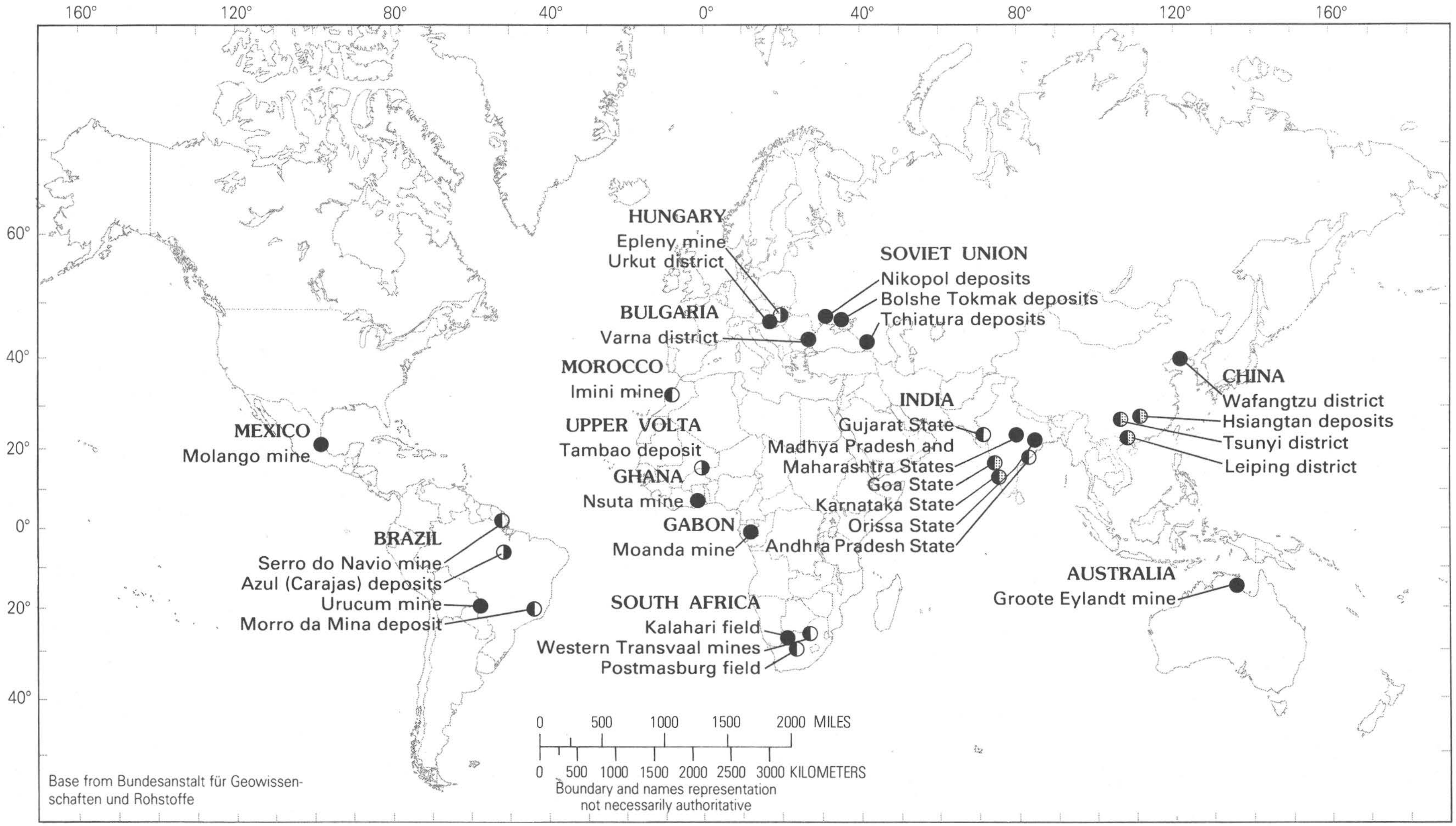
FIGURE 7.—Concentration ratios for selected nonfuel mineral commodity production in 1913 and 1980. The ratios are percent of total world production for the indicated commodities, designated by chemical-element symbols (PGE for platinum-group elements), for the four or eight countries with the largest reported production of that commodity in 1913 and 1980. (Sources of data: U.S. Geological Survey, 1921; U.S. Bureau of Mines, 1982.)

The Republic of South Africa holds the world's largest resources of manganese on land. Others of significance are in the Soviet Union, India, Brazil, Gabon, Australia, and China. Current demand for manganese is low because of the weak state of the world's steel industry. In the long term, that is, for at least four decades from now, the supply situation is unlikely to change, with South Africa and the Soviet Union providing the bulk of traded manganese and with lesser amounts available from Brazil, India, Gabon, and Australia.

PART II—SELECTED INVENTORY INFORMATION FOR MANGANESE DEPOSITS AND DISTRICTS

Tables 6 and 7 contain information from the International Strategic Minerals Inventory record forms for manganese deposits and districts. Only selected items of information about the location and geology (table 6) and mineral production and resources (table 7) of the deposits are listed here; some of this information has been abbreviated because of space limitations.

Summary descriptions and data are presented in the tables as closely as possible to the way that they were reported in the inventory records. For instance, significant digits for amounts of production or resources have been maintained as reported. Data that were reported in units other than metric tons have been converted to metric tons for comparability. Some of the data in the tables are more aggregated than in the inventory records, such as cumulative production totals that for some mines have been reported by year or by groups of years. Some of the abbreviations used in the inventory records forms have been used in these tables; they are explained in the footnotes.



EXPLANATION

- ● Producer in 1982; probably a significant producer in 2020
- ◐ Producer in 1982; probably an insignificant producer or exhausted by 2020
- ◍ Producer in 1982; information insufficient to permit any forecast as to future production
- ◑ No production in 1982; probably a significant producer in 2020

FIGURE 8.—**Major manganese deposits and districts, their present production status, and their probable production status in 2020.**

TABLES 6 AND 7

TABLE 6.—*Selected geologic and location information from*

Site name	Latitude	Longitude	Deposit type	Host rock[1/]
				AUSTRALIA
Groote Eylandt mine	14° 00'S	136° 30'E	Marine chemical sediment (not evaporite)	Clay, Mullamen beds, ECRET
				BRAZIL
Azul (Carajas) deposits	06° 08'S	50° 21'W	Secondary enrichment	Siltstone; Rio Fresco formation; PREC
Morro da Mina deposit	20° 35'S	43° 50'W	Marine chemical sediment; secondary enrichment	Graphitic phyllite, schist, and amphibolite; Lafaiete formation; PREC
Serro do Navio mine (Amapa)	01° 00'S	52° 00'W	Secondary enrichment	Graphitic facies of schist; Grupo Serro do Navio; PREC
Urucum mine	19° 08'S	57° 33'W	Marine chemical sediment	Iron formation; Band'alta formation; PREC?
				BULGARIA
Varna district	43° 13'N	27° 55'E	Marine chemical sediment	Clay, marl, and tuff; OLIGO
				CHINA
Hsiangtan deposits	27° 50'N	112° 55'E	Marine chemical sediment	Hung-Chiang series; ARCH
Leiping district	23° 30'N	109° 30'E	-do-	LPERM
Tsunyi district	27° 30'N	106° 30'E	-do-	-do-
Wafangtzu district	39° 35'N	122° 00'E	-do-	ARCH
				GABON
Moanda mine	01° 34'S	13° 17'E	Secondary enrichment	Black shale; Francevillian series; PREC (1740 ±20 Ma)
				GHANA
Nsuta mine	05° 14'N	01° 57'W	Secondary enrichment	Greenstones (tuff); Birrimian sed-volc series; PREC
				HUNGARY
Epleny mine	47° 13'N	17° 55'E	Marine chemical sediment	Marl; LJUR
Urkut district	47° 05'N	17° 40'E	-do-	-do-
				INDIA
Andhra Pradesh State	18° 22'N	83° 27'E	Marine chemical sediment(?); secondary enrichment	Metasediments; Penganga beds; PROT

1/ Includes some or all of the following items (separated by semicolons): main host rock type, formation name, and host rock age. See footnote 2 for age abbreviations.

2/ Age abbreviations and prefixes:

HOLOCENE	HOLO	PROTEROZOIC	PROT
OLIGOCENE	OLIGO	ARCHEAN	ARCH
CRETACEOUS	CRET	EARLY	E
JURASSIC	JUR	MIDDLE	M
PERMIAN	PERM	LATE	L
PRECAMBRIAN	PREC		

Age of mineralization[2/]	Tectonic setting	Local environment	Principal mineral assemblages[3/]	Comments	Reference
AUSTRALIA—continued					
ECRET	Stable platform	Sheltered basins with high pH.	CPML, PRLS; PLML, TDRK, MNGN, BXBT	Deposited during epeirogenic marine transgression	McIntosh and others (1975)
BRAZIL—continued					
PREC	---	---	CPML, BRNS, LHPT; GBST, KLNT, GTHT; RDCR	---	NMAB[4/] (1981)
-do-	Stable craton	---	RDCR, RDNT, SPSR; HSMN, MNGN, PRLS, CPML, BRNS, GRTT, NSTT, LHPT	Mn-carbonate-silicate rock is currently mined	Do.
-do-	-do-	---	RDCR; CPML,PRLS; HSMN, LHPT, MNGN; GRNT, LMON, MICA, DSPR, HDGL, BOHM	---	Do.
-do-	Stable PREC craton	---	CPML	Two main beds; only lower bed being mined	Dorr (1970)
BULGARIA—continued					
OLIGO	Stable craton	---	RDCR, Mn-CLCT	---	NMAB (1981)
CHINA—continued					
ARCH	---	---	PRLS; PLML	Deposits extend intermittently for 200 km	Ikonnikov (1975)
LPERM	---	---	---	Ferromanganese ores often with Co and Ni	Do.
-do-	---	---	---	Usually 3 beds	Do.
ARCH	---	---	PLML,PRLS; MNGN, RDCR,SRCT,CLCT, QRTZ,LMON,PYRT, HMTT	3 bedded deposits	NMAB (1981)
GABON—continued					
PREC	Stable PREC craton	---	MNGN,PRLS,CPML, NSTT, LHPT, LMON KLNT, ILLT	Largest deposit 19 sq km	NMAB (1981)
GHANA—continued					
PREC	Stable PREC craton	---	PRLS,PLML,MNGN, NSTT; SPSR, QRTZ,CLAY	Workable deposit length 3 km	NMAB (1981)
HUNGARY—continued					
LJUR	---	---	MNGN,PRLS,PLML; CLAY,CLCT	Strata up to 20 m thick	NMAB (1981)
-do-	---	---	MNGN,RDCR,PRLS, PLML; GLCN,GTHT, CLCT,DLMT,PYRT, CLAY	Clay-marl beds interstratified with Mn-carbonate ores	Do.
INDIA—continued					
PREC	Stable craton	---	WAD,PRLS,CPML, JCBS	Mn oxides conformably within sedimentary sequence	Roy (1980)

3/ Abbreviations for mineral names (after Longe and others, 1978, p. 63-68):

BIRNESSITE	BRNS	GLAUCONITE	GLCN	KUTNAHORITE	KTNH	RHODOCHROSITE	RDCR		
BIXBYITE	BXBT	GOETHITE	GTHT	LIMONITE	LMON	RHODONITE	RDNT		
BOEHMITE	BOHM	GROUTITE	GRTT	LITHIOPHORITE	LHPT	SERICITE	SRCT		
BRAUNITE	BRUN	HAUSMANNITE	HSMN	MANGANITE	MNGN	SPESSARTITE	SPSR		
CALCITE	CLCT	HEMATITE	HMTT	MICA	MICA	TEPHROITE	TPRT		
CLAY	CLAY	HOLLANDITE	HLDT	NSUTITE	NSTT	TODOROKITE	TDRK		
CRYPTOMELANE	CPML	HYDRARGILLITE	HDGL	PSILOMELANE	PLML	VREDENBURGITE	VRBG		
DOLOMITE	DLMT	ILLITE	ILLT	PYRITE	PYRT	WAD	WAD		
GARNET	GRNT	JACOBSITE	JCBS	PYROLUSITE	PRLS				
GIBBSITE	GBST	KAOLINITE	KLNT	QUARTZ	QRTZ				

4/ National Materials Advisory Board

Site name	Latitude	Longitude	Deposit type	Host rock1/
				INDIA
Goa State	15° 30'N	73° 55'E	Secondary enrichment	Quartz, phyllite, iron formation; Dharwar supergroup; PREC (950-1500 Ma)
Gujarat State	23° 00'N	72° 30'E	Marine chemical sediment(?)	Dharwar supergroup; PREC
Karnataka State (Mysore State)	13° 56'N	75° 31'E	Marine chemical sediment	Graywacke,dolostone,limestone,quartzite phyllite,banded iron formation; Dharwar supergroup; PREC (1200 Ma)
Madhya Pradesh and Maharashtra States	21° 50'N	80° 18'E	Marine chemical sediment(?)	Metasediments; Sausar group; PREC
Orissa State	21° 38'N	85° 40'E	Secondary enrichment	Mica schists and phyllites; Gangpur group; PREC
				MEXICO
Molango mine	20° 50'N	98° 44'W	Marine chemical sediment	Manganiferous limestone; Taman formation; LJUR
				MOROCCO
Imini mine	30° 44'N	06° 54'W	Marine chemical sediment; diagenesis	Dolostone; LCRET
				SOUTH AFRICA
Kalahari field	27° 11'S	22° 57'E	Syngenetic (marine chemical sediment)	Banded iron formation; Voelwater formation; PREC (2300-2070 Ma)
Postmasburg field	28° 03'S	23° 03'E	Epigenetic (secondary enrichment); replacement bodies	Shale and slump material; PREC (2300-2070 Ma)
Western Transvaal manganese deposits	26° 15'S	27° 01'E	Epigenetic (secondary enrichment); residual weathering and concentration	Dolostone; Malmani supergroup; PREC (2100-2224 Ma)
				SOVIET UNION
Bolshe Tokmak deposits	47° 15'N	35° 42'E	Marine chemical sediment	Fine clastic rocks; OLIGO
Nikopol deposits	47° 34'N	34° 25'E	-do-	-do-
Tchiatura deposits	42° 19'N	43° 18'E	-do-	-do-
				UPPER VOLTA
Tambao deposit	14° 47'N	00° 04'E	Secondary enrichment	Amphibolites; Gouba formation; PROT

1/ Includes some or all of the following items (separated by semicolons): main host rock type, formation name, and host rock age. See footnote 2 for age abbreviations.

2/ Age abbreviations and prefixes:

HOLOCENE	HOLO	PROTEROZOIC	PROT
OLIGOCENE	OLIGO	ARCHEAN	ARCH
CRETACEOUS	CRET	EARLY	E
JURASSIC	JUR	MIDDLE	M
PERMIAN	PERM	LATE	L
PRECAMBRIAN	PREC		

Age of mineralization[2]	Tectonic setting	Local environment	Principal mineral assemblages[3]	Comments	Reference
INDIA—continued					
PREC	Stable craton	---	PRLS,PLML,WAD	Lateritic ore deposits	Roy (1980)
-do-	-do-	---	PRLS,PLML; WAD, BRUN	Mn oxides conformably within sedimentary sequence	Do.
-do-	-do-	---	PRLS,CPML,MNGN, BRUN	Oxide bodies interbanded and co-folded with chert	Sawyer (1980)
-do-	-do-	---	BRUN,PLML,CPML, HLDT,PRLS,JCBS, BXBT,HSMN,MNGN, VRBG	Mn oxides in belt 200 km by 25 km	Roy (1980)
-do-	-do-	---	---	Mn oxides interstratified with gondite	Do.
MEXICO—continued					
LJUR	Stable craton	---	RDCR,CLCT, KTNH	Mn content decreases from base of limestone	Tavera and Alexándri (1972)
MOROCCO—continued					
LCRET	Stable craton	---	PRLS,CPML, LHPT	2 or 3 ore beds	[4] NMAB (1981)
SOUTH AFRICA—continued					
PREC (2300-2070 Ma)	Kalahari sedimentary basin	Dolomite and amygdaloidal andesitic lava	BRUN,HSMN,CPML, JCBS,BXBT, TDRK	Basin measures 41 km by 5 km	Taljaardt (1979)
-do-	Gamagara shale rests unconformably on Ghaap Plateau dolomite	Dolomite which contains 0.5-3% Mn	BXBT,BRUN,HSMN JCBS	Replacement bodies in shale and in slump material in karst pockets	Do.
HOLO	Fault zones which provid- ed drainage and weathering facilities.	Cherty dolostone	PRLS,PLML	Deposits seldom comprise more than a few million metric tons each	---
SOVIET UNION—continued					
OLIGO	Stable craton	---	PRLS,MNGN,PLML, Fe oxides, Poly- per-MNGN; CLCT, RDCR, Mn-CLCT	About 92% carbonate ores and 8% oxide ores	Shnyukov and Orlovsky (1980)
-do-	-do-	---	-do-	Both carbonate and oxide ores	Gryaznov and Danilov (1980)
-do-	-do-	---	PRLS,MNGN,PLML	---	Avaliani and
UPPER VOLTA—continued					
PROT	---	---	HSMN,CPML,MNGN, PRLS, NSTT, TPRT; RDCR, KTNH, Hydro- HSMN	Largest known Mn deposit in Upper Volta	NMAB (1981)

3/ Abbreviations for mineral names (after Longe and others, 1978, p. 63-68):

BIRNESSITE	BRNS	GLAUCONITE	GLCN	KUTNAHORITE	KTNH	RHODOCHROSITE	RDCR
BIXBYITE	BXBT	GOETHITE	GTHT	LIMONITE	LMON	RHODONITE	RDNT
BOEHMITE	BOHM	GROUTITE	GRTT	LITHIOPHORITE	LHPT	SERICITE	SRCT
BRAUNITE	BRUN	HAUSMANNITE	HSMN	MANGANITE	MNGN	SPESSARTITE	SPSR
CALCITE	CLCT	HEMATITE	HMTT	MICA	MICA	TEPHROITE	TPRT
CLAY	CLAY	HOLLANDITE	HLDT	NSUTITE	NSTT	TODOROKITE	TDRK
CRYPTOMELANE	CPML	HYDRARGILLITE	HDGL	PSILOMELANE	PLML	VREDENBURGITE	VRBG
DOLOMITE	DLMT	ILLITE	ILLT	PYRITE	PYRT	WAD	WAD
GARNET	GRNT	JACOBSITE	JCBS	PYROLUSITE	PRLS		
GIBBSITE	GBST	KAOLINITE	KLNT	QUARTZ	QRTZ		

4/ National Materials Advisory Board

Site name	Year of discovery	Mining method[1]	Year of first production	Commodities	Annual production[2]
					AUSTRALIA
Groote Eylandt mine	1961	S	1966	Mn	1,548 (concentrate); 48-49%; 1977-1981
					BRAZIL
Azul (Carajas) deposits	1971	N	---	Mn	---
Morro da Mina deposit	1894	S	1901	Mn	656; 35%; 1979
Serro do Navio mine (Amapa)	1949	S	1957	Mn	1,008; ~41%; 1980
Urucum mine	1870	U	1912	Mn	200; 40-46%; 1978
					BULGARIA
Varna district	about 1956	U	---	Mn	40; 27.5%; 1978
					CHINA
Hsiangtan deposits	---	---	---	Mn	---
Leiping district	---	---	---	Mn	---
Tsunyi district	---	---	---	Mn	---
Wafangtzu district	---	---	---	Mn	20; avg. 1980 (est)
					GABON
Moanda mine	1951	S	1962	Mn	1,695 (product), 50%; 1979
					GHANA
Nsuta mine	1914	S	1916	Mn	476; 50%; 1979
					HUNGARY
Epleny mine	1928	U	---	Mn	---
Urkut **district**	---	U	---	Mn	156.181; 23%; 1978
					INDIA
Andhra Pradesh State	---	---	1895	Mn	174.963; 40-45%; 1971
Goa State	---	S	---	Mn, Fe	202.7; 25-45%; 1970
Gujarat State	1869	S,U	1905	Mn	---
Karnataka State (Mysore State)	---	---	---	Mn	500; 30-40%; 1972

1/ S, surface; U, underground; N, not yet producing

2/ Includes some or all of the following items (separated by semicolons): production in thousand metric tons of material mined (unless other processing stage is indicated); grade of reported material in percent Mn (unless otherwise specified); and year of production (or range of years used to estimate average annual production).

Cumulative production[3]	Resources[4]	Comments
AUSTRALIA—continued		
18,876 (concentrate); 48-49%; 1966-1981	326,000; R1E; 35.0%; 1982 110,000; R2E; 35%; 1982	Expansion to 3 million metric tons capacity by 1986 has been deferred
BRAZIL—continued		
---	65,000; R1E; 38%; 1979	Detrital, pelitical, and grained ores 44% Mn
6,000; 1902-1956	1,500; R1E; 43%; 1981 3,000; R2E; 27%; 1979	Annual production is for State of Minas Gerais
20,750 (washed ore); 48.5%; 1957-1979	12,800; R1E; 40-45%; 1979 3,200; R2E; 40-45%; 1979 5,000; R1S; 1979	---
900; 46%; 1957-1973	17,000; R1E; 46%; 1979 27,000; R2E; 46%; 1979 15,000; R2S; 47%; 1979	Not thoroughly explored; marginally commercial
BULGARIA—continued		
60,000; 25%; 1961-1980	1,145; R1E; 23.1%; 1980 26,091; R1S; 17.3%; 1961 1,161; R2E; 20.6%; 1980	Annual production for all of Bulgaria; pisolites contain 30-70% of the ore
CHINA—continued		
---	>10,000; R1E; 40-50%; 1973	Little published data
---	>10,000; R1E; <30%; 1973	Chinese production: 1.1 million metric tons >30% Mn, 1973
---	>10,000; R1E; ~20%?; 1973	Ferruginous Mn ore with Co and Ni
---	4,000; R1E; 16-18%; 1964	Ferruginous Mn ore, 16-18% Fe
GABON—continued		
25,000; 1962-1978	78,000; R1E; 44%; 1980 142,000; R2E; 44%; 1980	Highest metallurgical grade product in world
GHANA—continued		
24,000; ~50%; 1916-1976	20,000; R1E; 30%; 1980	Metallurgical and battery grade ore
HUNGARY—continued		
---	---	Oxide ore 24.4% Mn; carbonate ore 14% Mn
---	215,000; R1E; 20.5%; 1980	Annual production combines oxide and carbonate ore; resources for all of Hungary
INDIA—continued		
>2,000; ~40-45%; 1892-1953	10; R1E; 38-46%; 1971 140; R1E; <38%; 1971 290; R2E; 38-46%; 1971 1,260; R2E; <38%; 1971	---
1,452; 25-45%; 1955-1965	850; R1E; 25-49%; 1980 7,700; R2S; 25-49%; 1980	195 pocket mines operating in 1970
---	2,010; R2E; >46%; 1971 540; R2E; 38-46%; 1971 350; R2E; overlapping grades; 1971	Very limited mining since 1964; high phosphorous content
---	230; R1E; 38-46%; 1971 60; R1E, <38%; 1971 980; R2E; >46%; 1971 1,540; R2E; 38-46%; 1971 1,020; R2E; <38%; 1971 11,420; R2E; overlapping grades; 1971	---

3/ Includes some or all of the following items (separated by semicolons): production in thousand metric tons of material mined (unless other processing stage is indicated); grade of reported material in percent Mn (unless otherwise specified); and years for reported cumulative production.

4/ Includes, for various resource categories, some or all of the following items (separated by semicolons): resource in thousand metric tons; U.N. resource classification (Schanz, 1980); grade in percent Mn; and year of estimate.

TABLE 7.—*Selected production and mineral-resource information from*

Site name	Year of discovery	Mining method[1]	Year of first production	Commodities	Annual production[2]
					INDIA
Madhya Pradesh and Maharashtra States	---	S,U	1899	Mn	---
Orissa State	1907	S	---	Mn	485.232 (metal); 1971
					MEXICO
Molango mine	1960	S,U	1968	Mn	925; ~28%; 1980
					MOROCCO
Imini mine	1918	U	1946	Mn	120; 46%; avg. 1980 (est)
					SOUTH AFRICA
Kalahari field	1940	S,U	1940	Mn	4,394.671; 42.3%; 1982
Postmasburg field	1922	S	1923	Mn	484.025; 30-40%; 1982
Western Transvaal manganese deposits	---	S	1943	Mn	303.731; 35% (MnO_2); 1982
					SOVIET UNION
Bolshe Tokmak deposits	1952	S,U	---	Mn	14,400; 18.5-26.4%; 1978
Nikopol deposits	1883	S,U	1886	Mn	See Bolshe Tokmak deposits
Tchiatura deposits	1846	S,U	1879	Mn	2,500 (concentrate); 2/3 is 48.7%; 1978
					UPPER VOLTA
Tambao deposit	1960	S	---	Mn	---

1/ S, surface; U, underground; N, not yet producing

2/ Includes some or all of the following items (separated by semicolons): production in thousand metric tons of material mined (unless other processing stage is indicated); grade of reported material in percent Mn (unless otherwise specified); and year of production (or range of years used to estimate average annual production).

Cumulative production3/	Resources4/	Comments
INDIA—continued		
>32,000; ~45-50%; 1899-1972	7,030; R1E; >46%; 1971 120; R1E; 38-46%; 1971 60; R1E; overlapping grades; 1971 36,930; R2E; >46%; 1971 4,510; R2E; 38-46%; 1971 170; R2E; <38%; 1971 170; R2E; overlapping grades; 1971	---
---	3,750; R2E; 38-46%; 1971 6,860; R2E; <38%; 1971 33,030; R2E; overlapping grades; 1971	Produced 34% of Indian high-grade ores in 1971
MEXICO—continued		
---	26,300; R1E; 27%; 1980 1,500,000; R2E+R2S; 27.7%; 1982	R1E includes 500,000 metric tons oxide ore at 47% Mn
MOROCCO—continued		
---	1,000; R1E; 46%; 1983 500; R2E; 46%; 1980	Ore is battery active
SOUTH AFRICA—continued		
59,290; ~42%; 1940-1982	334,800; R1E; >40%; 1979 8,294,000; R1E; ≤40%; 1979 6,000; R2E; >40%; 1979 3,931,000; R2E; ≤40%; 1979	80% mining recovery expected
27,805,425; 30-40%; 1923-1982	15,000; R1E; 30-48%; 1979	---
5,164,753; ~36% (MnO_2 grade); 1943-1952	5,000; unknown class; 1982 10,000; R2E; 1982	---
SOVIET UNION—continued		
---	149,000; R1E; 18.5%; 1980? 951,000; R2E; 18.5%; 1980	Oxide (8%) and carbonate (92%) ores, annual production is for Nikopol and Bolshe together
---	430,000; R1E; 22%; 1980? 225,000; R2E; 22%; 1980?	---
---	155,000; R1E; 24.5%; 1980?	Oldest significant Mn ore-producing region in world
UPPER VOLTA—continued		
---	16,100; R1S; 53.8%; 1970 730; R1S; 49.8%; 1970	---

3/ Includes some or all of the following items (separated by semicolons): production in thousand metric tons of material mined (unless other processing stage is indicated); grade of reported material in percent Mn (unless otherwise specified); and years for reported cumulative production.

4/ Includes, for various resource categories, some or all of the following items (separated by semicolons): resource in thousand metric tons; U.N. resource classification (Schanz, 1980); grade in percent Mn; and year of estimate.

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