CIRC. 930-D

U.S. GEOLOGICAL SURVEY CIRCULAR 930-D

International Strategic Minerals Inventory Summary Report—Nickel

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, the United Kingdom, and the United States of America

Major geologic age units

Age			Million years before present
Holocene	QUATERNARY	CENOZOIC	0.01
Pleistocene	QUATERNARY	CENOZOIC	2
Pliocene	TERTIARY	CENOZOIC	5
Miocene	TERTIARY	CENOZOIC	24
Oligocene	TERTIARY	CENOZOIC	38
Eocene	TERTIARY	CENOZOIC	55
Paleocene	TERTIARY	CENOZOIC	63
Late Cretaceous	Cretaceous	MESOZOIC	96
Early Cretaceous	Cretaceous	MESOZOIC	138
Jurassic		MESOZOIC	205
Triassic		MESOZOIC	~240
Permian		PALEOZOIC	290
Pennsylvanian	Carboniferous	PALEOZOIC	~330
Mississippian	Carboniferous	PALEOZOIC	360
Devonian		PALEOZOIC	410
Silurian		PALEOZOIC	435
Ordovician		PALEOZOIC	500
Cambrian		PALEOZOIC	~570
PRECAMBRIAN	Late Proterozoic	PROTEROZOIC	900
PRECAMBRIAN	Middle Proterozoic	PROTEROZOIC	1600
PRECAMBRIAN	Early Proterozoic	PROTEROZOIC	2500
PRECAMBRIAN		ARCHEAN	

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By John H. DeYoung, Jr., David M. Sutphin,
Antony B. T. Werner, and Michael P. Foose

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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 nickel, 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) and by Antony B. T. Werner of the Canadian Department of Energy, Mines and Resources (EMR), Mineral Policy Sector (MPS). Nickel inventory information was compiled by O. Roger Eckstrand, EMR, Geological Survey of Canada; Brian G. Elliott, Australian Bureau of Mineral Resources, Geology and Geophysics (BMR); Michael P. Foose (chief compiler), USGS; Ian Goldberg, South African Department of Mineral and Energy Affairs (MEA), Minerals Bureau; Erik C. I. Hammerbeck, MEA, Geological Survey; William H. Laughlin, EMR, MPS; Y. J. Lepinis, EMR, MPS; Colleen M. Mock, BMR; Suzanne W. Nicholson, USGS; C. Roger Pratt, BMR; Cynthia M. Sears-McGeehin, USGS, and A. G. Sozanski, EMR, MPS. Additional contributions to the report were made by Thomas F. Torries, College of Mineral and Energy Resources, West Virginia University; Michael P. Lee, USGS; Jan Zwartendyk, EMR, MPS; Ian Goldberg; and Don I. Bleiwas, James F. Lemons, David A. Buckingham, and Scott F. Sibley, U.S. Bureau of Mines.

Director

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INTERNATIONAL STRATEGIC MINERALS INVENTORY SUMMARY REPORT

NICKEL

By John H. DeYoung, Jr.,[1] David M. Sutphin,[1] Antony B. T. Werner,[2] and Michael P. Foose[1]

ABSTRACT

Major world resources of nickel 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, the United Kingdom, and the United States of America. This report, designed to be of benefit to policy analysts and geologists, contains two parts. Part I presents an overview of the resources and potential supply of nickel on the basis of inventory information, which covers only discovered deposits. 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 United States, Canada, and the Federal Republic of Germany. It was subsequently joined by the Republic of South Africa, Australia, and the United Kingdom.

The objective of ISMI reports 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 nickel in a format designed to be of benefit to policy analysts and geologists. Knowledge of the geologic aspects of mineral resources is essential in order to discover and develop mineral deposits. However, technical, financial, and political decisions must be made, and often transportation and marketing systems must be constructed before ore can be mined and processed and the products transported to the consumer; the technical, financial, and political aspects of mineral-resource development are not specifically addressed in this report. The report addresses the primary stages in the supply process for nickel and does not include considerations of nickel demand.

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 data in the ISMI nickel inventory were collected from August 1982 to November 1984. The report was submitted for review and publication in January 1985. The information used was the best available to the various agencies of the countries that contributed to the preparation of this report. Those agencies were

[1] U.S. Geological Survey.

[2] Canadian Department of Energy, Mines and Resources, Mineral Policy Sector.

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.

No geologic definition of a deposit (or district) is used for compiling records for this report. Deposits (or districts) are selected for the inventory on the basis of their present or expected future contribution to world supply. Records of all deposits compiled by ISMI participants meet this general "major deposit" criterion and are included in the inventory.[3] For some areas, such as Sudbury district (Canada) and Kambalda-St. Ives-Tramways district (Australia), inventory records have been compiled on a deposit-by-deposit basis, but data for district production and resources are presented only as district totals on one of the deposit records. In other cases, for example, the Biankouma deposit (Ivory Coast), little published data are available and resources of various deposits or mines may be grouped to give a more general regional picture that may be focused by further exploration and evaluation. Because the assignment of a specific number of records to the nickel resources of a district or of an area was not done with the same detail by all compilers, comparisons among numbers of nickel records in different geographic areas or among numbers of nickel records and those of other commodities reported on in this series are not meaningful.

The ISMI record collection and this report on nickel 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.

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

Not all companies or countries report resource data in the same way. Mining recovery from an ore body depends on individual conditions and may vary considerably, typically in the range of 75 to 90 percent for underground metal mining; that is, 10 to 25 percent of the in situ resources cannot be extracted.

The World Bank economic classification of countries (World Bank, 1983, p. 148–149), which is based primarily on GNP per capita, has been used in this and other ISMI reports to illustrate distribution of resources and production according to economic groupings of countries. This classification was chosen because it relies primarily on objective economic criteria and does not contain political bloc labels that might be perceived differently by different countries.

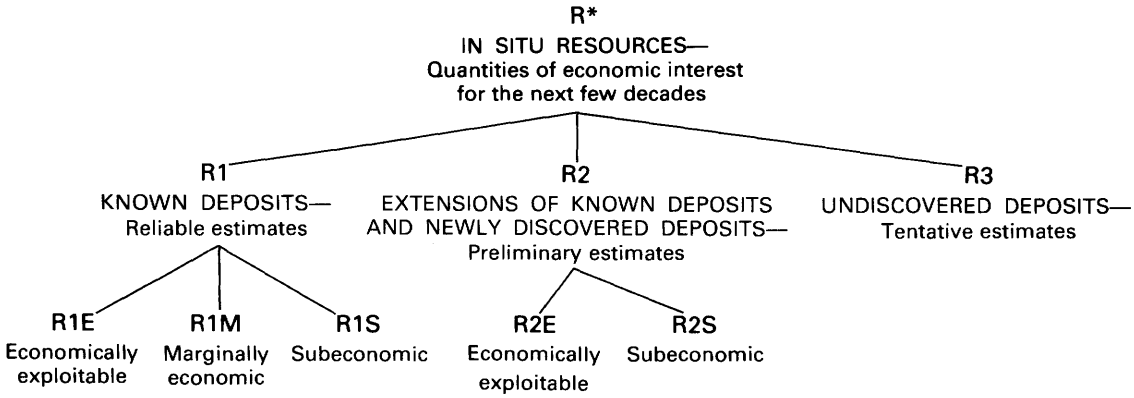
USES AND SUPPLY ASPECTS

Nickel is an important constituent of many stainless steels, alloy steels, and nonferrous alloys. It is also used for electroplating. Over 90 percent of the 620,000 metric tons of nickel produced in the world in 1983 was used for these purposes. Other uses, which constitute about 10 percent of nickel consumption, are in ceramics (oxide or sulfate), batteries (hydroxide), and catalysts (nickel metal or nickel compounds).

In the form of nickel metal, ferronickel, and oxide, nickel imparts corrosion resistance and strength to numerous alloys designed for specific applications (Sibley, 1983b, p. 2). Several other materials could take the place of nickel in most of its uses, except in superalloys for aerospace applications (which consumed about 4 percent of world mine production in 1979 (Roskill Information Services, 1981, p. 14 and p. 255)). However, with few exceptions, this substitution would entail increased cost or some sacrifice in physical and chemical characteristics and, hence, would affect the economics or performance of the product. Present and potential nickel substitutes for various applications include aluminum, coated steel, plastics, nickel-free specialty steels, titanium, platinum, cobalt, and copper (Chamberlain, 1985, p. 107).

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

- Between 1950 and 1982, the number of countries with significant nickel mine production in-



*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 Schanz, 1980, p. 313).

creased from three (Canada, New Caledonia (an overseas territory of France), and the Soviet Union) to over 20. In 1982, seven countries—Australia, Canada, Cuba, Indonesia, New Caledonia, South Africa, and the Soviet Union—accounted for over 80 percent of mine production. The number of nickel-producing companies and countries continued to increase. At the end of 1984, there were 44 companies in 25 countries producing nickel (Bannon, 1984).

- U.S. demand for nickel during and after the Korean War spurred development of nickel resources in the 1950's (Cameron and Vogely, 1976, p. 221).
- In the 1950's, developments in metallurgical extraction technology, such as pressure leaching and reduction-precipitation, enhanced the economic status of nickel laterite deposits. This status was further improved by the decline (in real terms) of energy prices in the 1960's (Canada Department of Energy, Mines and Resources, 1984, p. 8) and by market acceptance of ferronickel obtained from these sources.
- Successful mineral exploration in the Kambalda-St. Ives-Tramways district of Western Australia in 1964–66 (Raggatt, 1968, p. 143) led to the development of a nickel mining industry in Australia.
- The growth rate of nickel consumption declined after the first oil embargo in 1973. Except for a brief period in the late 1970's, world nickel consumption has not surpassed the 1974 peak (Canada Department of Energy, Mines and Resources, 1984, p. 8).
- The addition of new production capacity in many parts of the world in the 1970's, in the expectation of a continuation in the prior rate of growth, led to a severe surplus situation in the early 1980's. The surplus resulted in production cutbacks and mine closures in some countries; in others, state subsidization evolved.
- The price of nickel (U.S. spot price) declined from 1980 through early 1984.
- State ownership and control of nickel mining and smelting operations has increased significantly. In 1950, about 85 percent of world capacity was privately owned. By 1984, private ownership had decreased to about 60 percent (Canada Department of Energy, Mines and Resources, 1984, p. 9).
- The Soviet Union and Cuba have emerged as significant exporters of nickel. Net exports by COMECON (Council for Mutual Economic Assistance) countries are on the order of 45,000 metric tons per year, or about 10 percent of Western World consumption. The introduction of new technology (solvent extraction and electrowinning) is expected to increase Cuban output from a present 40,000 metric tons per year to at least 70,000 metric tons per year in 1990.
- Nickel may be produced as a coproduct with other commodities such as copper and cobalt, or nickel may be a byproduct from mining of another commodity such as platinum-group ele-

ments. Production of coproducts and byproducts makes more complete use of the material in the ore. However, it has the disadvantage that nickel production may bear little relation to the demand for nickel. In the coming decade, for example, an increase is expected in the output of byproduct nickel from South African platinum-mining operations. This increase could add to the world nickel overcapacity, but South African companies will be able to produce the nickel economically from low-grade ore as a byproduct of platinum mining.
- In the late 1970's, the nickel industry evolved from an oligopolistic industry with Inco as the predominant producer to a highly competitive industry with many independent sources of nickel.

DISTRIBUTION OF NICKEL DEPOSITS AND DISTRICTS

The world map in figure 2 shows the locations of major nickel deposits and districts. Some of the map locations represent only one of the site names listed in the tables in Part II, while others represent several sites (inventory records) within a country or district grouping. For example, 21 mining districts are represented by the map symbol for New Caledonia, and 22 deposits and mines are represented by the symbol for the Sudbury district in Ontario, Canada. The locations of nickel deposits in the Sudbury district are shown in figure 3. Figure 4 is a map of the deposits and mines in New Caledonia, and figure 5 shows the location of deposits of the Kambalda deposit group in the Kambalda-St. Ives-Tramways district in Western Australia.

Major nickel deposits in this report are of two distinctly different geologic types: magmatic sulfide and laterite. Figure 2 shows 27 locations of laterite deposits, representing 52 inventory records, and 26 locations of magmatic sulfide deposits, representing 69 inventory records. Figure 2 also indicates the size of the deposits or deposit groups at each location. There are nine large (greater than 3×10^6 metric tons of contained nickel in total resources) deposits or groups of deposits shown; these 9 represent 57 of the 121 records in the ISMI nickel inventory. The 25 medium-size (greater than 3×10^5 and less than 3×10^6 metric tons of contained nickel in total resources) locations represent 44 inventory records, and the 18 small-size (less than 3×10^5 metric tons of contained nickel in total resources) locations represent 19 records. The size of the Uitkomst deposit in South Africa is unreported.

Magmatic sulfide deposits form when sulfur combines with nickel and perhaps additional elements, such as copper, cobalt, and platinum-group metals, in magmas of mafic and ultramafic compositions. The dense sulfides concentrate at the bottom of the magma chamber and, upon solidification of the magma, may form minable lens-shaped deposits composed mostly of massive to disseminated pyrrhotite ($Fe_{1-x}S$), pentlandite ($(Fe, Ni)_9S_8$), and chalcopyrite ($CuFeS_2$). The magmatic sulfide deposit class is further subdivided by the host rock of the deposit, ultramafic or gabbroic (mafic).[4] Examples of gabbroic-hosted deposits are the Selebi-Pikwe district in Botswana (a mafic-ultramafic intrusive complex), the Bushveld Complex in South Africa (a large layered intrusion), and deposits in the Sudbury (Ontario) district, Canada. The emplacement of the Sudbury host intrusion is generally thought to be related to the impact of a large meteorite about 2 billion years ago (Dietz, 1964). (Pye and others (1984) and Rousell (1984, p. 64, 72–73) have reviewed the rival volcanic and astrobleme theories on Sudbury Basin origin.) Examples of ultramafic-hosted deposits[5] are the Agnew mine in Western Australia (intrusive dunite association) and the Kambalda-St. Ives-Tramways district in Western Australia (volcanic peridotite association). Later deformation and metamorphism may have significantly altered deposits so that the original deposit type can only be inferred. Examples of such deformed and metamorphosed deposits are the Thompson mine, Manitoba, Canada, and the Shebandowan mine, Ontario, Canada, which are classified in this report as "magmatic, ultramafic."

Nickel laterite deposits are soils formed during the deep tropical weathering of nickel-bearing ultramafic rocks. During weathering, the relatively small amounts of nickel (0.2–0.3 percent) in the primary rock are released and concentrated in the developing soil. The laterite typically has an upper zone in which nickel is combined with iron oxides and a lower zone in which nickel occurs in complex magnesium-rich silicates. In addition to nickel, laterites may contain minor amounts of chromium and cobalt. Most laterites occur in areas with tropical climates (fig. 2); deposits in New Caledonia, the Philippines, and Indonesia that are listed in the ISMI nickel inventory are examples of the laterite type.

Other types of nickel deposits exist, such as hydrothermal veins containing nickel sulfides and arsenides, and ocean-floor nodules and seamount crusts

[4] This classification of magmatic sulfide nickel deposits does not include the more detailed subdivisions of the classification system of Ross and Travis (1981) but is consistent with the larger classes of that system.

[5] Most of these are in a recently (1969) recognized type of ultramafic volcanic rocks that are called komatiites.

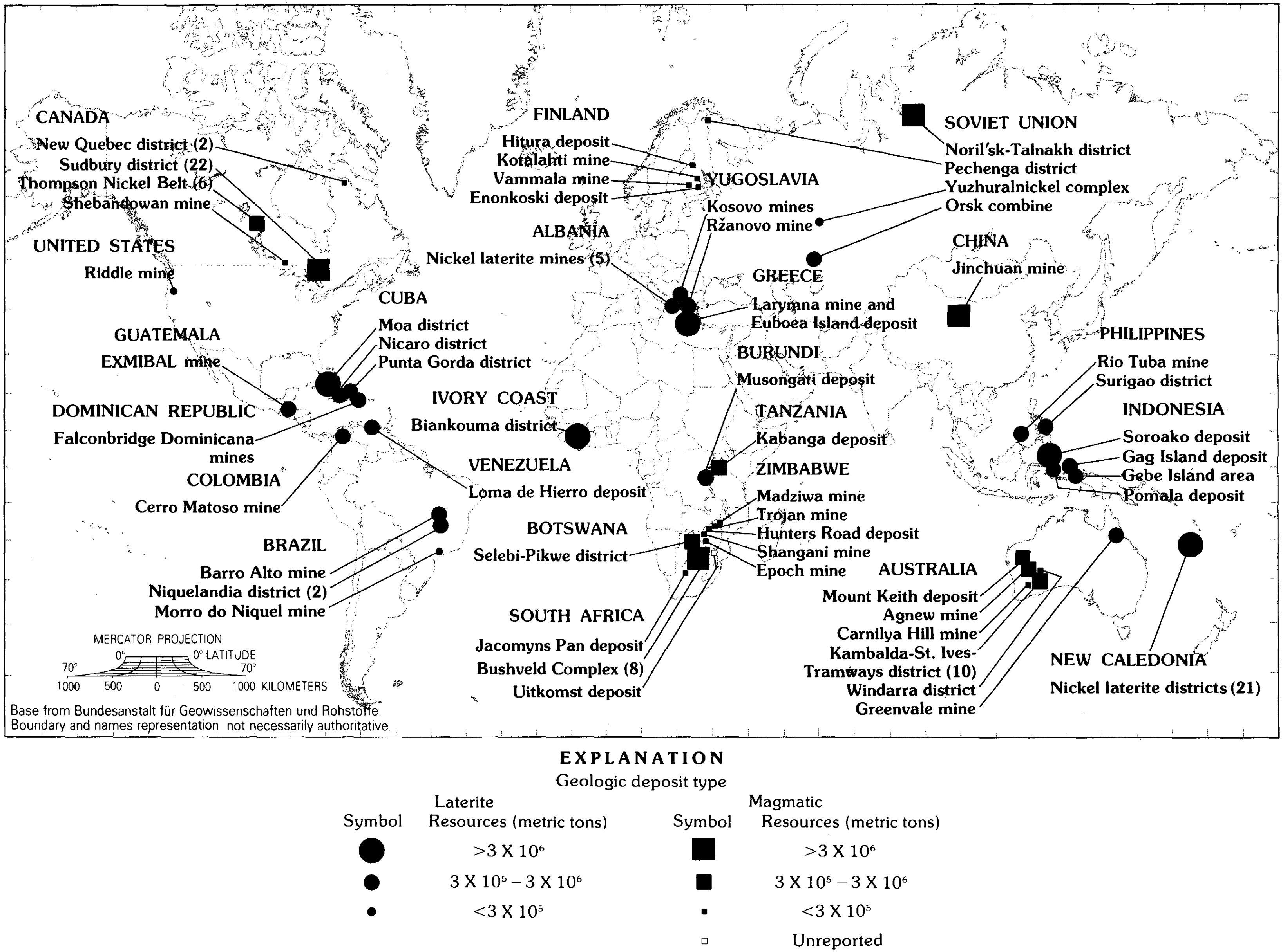
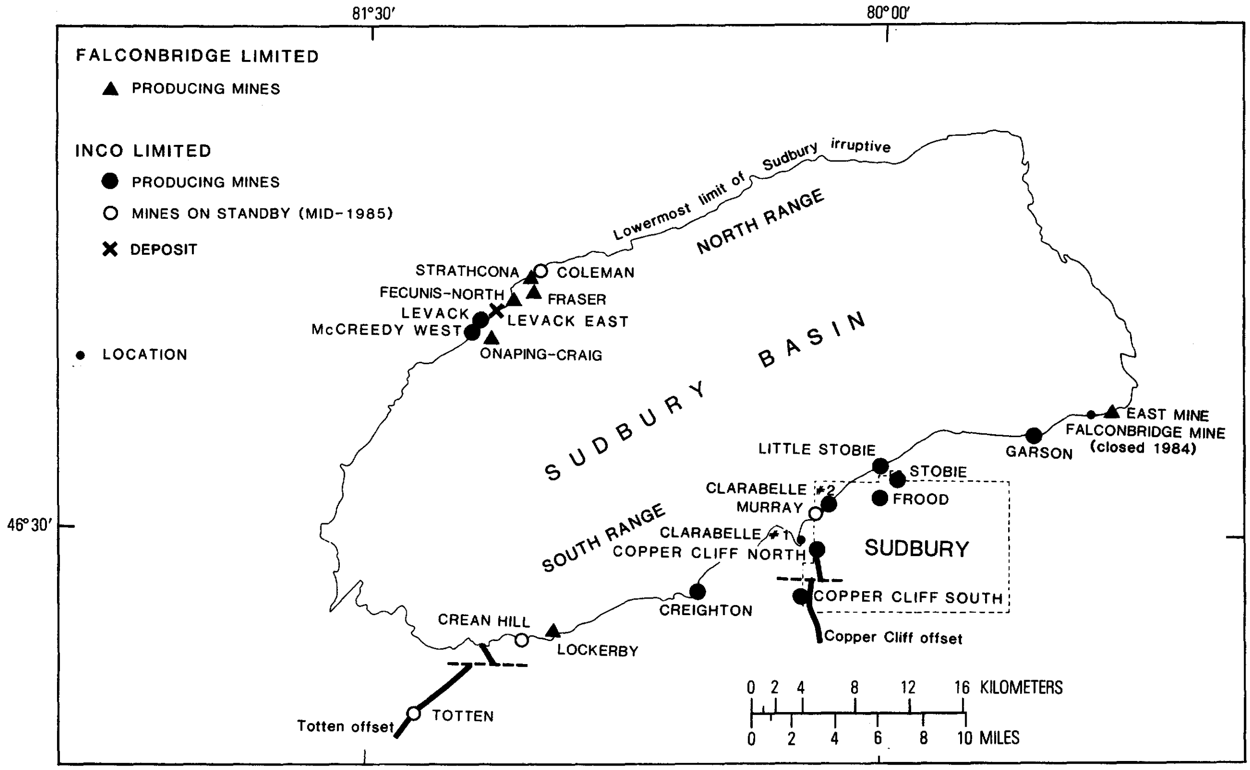
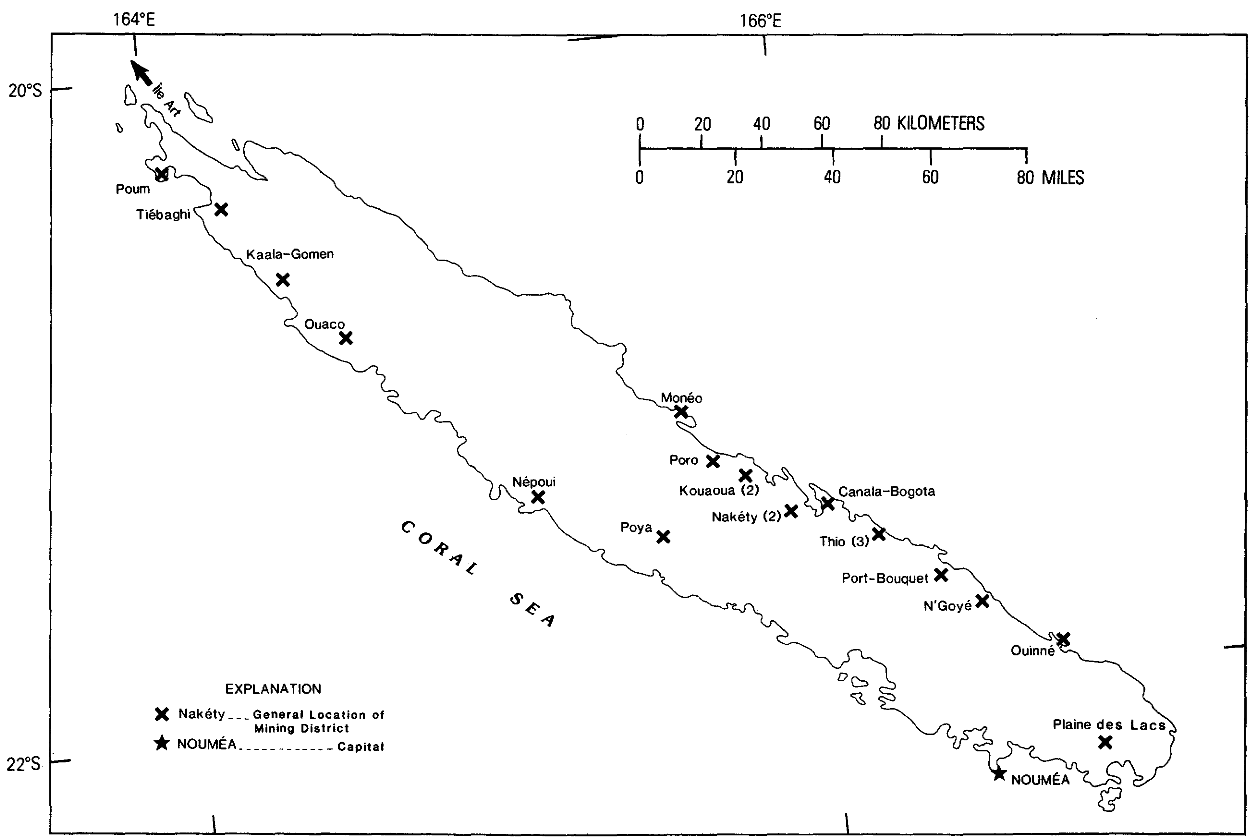


FIGURE 2.—Location, deposit type, and estimated resources of major nickel deposits and districts in the world. Numbers in parentheses indicate the number of records (deposits and districts) for each location. Location names are from the tables in Part II.



Base from Geological Survey of Canada.



Base from Service Géologique SLN-Nouméa

FIGURE 3 (top left).—Nickel deposits in the Sudbury district, Ontario, Canada. Location names are from the tables in Part II.

FIGURE 4 (bottom left).—Nickel districts in New Caledonia. Numbers in parentheses indicate the number of records for each district that has more than one record listed in the ISMI nickel inventory. Location names are from the tables in Part II.

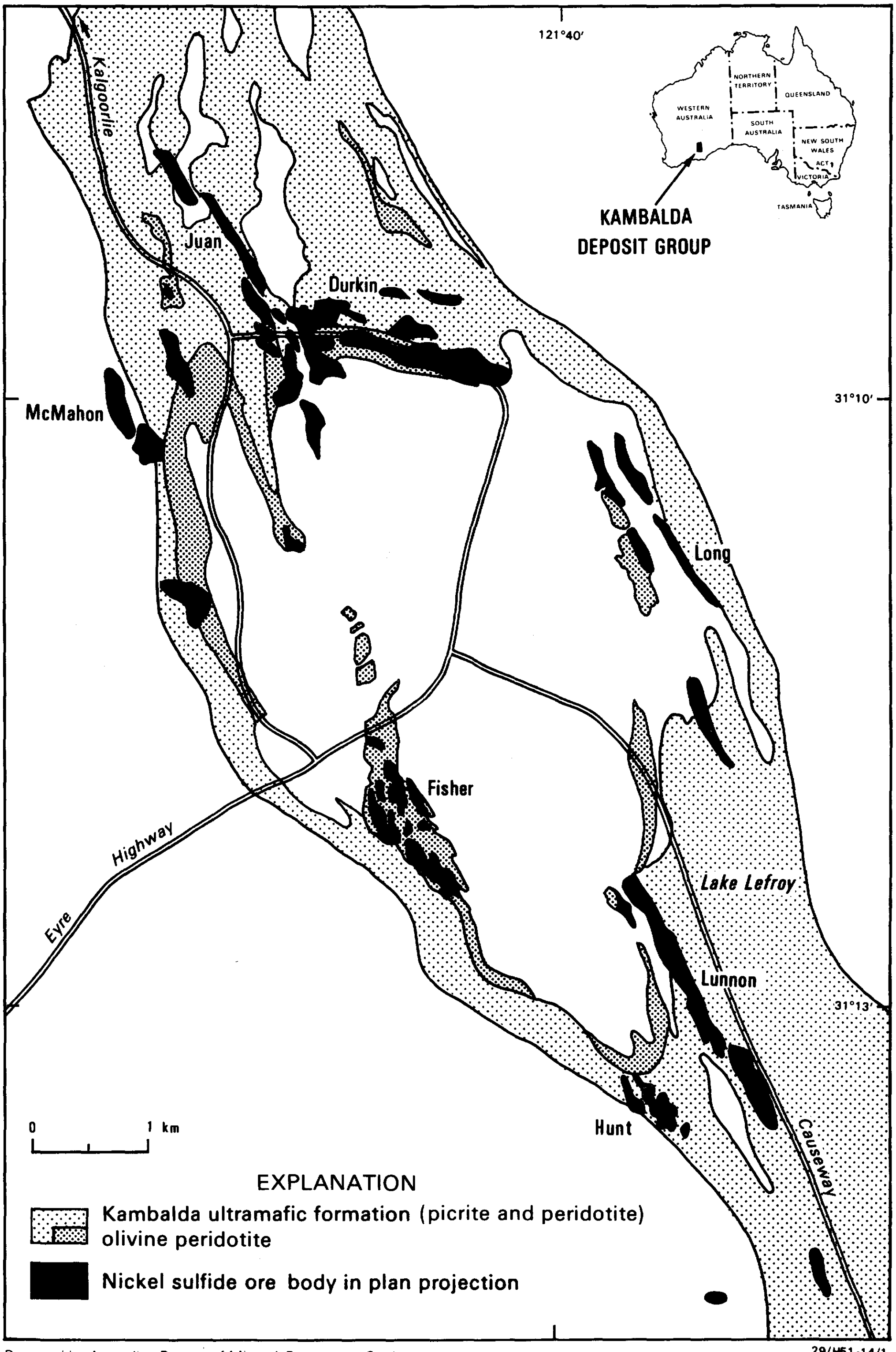


FIGURE 5.—Nickel deposits in the Kambalda deposit group, Western Australia. Location names are from the tables in Part II.

TABLE 1.—*Nickel 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 contained nickel; figures in parentheses are percent of column totals]

Geologic deposit type[1]	Number of records	Resource category: R1E[2]	Resource category: All other R1 and R2[3]	Cumulative production[4]
Laterite	52 (43)	69.9 (72)	16.1 (61)	4.97 (35)
Magmatic sulfide	69 (57)	27.4 (28)	10.4 (39)	9.40 (65)
Total[5]	121 (100)	97.4 (100)	26.5 (100)	14.4 (100)

1 Deposit types of the world's major nickel deposits are shown in figure 2.
2 Reliable estimates from identified deposits with economically exploitable resources (fig. 1).
3 That is, 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. With the exception of New Caledonian laterite deposits, for which Territorial production figures were used, no estimates were added for those deposits for which no cumulative production is 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 resources.
5 Figures may not add to totals shown due to rounding.

that contain up to 1.9 percent nickel in the form of nickel oxides. The hydrothermal deposits are not large enough to be included in this inventory of major nickel deposits and districts. The ocean-floor nodules and seamount crusts contain in total an enormous quantity of nickel. Mining consortia have been expending much effort on developing feasible extraction technology since the mid-1960's, but technological and legal barriers confront ocean mining. Antrim and Sebenius (1983, p. 98–99) argue that deep ocean mining is not likely to occur at least for the next 35 years for economic reasons.

The characteristics of different geologic types of nickel deposits influence the costs of producing nickel from them. For example, mining costs are higher for underground sulfide mines than for surface-mining operations at laterite deposits, but sulfide ores can be concentated readily by established mineral-dressing methods, and only a fraction (about 10 percent) of the mined material must pass from the concentrator to the energy-intensive smelting process (Dasher, 1976, p. 383). The laterite ores, however, cannot be effectively concentrated (Matthews and Sibley, 1980, p. 617), and the basic types of processing[6] for laterite ores must be applied to almost all of the mined ore (O'Kane, 1979, p. 504–507). Because the complete production process for nickel (from ore to metal) from laterite deposits is more energy-intensive than that for nickel from magmatic sulfide deposits, research on improved processing technologies for laterite nickel ores and on new energy sources will influence the distribution of future production between these two geologic deposit types.

6 Laterite ores high in silica and magnesium oxide require extremely energy-intensive pyrometallurgical processing, whereas generally lower grade, iron-oxide-rich ores may be amenable to less energy-intensive acid-leaching processes.

Comparison of costs of nickel from sulfide and laterite deposits encompasses other factors in addition to processing energy and mining methods. Sulfide deposits may involve less in transportation costs because of the ability to concentrate the ores. Ore grades for sulfide deposits are commonly higher than for laterite deposits, but more important, byproducts of copper, cobalt, and precious metals add considerably to the value of sulfide ores. While cobalt is present in some nickel laterite ores, the processing method used for nickel recovery does not always recover cobalt as a separate saleable product. Plants that use a pyrometallurgical process to make ferronickel from laterite ore produce only iron as a coproduct, but a cobalt byproduct is obtained from chemical processing (acid leach) or reduction roast (ammonia leach) of laterite ore (Matthews and Sibley, 1980, p. 621; O'Kane, 1979, p. 505–507).

Figure 6 shows the global distribution of major nickel deposits and districts and indicates the economic class (GNP per capita) of countries where major nickel deposits are located.

NICKEL RESOURCES

Table 1 shows the resources and cumulative production of major nickel deposits and districts, according to geologic deposit type. Although 65 percent of cumulative production has been from magmatic sulfide deposits, laterite deposits contain almost three-quarters of the identified, economic resources (R1E).[7]

7 Resource estimates for the years given in table 7 of Part II are used to calculate these resource totals in Part I. R1E may be overstated in this report because the currently low price of nickel and because a worldwide overcapacity for nickel production has resulted in a change from the R1E to the R1M or R1S category for some resources that are listed as R1E in this report.

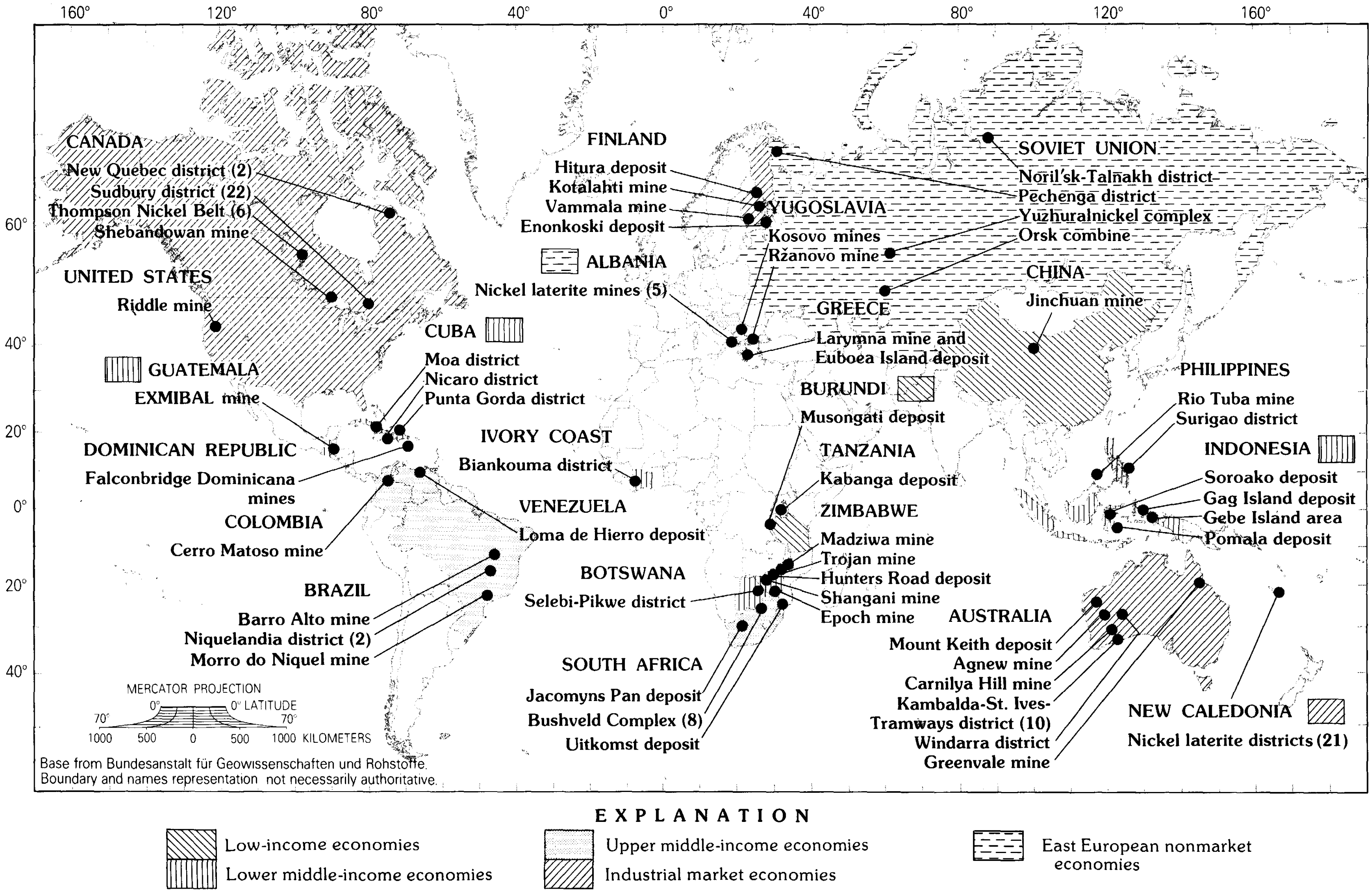


FIGURE 6.—Economic classification of the World Bank (1983, p. 148–149) for countries where the world's major nickel deposits and districts occur. Numbers in parentheses indicate the number of records (deposits and districts) for each location. Location names are from the tables in Part II.

Nickel deposits or districts represented by the nine large-size location symbols in figure 2 account for 78 percent of the R1E resources and at least 72 percent of the cumulative production shown in table 1. Deposits represented by the 25 medium-size symbols account for 21 percent of R1E and 19 percent of cumulative production, and those indicated by the 19 small-size symbols account for the remainder (just over 1 percent) of R1E and about 9 percent of cumulative production.

Table 2 shows the distribution of resources (tons of contained nickel) of major nickel deposits among the World Bank country economic classes from figure 6. Industrial market economy countries have most of the major nickel deposits and districts and 56 percent of R1E resources in these deposits. Most of these resources are in the Sudbury district (Canada), in New Caledonia laterite deposits, and in deposits in Western Australia.

The upper and lower middle-income countries follow the industrial-market-economy countries in nickel resources. Together, the 14 countries in the two middle-income-economy classes account for 37 major nickel deposits and districts that contain 33 percent of R1E resources and 85 percent of resources in other categories. The eastern European nonmarket-economy class (Albania with five deposits plus the Soviet Union with four deposits and totalling about 6 percent of R1E) and the low-income-economy class (Burundi, China, and Tanzania with three deposits, about 5 percent of R1E and 7 percent of resources in other categories) have the smallest amount of nickel resources in major deposits. The dominant position of the industrial-market-economy countries in nickel resources is quite different from the situation for manganese and chromium, where countries in the middle-income classes have over 80 percent, and the industrial-market-economy countries less than 4 percent, of R1E resources and of resources in other categories (DeYoung, Sutphin, and Cannon, 1984, p. 7; DeYoung, Lee, and Lipin, 1984, p. 12). A change in New Caledonia's status as a territory of France would decrease the industrial-market economies' share of R1E resources from 56 percent to 12 percent, if New Caledonia were to be classified in a different economic class by the World Bank.

Many countries not listed in table 2 as having major nickel deposits consume nickel in their metals industries. For this reason, there is significant international trade in nickel. It is estimated on the basis of data from Roskill Information Services (1981), U.S. Bureau of Mines (1984), and [New Caledonia] Service des Mines et de la Géologie (1980) that about 75 percent of nickel content of ores produced in 1979 was traded that year as ore, ferroalloys, matte, or unwrought nickel metal.

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

[Figures are in million metric tons of contained nickel; figures in parentheses are percent of column totals]

Economic class[1]	No. of records	Resource category[2] R1E		All other R1 and R2	
Low-income	3	5.2	(5.3)	1.8	(6.7)
Lower middle-income	19	18.2	(19)	10.4	(39)
Upper middle-income	18	13.8	(14)	12.0	(45)
Industrial market	72	54.9	(56)	2.3	(8.7)
Eastern European nonmarket	9	5.4	(5.5)	—	
Total[3]	121	97.4	(100)	26.5	(100)

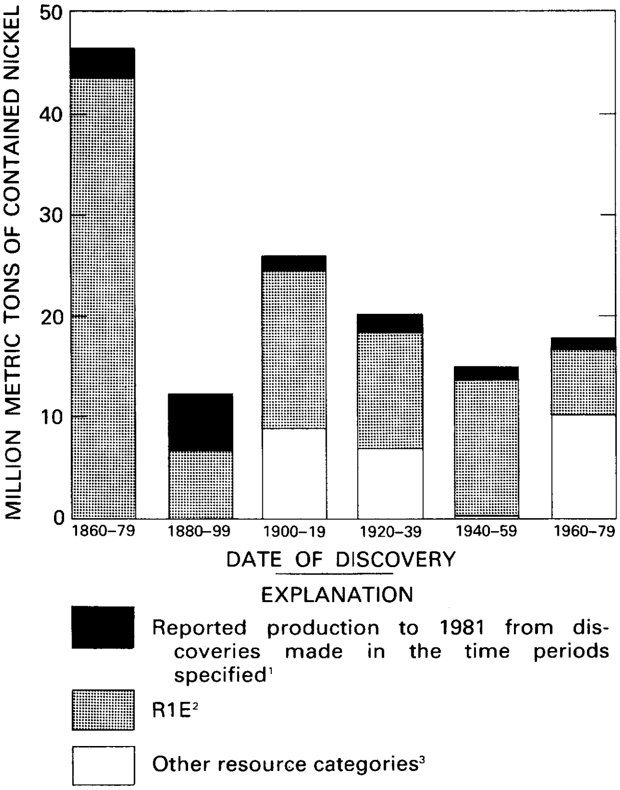
[1] Based principally on GNP per capita and, in some instances, other distinguishing economic characteristics (World Bank, 1983, p. 148–149). Countries where major nickel deposits or districts occur are, by class: low-income economies—Burundi, China, Tanzania; lower middle-income economies—Botswana, Colombia, Cuba, Dominican Republic, Guatemala, Indonesia, Ivory Coast, Philippines, Zimbabwe; upper middle-income economies—Brazil, Greece, South Africa, Venezuela, Yugoslavia; industrial market economies—Australia, Canada, Finland, New Caledonia, the United States; and eastern European nonmarket economies—Albania, the Soviet Union. A sixth economic class, high-income oil exporters, is not listed because those countries do not have identified major nickel deposits.

[2] Categories are defined in figure 1.

[3] Figures may not add to totals shown due to rounding.

The addition to world nickel resources in major deposits by discovery of new deposits is shown in figure 7. Some of the deposits near Sudbury and in New Caledonia were discovered in the 19th century; the Australian deposits were discovered in the 1960's. The discovery of nickel in New Caledonia in the 1860's accounts for almost all the 45 million metric tons of nickel in deposits found during the 1860–79 period. Discoveries of major nickel deposits and districts during each of the four following 20-year periods accounted for 15 to 20 million metric tons of contained nickel. Principal discoveries during these periods were: 1880–99, the Sudbury district in Canada (including resources in Inco and Falconbridge deposits); 1900–19, the deposits of eastern Cuba and the Soroako deposit in Indonesia; 1920–39, nickel in the Bushveld Complex of South Africa and in the Noril'sk-Talnakh district in the Soviet Union; and 1940–59, the Jinchuan mine in China, the Gag Island district in Indonesia, and deposits in the Thompson Nickel Belt (The Pas mining district), Manitoba, Canada.

Discoveries shown for the 1960–79 period include deposits in Indonesia, Australia, several African countries, and Yugoslavia. Conclusions drawn from this figure should take account (1) of the uncertainty of discovery dates due to difficulties in defining "discovery"; (2) of the limited validity of assigning all of the deposit's (or district's) resources to the initial discovery date,



[1]The production shown for deposits and districts in the inventory is about 14.4 million metric tons. Cumulative production from countries with deposits in the inventory for the same period (1875–1981) as reported by the sources listed in table 3 is 17.8 million metric tons. The difference (3.4 million metric tons) is because not all production is directly attributable to the specific deposits in the inventory and because the national production totals include deposits that are not in the inventory.

[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).

FIGURE 7.—Nickel 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. Years of discovery are listed in table 7 of Part II.

as done in figure 7; and (3) of the different standards used to report resource data from different deposits. The relatively smaller amount of resources contained in discoveries made in the last 20-year period shown in figure 7 may be a result of incomplete information about the resources of recently discovered deposits and of the time lag in reporting information about new discoveries; the smaller amount of resources may also reflect reduced exploration since 1975 due to depressed nickel market conditions.

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 Sudbury district of Ontario, Canada, provides a good example of the problem of assigning present-day resource estimates for a deposit or district to the date of discovery. The earliest reported discovery date of nickel-sulfide ore in the Sudbury district was 1883 during railroad construction. This date, listed for the Murray mine in table 7 of Part II, is the basis for assigning all Sudbury district resources (including the Shebandowan mine of western Ontario, whose resources are reported with Inco's Sudbury district totals) to the 1880–99 time period.

At the time of discovery, the magnitude of the Sudbury district resources was not yet recognized. In 1934, the district was thought to contain 6 million metric tons of metal ([Canada] Department of Mines, Mines Branch, 1935, p. 27). Recently, Ross and Travis (1981, p. 1325) estimated that the Sudbury district contained in situ 12.5 million metric tons of nickel before production began. Sudbury district resources and cumulative production[8] listed for the Falconbridge and Inco deposits in this report contain 12.4 million metric tons of nickel that are recoverable during mining (r1E). All of these Sudbury district resources have been assigned to the 1880–99 period on figure 7 because year-to-year resource estimates for deposits and districts are not consistently available and are not included in ISMI records.

The geological eras during which nickel resources in laterite and magmatic sulfide deposits in the inventory were formed are shown in figure 8. Most of the magmatic nickel resources (including cumulative production) were formed during the Proterozoic. Laterite nickel resources that formed during the Cenozoic era, including the 43.5 million metric tons of contained nickel in New Caledonia deposits, are larger than nickel resources formed during any other era.

NICKEL PRODUCTION

The 121 nickel deposits and districts in the International Strategic Minerals Inventory occur in 24 countries (fig. 9); these countries have collectively accounted for most of the world's nickel production since the late 19th century. The data plotted in figure 9 include a small, indeterminable amount of nickel from mines that are not in the inventory.

[8] Although the nickel resource figures include some nickel that will not be recovered during mining and processing, or during processing in the case of r1E, the cumulative production figures only include recovered nickel and are thus not strictly comparable to the resource figures.

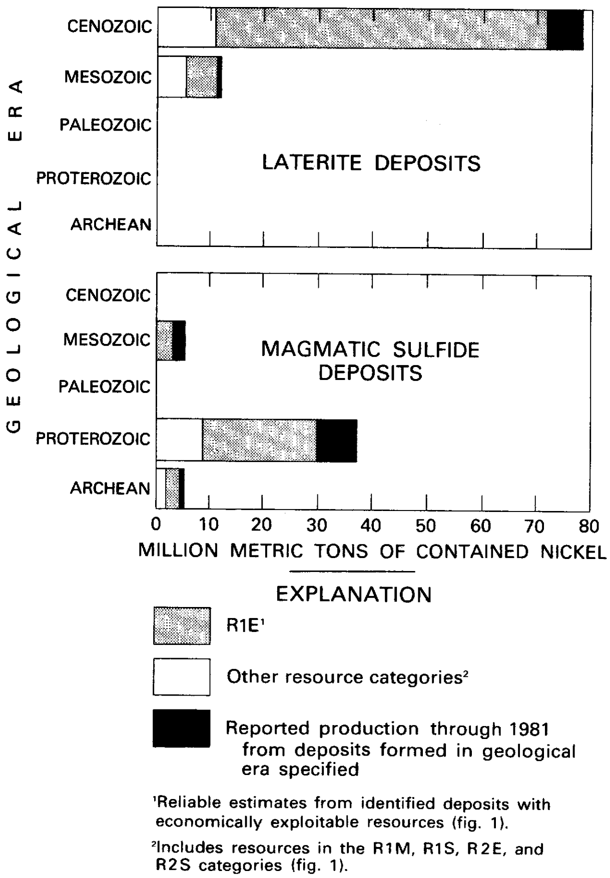


FIGURE 8.—Nickel resources in, and cumulative production from, the world's major deposits and districts according to geological era of mineralization and geologic deposit type. Ages of mineralization are listed in table 6 of Part II.

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

[Figures are in metric tons of contained nickel; numbers in parentheses denote production ranking of country]

Country[1]	Cumulative production 1875–1982	Annual production 1982[2]
Canada	8,700,000 (1)	89,000 (2)
Soviet Union	3,300,000 (2)	170,000 (1)
New Caledonia	2,500,000 (3)	60,000 (4)
Australia	840,000 (4)	89,000 (3)
Cuba	840,000 (5)	38,000 (6)
Indonesia	390,000 (6)	55,000 (5)
United States	350,000 (7)	2,900 (18)
South Africa	340,000 (8)	22,000 (7)
Greece	270,000 (9)	15,000 (10)
Philippines	230,000 (10)	21,000 (8)
Dominican Republic	230,000 (11)	6,000 (17)
Zimbabwe	180,000 (12)	13,000 (11)
Botswana	140,000 (13)	18,000 (9)
China	130,000 (14)	11,000 (13)
Finland	120,000 (15)	6,200 (15)
Brazil	64,000 (16)	7,000 (14)
Albania	52,000 (17)	5,800 (16)
Yugoslavia	19,000 (18)	12,000 (12)
Guatemala	15,000 (19)	—
Colombia	1,000 (20)	1,000 (19)
Venezuela	77 (21)	—

1 Includes all countries with major nickel deposits or districts in the International Strategic Minerals Inventory except for Burundi, the Ivory Coast, and Tanzania which had no nickel production through 1982.

2 Cumulative production calculated from reported production (Mackenzie, 1968, p. 159–160; [New Caledonia] Service des Mines et de la Géologie, 1981, p. 94; Metallgesellschaft Aktiengesellschaft, 1939–80; [United Kingdom] Imperial Mineral Resources Bureau, 1921–49; U.S. Bureau of Mines, 1927–34, 1933–84; U.S. Geological Survey, 1902–27). Data for all countries for all years are not always available. Production for 1982 is from Sibley, 1984, p. 642–643.

Figure 10 shows the production of nickel from each of the countries included in the figure 9 totals. Because of increases in production from several countries, including the Soviet Union, New Caledonia, Australia, the Philippines, and Cuba during the 1940–80 period shown, the proportion of world nickel production accounted for by Canada has fallen from over 80 percent in 1940 to about 25 percent in 1980 (fig. 9).

Information on 1982 production and cumulative production from 1875 to 1982 for countries with deposits in the inventory is shown in table 3. These production data have been grouped by World Bank economic class in table 4. About 39 percent of 1982 production and two thirds of cumulative production since 1875 took place in industrial-market-economy countries (principally Canada and New Caledonia, a French overseas territory classified under France by the World Bank). The eastern European nonmarket-economy class (the Soviet Union and Albania) and the lower middle-income class (principally Cuba, Indonesia, Botswana, and the Philippines) follow the industrial-market-economy class in amount of annual and cumulative nickel production. Note that the World Bank classification, based on per-capita income, does not classify countries by trading relationships. For example, New Caledonia is classified with France yet markets its own nickel production, while Cuban nickel production is marketed through the Soviet Union.

Nickel is produced from surface and underground mining operations. Table 5 shows the distribution of resources by mining method, which is listed for the individual mines and (or) deposits in table 7 of Part II. As a result of the weathering processes needed for the formation of laterite deposits, all but one of the nickel laterite deposits or districts are in either the surface mining class or in the not-mined class; Larymna mine in Greece is a surface and underground operation. Most of the magmatic sulfide nickel resources are in underground mines or in mines that have both surface and

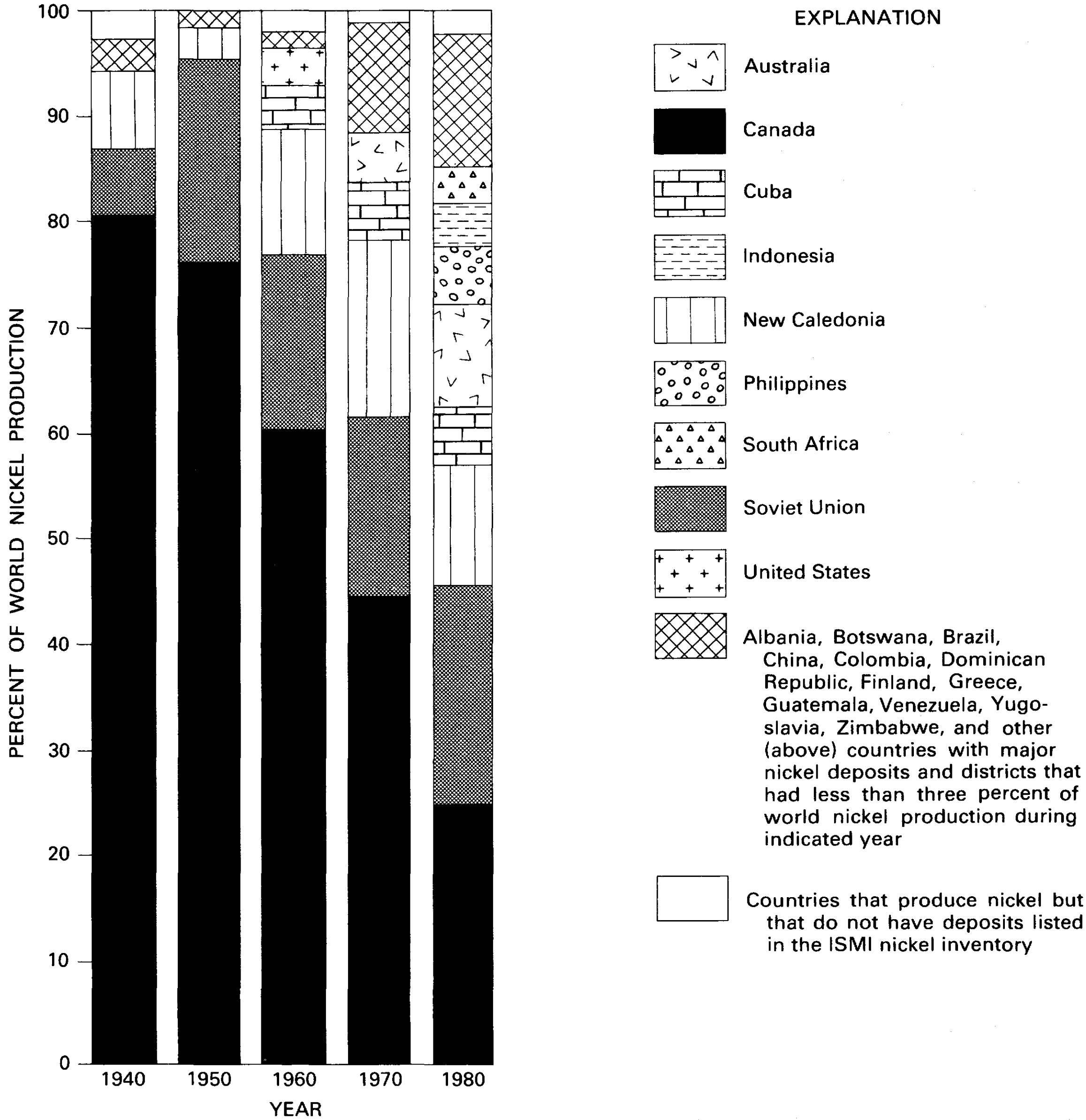


FIGURE 9.—Proportions of total world mine production of nickel accounted for by countries having major deposits and districts in the ISMI nickel inventory; selected years 1940–80. Reported production (U.S. Bureau of Mines, 1943–83) for those countries listed in table 3.

underground operations. Exceptions are the Clarabelle mine and the Pipe No. 2 open pit in Canada and the Hitura deposit in Finland, which are magmatic sulfide deposits with surface-mining operations. The resource total for laterite deposits and districts in New Caledonia has been apportioned between the surface and not-mined categories in table 5. Surface mines account for about 70 percent of nickel resources in major deposits that are being mined.

In studies of the structure of industrial markets, one way of measuring market concentration is to focus directly on observable dimensions, such as numbers 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 used for countries as well. Figure 11 shows the four-country and eight-country concentration ratios for 1913 and 1980 production of several nonfuel mineral commodities. By these measures, nickel ranked high among those mineral commodities controlled by a few producing countries in 1913. This concentration of nickel production declined from 1913 to

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

[Figures are in thousand metric tons; numbers in parentheses denote production ranking of economic class]

Economic class[2]	Cumulative production 1875–1982[3]	Annual production 1982[3]
Low-income	130 (5)	11 (5)
Lower middle-income	2,000 (3)	150 (3)
Upper middle-income	690 (4)	56 (4)
Industrial market	13,000 (1)	250 (1)
Eastern European nonmarket	3,300 (2)	170 (2)
Total[4]	19,000	630

1 Includes only countries having major nickel deposits and districts in ISMI. 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). Countries where major nickel deposits or districts occur are, by class: low-income economies—Burundi, China, Tazania; lower middle-income economies—Botswana, Colombia, Cuba, Dominican Republic, Guatemala, Indonesia, Ivory Coast, Philippines, Zimbabwe; upper middle-income economies—Brazil, Greece, South Africa, Venezuela, Yugoslavia; industrial market economies—Australia, Canada, Finland, New Caledonia, the United States; and eastern European nonmarket economies—Albania, the Soviet Union. A sixth economic class, high-income oil exporters, is not listed because those countries do not have identified major nickel deposits.
3 Reported production from countries in indicated economic class (Mackenzie, 1968, p. 159–160; [New Caledonia] Service des Mines et de la Géologie, 1981, p. 94; Metallgesellschaft Aktiengesellschaft, 1939–80; [United Kingdom] Imperial Mineral Resources Bureau, 1921–49; U.S. Bureau of Mines, 1927–34, 1933–84; U.S. Geological Survey, 1902–27.) Production for 1982 is from Sibley, 1983a, and from the country chapters of volume III of the 1982 Minerals Yearbook (U.S. Bureau of Mines, 1984). Data for all countries for all years are not always available.
4 Figures may not add to totals due to rounding.

1980 from about 95 to 66 percent based on the four-country ratio and from 100 to 85 percent based on the eight-country ratio.

However, in 1913 only one major nickel-mining company operated in each nickel-producing country except Canada, which had two—Inco and Falconbridge. By 1980, these two companies operated in Canada but had operations in other countries as well. Inco has operations in Canada, Guatemala, and Indonesia, while Falconbridge operates in Canada and the Dominican Republic. In addition, Hanna Mining Co. has operations in the United States and Colombia. Thus, country concentration may provide only a rough measure of industry (company) competition, because it may understate concentration of ownership, especially in the case where a few companies may own large production capacities in several different countries.

Present and probable future production of nickel from the major deposits included in the International Strategic Minerals Inventory are shown on the map in figure 12. Several present major producers (both laterite deposits such as New Caledonian deposits and the Moa and Punta Gorda districts of Cuba and magmatic sulfide deposits such as the Sudbury district, Canada,

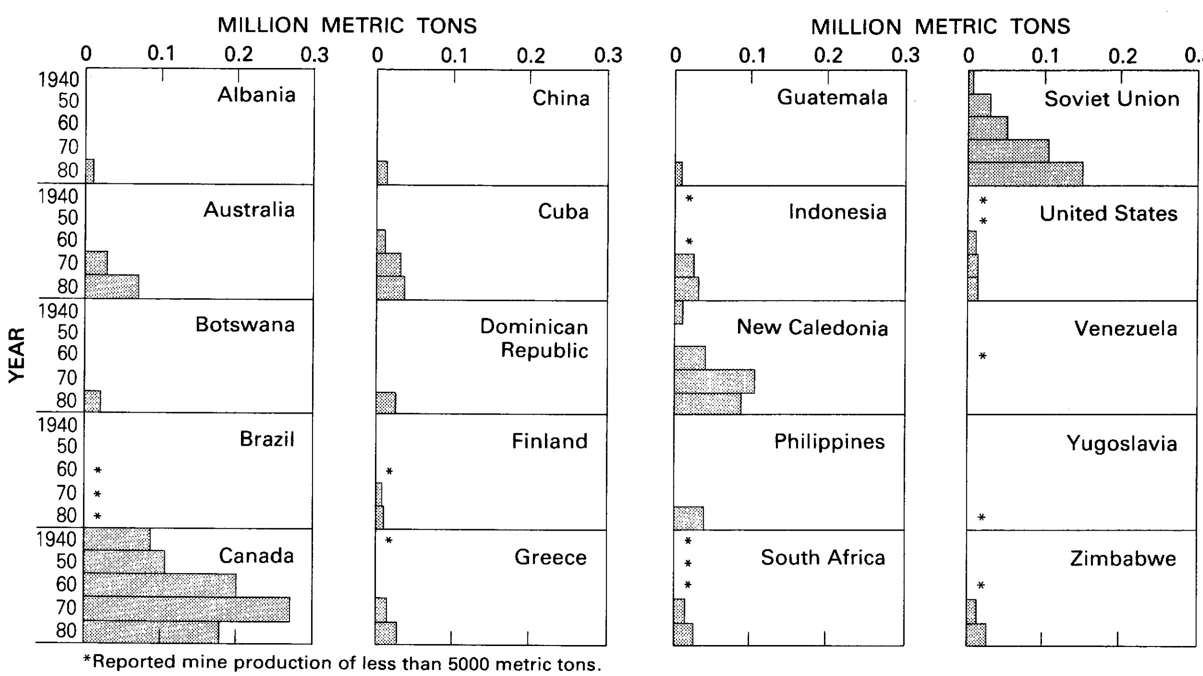


FIGURE 10.—Nickel mine production in countries having major deposits and districts in the ISMI nickel inventory; selected years 1940–80. Reported production (U.S. Bureau of Mines, 1943–83) for those countries listed in table 3, except for Colombia, which had no production through 1980.

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

[Figures are million metric tons of contained nickel]

Economic class[2]	Mining method			
	Surface	Underground	Surface and underground	Not mined
Low-income	—	—	5.2	1.8
Lower middle-income	19.7	0.3	.4	8.2
Upper middle-income	3.5	3.7	7.7	10.9
Industrial market	44.2	8.1	2.6	2.2
Eastern European nonmarket	1.6	3.8	—	—
Total[3]	68.9	15.9	15.9	23.1

[1] Includes resources in the R1 and R2 categories (fig. 1).
[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 nickel deposits.
[3] Figures may not add to totals shown due to rounding.

and Noril'sk-Talnakh district, Soviet Union) will probably continue to be large suppliers through the year 2020. Decrease in output from certain deposits (probably Madziwa, Zimbabwe; Riddle, United States; and Vammala, Finland) may be compensated for by production from other major deposits (primarily laterite deposits), such as the Soroako deposit, Indonesia; Gag Island district, Indonesia; Rio Tuba mine, Philippines; and Mount Keith deposit, Australia. Deposits in low-income-economy and middle-income-economy countries may become more important nickel producers in the future, so that the country concentration ratios for nickel may decline further.

CONCLUSIONS

The strategic nature of the nickel is due to its great importance as an alloying element in steelmaking and to the uneven global distribution of economically workable nickel resources. There are only limited opportunities for substitution for nickel, which is used in the production of stainless steels, alloy steels, and nonferrous alloys as well as for electroplating. Principal applications are in the aerospace, aircraft, motor vehicle, and shipbuilding industries.

World resources (R1E category) in major deposits listed in this report total over 97 million metric tons of contained nickel and are located mainly in New Caledonia, Indonesia, Canada, the Soviet Union, Cuba, Australia, and southern Africa (Botswana, Zimbabwe, and South Africa). Present (1982) world mine production of nickel from countries that have major deposits or districts is about 630,000 metric tons; about 85 percent of this total comes from eight countries—the Soviet Union, Canada, Australia, New Caledonia, Indonesia, Cuba, South Africa, and the Philippines. Production has become more diversified than it was in 1950 when

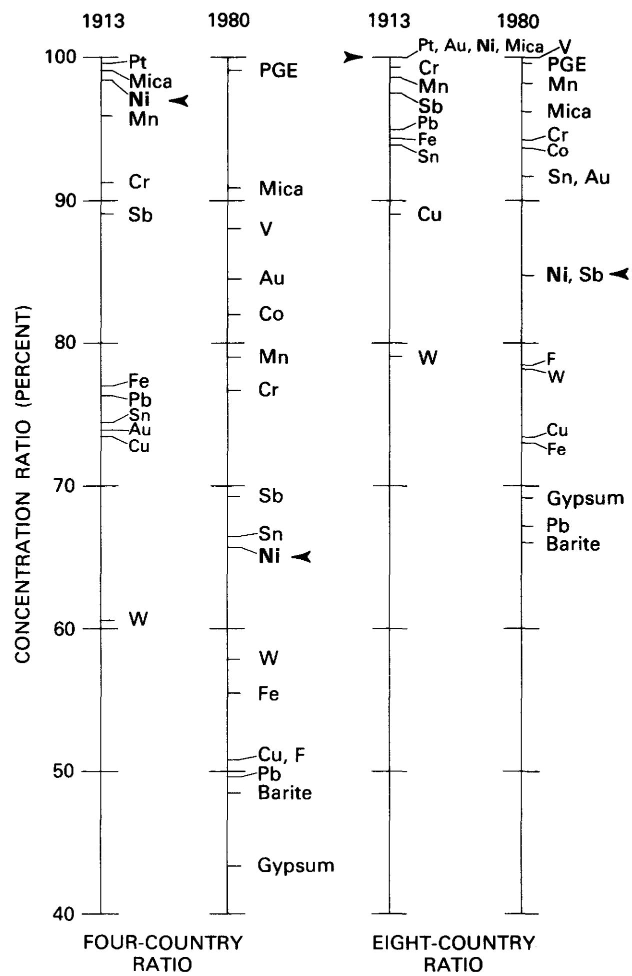
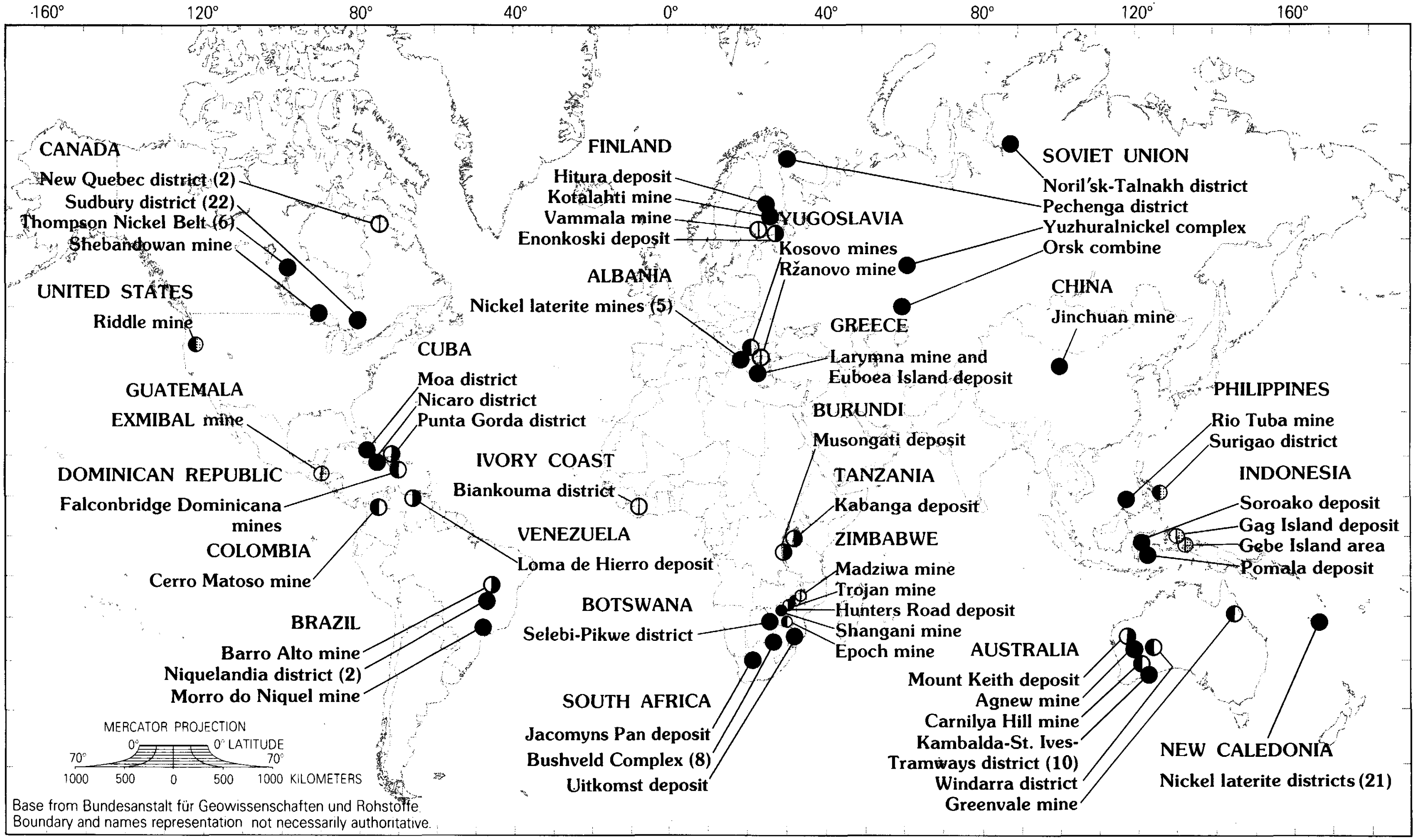


FIGURE 11.—Concentration ratios for selected nonfuel mineral commodity production in 1913 and 1980. The ratios are percent of total world production for the indicated commodities, designated by chemical-element symbols (PGE for platinum-group elements), for the four or eight countries with the largest reported production of the commodity in 1913 and 1980. (Sources of data: U.S. Geological Survey, 1921; U.S. Bureau of Mines, 1982.)



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
- ⦶ No production in 1982; probably an insignificant producer or no production in 2020
- ⦶ No production in 1982; information insufficient to permit any forecast as to future production

FIGURE 12.—Major nickel deposits and districts, their present production status, and their probable production status in 2020. Numbers in parentheses indicate the number of records (deposits and districts) for each location. Location names are from the tables in Part II.

only three countries, Canada, the Soviet Union, and New Caledonia, accounted for about 99 percent of world production. Nevertheless, many industrialized nations do not have enough domestic mine production of nickel to satisfy their own demand and have to rely on imports. The United States, for example, had an average annual mine production of only 10,600 metric tons of nickel from 1978 to 1982, and imported an average of 170,000 metric tons per year during that period to satisfy its average primary consumption of 142,000 metric tons per year plus exports and stock changes (Sibley, 1983a, p. 619).

Major deposits of nickel are classified into two geologic types: magmatic sulfide and laterite. Two-thirds of cumulative world nickel production has been from magmatic sulfide deposits, especially from those in Canada, but about 75 percent of R1E resources are represented by laterite deposits, especially in New Caledonia and Cuba.

In 1979, the world nickel market was affected adversely by an oversupply situation which continues through the present (1984). Consumption levels have since increased while production has decreased, but there is still an excess of capacity, and supply, relative to demand. During this period of oversupply and low nickel prices, producers have become more efficient and have lowered production costs in order to survive. This means there is even less incentive to open new high-cost mines. Not only is there an oversupply situation, but nickel prices have been lowered in accordance with overall lower industry production costs. Excess production and capacity may persist or even increase over the next 5 years due to announced capacity increases by Cuba, the Soviet Union, Indonesia, and South Africa, unless some producers decrease production in response to lower prices or unless new uses for nickel are established.

PART II—SELECTED INVENTORY INFORMATION FOR NICKEL DEPOSITS AND DISTRICTS

Tables 6 and 7 contain information from the International Strategic Minerals Inventory record forms for nickel 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.

Summary descriptions and data are presented in the tables essentially as 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 record forms have been used in these tables; they are explained in the footnotes.

Site name	Latitude	Longitude	Deposit type	Host rock1/
Albania				
Bitincke mine (Korca region)	40° 39'N	20° 59'E	Laterite, in situ	Peridotite; JUR
Kukes deposit (Kukes region)	42° 06'N	20° 23'E	Laterite	Laterite; CRET
Bushtrica mine (Librazhdi-Pogradeci region)	41° 07'N	20° 28'E	Laterite, autochthonous	Serpentinized peridotite; JUR
Guri Kuq mine (Librazhdi-Pogradeci region)	40° 55'N	20° 38'E	-do-	-do-
Prrenjas mine (Librazhdi-Pogradeci region)	41° 04'N	20° 33'E	Laterite, residual enrichment	Laterite; CRET
Australia				
Agnew mine (Western Australia)	27° 49'S	120° 42'E	Magmatic, mafic-ultramafic, stratiform, massive and disseminated	Serpentinized dunite; Perseverance ultramafic intrusion; ARCH (2.9-2.6 Ga)
Carnilya Hill mine (Western Australia)	31° 02'S	121° 47'E	Magmatic, ultramafic, stratiform, massive and disseminated	Serpentinized peridotite; Carnilya Hill ultramafics; PREC
Durkin mine (Kambalda-St. Ives-Tramways district, Western Australia)	31° 10'S	121° 39'E	-do-	Serpentinized peridotite; Kambalda sequence; ARCH (2.9-2.6 Ga)
Edwin mine (Kambalda-St. Ives-Tramways district, Western Australia)	31° 30'S	121° 49'E	-do-	-do-
Fisher mine (Kambalda-St. Ives-Tramways district, Western Australia)	31° 12'S	121° 39'E	-do-	-do-
Foster mine (Kambalda-St. Ives-Tramways district, Western Australia)	31° 21'S	121° 45'E	-do-	-do-

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:

CENOZOIC	CEN	MESOZOIC	MES	PALEOZOIC	PAL	EARLY	E
PLEISTOCENE	PLEIS	CRETACEOUS	CRET	PRECAMBRIAN	PREC	MIDDLE	M
TERTIARY	TERT	JURASSIC	JUR	PROTEROZOIC	PROT	LATE	L
PLIOCENE	PLIO	TRIASSIC	TRI	ARCHEAN	ARCH		
MIOCENE	MIO	DEVONIAN	DEV				

Age of mineralization[2]/	Tectonic setting	Local environment	Principal mineral assemblages[3]/	Comments	Reference
Albania—continued					
CRET	Dinarides Mountains, internal ophiolite	Eastern ultramafic belt	GTHT, hydro-GTHT, Ni-silicates	Peridotites covered by siliceous Ni-ore, limonitic zone, and marls and limestone	Pumo (1973)
-do-	-do-	-do-	---	Alteration zone 10-30 m thick; silicified ore zone up to 12 m thick	Do.
-do-	-do-	-do-	---	Pisolitic-limonitic Ni-Fe ore	Do.
-do-	-do-	-do-	---	Small nontronite layer (avg 1.3% Ni) covers main limonitic Fe-Ni ore (up to 20 m thick) with grades of 1% Ni, 50% Fe, 0.06% Co, 2.5% Cr	Do.
-do-	-do-	-do-	---	Two types of ore: pelitic ore which covers altered peridotites and pisolitic ore above the pelitic ore	Do.
Australia—continued					
ARCH (2.9-2.6 Ga)	ARCH greenstone belt	Structural embayments at basal contact of ultramafic intrusion with metasediments	PYTT, PNLD, CLCP, PYRT, MGNT, CRMT	Massive sulfides at margin of lens; disseminated sulfide within ultramafic body	Marston and others (1981)
PREC	Ocean floor	---	PNLD, PYTT, CLCP, MGNT, CRMT	Similar to Kambalda deposits; no specific geologic formation available	Do.
ARCH (2.9-2.6 Ga)	ARCH greenstone belt	Structural embayments at base of ultramafic lava flow along contact with underlying basalt	PYTT, PNLD, PYRT, CLCP, MGNT, CRMT, MLRT	Sequence domed as result of folding/intrusion	Gresham and Loftus-Hills (1981)
-do-	-do-	-do-	-do-	-do-	Do.
-do-	-do-	-do-	-do-	-do-	Do.
-do-	-do-	-do-	-do-	-do-	Do.

3/ **Abbreviations for mineral names (after Longe and others, 1978, p. 63-66):**

CALCITE	CLCT	HEMATITE	HMTT	PYRITE	PYRT
CHALCOPYRITE	CLCP	ILMENITE	ILMN	PYRRHOTITE	PYTT
CHLORITE	CLRT	LIMONITE	LMON	QUARTZ	QRTZ
CHROMITE	CRMT	MACKINAWITE	MCKN	SERPENTINE	SRPN
CLAY	CLAY	MAGNETITE	MGNT	SPHALERITE	SPLR
CUBANITE	CBNT	MARCASITE	MRCS	SPINEL	SPNL
DIASPORE	DSPR	MILLERITE	MLRT	TALC	TALC
DOLOMITE	DLMT	OPAL	OPAL	VALLERIITE	VLRT
GARNIERITE	GRNR	PENTLANDITE	PNLD	VIOLARITE	VOLR
GERSDORFFITE	GRDF	PLATINUM-GROUP ELEMENTS	PGE		
GOETHITE	GTHT	POLYDYMITE	PLDM		

Site name	Latitude	Longitude	Deposit type	Host rock[1/]
Australia—continued				
Hunt mine (Kambalda-St. Ives-Tramways district, Western Australia)	31° 13'S	121° 41'E	Magmatic, ultramafic stratiform, massive and disseminated	Serpentinized peridotite; Kambalda sequence; ARCH (2.9-2.6 Ga)
Jan mine (Kambalda-St. Ives-Tramways district, Western Australia)	31° 22'S	121° 48'E	-do-	-do-
Juan mine (Kambalda-St. Ives-Tramways district, Western Australia)	31° 10'S	121° 38'E	-do-	-do-
Long mine (Kambalda-St. Ives-Tramways district, Western Australia)	31° 10'S	121° 40'E	-do-	-do-
Lunnon mine (Kambalda-St. Ives-Tramways district, Western Australia)	31° 13'S	121° 41'E	-do-	-do-
McMahon mine (Kambalda-St. Ives-Tramways district, Western Australia)	31° 10'S	121° 38'E	-do-	-do-
Greenvale mine (Queensland)	18° 55'S	144° 59'E	Laterite, residual enrichment	Serpentinized peridotite; Greenvale serpentinite; TERT
Mount Keith deposit (Western Australia)	27° 24'S	120° 32'E	Magmatic, mafic-ultra-mafic, transgressive, disseminated	Serpentinized dunite (dike); ARCH (2.9-2.6 Ga)
Windarra district (Western Australia)	28° 29'S	122° 14'E	Magmatic, ultramafic, stratiform, massive and disseminated	Serpentinized peridotite; Windarra greenstone belt; ARCH (2.9-2.6 Ga)
Botswana				
Selebi-Pikwe district	22° 05'S	27° 52'E	Magmatic, gabbroic, stratiform, massive and disseminated, deformed	Amphibolite; Limpopo mobile belt; ARCH

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:

CENOZOIC	CEN	MESOZOIC	MES	PALEOZOIC	PAL	EARLY	E
PLEISTOCENE	PLEIS	CRETACEOUS	CRET	PRECAMBRIAN	PREC	MIDDLE	M
TERTIARY	TERT	JURASSIC	JUR	PROTEROZOIC	PROT	LATE	L
PLIOCENE	PLIO	TRIASSIC	TRI	ARCHEAN	ARCH		
MIOCENE	MIO	DEVONIAN	DEV				

Age of mineralization[2]/	Tectonic setting	Local environment	Principal mineral assemblages[3]/	Comments	Reference
Australia—continued					
ARCH (2.4-2.6 Ga)	ARCH greenstone belt	Structural embayment at base of ultramafic lava flow along contact with underlying basalt	PYTT, PNLD, PYRT, CLCP, MGNT, CRMT, MLRT	Sequence domed as result of folding/intrusion	Gresham and Loftus-Hills (1981)
-do-	-do-	-do-	-do-	-do-	Do.
-do-	-do-	-do-	-do-	-do-	Do.
-do-	-do-	-do-	-do-	-do-	Do.
-do-	-do-	-do-	-do-	-do-	Do.
-do-	-do-	-do-	-do-	-do-	Do.
DEV; TERT	Fault zone	Laterization of sheared and faulted ultrabasic intrusive	Ni/Co in silicate lattices + LMON	Serpentinite, limonite, siliceous, massive-siliceous, and boxwork ores present	Fletcher and Couper (1975)
ARCH (2.9-2.6 Ga)	ARCH greenstone belt	Dike intruded along major fissure	PNLD, PYTT, MLRT, VOLR, MGNT, CRMT, VLRT	Disseminated sulfide in serpentinized dunite dike cutting metabasalts and metasediments	Burt and Sheppy (1975)
ARCH (2.9-2.6 Ga)	-do-	Structural embayment at base of shallow subvolcanic sill	PYTT, PNLD, cobaltiferous-PYRT, CLCP, MGNT; PNLD, PYRT; MLRT, PNLD, PYRT, PYTT; MGNT, PYRT, MLRT	Ore associated with banded iron formation intercalation in upper ultramafic unit	Roberts (1975)
Botswana—continued					
ARCH	Mobile belt in PREC shield	Magmatic sulfides separated in mafic intrusion	PYTT, PNLD, MGNT, CLCP	Ore body occurs as a concordant sill-like body within gneissic country rocks	Wakefield (1976)

3/ **Abbreviations for mineral names (after Longe and others, 1978, p. 63-66):**

CALCITE	CLCT	HEMATITE	HMTT	PYRITE	PYRT
CHALCOPYRITE	CLCP	ILMENITE	ILMN	PYRRHOTITE	PYTT
CHLORITE	CLRT	LIMONITE	LMON	QUARTZ	QRTZ
CHROMITE	CRMT	MACKINAWITE	MCKN	SERPENTINE	SRPN
CLAY	CLAY	MAGNETITE	MGNT	SPHALERITE	SPLR
CUBANITE	CBNT	MARCASITE	MRCS	SPINEL	SPNL
DIASPORE	DSPR	MILLERITE	MLRT	TALC	TALC
DOLOMITE	DLMT	OPAL	OPAL	VALLERIITE	VLRT
GARNIERITE	GRNR	PENTLANDITE	PNLD	VIOLARITE	VOLR
GERSDORFFITE	GRDF	PLATINUM-GROUP ELEMENTS	PGE		
GOETHITE	GTHT	POLYDYMITE	PLDM		

Site name	Latitude	Longitude	Deposit type	Host rock[1]/
			Brazil	
Barro Alto mine (Goias)	14° 50'S	48° 50'W	Laterite, residual enrichment	Serpentinized peridotite; Araxa group; PREC
Morro do Niquel mine (Minas Gerais)	22° 55'S	46° 39'W	-do-	Serpentinite; Serie Minas; PREC
Tocantins mine (Niquelandia district--Goias)	14° 33'S	48° 23'W	-do-	Serpentinized peridotite; S. Jose dos Tocantins Complex; PREC
Codemin mine (Niquelandia district--Goias)	14° 33'S	48° 23'W	-do-	Serpentinized peridotite and pyroxenite; S. Jose dos Tocantins Complex; PREC
			Burundi	
Musongati deposit (Buhinda Plateau)	03° 45'S	30° 15'E	Laterite	---
			Canada	
East mine (Sudbury district (Ontario)-Falconbridge Ltd.)	46° 35'N	80° 47'W	Magmatic, gabbroic, Sudbury-type	Gabbro-norite; Sudbury nickel irruptive, EPROT (1849.5 ± 3 Ma)
Falconbridge mine (Sudbury district (Ontario)-Falconbridge Ltd.)	46° 35'N	80° 48'W	-do-	-do-
Fecunis-North mine (Sudbury district (Ontario)-Falconbridge Ltd.)	46° 39'N	81° 21'W	-do-	"Granite breccia"; probably Sudbury sublayer; EPROT
Fraser mine (Sudbury district (Ontario)-Falconbridge Ltd.)	46° 40'N	81° 21'W	-do-	-do-
Lockerby mine (Sudbury district (Ontario)-Falconbridge Ltd.)	46° 26'N	81° 20'W	-do-	Sudbury sublayer; EPROT

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:

CENOZOIC	CEN	MESOZOIC	MES	PALEOZOIC	PAL	EARLY	E
PLEISTOCENE	PLEIS	CRETACEOUS	CRET	PRECAMBRIAN	PREC	MIDDLE	M
TERTIARY	TERT	JURASSIC	JUR	PROTEROZOIC	PROT	LATE	L
PLIOCENE	PLIO	TRIASSIC	TRI	ARCHEAN	ARCH		
MIOCENE	MIO	DEVONIAN	DEV				

Age of mineralization2/	Tectonic setting	Local environment	Principal mineral assemblages3/	Comments	Reference
		Brazil—continued			
CEN	Ultramafic belt in PREC shield	Tropical weathering	GRNR, LMON	Located in the eastern side of an intrusive complex; associated with peridotites, dunites, gabbros	---
-do-	-do-	-do-	GRNR, LMON	Ni-rich garnierite has formed along joint cracks or in the interstices of weathered pyroxenite	Lefond (1973)
TERT	-do-	-do-	GRNR, CLAY	Ore-bearing green clays occur above ultrabasic belt within gabbroic complex	---
CEN	---	-do-	GRNR, PYTT, PNLD, PYRT, LMON	Discontinuous nickel deposits are remnants of a once more extensive nickel-bearing laterite mantle	Mining Journal (1982)
		Burundi—continued			
---	---	---	GRNR	Landlocked location will require a 1600-km roadway or a railroad spur; hydro-electric or peat-fired electric plant may be built	---
		Canada—continued			
EPROT, slightly before or after nickel irruptive (1849 Ma)	Intracratonic intrusion triggered by impact of meteorite	Penecontemporaneous fault cutting basal contact of irruptive	PYTT, PNLD, CLCP, PYRT; minor MGNT, GRDF, VOLR, MRCS	Ore body parallel to, but distinct from, Falconbridge mine ore body	Thomson (1959)
-do-	-do-	-do-	-do-	Consists of a sheet of massive and breccia-sulfide occupying a nearly vertical fault zone	Do.
-do-	-do-	Footwall breccia below the base of Sudbury nickel irruptive	PYTT, PNLD, CLCP	Ore body mainly in granite breccia	---
-do-	-do-	---	-do-	Deposit may consist of copper-rich footwall veins	---
-do-	-do-	---	-do-	No published geologic information	---

3/ Abbreviations for mineral names (after Longe and others, 1978, p. 63-66):

CALCITE	CLCT	HEMATITE	HMTT	PYRITE	PYRT
CHALCOPYRITE	CLCP	ILMENITE	ILMN	PYRRHOTITE	PYTT
CHLORITE	CLRT	LIMONITE	LMON	QUARTZ	QRTZ
CHROMITE	CRMT	MACKINAWITE	MCKN	SERPENTINE	SRPN
CLAY	CLAY	MAGNETITE	MGNT	SPHALERITE	SPLR
CUBANITE	CBNT	MARCASITE	MRCS	SPINEL	SPNL
DIASPORE	DSPR	MILLERITE	MLRT	TALC	TALC
DOLOMITE	DLMT	OPAL	OPAL	VALLERIITE	VLRT
GARNIERITE	GRNR	PENTLANDITE	PNLD	VIOLARITE	VOLR
GERSDORFFITE	GRDF	PLATINUM-GROUP ELEMENTS	PGE		
GOETHITE	GTHT	POLYDYMITE	PLDM		

Site name	Latitude	Longitude	Deposit type	Host rock[1]/
			Canada—continued	
Onaping-Craig mine (Sudbury district (Ontario)-Falconbridge Ltd.)	46° 38'N	81° 23'W	Magmatic, gabbroic, Sudbury-type	Probably "granite breccia"; Sudbury sublayer; EPROT
Strathcona mine (Sudbury district (Ontario)-Falconbridge Ltd.)	46° 40'N	81° 20'W	-do-	"Granite breccia"; probably Sudbury sublayer; EPROT
Clarabelle no. 2 open pit (Sudbury district (Ontario)-Inco Ltd.)	46° 31'N	81° 03'W	Magmatic, gabbroic, Sudbury-type, stratiform, disseminated	Xenolithic gabbro-norite; Sudbury sublayer; EPROT
Coleman mine (Sudbury district (Ontario)-Inco Ltd.)	46° 41'N	81° 20'W	Magmatic, gabbroic, Sudbury-type	Probably "leucocratic breccia"; Sudbury sublayer; EPROT
Copper Cliff North mine (Sudbury district (Ontario)-Inco Ltd.)	46° 30'N	81° 04'W	-do-	Quartz diorite; Copper Cliff offset; (Sudbury sublayer); EPROT
Copper Cliff South mine (Sudbury district (Ontario)-Inco Ltd.)	46° 28'N	81° 05'W	-do-	-do-
Crean Hill mine (Sudbury district (Ontario)-Inco Ltd.)	46° 26'N	81° 21'W	-do-	"Greenstone breccia"; Sudbury sublayer; EPROT
Creighton mine (Sudbury district (Ontario)-Inco Ltd.)	46° 28'N	81° 11'W	Magmatic, gabbroic, Sudbury-type, several ore types	Xenolithic gabbro-norite; Sudbury sublayer; EPROT
Frood mine (Sudbury district (Ontario)-Inco Ltd.)	46° 32'N	81° 00'W	Magmatic, gabbroic, Sudbury-type	Quartz diorite; Frood-Stobie offset; EPROT
Garson mine (Sudbury district (Ontario)-Inco Ltd.)	46° 34'N	80° 52'W	-do-	Gabbro-norite; Sudbury nickel irruptive; EPROT (1849.5 ± 3 Ma)
Levack mine (Sudbury district (Ontario)-Inco Ltd.)	46° 39'N	81° 23'W	-do-	"Leucocratic breccia"; Sudbury sublayer; EPROT

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:

CENOZOIC	CEN	MESOZOIC	MES	PALEOZOIC	PAL	EARLY	E
PLEISTOCENE	PLEIS	CRETACEOUS	CRET	PRECAMBRIAN	PREC	MIDDLE	M
TERTIARY	TERT	JURASSIC	JUR	PROTEROZOIC	PROT	LATE	L
PLIOCENE	PLIO	TRIASSIC	TRI	ARCHEAN	ARCH		
MIOCENE	MIO	DEVONIAN	DEV				

Age of mineralization2/	Tectonic setting	Local environment	Principal mineral assemblages3/	Comments	Reference
		Canada—continued			
EPROT, slightly before or after nickel irruptive (1849 Ma)	Intracratonic intrusion triggered by impact of meteorite	---	PYTT, PNLD, CLCP	Little published geologic information	---
-do-	-do-	Sudbury sublayer intrusion at base of nickel irruptive	PYTT, PNLD, CLCP; also minor PYRT, CBNT	Ore body consists of 3 zones: gabbro-norite, granite breccia, gneiss	Abel and others (1979)
-do-	-do-	-do-	PYTT, PNLD, CLCP; minor PYRT, MGNT	Xenoliths are of peridotite, gabbro, and metavolcanic rocks	Souch and others (1969)
-do-	-do-	---	PYTT, PNLD, CLCP	Ore body is an extension of Strathcona ore body	---
-do-	-do-	Apophysis (offset) of the sublayer intrusion at base of the nickel irruptive	PYTT, CLCP, PNLD, PYRT	Ore bodies consist of near vertical sheets or pipes	Pattison (1979)
-do-	-do-	-do-	-do-	No detailed geologic information published	Souch and others (1969)
-do-	-do-	Probably part of the sublayer intrusion at base of the nickel irruptive	PYTT, PNLD, CLCP	"Greenstone breccia" is probably xenolithic mineralized gabbro-norite	Card (1968)
-do-	-do-	Sudbury sublayer intrusion at base of the nickel irruptive	-do-	---	Souch and others (1969)
-do-	-do-	Apophysis (offset) of the sublayer intrusion at base of the nickel irruptive	PYTT, PNLD, CLCP; PGE and Ni-arsenide minerals are usually abundant	Offset is a downward-wedging body of quartz diorite	Zurbrigg and others (1957)
-do-	-do-	Penecontemporaneous fault cutting basal contact of the nickel irruptive	PYTT, PNLD, CLCP, GRDF	About 80% of ore is massive and breccia sulfides along branching fault zones	Souch and others (1969)
-do-	-do-	Sudbury sublayer intrusion (at base of the nickel irruptive) and underlying footwall breccia	PYTT, PNLD, CLCP	About 70% of ore is disseminated sulfides in a leucocratic breccia	Do.

3/ Abbreviations for mineral names (after Longe and others, 1978, p. 63-66):

CALCITE	CLCT	HEMATITE	HMTT	PYRITE	PYRT
CHALCOPYRITE	CLCP	ILMENITE	ILMN	PYRRHOTITE	PYTT
CHLORITE	CLRT	LIMONITE	LMON	QUARTZ	QRTZ
CHROMITE	CRMT	MACKINAWITE	MCKN	SERPENTINE	SRPN
CLAY	CLAY	MAGNETITE	MGNT	SPHALERITE	SPLR
CUBANITE	CBNT	MARCASITE	MRCS	SPINEL	SPNL
DIASPORE	DSPR	MILLERITE	MLRT	TALC	TALC
DOLOMITE	DLMT	OPAL	OPAL	VALLERIITE	VLRT
GARNIERITE	GRNR	PENTLANDITE	PNLD	VIOLARITE	VOLR
GERSDORFFITE	GRDF	PLATINUM-GROUP ELEMENTS	PGE		
GOETHITE	GTHT	POLYDYMITE	PLDM		

Site name	Latitude	Longitude	Deposit type	Host rock1/
			Canada—continued	
Levack East mine (Sudbury district (Ontario)-Inco Ltd.)	46° 39'N	81° 22'W	Magmatic, gabbroic, Sudbury-type	Probably "leucocratic breccia"; Sudbury sublayer; EPROT
Little Stobie mine (Sudbury district (Ontario)-Inco Ltd.)	46° 33'N	81° 00'W	-do-	Xenolithic gabbro-norite; Sudbury sublayer; EPROT
McCreedy West mine (Sudbury district (Ontario)-Inco Ltd.)	46° 38'N	81° 24'W	-do-	"Leucocratic breccia"; Sudbury sublayer; EPROT
Murray mine (Sudbury district (Ontario)-Inco Ltd.)	46° 31'N	81° 04'W	Magmatic, gabbroic, Sudbury-type, stratiform, disseminated	Xenolithic gabbro-norite; Sudbury sublayer; EPROT
Shebandowan mine (Thunder Bay district (Ontario)-Inco Ltd.)	48° 36'N	90° 15'W	Magmatic, ultramafic, deformed	Serpentinized peridotite; ARCH
Stobie mine (Sudbury district (Ontario)-Inco Ltd.)	46° 32'N	81° 00'W	Magmatic, gabbroic, Sudbury-type	Quartz diorite; Frood-Stobie offset; EPROT
Totten mine (Sudbury district (Ontario)-Inco Ltd.)	46° 23'N	81° 27'W	-do-	Quartz diorite; Worthington offset; EPROT
Donaldson deposit (New Quebec mining district--Quebec)	61° 40'N	73° 18'W	Magmatic, ultramafic	Peridotite; EPROT
Katiniq deposit (New Quebec mining district--Quebec)	61° 41'N	73° 40'W	-do-	-do-
Birchtree mine (Thompson Nickel Belt--Manitoba)	55° 42'N	97° 55'W	Magmatic, ultramafic, stratiform, deformed	Biotite schist; Pipe metasedimentary band; EPROT
Moak mine (Thompson Nickel Belt--Manitoba)	55° 57'N	97° 35'W	Magmatic, ultramafic	Serpentinized peridotite; EPROT
Pipe No. 1 mine (Thompson Nickel Belt--Manitoba)	55° 29'N	98° 09'W	Magmatic, ultramafic, stratiform, deformed	---

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:

CENOZOIC	CEN	MESOZOIC	MES	PALEOZOIC	PAL	EARLY	E
PLEISTOCENE	PLEIS	CRETACEOUS	CRET	PRECAMBRIAN	PREC	MIDDLE	M
TERTIARY	TERT	JURASSIC	JUR	PROTEROZOIC	PROT	LATE	L
PLIOCENE	PLIO	TRIASSIC	TRI	ARCHEAN	ARCH		
MIOCENE	MIO	DEVONIAN	DEV				

Age of mineralization2/	Tectonic setting	Local environment	Principal mineral assemblages3/	Comments	Reference
Canada—continued					
---	Intracratonic intrusion triggered by impact of meterorite	---	PYTT, PNLD, CLCP	Probably a typical North Range-type deposit (like Levack and Strathcona ore bodies	---
EPROT, slightly before or after nickel irruptive (1849 Ma)	-do-	Sudbury sublayer intrusion at base of the nickel irruptive	PYTT, PNLD, CLCP, minor PYRT, MGNT, ILMN	Little published geologic information	Hoffman and others (1979)
-do-	-do-	Footwall breccia and sulfide veins below the sublayer intrusion at base of the nickel irruptive	PYTT, PNLD, CLCP, MLRT; minor to trace PGE	Similar to Strathcona ore body	Do.
-do-	-do-	Sudbury sublayer intrusion at base of the nickel irruptive	PYTT, PNLD, CLCP, minor PYRT, MGNT	Xenoliths are peridotite, gabbro, and metavolcanic rocks	Souch and others (1969)
ARCH	ARCH greenstone belt	Sheared peridotite (serpentine) lenses in mafic metavolcanics (original environment uncertain)	PYTT, PNLD, CLCP, PYRT	Discontinous sheet of sulfides at contact of peridotite and overlying mafic volcanic rocks; tectonically reworked	Morin (1973)
EPROT, slightly before or after nickel irruptive (1849 Ma)	Intracratonic intrusion triggered by impact of meteorite	Apophysis (offset) of the Sudbury sublayer intrusion at the base of the nickel irruptive	PYTT, PNLD, CLCP	Common ore body with Frood mine	---
-do-	-do-	-do-	-do-	Presumed to be similar to Frood-Stobie ore body	---
EPROT	Circum-cratonic volcanic fold belt	Mafic volcanic rocks, interflow slate, greywacke	PYTT, PNLD, CLCP, SRPN, MGNT, CLRT	Conformable zones of massive, matrix, and disseminated Ni-Cu sulfides in sills	---
-do-	-do-	-do-	-do-	Ultramafic sill occupies contact between slate and overlying pillow basalt	Barnes (1979)
EPROT, whole rock Pb on sulfide ore (2.32 $\pm$.03 Ga)	PROT supracrustal sequence near margin of ARCH craton	Sheared ultramafic sill in metasedimentary sequence	PYTT, PNLD, CLCP, PYRT, Ni-arsenides	Ore is associated with serpentinized peridotite and biotite schist	Theyer (1980)
EPROT	-do-	Ultramafic sills emplaced in metasedimentary sequence	PYTT, PNLD, CLCP, VOLR	Mineralization within folded peridotite-dunite sill intruding metasedimentary rocks	Patterson (1963)
EPROT, whole rock Pb on sulfide ore (2.32 $\pm$ .03 Ga)	-do-	---	---	Ore is associated with serpentinized peridotite	---

3/ **Abbreviations for mineral names (after Longe and others, 1978, p. 63-66):**

CALCITE	CLCT	HEMATITE	HMTT	PYRITE	PYRT
CHALCOPYRITE	CLCP	ILMENITE	ILMN	PYRRHOTITE	PYTT
CHLORITE	CLRT	LIMONITE	LMON	QUARTZ	QRTZ
CHROMITE	CRMT	MACKINAWITE	MCKN	SERPENTINE	SRPN
CLAY	CLAY	MAGNETITE	MGNT	SPHALERITE	SPLR
CUBANITE	CBNT	MARCASITE	MRCS	SPINEL	SPNL
DIASPORE	DSPR	MILLERITE	MLRT	TALC	TALC
DOLOMITE	DLMT	OPAL	OPAL	VALLERIITE	VLRT
GARNIERITE	GRNR	PENTLANDITE	PNLD	VIOLARITE	VOLR
GERSDORFFITE	GRDF	PLATINUM-GROUP ELEMENTS	PGE		
GOETHITE	GTHT	POLYDYMITE	PLDM		

Site name	Latitude	Longitude	Deposit type	Host rock[1]
			Canada—continued	
Pipe No. 2 open pit (Thompson Nickel Belt--Manitoba)	55° 30'N	98° 09'W	Magmatic, ultramafic, stratiform, disseminated	Serpentinized peridotite; EPROT
Soab North and South mines (Thompson Nickel Belt--Manitoba)	55° 13'N	98° 25'W	Magmatic, ultramafic, stratiform, deformed	Serpentinized peridotite and biotite schist; Pipe metasedimentary band; EPROT
Thompson mine (Thompson Nickel Belt--Manitoba)	55° 43'N	97° 51'W	-do-	"Biotite schist"; Thompson metasedimentary band; EPROT
			China	
Jinchuan mine (Gansu Province)	39°N	100°E	Magmatic, gabbroic, stratiform, massive and disseminated	Ultramafites
			Colombia	
Cerro Matoso mine (Cordoba)	07° 55'N	75° 35'W	Laterite, residual enrichment	Peridotite
			Cuba	
Moa Bay district (Oriente Province)	20° 37'N	74° 58'W	Laterite, residual enrichment	Peridotite; Cauto belt; TERT
Nicaro district (Oriente Province)	20° 35'N	75° 33'W	-do-	Serpentinized peridotite; Cauto belt; TERT
Punta Gorda district (Oriente Province)	20° 35'N	74° 51'W	-do-	-do-
			Dominican Republic	
Falconbridge Dominicana mines	19° 01'N	70° 23'W	Laterite, residual enrichment	Harzburgite; TERT
			Finland	
Enonkoski deposit	62° 05'N	28° 55'E	Magmatic, ultramafic, stratiform	---
Hitura deposit	63° 51'N	25° 03'E	Magmatic, ultramafic, stratiform, massive and disseminated	Serpentinite; Sveckarelidic fold belt; 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:

CENOZOIC	CEN	MESOZOIC	MES	PALEOZOIC	PAL	EARLY	E
PLEISTOCENE	PLEIS	CRETACEOUS	CRET	PRECAMBRIAN	PREC	MIDDLE	M
TERTIARY	TERT	JURASSIC	JUR	PROTEROZOIC	PROT	LATE	L
PLIOCENE	PLIO	TRIASSIC	TRI	ARCHEAN	ARCH		
MIOCENE	MIO	DEVONIAN	DEV				

Age of mineralization[2]/	Tectonic setting	Local environment	Principal mineral assemblages[3]/	Comments	Reference
			Canada—continued		
EPROT, whole rock Pb on sulfide ore (2.32 ±.03 Ga)	PROT supracrustal sequence near margin of ARCH craton	Ultramafic sill emplaced in metasedimentary sequence	PYTT, PNLD, PYRT, VOLR	Ore is found in serpentine lens which occupies west limb of a tight, steeply-dipping fold	Coats and others (1972)
-do-	-do-	---	PYTT, PYRT, PNLD, CLCP	Ore consists of massive and mineralized schist, pegmatite, and peridotite	Do.
-do-	-do-	Ultramafic sills emplaced in metasedimentary sequence	PYTT, PNLD, PYRT, CLCP	Irregular, continuous sulfide sheet within folded biotite schist; intensely deformed and metamorphosed	Do.
			China—continued		
EPROT	PREC mobile belt	Magmatic sulfides	Includes VOLR	Little published geologic information; location approximate	Brady (1981)
			Colombia—continued		
---	---	Tropical weathering	GRNR; LMON	Deposit is irregular blanket 1700m x 2000m, 80m thick	Gomez and others (1979)
			Cuba—continued		
CEN	Obducted ophiolite in orogenic belt	Tropical weathering of obducted ophiolite	GTHT, HMTT, halloysite, hydrargillite, SPNL, QRTZ, MGNT, SRPN	---	Linchenat and Shirokova (1964)
TERT	-do-	-do-	GTHT, LMON, MGNT; CRMT, GRNR, QRTZ, SRPN	Laterites derived from ultramafic oceanic rocks implaced in late Mesozoic to middle Eocene	Case (1980)
-do-	-do-	-do-	-do-	-do-	Do.
			Dominican Republic—continued		
PLEIS	Thrust belt of ultramafic rocks	Tropical weathering of ultramafic rocks	GRNR, SRPN; LMON; SPNL	Ultramafics emplaced in Eocene, laterization occurred in Pleistocene	Haldeman and others (1982)
			Finland—continued		
EPROT	PREC shield	---	---	---	---
EPROT (1877 Ma)	Linear belt in PREC shield	Immiscible sulfides in ultramafic rock	PNLD, CLCP, PYTT, MGNT	Part of a linear belt (Kotalahti nickel belt) in south Finland that was subsequently highly deformed	Mining Journal (1984)

3/ Abbreviations for mineral names (after Longe and others, 1978, p. 63-66):

CALCITE	CLCT	HEMATITE	HMTT	PYRITE	PYRT
CHALCOPYRITE	CLCP	ILMENITE	ILMN	PYRRHOTITE	PYTT
CHLORITE	CLRT	LIMONITE	LMON	QUARTZ	QRTZ
CHROMITE	CRMT	MACKINAWITE	MCKN	SERPENTINE	SRPN
CLAY	CLAY	MAGNETITE	MGNT	SPHALERITE	SPLR
CUBANITE	CBNT	MARCASITE	MRCS	SPINEL	SPNL
DIASPORE	DSPR	MILLERITE	MLRT	TALC	TALC
DOLOMITE	DLMT	OPAL	OPAL	VALLERIITE	VLRT
GARNIERITE	GRNR	PENTLANDITE	PNLD	VIOLARITE	VOLR
GERSDORFFITE	GRDF	PLATINUM-GROUP ELEMENTS	PGE		
GOETHITE	GTHT	POLYDYMITE	PLDM		

Site name	Latitude	Longitude	Deposit type	Host rock[1]/
		Finland—continued		
Kotalahti mine (Outokumpu district)	62° 34'N	27° 37'E	Magmatic, ultramafic, stratiform, basic to ultrabasic intrusives into highly metamorphosed gneisses	Ultrabasic plutons; Karelian; EPROT
Vammala mine	61° 20'N	24° 54'E	Magmatic, ultramafic, stratiform, intrusive	Peridotite; EPROT
		Greece		
Larymna mine and Euboea Island deposit	38° 28'N	23° 17'E	Laterite, residual enrichment	Chemical sediments; CRET
		Guatemala		
EXMIBAL mine (Izabal district)	16° 30'N	89° 20'W	Laterite, residual enrichment	Peridotite; Sierra de Santa Cruz
		Indonesia		
Gag Island deposit	00° 30'S	129° 45'E	Laterite, residual enrichment	Peridotite (harzburgite); TERT
Gebe Island mining area	00° 04'S	129° 26'E	-do-	Serpentinite; TERT
Pomala deposit (Sulawesi Island)	04° 00'S	121° 00'E	-do-	Peridotite; CRET
Soroako deposit (Central Sulawesi district)	02° 30'S	121° 30'E	-do-	Harzburgite; LCRET
		Ivory Coast		
Biankouma district	07° 43'N	07° 36'W	Laterite, residual enrichment	---
		New Caledonia		
Canala-Bogota mining district	21° 31'S	166° 12'E	Laterite, residual enrichment	Peridotite; TERT
Ile Art mining district	19° 43'S	163° 40'E	-do-	-do-
Kaala-Gomen mining district	20° 37'S	164° 22'E	-do-	-do-

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:

CENOZOIC	CEN	MESOZOIC	MES	PALEOZOIC	PAL	EARLY	E
PLEISTOCENE	PLEIS	CRETACEOUS	CRET	PRECAMBRIAN	PREC	MIDDLE	M
TERTIARY	TERT	JURASSIC	JUR	PROTEROZOIC	PROT	LATE	L
PLIOCENE	PLIO	TRIASSIC	TRI	ARCHEAN	ARCH		
MIOCENE	MIO	DEVONIAN	DEV				

ISMI records for nickel deposits and districts—Continued

Age of mineralization 2/	Tectonic setting	Local environment	Principal mineral assemblages 3/	Comments	Reference
			Finland—continued		
EPROT (1883 Ma)	Baltic PREC shield	---	PNLD; PYTT; CLCP, SPLR, GRDF, PYRT	Disseminated and breccia ore types in 5 separate ore bodies	Isokangas (1978)
EPROT	-do-	---	PYTT; PNLD; CLCP, PYRT	Ultramafic intrusion has at least 3 layers; sulfide concentrated in peridotite layer by magmatic segregation	Häkli and others (1979)
			Greece—continued		
LCRET	Epicontinental platform	Shallow water transgression	HMTT, GRNR; LMON	Irregularly shaped; complicated by folding and faulting in the late Cretaceous	Albandakis (1980)
			Guatemala—continued		
CEN	Orogenic belt	Tropical weathering of ophiolite	LMON, SRPN, GRNR	Occurs as irregular-tabular body	Mining Annual Review (1982)
			Indonesia—continued		
---	MES-CEN mobile belt	Tropical weathering of ultramafic rocks	LMON; GRNR	Island consists of exposed oceanic crust and mantle	Havryluk and Huff (1979)
TERT	-do-	-do-	-do-	---	Prijono (1977)
CEN	TERT orogenic belt	-do-	GRNR; LMON	Nickel deposits are generally concentrated in the low-iron profile near the bedrock contact	Golightly (1979)
-do-	MES-CEN mobile belt	Tropical weathering of ophiolite	GRNR; SRPN; LMON	Ore is an irregular blanket 5m thick	Suriaatmadja and Wahju (1972)
			Ivory Coast—continued		
TERT	---	---	---	Little published information is available, several deposits are in the area	---
			New Caledonia—continued		
TERT	MES-CEN mobile belt	Tropical weathering	GRNR, LMON, SRPN	---	Paris (1981)
-do-	-do-	-do-	-do-	---	Do.
-do-	-do-	-do-	-do-	---	Do.

3/ Abbreviations for mineral names (after Longe and others, 1978, p. 63-66):

CALCITE	CLCT	HEMATITE	HMTT	PYRITE	PYRT
CHALCOPYRITE	CLCP	ILMENITE	ILMN	PYRRHOTITE	PYTT
CHLORITE	CLRT	LIMONITE	LMON	QUARTZ	QRTZ
CHROMITE	CRMT	MACKINAWITE	MCKN	SERPENTINE	SRPN
CLAY	CLAY	MAGNETITE	MGNT	SPHALERITE	SPLR
CUBANITE	CBNT	MARCASITE	MRCS	SPINEL	SPNL
DIASPORE	DSPR	MILLERITE	MLRT	TALC	TALC
DOLOMITE	DLMT	OPAL	OPAL	VALLERIITE	VLRT
GARNIERITE	GRNR	PENTLANDITE	PNLD	VIOLARITE	VOLR
GERSDORFFITE	GRDF	PLATINUM-GROUP ELEMENTS	PGE		
GOETHITE	GTHT	POLYDYMITE	PLDM		

Site name	Latitude	Longitude	Deposit type	Host rock[1]/
New Caledonia—continued				
Kouaoua (NMC) mining district	21° 24'S	165° 45'E	Laterite, residual enrichment	Peridotite; TERT
Kouaoua (SLN) mining district	21° 27'S	165° 45'E	-do-	-do-
Monéo mining district	21° 09'S	165° 29'E	-do-	-do-
Nakéty (CGMC) mining district	21° 32'S	166° 06'E	-do-	-do-
Nakéty (Nouméa Nickel) mining district	21° 33'S	166° 02'E	-do-	-do-
Nepoui mining district	21° 19'S	164° 43'E	-do-	-do-
N'Goyé mining district	21° 50'S	166° 27'E	-do-	-do-
Ouaco mining district	20° 45'S	164° 29'E	-do-	-do-
Ouinné mining district	21° 58'S	166° 40'E	-do-	-do-
Plaine des Lacs mining district	22° 40'S	166° 33'E	-do-	-do-
Poro mining district	21° 43'S	166° 08'E	-do-	-do-
Port Bouquet mining district	21° 27'S	166° 18'E	-do-	-do-
Poum mining district	20° 15'S	164° 03'E	-do-	-do-
Poya mining district	21° 21'S	165° 09'E	-do-	-do-
Thio-Ningua mining district	21° 41'S	166° 11'E	-do-	-do-
Thio-Plateau mining district	21° 37'S	166° 10'E	-do-	-do-
Thio-Mission mining district	21° 38'S	166° 15'E	-do-	-do-
Tiébaghi mining district	20° 27'S	164° 13'E	-do-	-do-
Philippines				
Rio Tuba mine	08° 35'N	117° 24'E	Laterite, residual enrichment	Pyroxenite; CRET
Surigao district	09° 51'N	125° 37'E	-do-	Dunite; CRET

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:

CENOZOIC	CEN	MESOZOIC	MES	PALEOZOIC	PAL	EARLY	E
PLEISTOCENE	PLEIS	CRETACEOUS	CRET	PRECAMBRIAN	PREC	MIDDLE	M
TERTIARY	TERT	JURASSIC	JUR	PROTEROZOIC	PROT	LATE	L
PLIOCENE	PLIO	TRIASSIC	TRI	ARCHEAN	ARCH		
MIOCENE	MIO	DEVONIAN	DEV				

Age of mineralization[2]/	Tectonic setting	Local environment	Principal mineral assemblages[3]/	Comments	Reference
		New Caledonia—continued			
TERT	MES-CEN mobile belt	Tropical weathering	GRNR, LMON, SRPN	---	Paris (1981)
-do-	-do-	-do-	-do-	---	Do.
-do-	-do-	-do-	-do-	---	Do.
-do-	-do-	-do-	-do-	---	Do.
-do-	-do-	-do-	-do-	---	Do.
-do-	-do-	-do-	-do-	---	Do.
-do-	-do-	-do-	-do-	---	Do.
-do-	-do-	-do-	-do-	---	Do.
-do-	-do-	-do-	-do-	---	Do.
-do-	-do-	-do-	-do-	---	Do.
-do-	-do-	-do-	-do-	---	Do.
-do-	-do-	-do-	-do-	---	Do.
-do-	-do-	-do-	-do-	---	Do.
-do-	-do-	-do-	-do-	---	Do.
-do-	-do-	-do-	-do-	---	Do.
-do-	-do-	-do-	-do-	---	Do.
-do-	-do-	-do-	-do-	---	Do.
-do-	-do-	-do-	-do-	---	Do.
		Philippines—continued			
CRET	MES-CEN mobile belt	Tropical weathering of ultramafic rocks	GRNR, LMON; DSPR, CLRT, TALC	Laterite is an irregular, tabular body	Wolff (1978)
CEN	Plate margin	Tropical weathering of serpentinite	GTHT, GRNR	Laterization of land surface of Nonoc Island during Pliocene or early Pleistocene	Philippines Bureau of Mines and Geo-Sciences (1980)

3/ Abbreviations for mineral names (after Longe and others, 1978, p. 63-66):

CALCITE	CLCT	HEMATITE	HMTT	PYRITE	PYRT
CHALCOPYRITE	CLCP	ILMENITE	ILMN	PYRRHOTITE	PYTT
CHLORITE	CLRT	LIMONITE	LMON	QUARTZ	QRTZ
CHROMITE	CRMT	MACKINAWITE	MCKN	SERPENTINE	SRPN
CLAY	CLAY	MAGNETITE	MGNT	SPHALERITE	SPLR
CUBANITE	CBNT	MARCASITE	MRCS	SPINEL	SPNL
DIASPORE	DSPR	MILLERITE	MLRT	TALC	TALC
DOLOMITE	DLMT	OPAL	OPAL	VALLERIITE	VLRT
GARNIERITE	GRNR	PENTLANDITE	PNLD	VIOLARITE	VOLR
GERSDORFFITE	GRDF	PLATINUM-GROUP ELEMENTS	PGE		
GOETHITE	GTHT	POLYDYMITE	PLDM		

Site name	Latitude	Longitude	Deposit type	Host rock1/
			South Africa	
Eastern Bushveld sector: Merensky Reef (Bushveld Complex)	24° 18'S	29° 52'E	Magmatic, gabbroic, stratiform, disseminated	Pyroxenite; Merensky Reef; EPROT (~2100 Ma)
Grasvally deposit (Bushveld Complex)	24° 20'S	28° 59'E	-do-	Gabbro-norite; EPROT (~2100 Ma)
Potgietersrus sector: Platreef (Bushveld Complex)	23° 59'S	28° 54'E	-do-	Pyroxenite; Platreef; EPROT (~2100 Ma)
Rustenburg-Brits sector: Merensky Reef (Bushveld Complex)	25° 42'S	27° 34'E	-do-	Pyroxenite; Merensky Reef; EPROT (~2100 Ma)
Rustenburg-Impala sector: Merensky Reef--Bophuthatswana (Bushveld Complex)	25° 32'S	27° 12'E	-do-	-do-
Union-Amandelbult sector: Merensky Reef (Bushveld Complex)	24° 46'S	27° 20'E	-do-	-do-
Volspruit PGE pyroxenite deposit (Bushveld Complex)	24° 22'S	28° 58'E	-do-	Pyroxenite; EPROT (~2100 Ma)
Uitkomst deposit (Bushveld satellite intrusion)	24° 45'S	30° 37'E	-do-	Pyroxenite; EPROT (2025 Ma)
Jacomyns Pan deposit (North-Western Cape area)	29° 19'S	21° 45'E	Magmatic, gabbroic, podiform	Biotite-tremolite schist; EPROT
Vlakfontein deposit--Bophuthatswana	25° 20'S	26° 55'E	-do-	Bronzitite; Vlakfontein subsuite; EPROT (~2100 Ma)
			Soviet Union	
Noril'sk-Talnakh district	69° 20'N	88° 08'E	Magmatic, gabbroic, stratiform	Tholeiitic basalt; Siberian traps; TRI

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:

CENOZOIC	CEN	MESOZOIC	MES	PALEOZOIC	PAL	EARLY	E
PLEISTOCENE	PLEIS	CRETACEOUS	CRET	PRECAMBRIAN	PREC	MIDDLE	M
TERTIARY	TERT	JURASSIC	JUR	PROTEROZOIC	PROT	LATE	L
PLIOCENE	PLIO	TRIASSIC	TRI	ARCHEAN	ARCH		
MIOCENE	MIO	DEVONIAN	DEV				

Age of mineralization[2]/	Tectonic setting	Local environment	Principal mineral assemblages[3]/	Comments	Reference
South Africa—continued					
EPROT	Intracratonic (anorogenic)	Plutonic	PYTT, PNLD, CLCP; PYRT, CBNT, MCKN	Merensky Reef forms part of Dwars River subsuite of Rustenburg layered suite	Schwellnus and others (1976)
-do-	-do-	-do-	---	Gabbro-norite is only mineralized with sulfides where the Rooipoort norite-anorthosite transgresses Zoetveld subsuite	Hulbert and von Gruene-waldt (1982)
-do-	-do-	-do-	PGE-sulfides, tellurides, arsenides; PYTT, PNLD, CLCP	Located in the Rooipoort norite-anorthosite	von Gruene-waldt (1977)
-do-	-do-	-do-	PYTT, PNLD, CLCP; PYRT, CBNT, MCKN	---	Do.
-do-	-do-	-do-	-do-	Merensky Reef forms part of the Schildpadnest subsuite of Rustenburg layered suite	Do.
-do-	-do-	-do-	-do-	-do-	Do.
-do-	-do-	-do-	PGE-sulphides, tellurides, arsenides; PYTT, PNLD, CLCP	Only significant PGE-Ni-Cu occurrence known in Zoetveld subsuite and other lower zone equiva-lents	Hulbert and von Gruene-waldt (1982)
EPROT (2025 Ma)	-do-	-do-	PYTT, PNLD, CLCP, PYRT	Seemingly inverted sill in Transvaal sequence	Kenyon and others (1981)
EPROT	Syntectonic	Metamorphic	CLCP, PYTT, PNLD	Intrusive basic to ultra-basic body of Keimoes suite	Attridge (in press)
---	Intracratonic (anorogenic)	Plutonic	PYTT, PNLD, CLCP, CBNT	238 pipes known; six pipes mined	Vermaak and von Gruene-waldt (1981)
Soviet Union—continued					
TRI	Crustal rift zone	Magmatic sulfides separated in gabbroic liquids	---	Ore concentrated along extensive fault in Siberian Platform	Naldrett (1981)

3/ Abbreviations for mineral names (after Longe and others, 1978, p. 63-66):

CALCITE	CLCT	HEMATITE	HMTT	PYRITE	PYRT
CHALCOPYRITE	CLCP	ILMENITE	ILMN	PYRRHOTITE	PYTT
CHLORITE	CLRT	LIMONITE	LMON	QUARTZ	QRTZ
CHROMITE	CRMT	MACKINAWITE	MCKN	SERPENTINE	SRPN
CLAY	CLAY	MAGNETITE	MGNT	SPHALERITE	SPLR
CUBANITE	CBNT	MARCASITE	MRCS	SPINEL	SPNL
DIASPORE	DSPR	MILLERITE	MLRT	TALC	TALC
DOLOMITE	DLMT	OPAL	OPAL	VALLERIITE	VLRT
GARNIERITE	GRNR	PENTLANDITE	PNLD	VIOLARITE	VOLR
GERSDORFFITE	GRDF	PLATINUM-GROUP ELEMENTS	PGE		
GOETHITE	GTHT	POLYDYMITE	PLDM		

Site name	Latitude	Longitude	Deposit type	Host rock[1]/
Soviet Union—continued				
Orsk combine (southern Urals)	51° 13'N	58° 35'E	Laterite, residual enrichment	Serpentinized peridotite; PAL
Pechenga district	69° 20'N	29° 44'E	Magmatic, gabbroic, stratiform, massive and disseminated	Serpentinite; Pechenga series; PROT
Yuzhuralnickel complex (central Urals)	56° 46'N	60° 18'E	Laterite, residual enrichment	Serpentinite; PAL
Tanzania				
Kabanga deposit (West Lake Region)	02° 50'S	30° 40'E	Magmatic, ultramafic, dessiminated and massive	Ultramafic intrusives; Karagwe-Ankolean; MPROT (1200-1400 Ma)
United States				
Riddle mine (Riddle district--Oregon)	42° 58'N	123° 27'W	Laterite, residual enrichment	Serpentinite; JUR
Venezuela				
Loma de Hierro deposit	10° 20'N	67° 20'W	Laterite, residual enrichment	Serpentinized harzburgite; Paracotos
Yugoslavia				
Kosovo mines (Kosovo)	42° 28'N	21° 03'E	Laterite, residual enrichment	Serpentinite
Ržanovo mine (Macedonia)	41° 14'N	22° 16'E	-do-	Serpentinite; PAL
Zimbabwe				
Epoch mine (Filabusi district)	20° 25'S	29° 15'E	Magmatic, ultramafic, stratiform	Schistose serpentinite; Sebakwian group; ARCH

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:

CENOZOIC	CEN	MESOZOIC	MES	PALEOZOIC	PAL	EARLY	E
PLEISTOCENE	PLEIS	CRETACEOUS	CRET	PRECAMBRIAN	PREC	MIDDLE	M
TERTIARY	TERT	JURASSIC	JUR	PROTEROZOIC	PROT	LATE	L
PLIOCENE	PLIO	TRIASSIC	TRI	ARCHEAN	ARCH		
MIOCENE	MIO	DEVONIAN	DEV				

Age of mineralization[2]/	Tectonic setting	Local environment	Principal mineral assemblages[3]/	Comments	Reference
Soviet Union—continued					
TRI-JUR	Ural Mountains	---	---	Kempirsai, Chalilovo, and Sakhara are blanket laterites; Akkermanovka, and Buruktal are linear-type laterites in grabens	---
---	Fault in PREC shield	Sulfides separated in mafic magmas	PYTT, PNLD, CLCP; PYRT; MGNT; VOLR	Deposit associated with ultramafic intrusions that lie within low-metamorphic volcanic rocks and sediments	Naldrett (1981)
TRI-JUR	Ural Mountains	---	SRPN, OPAL, Nontronite, GRNR, Nepouite, Ni-Kerolite, Rewdanskite; minor DLMT, CLCT, CRMT, LMON	Laterites often in karst-pockets, in faulted zones, or sometimes in blankets	---
Tanzania—continued					
MPROT (1200-1400 Ma)	Elongate PREC fold belts overlying and surrounding ARCH shields	---	PYTT; minor CLCP, PYRT, VOLR	At the SW end of a 300-km belt of magnetic anomalies	---
United States—continued					
MIO-PLIO	Orogenic belt	Tropical weathering of ultramafic rocks	GRNR, LMON, SRPN	Jurassic ophiolite weathered in Miocene; weathering stopped in Pleistocene; deposit uplifted	Chace and others (1969)
Venezuela—continued					
CRET	Orogenic belt	Tropical weathering of serpentinized peridotite	---	Serpentinized harzburgite sill 700m long	Lavie (1971)
Yugoslavia—continued					
---	---	Weathering of ultramafic rocks	---	---	Berthold (1980)
PAL	---	-do-	LMON, GTHT, Ni-silicate, HMTT, MGNT, CRMT	10-40 m of laterite ore overly serpentinite	Do.
Zimbabwe—continued					
---	ARCH greenstone belt	---	PNLD, MLRT, PLDM, CLCP	Ore body has a roughly tabular shape	Clutten and others (1981)

3/ Abbreviations for mineral names (after Longe and others, 1978, p. 63-66):

CALCITE	CLCT	HEMATITE	HMTT	PYRITE	PYRT
CHALCOPYRITE	CLCP	ILMENITE	ILMN	PYRRHOTITE	PYTT
CHLORITE	CLRT	LIMONITE	LMON	QUARTZ	QRTZ
CHROMITE	CRMT	MACKINAWITE	MCKN	SERPENTINE	SRPN
CLAY	CLAY	MAGNETITE	MGNT	SPHALERITE	SPLR
CUBANITE	CBNT	MARCASITE	MRCS	SPINEL	SPNL
DIASPORE	DSPR	MILLERITE	MLRT	TALC	TALC
DOLOMITE	DLMT	OPAL	OPAL	VALLERIITE	VLRT
GARNIERITE	GRNR	PENTLANDITE	PNLD	VIOLARITE	VOLR
GERSDORFFITE	GRDF	PLATINUM-GROUP ELEMENTS	PGE		
GOETHITE	GTHT	POLYDYMITE	PLDM		

Site name	Latitude	Longitude	Deposit type	Host rock[1]
Zimbabwe—continued				
Hunters Road deposit (Gweru district)	19° 10'S	29° 50'E	Magmatic, ultramafic	Serpentinite; Bulawayan group; ARCH (about 2700 Ma)
Madziwa mine (Shamva district)	17° 05'S	31° 50'E	Magmatic, gabbroic, metamorphic	Ultrabasic rocks; Madziwa Complex; ARCH
Shangani mine (Bulawayo district)	19° 40'S	29° 15'E	Magmatic, ultramafic, stratiform, massive and disseminated, metamorphic	Serpentinized peridotite; Sebakwian group; ARCH
Trojan mine (Harare district)	17° 18'S	31° 20'E	Magmatic, ultramafic, metamorphic	Komatiite; Bulawayan group; ARCH

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:

CENOZOIC	CEN	MESOZOIC	MES	PALEOZOIC	PAL	EARLY	E
PLEISTOCENE	PLEIS	CRETACEOUS	CRET	PRECAMBRIAN	PREC	MIDDLE	M
TERTIARY	TERT	JURASSIC	JUR	PROTEROZOIC	PROT	LATE	L
PLIOCENE	PLIO	TRIASSIC	TRI	ARCHEAN	ARCH		
MIOCENE	MIO	DEVONIAN	DEV				

Age of mineralization2/	Tectonic setting	Local environment	Principal mineral assemblages3/	Comments	Reference
		Zimbabwe—continued			
ARCH	Zimbabwean ARCH Craton	Thin ultra-mafic intrusions or flows	PYTT, PNLD, PYRT CLCP, MLRT, VOLR	Deposit is komatiitic portion of volcanic sequence	Moubray and others (1979)
---	PREC greenstone belt	---	PYTT, PNLD, CLCP; lesser VOLR, MLRT, SPLR, PLDM, CLRT	Ore bodies parallel NW trend of mafic pods	Do.
ARCH	African PREC shield	Base of ultramafic intrusion or flow	PYTT, PNLD; CLCP; PYRT; MGNT	Mineralized body occurs as a mushroom-like structure protruding from an ultra-mafic body	Viljoen and others (1976)
PREC	PREC greenstone belt	Magmatic sulfide segregations in ultramafic rocks	PNLD, MLRT; PYTT; MGNT; ILMN	Serpentinites in greenstone series contain nickel sul-fides	Clutten and others (1981)

3/ Abbreviations for mineral names (after Longe and others, 1978, p. 63-66):

CALCITE	CLCT	HEMATITE	HMTT	PYRITE	PYRT
CHALCOPYRITE	CLCP	ILMENITE	ILMN	PYRRHOTITE	PYTT
CHLORITE	CLRT	LIMONITE	LMON	QUARTZ	QRTZ
CHROMITE	CRMT	MACKINAWITE	MCKN	SERPENTINE	SRPN
CLAY	CLAY	MAGNETITE	MGNT	SPHALERITE	SPLR
CUBANITE	CBNT	MARCASITE	MRCS	SPINEL	SPNL
DIASPORE	DSPR	MILLERITE	MLRT	TALC	TALC
DOLOMITE	DLMT	OPAL	OPAL	VALLERIITE	VLRT
GARNIERITE	GRNR	PENTLANDITE	PNLD	VIOLARITE	VOLR
GERSDORFFITE	GRDF	PLATINUM-GROUP ELEMENTS	PGE		
GOETHITE	GTHT	POLYDYMITE	PLDM		

Site name	Year of discovery	Mining method1/	Year of first production	Elements of economic interest	Annual production2/
Albania					
Bitincke mine (Korca region)	---	---	---	Ni, Co, Fe	Planned capacity 800; about 1.0% Ni; 1983
Kukes deposit (Kukes region)	---	---	---	Ni, Co, Fe	See Bushtrica mine
Bushtrica mine (Librazhdi-Pogradeci region)	---	---	---	Ni, Co, Fe	Capacity 400; about 1.0% Ni; 1984 (est)
Guri Kuq mine (Librazhdi-Pogradeci region)	---	S	1978	Ni, Co, Fe	Capacity 400; 0.6-0.9% Ni; 1984 (est)
Prrenjas mine (Librazhdi-Pogradeci region)	---	S	1966	Ni, Fe, Cr	Capacity 400; 0.6-0.9% Ni; 1984 (est)
Australia					
Agnew mine (Western Australia)	1971	U	1978	Ni, Cu, Co	326; 2.76% Ni, 0.48% Cu, 0.23% Co; 1979-81 with 83% recovery
Carnilya Hill mine (Western Australia)	Late 1970's	U	1980	Ni, Cu	Western Mining Corp. share (56%) included in total for Juan mine (Kambalda-St. Ives-Tramways district)
Durkin mine (Kambalda-St. Ives-Tramways district, Western Australia)	1967	U	Early 1969	Ni, Cu, Co, Au, Ag, S, Pd, Pt	See Juan mine
Edwin mine (Kambalda-St. Ives-Tramways district, Western Australia)	1969	U	Late 1975	Ni, Cu, Co, Au, Ag, S, Pd, Pt	-do-
Fisher mine (Kambalda-St. Ives-Tramways district, Western Australia)	1965	U	Late 1972	Ni, Cu, Co, Au, Ag, S, Pd, Pt	-do-
Foster mine (Kambalda-St. Ives-Tramways district, Western Australia)	1971	U	Late 1981	Ni, Cu, Co, Au, Ag, S, Pd, Pt	-do-
Hunt mine (Kambalda-St. Ives-Tramways district, Western Australia)	1970	U	1976	Ni, Cu, Co, Au, Ag, S, Pd, Pt	-do-

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; and year of production (or range of years used to estimate average annual production).

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; and years for reported cumulative production.

Cumulative production3/	Resources4/	Comments
	Albania—continued	
---	15,000; R1E; about 1.0% Ni; 1984	Resources for Albania, not including Librazhdi-Pogradeci region
---	R1E (see Bitincke mine)	---
---	8,000; R1E; 0.9-1.0% Ni; 1984	Annual production from all Albanian deposits estimated at 1 million metric tons at 1.0% Ni in 1983; resources include Bushtrica and other small deposits; ore sent to Czechoslovakia for processing
---	23,000; R1E; 0.9-1.0% Ni; 1984	Ore processed at Elbasan Metallurgical Complex
---	23,000; R1E; 0.9-1.0% Ni; 1984	Do.

	Australia—continued	
1,004; 2.74% Ni, 0.49% Cu, 0.23% Co; 1978-81 with 83% recovery	400; r1E; 3.1% Ni; 1982 (proved) 2,300; r1E; 2.2% Ni; 1982 (probable-shallow) 35,000; R1E; 1.9% Ni; 1982 (probable-deep)	Grades for cumulative (1978-81) production estimated using reported 1979-81 ore and metal production and grades for 1978 estimated from 1979-81 data
Western Mining Corp. share (56%) included in total for Juan mine (Kambalda-St. Ives-Tramways district)	700; R1E; 4.0% Ni; 1982	Announced mine life probably 6 years
See Juan mine	R1E (see Juan mine)	---
-do-	-do-	---
-do-	-do-	---
-do-	-do-	---
-do-	-do-	---

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 (unless resource is specified as contained metal); and year of estimate. Grades reported for mining properties often are the grade of mill feed, while for undeveloped properties, in situ grades are usually reported. Dilution in the mill feed grades may be about 5 percent for open-pit mining and 15 percent for underground mining.

Site name	Year of discovery	Mining method[1]	Year of first production	Elements of economic interest	Annual production[2]
Australia—continued					
Jan mine (Kambalda-St. Ives-Tramways district, Western Australia)	1966	U	Late 1975	Ni, Cu, Co, Au, Ag, S, Pd, Pt	See Juan mine
Juan mine (Kambalda-St. Ives-Tramways district, Western Australia)	1966	U	1969	Ni, Cu, Co, Au, Ag, S, Pd, Pt	1,376; 3.02% Ni, 0.23% Cu; 1977-81
Long mine (Kambalda-St. Ives-Tramways district, Western Australia)	1973	U	1977	Ni, Cu, Co, Au, Ag, S, Pd, Pt	See Juan mine
Lunnon mine (Kambalda-St. Ives-Tramways district, Western Australia)	1966	U	1967	Ni, Cu, Co, Au, Ag, S, Pd, Pt	-do-
McMahon mine (Kambalda-St. Ives-Tramways district, Western Australia)	1968	U	Late 1972	Ni, Cu, Co, Au, Ag, S, Pd, Pt	-do-
Greenvale mine (Queensland)	1967	S	1974	Ni, Co	1,996; 1.32% Ni, 0.11% Co; 1977-81
Mount Keith deposit (Western Australia)	1968	N	None	Ni, Co	None
Windarra district (Western Australia)	1969	S, U	1974	Ni, Cu, Co	778; 1.58% Ni, 0.14% Cu; 1975-77, 1981-82 (75% recovery)
Botswana					
Selebi-Pikwe district	1963 (Selebi), 1966 (Pikwe)	S, U	1974	Ni, Cu	2,039; 1.01% Ni, 0.81% Cu; 1977-79
Brazil					
Barro Alto mine (Goias)	1945	S	---	Ni, Co	---
Morro do Niquel mine (Minas Gerais)	1922	S	1962	Ni, Co, Fe	206; 1.28% Ni; 1978

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; and year of production (or range of years used to estimate average annual production).

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; and years for reported cumulative production.

Cumulative production3/	Resources4/	Comments
	Australia—continued	
See Juan mine	R1E (see Juan mine)	---
15,763; 3.33% Ni, 0.25% Cu; 1967-81	25,000; R1E; 3.3% Ni; 1982	Production and resources are for entire Kambalda-St. Ives-Tramways district; production totals include Western Mining Corp. share (56%) of Carnilya Hill mine, which came on stream in 1980
See Juan mine	R1E (see Juan mine)	---
-do-	-do-	---
-do-	-do-	---
11,617; 1.35% Ni, 0.11% Co; 1975-81	26,691; R1E; 1.28% Ni, 0.11% Co; 1980	Report year for production data ends in June
None	270,000; R1S; 0.6% Ni; 1982	Development not economic and unlikely before 1990's
3,961; 1.58% Ni; 1974-82 (74% recovery)	9,200; R1E; 1.4% Ni; 1982	Includes Mount Windarra and South Windarra mines
	Botswana—continued	
9,999; 1.06% Ni, 0.86% Cu; 1974-79	18,191; R1E; 1.27% Ni, 1.10% Cu (Pikwe); 1979 (proven) 8,617; R1E; 0.96% Ni, 0.90% Cu (Pikwe); 1979 (probable) 9,955; R1E; 0.70% Ni, 1.56% Cu (Selebi); 1979 (proven) 2,682; R1E; 0.88% Ni, 1.28% Cu (Selebi); 1979 (probable)	Cumulative production for Pikwe only
	Brazil—continued	
---	59,000; R1E; 1.88% Ni; 1981 7,200; R2E; 1.88% Ni; 1982	Production plans for 55,000 metric tons/yr of ferronickel containing 22,700 metric tons Ni
25; Ni in products; 1969-78	2,282; R1E; 1.5% Ni; 1982 1,118; R2E; 1.2% Ni; 1977	Smelter capacity 2,500 metric tons/yr Ni in ferronickel of 23% Ni

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 (unless resource is specified as contained metal); and year of estimate. Grades reported for mining properties often are the grade of mill feed, while for undeveloped properties, in situ grades are usually reported. Dilution in the mill feed grades may be about 5 percent for open-pit mining and 15 percent for underground mining.

Site name	Year of discovery	Mining method1/	Year of first production	Elements of economic interest	Annual production2/
Brazil—continued					
Tocantins mine (Niquelandia district--Goias)	1908	S	1979	Ni, Co, Fe	---
Codemin mine (Niquelandia district--Goias)	1908	S	1982	Ni, Fe	5 to 5.9; Ni in ferronickel; designed capacity
Burundi					
Musongati deposit (Buhinda Plateau)	1972	N	None	Ni, Cu, Co, PGE, Cr	---
Canada					
East mine (Sudbury district (Ontario)-Falconbridge Ltd.)	1949	U	1953	Ni, Cu, PGE, Au, Ag, Co, Se, Te	See Falconbridge mine
Falconbridge mine (Sudbury district (Ontario)-Falconbridge Ltd.)	1916	U	1930	Ni, Cu, PGE, Au, Ag, Co, Se, Te	2,578; 1.3% Ni, 0.9% Cu, 0.04% Co; 1977-81 with about 79% Ni recovery
Fecunis-North mine (Sudbury district (Ontario)-Falconbridge Ltd.)	1964	U	1965	Ni, Cu, PGE, Au, Ag, Co, Se, Te	See Falconbridge mine
Fraser mine (Sudbury district (Ontario)-Falconbridge Ltd.)	Pre-1970	U	1981	Ni, Cu, PGE, Au, Ag, Co, Se, Te	-do-
Lockerby mine (Sudbury district (Ontario)-Falconbridge Ltd.)	1919	U	1975	Ni, Cu, PGE, Au, Ag, Co, Se, Te	-do-
Onaping-Craig mine (Sudbury district (Ontario)-Falconbridge Ltd.)	1942	U	1961	Ni, Cu, PGE, Au, Ag, Co, Se, Te	-do-
Strathcona mine (Sudbury district (Ontario)-Falconbridge Ltd.)	1951	U	1962	Ni, Cu, PGE, Au, Ag, Co, Se, Te	-do-
Clarabelle no. 2 open pit (Sudbury-district (Ontario)-Inco Ltd.)	1883	S	1979	Ni, Cu, PGE, Au, Ag, Co, Se, Te	See Creighton mine
Coleman mine (Sudbury district (Ontario)-Inco Ltd.)	Pre-1964	U	1971	Ni, Cu, PGE, Au, Ag, Co, Se, Te	-do-

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; and year of production (or range of years used to estimate average annual production).

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; and years for reported cumulative production.

Cumulative production3/	Resources4/	Comments
Brazil—continued		
---	32,000; R1E; 1.46% Ni; 1981 (measured) 4,900; R1E; 1981 (indicated) 3,250; R2S; 1981 (inferred)	R1E and R2S data for entire district
---	16,000; R1E; 1.45% Ni; 1983	Mine life of 20 years expected with 85% recovery; produces ferronickel with 35% Ni
Burundi—continued		
---	73,000; R2S; 1.6% Ni, 0.3% Cu, 0.1% Co, PGE and chromite present;1978 300,000; R2S (probable ore); 1978	Overburden/ore ratio is 1:8.1
Canada—continued		
See Falconbridge mine	r1E (see Falconbridge mine)	---
85,095; 1.5% Ni, 0.8% Cu; 1930-81	71,814; r1E; 1.49% Ni, 0.93% Cu; 1981	Production and resources for all Falconbridge operations in Sudbury district (Ontario); Falconbridge mine closed after Jun 84 rock burst
See Falconbridge mine	r1E (see Falconbridge mine)	---
-do-	-do-	---
-do-	-do-	Believed to be an extension of Crean Hill No. 2 deposit.
-do-	-do-	Operation suspended indefinitely Sep 82
-do-	-do-	---
See Creighton mine	r1E (see Creighton mine)	---
-do-	-do-	Last production in 1982

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 (unless resource is specified as contained metal); and year of estimate. Grades reported for mining properties often are the grade of mill feed, while for undeveloped properties, in situ grades are usually reported. Dilution in the mill feed grades may be about 5 percent for open-pit mining and 15 percent for underground mining.

Site name	Year of discovery	Mining method1/	Year of first production	Elements of economic interest	Annual production2/
Canada—continued					
Copper Cliff North mine (Sudbury district (Ontario)-Inco Ltd.)	Pre-1960	U	1967	Ni, Cu, PGE, Au, Ag, Co, Se, Te	See Creighton mine
Copper Cliff South mine (Sudbury district (Ontario)-Inco Ltd.)	Pre-1967	U	1970	Ni, Cu, PGE, Au, Ag, Co, Se, Te	-do-
Crean Hill mine (Sudbury district (Ontario)-Inco Ltd.)	Pre-1905	U	1905	Ni, Cu, PGE, Au, Ag, Co, Se, Te	-do-
Creighton mine (Sudbury district (Ontario)-Inco Ltd.)	1900	U	1901	Ni, Cu, PGE, Au, Ag, Co, Se, Te	9,368; 1.37% Ni, 1.27% Cu; 1977-81 (81% Ni recovery)
Frood mine (Sudbury district (Ontario)-Inco Ltd.)	1884	U	1889	Ni, Cu, PGE, Au, Ag, Co, Se, Te	See Creighton mine
Garson mine (Sudbury district (Ontario)-Inco Ltd.)	1891	U	1908	Ni, Cu, PGE, Au, Ag, Co, Se, Te	-do-
Levack mine (Sudbury district (Ontario)-Inco Ltd.)	1888	U	1914	Ni, Cu, PGE, Au, Ag, Co, Se, Te	-do-
Levack East mine (Sudbury district (Ontario)-Inco Ltd.)	Pre-1970	U	---	Ni, Cu, PGE, Au, Ag, Co, Se, Te	-do-
Little Stobie mine (Sudbury district (Ontario)-Inco Ltd.)	1885	U	1902	Ni, Cu, PGE, Au, Ag, Co, Se, Te	-do-
McCreedy West mine (Sudbury district (Ontario)-Inco Ltd.)	Pre-1939	U	1973	Ni, Cu, PGE, Au, Ag, Co, Se, Te	-do-
Murray mine (Sudbury district (Ontario)-Inco Ltd.)	1883	U	1889	Ni, Cu, PGE, Au, Ag, Co, Se, Te	-do-
Shebandowan mine (Thunder Bay district (Ontario)-Inco Ltd.)	Pre-1936	U	1972	Ni, Cu, PGE, Co, Se, Te	-do-
Stobie mine (Sudbury district (Ontario)-Inco Ltd.)	1884	U	1887	Ni, Cu, PGE, Au, Ag, Co, Se, Te	-do-
Totten mine (Sudbury district (Ontario)-Inco Ltd.)	1885	U	1966	Ni, Cu, PGE, Au, Ag, Co, Se, Te	-do-
Donaldson deposit (New Quebec mining district--Quebec)	1954	N	None	Ni, Cu, PGE	None

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; and year of production (or range of years used to estimate average annual production).

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; and years for reported cumulative production.

Cumulative production3/	Resources4/	Comments
	Canada—continued	
See Creighton mine	r1E (see Creighton mine)	Last production in 1978
-do-	-do-	---
-do-	-do-	Placed on standby in 1973
427,880; 1.25% Ni, 1.03% Cu, 0.02% Co, 4.11 g/t Ag, 0.206 g/t Au; 1950-81 (79% Ni recovery)	366,503; r1E; 1.29% Ni, 1.10% Cu; 1981	Production and resources for all Inco operations in Sudbury district (Ontario) and for Shebandowan mine
See Creighton mine	r1E (see Creighton mine)	---
-do-	-do-	---
-do-	-do-	---
-do-	-do-	---
-do-	-do-	---
-do-	-do-	---
-do-	-do-	Last production in 1971 (on standby)
-do-	-do-	---
-do-	-do-	---
-do-	-do-	Last production in 1972
None	2,377; R1M; 4.43% Ni, 0.99% Cu; 1969	---

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 (unless resource is specified as contained metal); and year of estimate. Grades reported for mining properties often are the grade of mill feed, while for undeveloped properties, in situ grades are usually reported. Dilution in the mill feed grades may be about 5 percent for open-pit mining and 15 percent for underground mining.

Site name	Year of discovery	Mining method[1]	Year of first production	Elements of economic interest	Annual production[2]
Canada—continued					
Katiniq deposit (New Quebec mining district--Quebec)	1961	N	None	Ni, Cu	None
Birchtree mine (Thompson Nickel Belt--Manitoba)	1964	U	1969	Ni, Cu, Co, PGE, Au, Ag, Se, Te	See Thompson mine
Moak mine (Thompson Nickel Belt--Manitoba)	1952	N(U)	None	Ni, Cu	None
Pipe No. 1 mine (Thompson Nickel Belt--Manitoba)	1959	U	1970	Ni, Cu, Co, PGE, Au, Ag, Se, Te	See Thompson mine
Pipe No. 2 open pit (Thompson Nickel Belt--Manitoba)	1959	S	1970	Ni, Cu, Co, PGE, Au, Ag, Se, Te	-do-
Soab North and South mines (Thompson Nickel Belt--Manitoba)	1959	U	1967	Ni, Cu, Co, PGE, Au, Ag, Se, Te	-do-
Thompson mine (Thompson Nickel Belt--Manitoba)	1956	S, U	1961	Ni, Cu, Co, PGE, Au, Ag, Se, Te	2,359; 1.83% Ni, 0.14% Cu; 1977-81
China					
Jinchuan mine (Gansu Province)	1958	S, U	1964	Ni, Cu, Co	10; Ni and Cu metal (capacity); 1980 17; Ni in products (capacity); 1982
Colombia					
Cerro Matoso mine (Cordoba)	1956	S	1982	Ni, Fe, Co, Cr	16; Ni in ferronickel; 1983
Cuba					
Moa Bay district (Oriente Province)	1905	S	1959	Ni, Fe, Co	20; 55% Ni, 5% Co (concentrate); 1983 (from ore of 1.35% Ni, 0.10% Co at 1.0% Ni cutoff)
Nicaro district (Oriente Province)	1905	S	1944	Ni, Co, Fe, Cr	21; Ni in matte from ore of 1.24% Ni, 0.09% Co; 1983 (1.1% Ni cutoff)
Punta Gorda district (Oriente Province)	1905	N(S)	None	Ni, Co, Fe	Planned matte production from ore of 1.33% Ni, 0.11% Co (0.9% Ni cutoff)
Dominican Republic					
Falconbridge Dominicana mines	1918	S	1971	Ni, Fe, Co	23.28; Ni in ferronickel; 1973-81

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; and year of production (or range of years used to estimate average annual production).

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; and years for reported cumulative production.

Cumulative production3/	Resources4/	Comments
Canada—continued		
None	4,411; R1M; 3.05% Ni, 0.86% Cu; 1969	---
See Thompson mine	r1E (see Thompson mine)	Last production in 1977 (on standby)
None	45,000; R1M; about 0.75% Ni; 1984	Development suspended once larger Thompson mine deposit was brought into production
-do-	-do-	Last production in 1971 (on standby)
-do-	-do-	Last production 1984
-do-	-do-	Last production 1971 (on standby)
58,967; 2.0% Ni, 0.12% Cu, 0.01% Co; 1961-81	88,904; r1E; 2.48% Ni, 0.18% Cu; 1981	Production and resources for all Inco operations in Thompson Nickel Belt excepting Moak mine
China—continued		
120; Ni from ore of 1.13% Ni; 1966-80	470,000; R1E; 1.1% Ni, 0.5-0.6% Cu; 1980	Increase in production in near future due to foreign financial assistance; produces ferronickel with no recovery of Co
Colombia—continued		
100; 2.5% Ni; 1980-82 (includes pre-production pilot plant)	23,000; R1E; 2.6% Ni, cutoff grade 1.5% Ni; 1979	Planned mine life of over 25 yrs; temperature control problems kept production to 70% of capacity in 1983
Cuba—continued		
---	400,000; R1E; 1.3% Ni; 1964	Laterites are limonitic, low in magnesia, high in cobalt
64.2; Ni-Co oxide 77-78% Ni, 0.9-1.3% Co; 1967-73 63.4; Ni-Co sinter 90% Ni, 1.1-1.6% Co; 1967-73	46,000; R1E; 1.4-2.0% Ni; 1978	Ni oxide is produced in lump and powder form with Ni content of 87% and 90% respectively
None	60,000; R1E; 1.33% Ni; 1984 100,000; R2E; 1.37% Ni; 1984	Government planning 30,000 metric tons/yr nickel oxide plant to be on line late 1984
Dominican Republic—continued		
210; Ni in ferronickel; 1973-81	56,246; R1E; 1.64% Ni; 1981	Upper stripping cutoff limit is 1.05% Ni, bottom cutoff is 1.9% Ni; produces ferronickel with no recovery of Co

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 (unless resource is specified as contained metal); and year of estimate. Grades reported for mining properties often are the grade of mill feed, while for undeveloped properties, in situ grades are usually reported. Dilution in the mill feed grades may be about 5 percent for open-pit mining and 15 percent for underground mining.

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

Site name	Year of discovery	Mining method[1]	Year of first production	Elements of economic interest	Annual production[2]
			Finland		
Enonkoski deposit	1950's	N(U)	About 1986	Ni, Cu	None
Hitura deposit	1937	S	1970	Ni, Cu, PGE	281; 0.43% Ni, 0.15% Cu; 1975 463; 0.5% Ni; 1979
Kotalahti mine (Outokumpu district)	1954	U	1959	Ni, Cu, PGE	481; 0.60% Ni, 0.14% Cu (recovered); 1974-80
Vammala mine	1961	S, U	1975	Ni, Cu, PGE	320; 0.58% Ni (yield); 1979-81
			Greece		
Larymna mine and Euboea Island deposit	1900	S, U	1966	Ni, Fe	586; 1.4% Ni; 1976-81
			Guatemala		
EXMIBAL mine (Izabal district)	1955	S	1977	Ni, Co, Cu	5; Ni in products; 1981
			Indonesia		
Gag Island deposit	1952	N(S)	None	Ni, Co, Fe	None
Gebe Island mining area	1974	S	1979	Ni, Co, Fe	920; about 2.22% Ni; 1981-82
Pomala deposit (Sulawesi Island)	---	S	1963	Ni, Co, Fe	800; >2% Ni; 1975 1,256; >2% Ni; 1978
Soroako deposit (Central Sulawesi district)	1900	S	1977	Ni, Fe	27; Ni in products; 1981
			Ivory Coast		
Biankouma district	1975 or before	N	None	Ni	None
			New Caledonia		
Canala-Bogota mining district	1864	S	1875	Ni, Co	No production 1978-83
Ile Art mining district	1864	S	1875	Ni, Co	None

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; and year of production (or range of years used to estimate average annual production).

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; and years for reported cumulative production.

Cumulative production3/	Resources4/	Comments
	Finland—continued	
None	3,800; R1E; 1.2% Ni, 0.3% Cu; 1984	Production will be about 400,000 metric tons ore/yr for first 2 years
4,000; 0.47% Ni, 0.069% Cu; 1970-82	8,300; R1E; 0.6% Ni, 0.2% Cu; 1980	Closed at end of 1982 due to low nickel prices; reopened June 1984
8,900; 0.7% Ni, 0.3% Cu; through 1980	14,300; R1E; 0.7% Ni, 0.3% Cu; 1980	Disseminated ore (Ni/Cu = 10) and breccia ore (Ni/Cu = 2)
1,517; 0.5% Ni; 1975-81	10,000; R1E; 0.57% Ni; 1981 18,000; R1E; 0.50% Ni, 0.29% Cu; 1980	---
	Greece—continued	
7,130; 1.4% Ni; 1966-81	35,000; R1E; 1.4% Ni; 1973 (high As) 200,000; R1E; 1.1-1.3% Ni; 1973 (Euboea Island) 400,000; R2E; 1.1-1.3% Ni; 1973 (Euboea Island)	Ferronickel from Larymna mine is 70-75% Fe, 25-30% Ni-Co with up to 0.04% S; produces ferronickel with no recovery of Co
	Guatemala—continued	
19.32; Ni in products; 1977-81	50,000; R1E; 1.80% Ni; 1980	Operations closed at end of 1981
	Indonesia—continued	
None	160,000; R1E; 1.64% Ni, 0.12% Co; 1981 (1.1% Ni cutoff)	Development plans abandoned in 1983
3,306; about 2.22% Ni; 1979-82	32,000; R1E; 2.22% Ni (silicate ore); 1976 68,000; R1S; 1.25% Ni (limonitic ore); 1975	---
5,000; >2% Ni; 1963-78	45,000; R1E; 1.5% Ni; 1976 100,000; R2E; 1.28% Ni; 1976	Dried ore is shipped to Tokyo for refining
56.6; Ni in products; 1979-81	110,000; R1E; 1.67% Ni, <0.15% Co, 1975 145,000; R1M+R1S+R2E+R2S; 1.75% Ni, 0.1% Co; 1976	Limonite: 1.45% Ni, 44% Fe, 3% MgO, 7-10% SiO_2; produces matte and ferronickel
	Ivory Coast—continued	
None	200,000; R1S; 1.6% Ni; 1983	---
	New Caledonia—continued	
9.9; Ni+Co in products; through 1978	43,500; R1E; Ni metal; 1974	Resources are for all New Caledonian deposits and districts; year of discovery refers to the identification of nickel laterites for all New Caledonia; year of first production refers to first production for all New Caledonia
None	11,000; R1E; 2.80% Ni+Co; 1976	District resources included in total of Territorial resources listed for Canala-Bogota mining district

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 (unless resource is specified as contained metal); and year of estimate. Grades reported for mining properties often are the grade of mill feed, while for undeveloped properties, in situ grades are usually reported. Dilution in the mill feed grades may be about 5 percent for open-pit mining and 15 percent for underground mining.

Site name	Year of discovery	Mining method[1]/	Year of first production	Elements of economic interest	Annual production[2]/
New Caledonia—continued					
Kaala-Gomen mining district	1864	S	1875	Ni, Co	2.5; Ni in products; 1980-82 0.24; Ni in products; 1983
Kouaoua (NMC) mining district	1864	S	1875	Ni, Co	10.2; Ni+Co in products; 1979 7.4; Ni in products; 1980-83
Kouaoua (SLN) mining district	1864	S	1875	Ni, Co	10.4; Ni+Co in products; 1979 14.8; Ni in products; 1980-83
Monéo mining district	1864	S	1875	Ni, Co	7.1; Ni+Co in products; 1979 4.5; Ni in products; 1980-83
Nakéty (CGMC) mining district	1864	S	1875	Ni, Co	0.45; Ni in products; 1980-83
Nakéty (Nouméa Nickel) mining district	1864	S	1875	Ni, Co	4.3; Ni+Co in products; 1979 3.7; Ni in products; 1980-83
Nepoui mining district	1864	S	1875	Ni, Co	17.2; Ni+Co in products; 1979 10.5; Ni in products; 1980-82
N'Goyé mining district	1864	S	1875	Ni, Co	0.3; Ni+Co in products; 1979 0.9; Ni in products; 1980-82
Ouaco mining district	1864	S	1875	Ni, Co	6.6; Ni+Co in products; 1979 4.0; Ni in products; 1980-83
Ouinné mining district	1864	S	1875	Ni, Co	2.9; Ni+Co in products; 1979 3.6; Ni in products; 1980-82 0.3; Ni in products; 1983
Plaine des Lacs mining district	1864	S	1875	Ni, Co	---
Poro mining district	1864	S	1875	Ni, Co	9.8; Ni+Co in products; 1979 6.8; Ni in products; 1980-83

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; and year of production (or range of years used to estimate average annual production).

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; and years for reported cumulative production.

Cumulative production3/	Resources4/	Comments
New Caledonia—continued		
70; Ni+Co in products; through 1979 7.8; Ni in products; 1980-83	R1E (see Canala-Bogota mining district)	---
259; Ni+Co in products; through 1979 30; Ni in products; 1980-83	-do-	---
10; Ni+Co in products; 1979 59; Ni in products; 1980-83	-do-	---
47; Ni+Co in products; through 1979 18; Ni in products; 1980-83	-do-	---
71; Ni+Co in products; through 1979 1.8; Ni in products; 1980-83	-do-	No production reported in 1979
4.3; Ni+Co in products; 1979 15; Ni in products; 1980-83	-do-	---
265; Ni+Co in products; through 1979 66; Ni in products; 1980-83	11,000; R1E; 2.7% Ni; 1972	District resources included in total of Territorial resources listed for Canala-Bogota mining district
5.9; Ni+Co in products; through 1979 2.8; Ni in products; 1980-83	R1E (see Canala-Bogota mining district	No production reported for 1983
132; Ni+Co in products; through 1979 15.9; Ni in products; 1980-83	-do-	---
44; Ni+Co in products; through 1979 11.1; Ni in products; 1980-83	-do-	---
0.28; Ni+Co in products; through 1983	-do-	No production reported 1979-83
258; Ni+Co in products; through 1979 27; Ni in products; 1980-83	30,000; R1E; 2.5% Ni; 1972	District resources included in total of Territorial resources listed for Canala-Bogota mining district

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 (unless resource is specified as contained metal); and year of estimate. Grades reported for mining properties often are the grade of mill feed, while for undeveloped properties, in situ grades are usually reported. Dilution in the mill feed grades may be about 5 percent for open-pit mining and 15 percent for underground mining.

Site name	Year of discovery	Mining method1/	Year of first production	Commodities	Annual production2/
New Caledonia—continued					
Port Bouquet mining district	1864	S	1875	Ni, Co	0.5; Ni in products; 1983
Poum mining district	1864	S	1875	Ni, Co	No production in 1978-83
Poya mining district	1864	S	1875	Ni, Co	0.23; Ni in products; 1980-82
Thio-Ningua mining district	1864	S	1875	Ni, Co	---
Thio-Plateau mining district	1864	S	1875	Ni, Co	8.4; Ni+Co in products; 1979 8.0; Ni in products; 1980-83
Thio-Mission mining district	1864	S	1875	Ni, Co	4.4; Ni+Co in products; 1979 3.6; Ni in products; 1980-83
Tiébaghi mining district	1864	S	1875	Ni, Co	None
Philippines					
Rio Tuba mine	1967	S	1977	Ni, Fe	350; 2.2% Ni; 1977 750; 1978
Surigao district	1912	S	1974	Ni, Co, Fe	2,600; 1.24% Ni, 0.13% Co, 41.6% Fe; 1981-82
South Africa					
Eastern Bushveld sector: Merensky Reef (Bushveld Complex)	1924	U	Between 1924 and 1930	PGE, Ni, Cu, Co, Au	Proprietary data
Grasvalley deposit (Bushveld Complex)	---	N	None	PGE, Ni, Cu	None
Potgietersrus sector: Platreef (Bushveld Complex)	1925	N	None	Ni, Cu, PGE	None
Rustenburg-Brits sector: Merensky Reef (Bushveld Complex)	Middle 1920's	U	1960's	PGE, Ni, Cu, Co, Au	Proprietary data

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; and year of production (or range of years used to estimate average annual production).

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; and years for reported cumulative production.

Cumulative production3/	Resources4/	Comments
New Caledonia—continued		
4.7; Ni+Co in products; through 1979 0.66; Ni in products; 1980-83	R1E (see Canala-Bogota mining district)	---
27.9; Ni+Co in products; through 1983	35,000; R1E; 2.15% Ni (dry garnierite ore); 1976 41,000; R1E; 1.34% Ni+Co (dry laterite ore); 1976	No production reported 1979-83; district resources included in total of Territorial resources listed for Canala-Bogota mining district
72; Ni+Co in products; through 1979 0.7; Ni in products; 1980-82	R1E; (see Canala-Bogota mining district	No production reported 1983
180; Ni+Co in products; through 1983	-do-	No production reported 1979-83
416; Ni+Co in products; through 1979 32; Ni in products; 1980-83	-do-	---
9.4; Ni+Co in products; through 1979 14.2; Ni in products; 1980-83	-do-	---
None	13,300; R1E; 2.90% Ni (dry garnierite ore); 1976 12,600; R1E; 1.20% Ni+Co (dry laterite ore); 1976	District resources included in total of Territorial resources listed for Canala-Bogota mining district
Philippines—continued		
---	24,000; R1E; 2.2% Ni; 1981 40,000; R2E; 2.2% Ni; 1981	Japan is taking entire output of mine
18,800; 1.22% Ni; 1975-82	66,600; R1E; 1.23% Ni; 1980 2,694; R2S; 0.75% Ni; 1978 (North Surigao)	Ore about 40% Fe
South Africa—continued		
---	80; r1E+r2E+r1M; contained Ni (0.1% Ni recovery grade); 1982	Subeconomic nickel resources of Merensky Reef in Eastern Bushveld not quantified
None	---	No production planned for near future
None	690,000; r1E+r2E; 0.36% Ni, 0.18% Cu recovery grade; 1982 970,000; r1M; 0.36% Ni, 0.18% Cu recovery grade; 1982	r1E+r2E to 200 m depth; r1M to 200-500 m depth
---	410; r1E+r2E; Ni metal recoverable from ore of 0.2-0.25% Ni; 1982 220; r1M; Ni metal recoverable from ore of 0.2-0.25% Ni; 1982	Resources over 18.75 km strike to 1200 m vertical depth, 0.8 m thick, 12° dip, 60% recovery; mined for PGE, Ni and Co are byproducts

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 (unless resource is specified as contained metal); and year of estimate. Grades reported for mining properties often are the grade of mill feed, while for undeveloped properties, in situ grades are usually reported. Dilution in the mill feed grades may be about 5 percent for open-pit mining and 15 percent for underground mining.

Site name	Year of discovery	Mining method1/	Year of first production	Elements of economic interest	Annual production2/
South Africa—Continued					
Rustenburg-Impala sector: Merensky Reef--Bophuthatswana (Bushveld Complex)	1924	U	Between 1924 and 1930	PGE, Ni, Cu, Co, Au	Proprietary data
Union-Amandelbult sector: Merensky Reef (Bushveld Complex)	Middle 1920's	U	---	PGE, Ni, Cu, Co, Au	-do-
Volspruit PGE pyroxenite deposit (Bushveld Complex)	Late 1960's	N	None	PGE, Ni, Cu	None
Uitkomst deposit (Bushveld satellite intrusion)	1928	N	-do-	Ni, Cu, PGE	-do-
Jacomyns Pan deposit (North-Western Cape area)	Early 1970's	N	-do-	Ni, Cu, Ag	-do-
Vlakfontein deposit--Bophuthatswana	1910	U	Pre-1936	Ni, Cu	See comments
Soviet Union					
Noril'sk-Talnakh district	1920	U	---	Ni, Cu, Co, Pt, Pd, Rh, Ru, Os, Ir	89; Ni in products (ore grade 0.5% Ni, 0.8% Cu); 1977
Orsk combine (southern Urals)	---	S	1938	Ni, Co, Fe	See Yuzhuralnickel complex
Pechenga district	1937	U	---	Cu, Ni, Se, Te, Au, Ag	20.25; Ni in products; 1977
Yuzhuralnickel complex (central Urals)	---	S	1874	Ni, Co, Fe	19 (est); Ni in products; 1977
Tanzania					
Kabanga deposit (West Lake Region)	1976	N	None	Ni, Cu, Co	None
United States					
Riddle mine (Riddle district--Oregon)	1864	S	1954	Ni, Fe	14.05; Ni in ferronickel; 1972-81

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; and year of production (or range of years used to estimate average annual production).

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; and years for reported cumulative production.

Cumulative production[3]/	Resources[4]/	Comments
South Africa—continued		
---	930; r1E+r2E; Ni metal recoverable from ore of 0.2-0.25% Ni; 1982 220; r1M; Ni metal recoverable from ore of 0.2-0.25% Ni; 1982	r1E+r2E. over 47.5 km strike to 1200 m depth, 0.8 m thick, 12° dip, 60% recovery; mined for PGE, Ni and Co are byproducts
---	340; r1E+r2E; Ni metal recoverable from ore of 0.2-0.25% Ni; 1982	Resources over 18.75 km strike to 1200 m depth, 0.8 m thick, 12° dip, 60% recovery
None	---	No production planned for the near future
-do-	---	Do.
-do-	290; R1S+R2S; Ni contained in ore of 0.25% Ni, 0.20% Cu; 1981	No associated PGE; underground mining will be necessary
62.6; 1.66% Ni; 1962-65	20; R1M; Ni contained in ore of 2.81% Ni; 1981	Most mining at Vlakfontein (Pilanesberg nickel mine) done before 1936; last production in 1965; resources depleted; no new development foreseen
Soviet Union—continued		
169,700; 0.83% Ni; through 1980	40,000; R1E; 0.5% Ni, 0.8% Cu (Noril'sk deposit); 1980 54,800; R1E; 3.65% Ni, 4.7% Cu (Oktyabr'skiy deposit); 1980 33,300; R1E; 1.5% Ni, 3.0% Cu (Talnakh deposits); 1980 40,000; R1E; 2.5% Ni (Tamyr deposit); 1980	---
---	60,000-65,000; R1E; 0.9%-1.3 Ni; 1984	Resource distribution--Buruktal and Kempirsai about 80%, Sakhara (Magnitogorsk) about 10%, and Chalilovo and Akkermanovka about 10%
26,000; 1.0% Ni; through 1982	10,000; R1E; 1.0% Ni, 0.4% Cu; 1980	Over 20 deposits in district; Ni:Cu:Co approximately 50:20:1
---	10,000-15,000; R1E; 1.6% Ni; 1984	Annual production for central and southern Urals
Tanzania—continued		
None	5,000; r1S; 2.5% Ni, 0.20% Co, 0.17% Cu, 0.3 g/t Au; 1984 (recovery rate not specified) 25,000; r2S; 2.5% Ni, 0.20% Co, 0.17% Cu, 0.3 g/t Au; 1984 (recovery rate not specified)	Remote location and lack of infrastructure will delay development
United States—continued		
354; Ni in ferronickel; 1954-82	15,000-20,000; R1E; 1.0% Ni; 1978	Due to high energy cost and low nickel price, mine shut down in 1982 and reopened in early 1984 at 11,000 metric tons/yr rate during periods of off-peak power

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Site name	Year of discovery	Mining method1/	Year of first production	Elements of economic interest	Annual production2/
Venezuela					
Loma de Hierro deposit	1941	N(S)	None	Ni, Fe, Co	None
Yugoslavia					
Kosovo mines (Kosovo)	1970	S	1982	Ni, Co	12; Ni and Co in ferronickel (capacity); 1982
Ržanovo mine (Macedonia)	About 1972	S	---	Ni, Co	2,300; 1.03% Ni; 1981
Zimbabwe					
Epoch mine (Filabusi district)	1969	U	1976	Ni	441; 0.62% Ni; 1980-81
Hunters Road deposit (Gweru district)	Late 1970's	N	None	Ni, Co, Cu	None
Madziwa mine (Shamva district)	1958	U	1967	Ni, Cu	400; 0.53% Ni; 1981
Shangani mine (Bulawayo district)	1969	U	1975	Ni, Cu	748; milled ore; 1978
Trojan mine (Harare district)	1957	U	1968	Ni, Cu, Co	865; 0.60% Ni; 1981

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; and year of production (or range of years used to estimate average annual production).

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; and years for reported cumulative production.

Cumulative production[3]/	Resources[4]/	Comments
	Venezuela—continued	
None	40,000; R1E; 1.55% Ni, 0.03% Co, 26.27% Fe; 1975	Poor nickel market delayed start of operations
	Yugoslavia—continued	
---	25,000; R1E; 1.3% Ni; 1981	Recovery rate 88.3%; ferronickel product contains 25% Ni
---	110,000; R1E; 1.09% Ni, 0.006% Co; 1980	Technical and financial difficulties delayed startup; planned capacity 2.3 million metric tons ore/yr
	Zimbabwe—continued	
---	1,000; R1E; 0.95% Ni; 1984 4,830; R1E+R2E; 0.63% Ni; 1982	Monthly capacity 30,000 metric tons
None	30,000; R2S; 0.7% Ni, Co present; 1980	Little published data available
2,500; 0.8% Ni; through 1979	1,500; R1E; 0.9% Ni; 1.2% Cu; 1984 2,580; R1E+R2E; 0.61% Ni; 1982	Exploration for ore body extensions in 1981 was unsuccessful
2,000; 0.85% Ni; through 1979	20,000; R1E; 0.7% Ni; 1980	Ni/Cu = 30:1
7,700; 0.7% Ni; through 1979	10,400; R1E; 0.71% Ni; 1981 12,650; R1E+R2E; 0.67% Ni; 1982	Largest nickel producer in Zimbabwe

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 (unless resource is specified as contained metal); and year of estimate. Grades reported for mining properties often are the grade of mill feed, while for undeveloped properties, in situ grades are usually reported. Dilution in the mill feed grades may be about 5 percent for open-pit mining and 15 percent for underground mining.

REFERENCES CITED

Abel, M. K., Buchan, R., Coats, C. J. A., and Penstone, M. E., 1979, Copper mineralization in the footwall complex, Strathcona mine, Sudbury, Ontario, *in* Naldrett, A. J., ed., Nickel-sulfide and platinum-group-element deposits: Canadian Mineralogist, v. 17, pt. 2, p. 275–286.

Albandakis, N., 1980, The nickel bearing iron-ores in Greece [abs.], *in* UNESCO, An international symposium on metallogeny of mafic and ultramafic complexes—The eastern Mediterranean-western Asia area and its comparison with similar metallogenic environments in the world: [Greece] National Technical University, Papers of the Athens Symposium, Oct. 9–11, p. 2–3 (IGCP Project 169).

Antrim, L. N., and Sebenius, J. K., 1983, Incentives for ocean mining under the Convention, *in* Oxman, B. H., Caron, D. D., and Buderi, C. L. O., eds., Law of the sea—U.S. policy dilemma: San Francisco, Institute for Contemporary Studies (ICS) Press, p. 79–99.

Attridge, R. L., in press, The Jacomyns Pan copper-nickel occurrence, Kenhardt district, Northern Cape, *in* Geological Society of South Africa, Mineral deposits of southern Africa.

Bannon, Lisa, 1984, Nickel facing era of crisis: American Metal Market, v. 92, no. 249, Dec. 27, p. 1, 7.

Barnes, S. J., 1979, Petrology and geochemistry of the Katiniq nickel deposit and related rocks, Ungava, Northern Quebec: University of Toronto, unpublished M. S. thesis, 205 p.

Berthold, Gunther, 1980 Rohstoffwirtschafliche Länderberichte, XXV. Jugoslawien: Hannover (Germany, Federal Republic), Bundesanstalt für Geowissenschaften und Rohstoffe, 186 p.

Brady, E. S., 1981, China's strategic minerals and metals: China Business Review, Sept./Oct., p. 55–73.

Burt, D. R. L., and Sheppy, N. R., 1975, Mount Keith nickel sulphide deposit, *in* Knight, C. L., ed., Economic geology of Australia and Papua New Guinea, v. 1, Metals: Australasian Institute of Mining and Metallurgy, Monograph 5, p. 159–168.

Cameron, J. I., and Vogely, W. A., 1976, Interim report—Investment in the nickel industry, 1950–75: U.S. National Technical Information Service #PB-265759, 281 p.

[Canada] Department of Mines, Mines Branch, 1935, The Canadian mineral industry in 1934: Ottawa, King's Printer, Mines Branch Report, no. 760, 119 p.

Canada Department of Energy, Mines and Resources, 1984, Canada's nonferrous metal industry—Nickel and copper, a special report: Ottawa, Energy, Mines and Resources Canada, 102 p.

Card, K. D., 1968, Geology of the Denison-Waters area (District of Sudbury): Ontario Department of Mines, Geology Report 60, 63 p.

Case, J. E., 1980, Crustal setting of mafic and ultramafic rocks and associated ore deposits of the Caribbean region: U.S. Geological Survey Open-File Report 30–304, 95 p.

Chace, F. M., Cumberlidge, J. T., Cameron, W. L., and Van Nort, S. D., 1969, Applied geology at the Nickel Mountain mine, Riddle, Oregon: Economic Geology, v. 64, no. 1, p. 1–16.

Chamberlain, P. G., 1985, Nickel, *in* U.S. Bureau of Mines, Mineral Commodity Summaries 1985: Washington D.C., U.S. Government Printing Office, p. 106–107.

Clutten, J. M., Foster, R. P., and Martin, A., 1981, Nickel mineralization in Zimbabwe: Episodes, v. 1981, no. 2, p. 10–15.

Coats, C. J. A., Quirke, T.T., Jr., Bell, C. K., Cranstone, D. A., and Campbell, F. H. A., 1972, Geology and mineral deposits of the Flin Flon, Lynn Lake and Thompson areas, Manitoba, and the Churchill-Superior front of the western Precambrian shield: International Geological Congress, 24th, Montreal, Field Excursions Guidebook A31 and C31, 96 p.

Dasher, John, 1976, The energy picture in nickel production: Mining Magazine, v. 134, no. 5, p. 379–389.

DeYoung, J. H., Jr., Sutphin, D. M., and Cannon, W. F., 1984, International Strategic Minerals Inventory summary report—Manganese: U.S. Geological Survey Circular 930–A, 22 p.

DeYoung, J. H., Jr., Lee, M. P., and Lipin, B. R., 1984, International Strategic Minerals Inventory summary report—Chromium: U.S. Geological Survey Circular 930–B, 41 p.

Dietz, R. S., 1964, Sudbury structure as an astrobleme: Journal of Geology, v. 72, p. 412–434.

Fletcher, K., and Couper, J., 1975, Greenvale nickel laterite, North Queensland, *in* Knight, C. L., ed., Economic geology of Australia and Papua New Guinea, v. 1, Metals: Australasian Institute of Mining and Metallurgy, Monograph 5, p. 995–1001.

Golightly, J. P., 1979, Geology of the Soroako nickeliferous laterite deposits, *in* Evans, D. J. I., Shoemaker, R. S., and Veltman, H., eds., International laterite symposium: New York, American Institute of Mining, Metallurgical and Petroleum Engineers, p. 38–56.

Gomez, Ricardo, Ogryzlo, C. T., and Dor, A. A., 1979, The Cerro Matoso nickel project, *in* Evans, D. J. I., Shoemaker, R. S., and Veltman, H., eds., International laterite symposium: New York, American Institute of Mining, Metallurgical and Petroleum Engineers, p. 412–458.

Gresham, J. J., and Loftus-Hills, G. D., 1981, The geology of the Kambalda nickel field, Western Australia: Economic Geology, v. 76, no. 6, p. 1373–1415.

Häkli, T. A., Vormisto, K., and Hänninen, E., 1979, Vammala—A nickel deposit in layered ultramafite, southwest Finland: Economic Geology, v. 74, no. 5, p. 1166–1182.

Haldeman, E. G., Buchan, R., Blowes, J. H., and Chandler, T., 1982, Geology of lateritic nickel deposits, Dominican Republic: Society of Economic Geologists Fall Field Trip, October 1982, p. 16–39.

Havryluk, Ihor, and Huff, V. R., 1979, The current status of the Gag Island nickel laterite project, *in* Evans, D. J. I., Shoemaker, R. S., and Veltman, H., eds., International laterite symposium: New York, American Institute of Mining, Metallurgical and Petroleum Engineers, p. 382–394.

Hoffman, E. L., Naldrett, A. J., Alcock, R. A., and Hancock, R. G. V., 1979, The noble-metal content of the ore in the Levack West and Little Stobie mines, Ontario, *in* Naldrett, A. J., ed., Nickel-sulfide and platinum-group-element deposits: Canadian Mineralogist, v. 17, pt. 2, p. 437–451.

Hulbert, L. T., and von Gruenewaldt, Gerhard, 1982, Nickel, copper, and platinum mineralization in the lower zone of the Bushveld Complex, south of Potgietersrus: Economic Geology, v. 77, no. 6, p. 1296–1306.

Isokangas, Pauli, 1978, Finland, *in* Bowie, S. H. U., Kualheim, A., and Haslam, H. W., eds., Mineral deposits of Europe, v. 1—Northeast Europe: London, The Institution of Mining and Metallurgy and The Mineralogical Society, p. 39–92.

Kenyon, A. K., Attridge, R. L., and Coetzee, G. L., 1981, The Uitkomst nickel-copper deposit [abs.]: Geocongress 81, open session, Geological Society of South Africa.

Lavie, H. J., 1971, Yacimientos de lateritas niqueliferas de Loma de Hierro, Estados Miranda y Aragua, *in* Congresso Geologico Venezolano, 4th, Memoria, v. 1: [Venezuela] Direccion de Geologia, Boletin de Geologia Publicacion Especial no. 5, p. 357-362.

Lefond, S. J., 1973, Brazilian mining—Relaxed gov't. attitudes pave the way for exploiting critical reserves: Mining Engineering, v. 25, no. 11, p. 31-45.

Linchenat, A., and Shirokova, I., 1964, Individual characteristics of the nickeliferous iron (laterite) deposits of the northeastern part of Cuba (Pinares de Mayri, Nicaro and Moa), *in* Sundaram, R.K., ed., Report of the twenty-second session—India 1964: International Geological Congress, 22d, New Delhi 1964, pt. 14, section 14, p. 171-187.

Longe, R. V., and others, 1978, Computer-based files on mineral deposits—Guidelines and recommended standards for data content [prepared by the Mineral Deposits Working Committee, National Advisory Committee on Research in the Geological Sciences]: Canada Geological Survey Paper 78-26, 72 p.

Mackenzie, B. W., 1968, Nickel—Canada and the world: Canada Department of Energy, Mines and Resources Mineral Report 16, 176 p.

Marston, R. J., Groves, D. I., Hudson, D. R., and Ross, J. R., 1981, Nickel sulfide deposits in Western Australia—A review: Economic Geology, v. 76, no. 6, p. 1330-1363.

Matthews, N. A., and Sibley, S. F., 1980, Nickel, *in* Knoerr, A. W., ed., Mineral facts and problems 1980 edition: U.S. Bureau of Mines Bulletin 671, p. 611-627.

Metallgesellschaft Aktiengesellschaft, 1939-83, Metal statistics (1929-82): Frankfurt am Main (Germany, Federal Republic), Metallgesellschaft A. G., 31 v.

Mining Annual Review, 1982, The steel industry metals—Nickel: London, Mining Journal Limited, p. 67-68.

Mining Journal, 1982, Codemin's new Ni mine commissioned: Mining Journal, v. 299, no. 7688 (24 Dec.), p. 443.

———1984, Finland—New mine for Outokumpu: Mining Journal, v. 302, no. 7763 (1 June), p. 364-365.

Morin, J. A., 1973, Geology of the Lower Shebandowan Lake area—District of Thunder Bay: Ontario Division of Mines, Geological Report 110, 45 p.

Moubray, R. J., Brand, E. L., Hofmeyr, P. K., and Potter, M., 1976, The Hunters Road nickel prospect, *in* Anhaeuser, C. R., Foster, R. P., and Stratten, T., A symposium on mineral deposits and the transportation and deposition of metals: Salisbury [Harare], Geological Society of South Africa, Special publication no. 5, p. 109-116.

Naldrett, A. J., 1981, Nickel sulfide deposits—Classification, composition, and genesis, *in* Skinner, B. J., ed., Economic Geology—Seventy-fifth anniversary volume, 1905-1980: Economic Geology Publishing Co., p. 628-685.

[New Caledonia] Service des Mines et de la Géologie, [1980-84], Rapport annuel—Nouvelle-Calédonie et dépendances 1979-83: Service des Mines et de la Géologie, 5 v.

O'Kane, P. T., 1979, Energy consumption and economic trends in the production of nickel from laterites, *in* Evans, D. J. I., Shoemaker, R. S., and Veltman, H. eds., International laterite symposium: New York, American Institute of Mining, Metallurgical and Petroleum Engineers, p. 503-523.

Paris, J. P., 1981, Géologie de la Nouvelle-Calédonie—Un essai de synthèse: [France] Bureau de Recherches Géologiques et Minières, Mémoire du B.R.G.M., no. 113, 278 p.

Patterson, J. M., 1963, Geology of the Thompson-Moak Lake area: Manitoba Department of Mines and Natural Resources, Publication 60-4, 50 p.

Pattison, E. F., 1979, The Sudbury sub-layer—Its characteristics and relationships with the main mass of the Sudbury Irruptive, *in* Naldrett, A. J., ed., Nickel-sulfide and platinum-group-element deposits: Canadian Mineralogist, v. 17, pt. 2, p. 257-274.

[Philippines] Bureau of Mines and Geo-Sciences, Geological Survey Section, Regional Office X, 1980, Geology and mineral resources of Surigao del Norte: [Philippines] Bureau of Mines Report of Investigations 110, 28 p.

Prijono, A., 1977, Potential of the lateritic-nickel deposits in Indonesia and their successful development—Much depends on the right processing method, *in* Prijono, A., Long, C., and Sweatman, R., eds., The Indonesian mining industry—Its present and future: Jakarta, The Indonesian Mining Association, Proceedings of the First Indonesian Mining Symposium, p. 184-250.

Pumo, F., 1973, Données générales sur les gîtes minéraux de l'Albanie et caractères particuliers de ses importants gisements de nickel latéritique: [France] Bureau de Recherches Géologiques et Minières Bulletin, sec. 2, no. 6, p. 451-465.

Pye, E. G., Naldrett, A. J., and Giblin, P. E., eds., 1984, The geology and ore deposits of the Sudbury structure: Ontario Geological Survey Special Volume No. 1, 603 p.

Raggatt, H. G., 1968, Mountains of ore: Melbourne, Lansdowne Press Pty. Ltd., 406 p.

Roberts, J. B., 1975, Windarra nickel deposits, *in* Knight, C. L., eds., Economic geology of Australia and Papua New Guinea, v. 1, Metals: Australasian Institute of Mining and Metallurgy, Monograph 5, p. 129-143.

Roskill Information Services, [1981], The economics of nickel (3d edition): London, Roskill Information Services [498 p.].

Ross, J. R., and Travis, G. A., 1981, The nickel sulfide deposits of Western Australia in global perspective: Economic Geology, v. 76, no. 6, p. 1291-1329.

Rousell, D. H., 1984, Nature and origin of mineral occurrences inside the Sudbury Basin: Canadian Institute of Mining and Metallurgy Bulletin, v. 77, no. 872, p. 63-75.

Schanz, J. J., Jr., 1980, The United Nations' endeavor to standardize mineral resource classification: Natural Resources Forum, v. 4, no. 3, p. 307-313.

Scherer, F. M., 1970, Industrial market structure and economic performance: Chicago, Rand McNally College Publishing Co., 576 p.

Schwellnus, J. S. I., Hiemstra, S. A., and Gasparrin, Elvira, 1976, The Merensky Reef at Atok platinum mine and its environs: Economic Geology, v. 71, no. 1, p. 249-260.

Sibley, S. F., 1983a, Nickel, *in* U.S. Bureau of Mines, Minerals yearbook 1982, v. I, Metals and minerals: Washington, D.C., U.S. Government Printing Office, p. 619-633.

———1983b, Nickel: U.S. Bureau of Mines Mineral Commodity Profiles, 18 p.

———1984, Nickel, *in* U.S. Bureau of Mines, Minerals yearbook 1983, v. I, Metals and minerals: Washington, D.C., U.S. Government Printing Office, p. 631-645.

Souch, B. E., Podolsky, T., and geological staff, The International Nickel Company of Canada, Limited, 1969, The sulphide ores of Sudbury—Their particular relationship to a distinctive inclusion-bearing facies of this nickel irruptive, *in* Wilson, H. D. B., ed., Magmatic ore deposits: Economic Geology, Monograph 4, p. 252-261.

Suriaatmadja, R., and Wahju, B. N., 1972, Mafic and ultramafic rock associations in the east arc of Sulawesi, *in* Haile, N. S., ed., Regional Conference on the geology of Southeast

Asia—Abstracts of papers: Geological Society of Malaysia, Kuala Lumpur, Annex to Newsletter no. 34, p. 55.

Theyer, P., 1980, Stratigraphic setting of selected ultramafic bodies in the Superior and Churchill Provinces and certain aspects of nickel-copper deposits in the Thompson nickel belt: Manitoba Department of Energy and Mines, Economic Geology Report 79-2, 71 p.

Thomson, J. E., 1959, Geology of Falconbridge Township: Ontario Department of Mines, Annual Report (1957), v. LXVI, p. 6, 42 p.

[United Kingdom] Imperial Mineral Resources Bureau, 1921-49, The mineral industry of the British Empire and foreign countries—Statistical summary [1913-47]: His Majesty's Stationery Office, 13 v. (Continued by Institute of Geological Sciences, statistical summary of the mineral industry.)

U.S. Bureau of Mines, 1927-34, Mineral resources of the United States, 1924[-1931]: Washington, D.C., U.S. Government Printing Office, 16 v. (Continued as U.S. Bureau of Mines Minerals Yearbook.)

———1933-84, Minerals yearbook (1932-82): Washington, D.C., U.S. Government Printing Office, 116 v.

U.S. Geological Survey, 1902-27, Mineral resources of the United States [1901-23]: Washington, D.C., U.S. Government Printing Office, 45 v. (Continued by U.S. Bureau of Mines.)

———1921, World atlas of commercial geology—Part I, Distribution of mineral production: Washington, D.C. [144 p.]

Vermaak, C. F., and von Gruenewaldt, Gerhard, compilers, 1981, Guide to the Bushveld excursion (June 28-July 4, 1981): Geological Survey of South Africa, 62 p. (Third International Platinum Symposium, Pretoria, July 6-10, 1981).

Viljoen, M. J., Bernasconi, A., van Coller, N., Kinloch, E., and Viljoen, R. P., 1976, The geology of the Shangani nickel deposit, Rhodesia: Economic Geology, v. 71, no. 1, p. 76-95.

von Gruenewaldt, Gerhard, 1977, The mineral resources of the Bushveld Complex: Materials Science and Engineering, v. 9, no. 2, p. 83-95 (Published by National Institute of Metallurgy, South Africa.)

Wakefield, J., 1976, The structural and metamorphic evolution of the Pikwe Ni-Cu sulfide deposit, Selebi-Pikwe, eastern Botswana: Economic Geology, v. 71, no. 6, p. 988-1005.

Wolff, Friedrich, 1978, Rohstoffwirtschafliche Länderberichte, XV. Philippinen: Hannover (Germany, Federal Republic), Bundesanstalt für Geowissenschaften und Rohstoffe, 190 p.

World Bank, 1983, World development report 1983: New York, Oxford University Press, 214 p.

Zurbrigg, H. F., and geological staff, 1957, The Frood-Stobie mine, *in* General Committee of the Sixth Commonwealth Mining and Metallurgical Congress, Structural geology of Canadian ore deposits (Congress volume), v. II: Montreal, Canadian Institute of Mining and Metallurgy, p. 341-350.

ADDITIONAL REFERENCES ON NICKEL RESOURCES

Adams, R. B., 1983, Nickel and platinum in the Soviet Union, *in* Jensen, R. G., Shabad, Theodore, and Wright, A. W., eds., Soviet natural resources in the world economy: Chicago, University of Chicago Press, p. 536-555.

Baldessari, B. M., 1982, Nickel resources: Mining Magazine, v. 146, no. 1, p. 61-66.

Duke, J. M., and Naldrett, A. J., 1983, Lower grade nickel sulfide resources, *in* Shanks, W. C., III, ed., Unconventional mineral deposits (Cameron volume): New York, American Institute of Mining, Metallurgical and Petroleum Engineers, p. 23-34.

Gauvin, M. J., Peeling, G. R., and Schell, D., 1976, Nickel: [Canada] Department of Energy, Mines and Resources, Mineral Bulletin MR 157, 53 p.

Golightly, J. P., 1981, Nickeliferous laterite deposits, *in* Skinner, B. J., ed., Economic Geology—Seventy-fifth anniversary volume, 1905-1980: Economic Geology Publishing Co., p. 710-735.

Groves, D. I., Hudson, D. R., Marston, R. J., and Ross, J. R., eds., 1981, Economic Geology—A special issue on nickel deposits and their host rocks in Western Australia: Economic Geology, v. 76, no. 6, p. 1287-1816 (27 papers).

Mining Magazine, 1974, Nickel production in New Caledonia: Mining Magazine, v. 130, no. 5 (May), p. 336-349.

Peters, H. D., 1975, Nickel—Vorkommen, Produktion, Bedarfsdeckung in Rahmen der Weltwirtschaft [Nickel—Occurrence, production, and supply in world trade]: Bergbau Rohstoffe Energie, Band 9, 110 p.

Prokop, F. W., 1975, The future economic significance of large low-grade copper and nickel deposits: Berlin-Stuttgart, Gebruder Borntraeger, Monograph Series on Mineral Deposits 13, 67 p.

Ridge, J. D., 1972, Annotated bibliographies of mineral deposits of the Western Hemisphere: Boulder, Colorado, Geological Society of America Memoir 131, 681 p.

———1976, Annotated bibliographies of mineral deposits in Africa, Asia (exclusive of the USSR), and Australia: Oxford, United Kingdom, Pergamon Press, 546 p.

———1984, Annotated bibliographies of mineral deposits in Europe, Part 1—Northern Europe including examples from the USSR in both Europe and Asia: Oxford, United Kingdom, Pergamon Press, 778 p.

Troly, G., Esterle, M., Pelletier, B., and Reibell, W., 1979, Nickel deposits in New Caledonia—Some factors influencing their formation, *in* Evans, D. J. I., Shoemaker, R. S., and Veltman, H., eds., International laterite symposium: New York, American Institute of Mining, Metallurgical and Petroleum Engineers, p. 85-119.

Wens, H. G., 1972, Nickelerzlagerstaetten im Pazifischen Raum unter besonderer Berucksichtigung Neukaledoniens: Stahl und Eisen, v. 92, no. 14, p. 653-663.

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