RC. 930–E

U.S. GEOLOGICAL SURVEY CIRCULAR 930–E

International Strategic Minerals Inventory Summary Report—Platinum-Group Metals

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 David M. Sutphin and Norman J Page

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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 platinum-group metals, one of the mineral commodities selected for the inventory.

The report was prepared by David M. Sutphin and Norman J Page of the U.S. Geological Survey (USGS). The platinum-group-metals inventory was compiled by O. R. Eckstrand, Canadian Department of Energy, Mines and Resources (EMR), Geological Survey of Canada; Gabriele I. C. Schneider, South African Department of Mineral and Energy Affairs (MEA), Geological Survey; and Norman J Page (chief compiler), USGS. Additional contributions to the report were made by Antony B. T. Werner and Jan Zwartendyk, EMR, Mineral Policy Sector; Ian Goldberg, MEA, Minerals Bureau; C. Roger Pratt and Paul Coker, Australian Bureau of Mineral Resources, Geology and Geophysics; and Robert L. Marovelli, U.S. Bureau of Mines.

Director

LATE INFORMATION

Price increases in the latter part of 1986 have led to a surge in exploration for platinum-group metals. The following three discoveries in South Africa, Australia, and Botswana were reported too late to be included in the platinum-group-metals inventory.

In August 1986, the development of a major new platinum mine was announced in South Africa (E.C.I. Hammerbeck, Geological Survey of South Africa, written commun., 1986; Siconolfi, 1986). The platinum-group-metal resources of the Bushveld Complex were previously calculated to a vertical depth of 1,200 meters, but down-dip extensions of both the Merensky Reef and the UG2 chromitite layer are to be exploited in the new mine to a depth of 2,700 meters below the surface.

This new development adds about 1,600 metric tons of platinum-group metals, contained in ore of an average grade of 10.1 grams per ton (g/t), to the R1E resources of the Merensky Reef, and 2,100 metric tons of platinum-group metals, in ore of an average grade of 6.6 g/t, to the R1E resources of the UG2 chromitite layer. These figures are additional to the resources reported in table 9 of this circular. (Resource categories are outlined in figure 1 of this circular.)

A gold deposit having important platinum-group-metal values has been discovered at Coronation Hill, in the Alligator Rivers Region of the Northern Territory (Australian Bureau of Mineral Resources, written commun., 1986). The deposit and other similar prospects in that Region are still being tested. Resources of contained metal in the R2 category at the Coronation Hill deposit are 31 metric tons of gold, 5 metric tons of palladium, and 2½ metric tons of platinum. The deposit is unusual in that the gold and the platinum-group metals occur in metamorphosed interbedded felsic volcanics and clastic sediments intruded by diorite.

In September 1986, it was reported (Todd, 1986) that exploratory drilling 140 kilometers southwest of Gaborone, Botswana, had led to the discovery of the 9,000-square-kilometer Molopo Farms Complex, which is similar to the Bushveld Complex of South Africa. Preliminary reports from very early stages of drilling indicate combined platinum-palladium grades of 1 g/t.

References Cited

Siconolfi, Michael, 1986, Platinum surges despite discovery of new deposits: Wall Street Journal, August 22, p. 30.

Todd, J. C., 1986, Potentially major platinum find being explored in Botswana: Engineering and Mining Journal, v. 187, no. 9, p. 9–10.

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INTERNATIONAL STRATEGIC MINERALS INVENTORY SUMMARY REPORT

PLATINUM-GROUP METALS

By David M. Sutphin and Norman J Page

ABSTRACT

Major world resources of platinum-group metals 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 platinum-group metals 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 is to make publicly available, in convenient form, nonproprietary data and characteristics of major deposits of strategic mineral commodities for policy considerations in regard to short-term, medium-term, and long-term world supply. This report provides a summary statement of the data compiled and an overview of the supply aspects of platinum-group metals 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 infrastructure 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 platinum-group metals and includes only peripheral considerations of platinum-group-metal 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. All of these studies have now been published. Additional reports on cobalt, vanadium, graphite, tin, titanium, and tungsten are in preparation.

The data in the ISMI platinum-group-metal inventory were collected from August 1984 to January 1986. The report was submitted for review and publication in January 1986. The information used was the best available in various agencies of the countries that contributed to the preparation of this report. Those agencies were the Bureau of Mines and the Geological Survey of the U.S. Department of the Interior; the Geological Survey of Canada 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; the Bureau of Mineral Resources, Geology and Geophysics of the Australian Department of Resources and Energy; and the British Geological Survey, a component of the Natural Environment Research Council.

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

The ISMI record collection and this report on platinum-group metals have adopted the international classification system for mineral resources recommended by the United Nations Group of Experts on Definitions and Terminology for Mineral Resources (United Nations Economic and Social Council, 1979; 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.

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-place resources cannot be extracted.

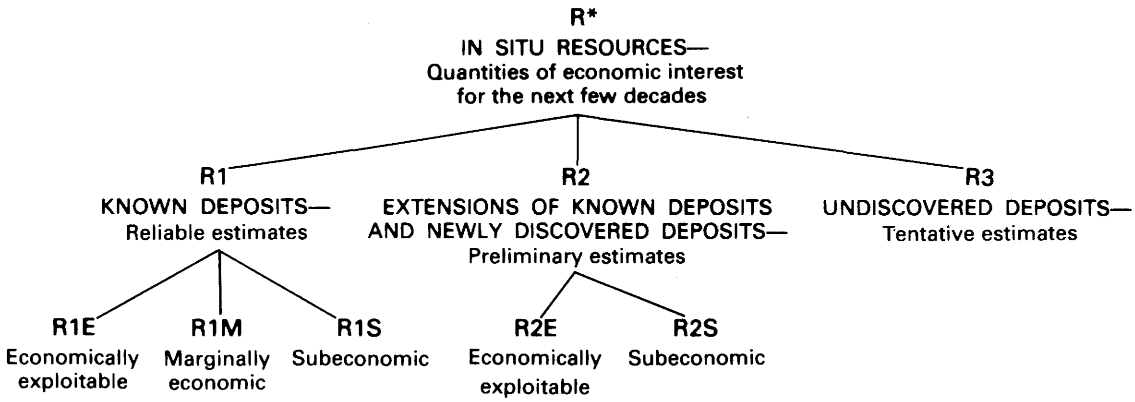
The World Bank economic classification of countries (World Bank, 1985, p. 174–175), which is based primarily on GNP per capita, has been used in this and other ISMI reports to illustrate distribution of resources and production according to economic groupings of countires. This classification was chosen 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

The platinum-group metals[2] are platinum, palladium, rhodium, ruthenium, iridium, and osmium. Platinum and palladium are found in larger quantities than the others and therefore have the larger volume usages. Although rhodium, ruthenium, iridium, and osmium are normally byproducts of mining of platinum-palladium and nickel-copper deposits, they have been produced in the past as major products of placer mining. Estimates of sales from primary platinum-group-metal mines to the Western World ranged from 72 to 87 metric tons (2.3–2.8 million troy ounces) of platinum per year between 1975 and 1984 and from 72 to 90 metric tons (2.3–2.9 million troy ounces) of palladium per year between 1980 and 1984 (Robson, 1985). Most of the world's platinum-group-metal supply comes from only eight mining districts, predominantly

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

[2]In this report, the term "platinum-group metals" is used synonymously with platinum-group elements and encompasses platinum, palladium, rhodium, ruthenium, iridium, and osmium. The abbreviation PGM is used sparingly in tables and figures and is defined as "platinum-group metals" in each place where it is used. This approach is taken to avoid confusion with the use of PGM by mineralogists to mean platinum-group *minerals*, such as atokite, insizwaite, osmiridium, and zvyagintsevite.



*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).

from four mining districts in two countries—South Africa and the Soviet Union.

The unique combinations of chemical, physical, and mechanical properties (including extraordinary catalytic activity, chemical inertness, high melting points, and high ductility) of the platinum-group metals have resulted in their use in many vital industrial processes. Platinum-group-metal catalysts are used in processing petroleum and other fossil fuels, in ammonium oxidation to produce nitric acid for fertilizers, and in other chemical processing as well as in emission controls for automobiles and industrial processes. Other uses are in fuel cells, electrical and electronic hardware, the manufacture of special glasses, spinnerettes for making glass fibers, jewelry, and dental and medical work. Much scientific effort has gone into finding substitutes, but this effort has met with little success.

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

- Platinum mining in the Bushveld Complex in South Africa is a function of demand, because its resources of platinum can meet all projected demands, in contrast to the situation in Canada and the Soviet Union, where platinum-group metals are a byproduct of nickel mining. The supply of other platinum-group metals produced from Bushveld Complex deposits, rhodium, ruthenium, and so on, is fixed because these metals are byproducts of platinum mining.
- Platinum-group-metal sales by the Soviet Union do not seem to reflect world demand but do reflect the relative independence of the Soviet Union in the world market at a particular time.
- In 1984, the United States and Japan accounted for 77 percent of the Western World's use of the available platinum produced. About two-thirds of the platinum used by Japan goes into jewelry, whereas only about 5 percent of platinum use in the United States is for jewelry.
- The European Economic Community is moving toward the reduction of lead in gasoline and toward emission standards similar to those in the United States. Significant quantities of platinum-group-metal automobile catalysts may be required in 1988 with full emission standards on line by 1993 (Robson, 1985). Implementation of these standards will definitely increase the demand for platinum-group metals.

- Australia (starting in January 1986 for new gasoline-powered automobiles and July 1988 for all other new gasoline-powered vehicles) and South Korea (in 1987 or 1988) also intend to introduce emission control legislation which will involve increased use of platinum-group metals.
- Japan's commitment to fuel cells and the United States' preliminary trials with small generating stations where electricity is created by fuel cells probably will raise the demand for platinum-group metals in the 1990's.

DISTRIBUTION OF PLATINUM-GROUP-METAL DEPOSITS

The world map in figure 2 shows the locations of the major platinum-group-metal deposits and districts. Major deposits in the Soviet Union and South Africa together account for about 98 percent of reserves (Buchanan, 1979). The Stillwater Complex, presently under exploration in southwestern Montana, could contribute enough material to meet about 10 percent of the United States' demand for platinum-group metals. Additional deposits of platinum-group metals occur in Australia, Brazil, Burma, Chile, Colombia, Ethiopia, Finland, Japan, Papua-New Guinea, Sierra Leone, Zaire, and Zimbabwe, as well as in the Soviet Union, the United States, South Africa, and Canada (Mertie, 1969; Cabri, 1981; Blair and others, 1977; Till and Page, 1979; Mohide, 1979; National Materials Advistory Board, 1980).

The world's most important deposits of platinum-group metals are associated with magmatic intrusions of mafic and ultramafic rocks. They fall into three main categories:

- Stratiform deposits in which platinum-group-metal deposits occur as layer-like zones in large Precambrian complexes (Bushveld Complex, South Africa; Great Dyke, Zimbabwe; and Stillwater Complex, United States).
- A unique intrusion of norite (Sudbury irruptive complex, Canada), which probably was initiated by the impact of a meteor on the Earth's crust (Dietz, 1964; Rousell, 1984).
- Nickel- and copper-bearing dikes and sills, which are found in association with rift structures (Noril'sk-Talnakh district, Soviet Union).

The stratiform deposits are the only ones mined principally for platinum-group metals, with nickel, copper, and cobalt being produced as byproducts. In the other deposit types, except for some placer deposits, platinum-group metals are byproducts of nickel and copper mining.

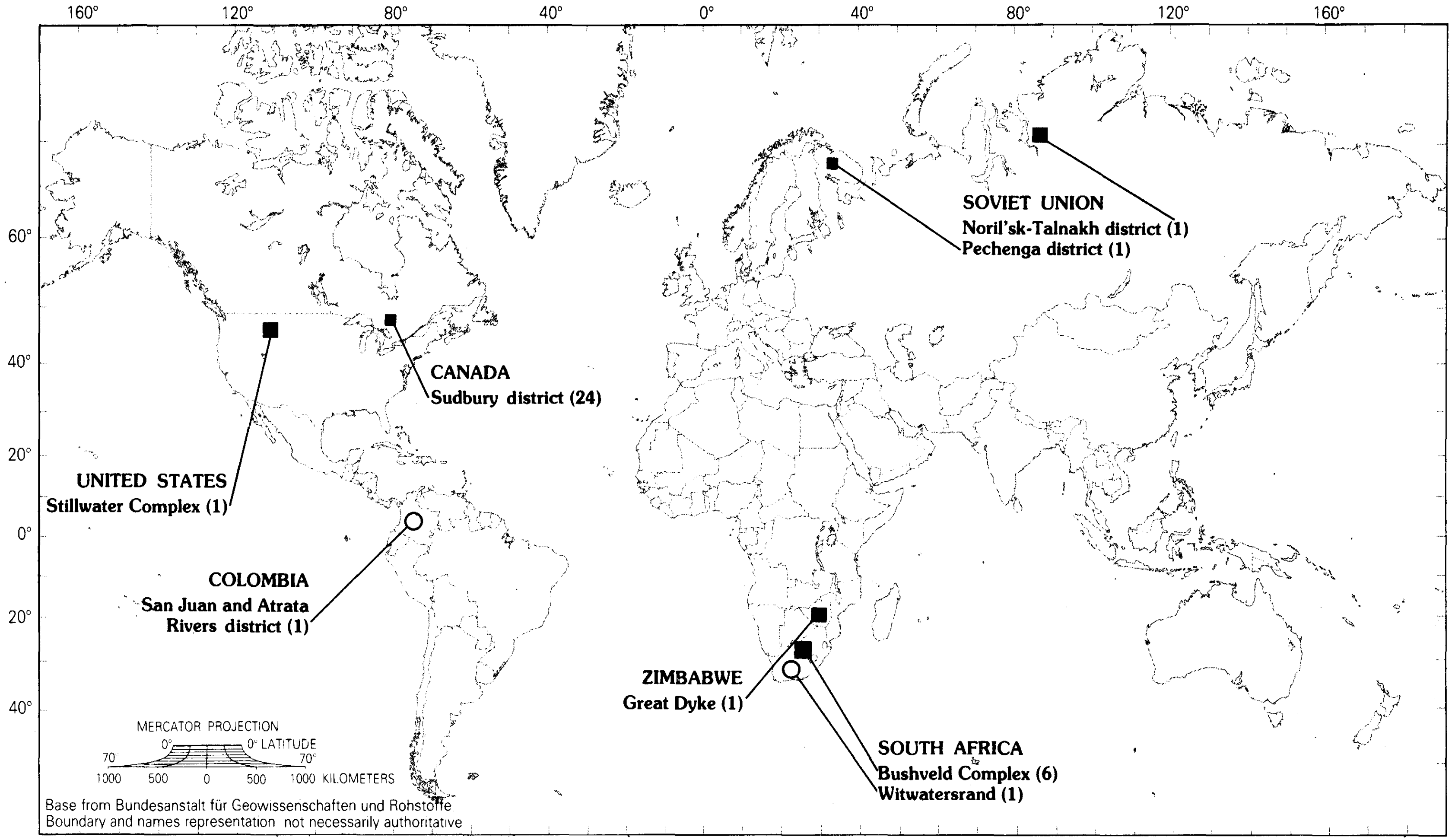
Other deposits that contribute to the remaining 2 percent of the reserves are of several geologic types and include placer deposits (such as Upper San Juan and Atrato Rivers district of Colombia, which includes the Choco-Pacifico area and which in the past contributed a major part to the supplies of platinum-group metals); nickel-sulfide deposits associated with komatiitic extrusive rocks; sulfide deposits associated with zoned ultramafic to mafic intrusions (such as Uralan, Alaskan, and concentrically zoned deposits); platinum-group metals in stratiform and podiform chromite deposits, porphyry copper deposits, and shale-hosted base-metal sulfide deposits; and miscellaneous hydrothermal platinum-group-metal deposits.

One deposit listed in table 1, Jinchuan in the People's Republic of China, may eventually affect supply patterns of the platinum-group metals. Nickel ores discovered in 1958 in Gansu Province have become China's largest producer of nickel, copper, platinum-group metals, and cobalt. Ross and Travis (1981) estimated the resources of this district at 514 million metric tons of ore with 1.06 percent nickel; the platinum-group-metal content is unknown, but using a value similar to that for Sudbury (0.9 grams per metric ton) would suggest 440 to 470 metric tons (14–15 million troy ounces) of platinum-group metals. Robson (1985) suggests that expansion at Jinchuan would quadruple nickel output and thus increase the platinum-group-metal output in the 1990's.

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

PLATINUM-GROUP-METAL RESOURCES

Magmatic, stratiform, Merensky Reef-type deposits of platinum-group metals account for 92 to 93 percent of the resources reported in R1 and R2 categories. Tables 2 and 3 report resource estimates based on data in Part II and on an earlier resource estimate by Buchanan (1979), respectively. Comparison of the data in these tables highlights some of the problems of making,



EXPLANATION

Geologic deposit type

Symbol	Placer Resources (metric tons)	Symbol	Magmatic Resources (metric tons)
○	Unreported	■	>10,000
		■	1,000–10,000
		■	<1,000

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

TABLE 1.—*Platinum-group-metal deposits, districts, and prospects not included in the International*

Name	Geologic deposit type
Australia	
Wannaway	Magmatic, komatiitic.
Carnilya Hill mine	Do.
Agnew mine	Do.
Kambalda-St. Ives-Tramways district	Do.
Windarra district	Do.
Botswana	
Pikwe district	Magmatic.
Phoenix	Do.
Selebi district	Do.
Selkirk	Do.
Brazil	
Serra Pelada	Hydrothermal gold deposit
Canada	
Lac de Iles	Magmatic, stratiform.
Great Lakes Nickel	Magmatic.
Ungava district	Magmatic, komatiitic.
Shebandowan mine	Do.
Texmont	Magmatic.
Redstone	Do.
Moak Lake mine	Magmatic, dunitic.
Mystery Lake	Do.
Bucko mine	Do.
Birchtree mine	Magmatic.
Pipe No. 1 mine	Do.
Soab North and South mines	Do.
Thompson mine	Do.
Pipe No. 2 open pit center	Do.
China	
Jinchuan mine	Magmatic, stratiform.
Ophiolite chromite—western China	Magmatic, ophiolite.
Ethiopia	
Yubdo	Placer, alluvial and eluvial.
Finland	
Kotalahti mine	Magmatic.
Vammala mine	Do.
Hitura mine	Do.
Kontijarvi	Do.
Kuohunki	Do.
Penikat Layered Intrusion	Magmatic, stratiform.
Indonesia	
Goenoegn-Lawack (Borneo)	Placer, alluvial.
Papua New Guinea	
Yodda Rivers	Placer, alluvial.
Gira Rivers	Do.
Philippines	
Acoje mine	Magmatic, ophiolite.
Poland	
Zechstein basin—Kupferschiefer (also would include parts of Germany)	Shale-hosted base-metal sulfide deposit.
Norway	
Bruvann—Rana-Espedalen	Magmatic, synorogenic.
Sierra Leone	
Freetown layered complex	Magmatic, stratiform and placer, alluvial.
South Africa	
Insizwa	Magmatic, rift-related.
Uitkomst deposit	Magmatic.
Messina	Hydrothermal.
Phalaborwa mine	Carbonatite, copper deposit.
Soviet Union	
Ural Mountain mines and deposits.	Placer, alluvial, eluvial; magmatic, zoned.
Gusevogorsky deposit	Magmatic, zoned.
Monchegorsk	Magmatic, stratiform.
Sweden	
Lappvatlnet	Magmatic.
Risliden	Do.
Mjoedvattnet	Do.
United States of America	
La Perouse—Brady Glacier	Magmatic, stratiform.
Duluth Complex:	
Ely Spruce	Magmatic, rift-related.
Minnamax	Do.
Salt Chuck	Magmatic, zoned.
Snettisham	Do.
Union Bay	Do.
Yakobi Island—Bohemia Basin	Do.
New Rambler	Hydrothermal platinum-group-metal deposit.
Salmon River—Goodnews Bay district	Placer, alluvial.
California—Sierran placers	Do.
California—Klamath placers	Do.
Porphyry copper deposits in Western United States	Porphyry copper deposits.
Yugoslavia	
Bor district	Porphyry copper deposits.

Name	Geologic deposit type
Zaire	
Copper belt:	
Kolwezi district, Musoni, Rwe, Shinkolobwe	Sediment-hosted red-bed copper.
Zimbabwe	
Hunters Road deposit	Magmatic, komatiitic.
Shangani mine	Do.
Damba	Do.
Trojan mine	Do.
Epoch mine	Do.
Selukwe mine	Do.
Empress mine	Magmatic.
Madziwa mine	Do.

interpreting, and using estimates of platinum-group-metal resources. The problems revolve around the lack of published reliable estimates of grade and tonnage. Buchanan (1979), for example, estimates 6,000 metric tons (200 million troy ounces) of platinum-group metals at Noril'sk with a grade of 3.8 grams per metric ton (g/t). These estimates suggest that there are about 1.64 billion metric tons of ore at Noril'sk. Ross and Travis (1981), however, estimate that ore reserves in the Noril'sk district are only 178 million metric tons. In addition, Newman (1973) estimates that the more massive ores contained 9.7 g/t and the disseminated ores 3.5 g/t. There appears to be no solution to this particular problem. Other discrepancies can occur in defining platinum-group-metal resources for the Stillwater Complex as R1 or R2. The more encouraging estimates are those that are independent and tend to converge. For example, von Gruenewaldt (1977) estimates 62,890 metric tons (2.02 billion troy ounces) of platinum-group metals in the Bushveld Complex; his estimate is similar to Buchanan's (1979) estimate of 61,770 metric tons (1.99 billion troy ounces) and to an estimate of 75,000 metric tons

TABLE 2.—*Platinum-group-metal resources in the world's major deposits and districts, by geologic deposit type and resource category*

[Figures are in metric tons of platinum-group-metal resource; N.r. = None reported; numbers in parentheses are percent of column totals. Figures may not add to totals shown due to rounding]

Geologic deposit type[1]	No. of records	Resource category	
		R1E[2]	All other R1 and R2[3]
Magmatic, stratiform, Merensky Reef-type	8	23,600 (96)	55,400 (100)
Magmatic, rift-related	2	488 (2.0)	N.r.
Magmatic, noritic	24	383 (1.6)	N.r.
Placer	2	N.r.	N.r.
Total	36	24,500 (100)	55,400 (100)

[1]Deposit types of the world's major platinum-group-metal deposits are shown in figure 2 and in table 8 of Part II.

[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).

TABLE 3.—*Tonnage and grade of identified economic resources of platinum-group metals and gold in selected deposits and districts by geologic deposit type*

[Table is after Buchanan (1979). Identified economic resources are generally equivalent to R1E and R2E. (See fig. 1.) Deposit locations are shown in figure 2. Resources reported in metric tons with grade in grams per metric ton (g/t); numbers in parentheses are percent of column totals as reported in original source; resources tonnages calculated on the basis of percentages given and total resources for each deposit. N.a.=Data not available. Figures may not add to totals shown due to rounding]

	Stratiform[1]				Noritic	Rift-related	Placer
	Bushveld Complex			Stillwater Complex—J–M Reef	Sudbury	Noril'sk-Talnakh	Upper San Juan and Atrato Rivers
	Merensky Reef	UG2	Platreef				
Platinum	10,300 (59)	13,600 (42)	4,960 (42)	210 (19)	106 (38)	1,560 (25)	N.a. (93)
Palladium	4,380 (25)	11,300 (35)	5,430 (46)	730 (66.5)	112 (40)	4,420 (71)	N.a. (1)
Ruthenium	1,400 (8)	3,890 (12)	470 (4)	44 (4.0)	8 (2.9)	60 (1)	
Rhodium	530 (3)	2,600 (8)	350 (3)	84 (7.6)	9 (3.3)	190 (3)	N.a. (2)
Iridium	180 (1)	750 (2.3)	94 (0.8)	26 (2.4)	3 (1.2)		N.a. (3)
Osmium	140 (0.8)		71 (0.6)		3 (1.2)		N.a. (1)
Gold	560 (3.2)	230 (0.7)	400 (3.4)	6 (0.5)	38 (13.5)		
Total	17,500 (100)	32,400 (100)	11,800 (100)	1,100 (100)	280 (100)	6,220 (100)	N.a. (100)
Grade (g/t)	8.1	8.71	7–27	22.3	0.9	3.8	N.a.

[1]Calculated to 1,200 m vertical depth.

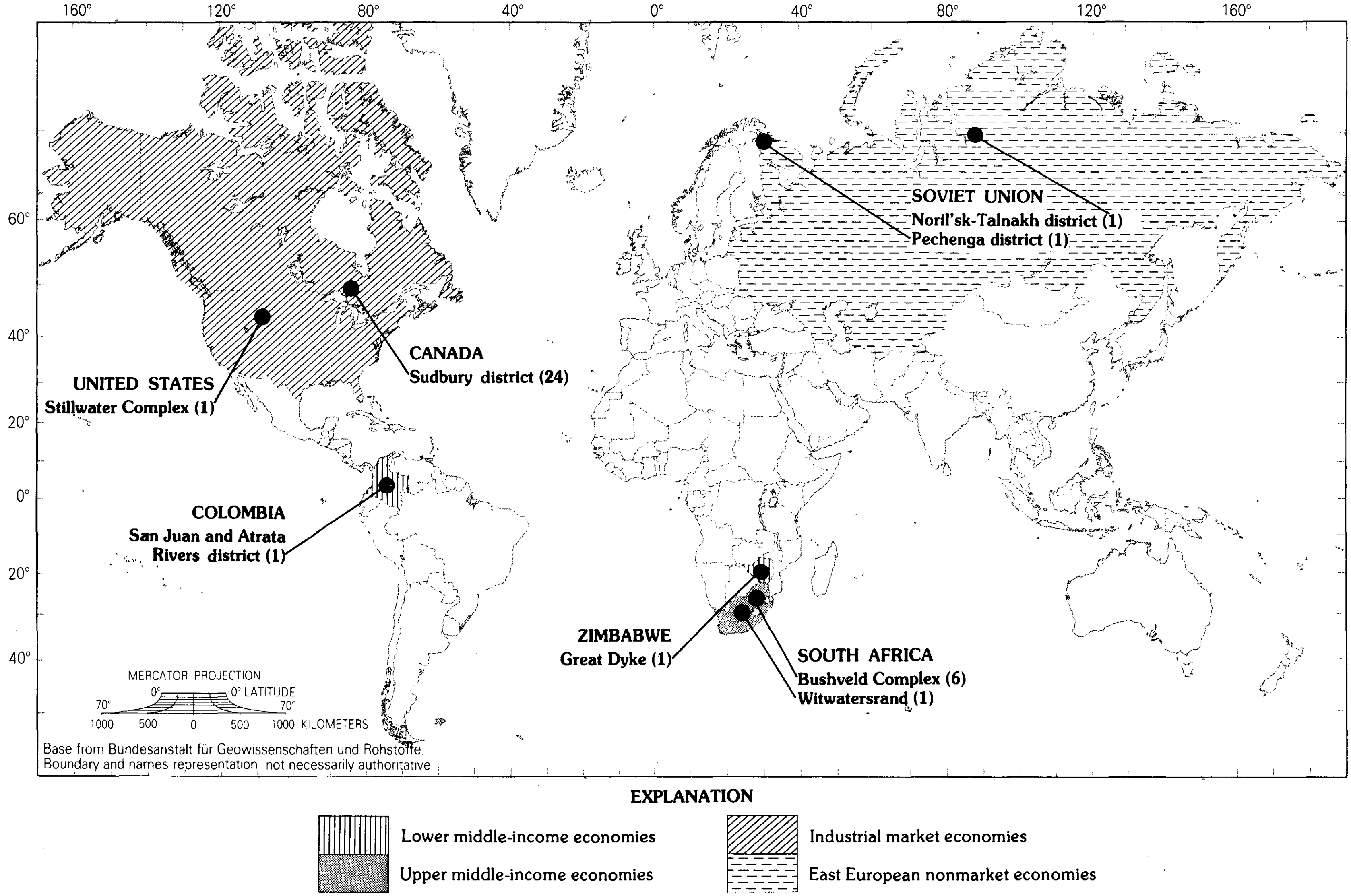


FIGURE 3.—Economic classification of the World Bank (1985, p. 174-175), based principally on GNP per capita, for countries where the world's major platinum-group-metal deposits and districts occur. Numbers in parentheses indicate the number of records (deposits and districts) for each location. Location names are from the tables in Part II.

(2.4 billion ounces) of R1 and R2 resources derived from the inventory record forms.

Other problems with estimates of platinum-group-metal resources are exemplified by the listing of deposits in table 1. Among those deposits listed are large magmatic stratiform complexes in which a Merensky Reef-type deposit has yet to be identified, but for which observed geologic and geochemical characteristics indicate there is a possibility for such an occurrence. (The Penikat Layered Intrusion in Finland may be such a deposit.) New discoveries of this type of deposit could drastically change the distribution of the world's resources of platinum-group metals.

Table 4 shows the distribution of resources (metric tons of in-place material) of major platinum-group-metal deposits among the World Bank country economic classes from figure 3. Upper middle-income countries, represented only by major deposits in South Africa, have most of the platinum-group-metal resources of the major deposits (72 percent of R1E and 89 percent of reported resources in other categories). Deposits in the Soviet Union, the one country representing eastern European nonmarket economy class, contribute 27 percent of reported R1E, and deposits in Canada and the United States, the two countries representing the industrial market economy class, contribute 1.5 percent of reported R1E and 4.2 percent of resources in other categories. Deposits in Zimbabwe and Colombia, countries in the lower middle-income class, have 6.9 percent of reported resources in categories other than R1E (although resources for Colombia are not reported).

The addition to world platinum-group-metal resources in major deposits by discovery of new deposits is shown in figure 4. Production from platinum-group-metal-bearing placers in the San Juan and Atrato Rivers district, Colombia, was the major source of platinum-group metals until additional discoveries were made in the Sudbury irruptive complex, Canada, in the 1880–99 period. The deposits of the Great Dyke were discovered during the 1900–19 period. Discoveries in the Bushveld Complex, South Africa, and in the Noril'sk-Talnakh and Pechenga districts in the Soviet Union make the 1920–39 period one in which 91 percent of currently reported resources were discovered. Resources in Canada's Thompson Nickel Belt, which were discovered in 1956 and 1959, are included in the resource estimates for the Sudbury irruptive complex, and resources in the Stillwater Complex, United States, which were discovered in 1973, are the only major platinum-group-metal deposits discovered since 1939.

Conclusions drawn from figure 4 should take account of (1) the uncertainty of discovery date due to difficulties in defining "discovery"; (2) the limited validity of assigning all of a deposit's (or district's) resources to the initial discovery date, as done in figure 4; and (3) the different standards used by different countries to report resource data. The relatively smaller size of discoveries made since 1939 may be a result of incomplete information about the extent of recently discovered deposits and of the time lag in reporting information about new discoveries and may also reflect reduced exploration more recently due to depressed market conditions.

PLATINUM-GROUP-METAL PRODUCTION

The 36 platinum-group-metal deposits and districts in the International Strategic Minerals Inventory occur in six countries (fig. 5); these countries have collectively accounted for the vast majority (99.5 percent) of the world's platinum-group-metal production since the early 1700's. The data plotted in figure 5 include a very small amount of platinum-group metals from countries that are not in the inventory.

Figure 6 shows the production of platinum-group metals from each of the countries included in the figure 5 totals. Because of sharp increases in production from South Africa and the Soviet Union during the 1940–80 period shown, the proportion of world platinum-group-metal production accounted for by other countries, such as Canada, Colombia, and the United States, has fallen from about 53 percent in 1940 to about 7 percent in 1980. Production growth has been so rapid in South Africa and the Soviet Union that Canada's proportion of world platinum-group-metal production has fallen from 43 percent in 1940 to 6 percent in 1980 even though Canadian output in 1980 was more than double the 1940 production.

TABLE 4.—*Platinum-group-metal resources in the world's major deposits and districts, by economic class of country and resource category*

[Figures are in metric tons of resource; N.r.=None reported; numbers in parentheses are percent of column totals. Figures may not add to totals shown due to rounding]

Economic class[1]	No. of records	Resource category[2]	
		R1E	All other R1 and R2
Lower middle-income	2	N.r.	4,320 (6.9)
Upper middle-income	7	16,600 (72)	55,400 (89)
Industrial market	25	359 (1.5)	2,600 (4.2)
Eastern European nonmarket	2	6,240 (27)	N.r.
Total	36	23,200 (100)	62,300 (100)

[1]Based principally on GNP per capita and, in some instances, other distinguishing economic characteristics (World Bank, 1985, p. 174–175). Countries where major platinum-group-metal deposits or districts occur are, by class: lower middle-income economies—Colombia, Zimbabwe; upper middle-income economies—South Africa; industrial market economies—Canada, the United States; eastern European nonmarket economies—the Soviet Union. Two economic classes, low-income economies and high-income oil exporters, are not listed because those countries do not have identified major platinum-group-metal deposits. See figure 3.

[2]Categories are defined in figure 1.

Information for 1983 production and cumulative production from 1735 to 1983 for countries with deposits in the inventory is shown in table 5. Production at 1983 levels would double world cumulative production in about 20 years. These production data have been grouped by World Bank economic class in table 6.

The eastern European nonmarket economy class (the Soviet Union) accounted for 56 percent of 1983 production and about half of reported world production since 1735. About one third of cumulative production and 41 percent of 1983 production took place in upper middle-income countries (South Africa). Industrial market economy countries (Canada and the United States) rank a distant third in cumulative production (14 percent) and 1983 production (less than 3 percent).

Platinum-group metals are produced from surface and underground mining operations. Table 7 shows the distribution of reported resources by mining method. In general, surface-mining methods are used on placer deposits (resources for placer deposits were not reported), and other types of deposits are mined underground. The exceptions are the Witwatersrand of South Africa, which is a placer deposit of Early Proterozoic age that extends to great depth and must be mined underground, and the Thompson Nickel Belt, a magmatic-stratiform deposit which has surface and underground mines. Of the resources

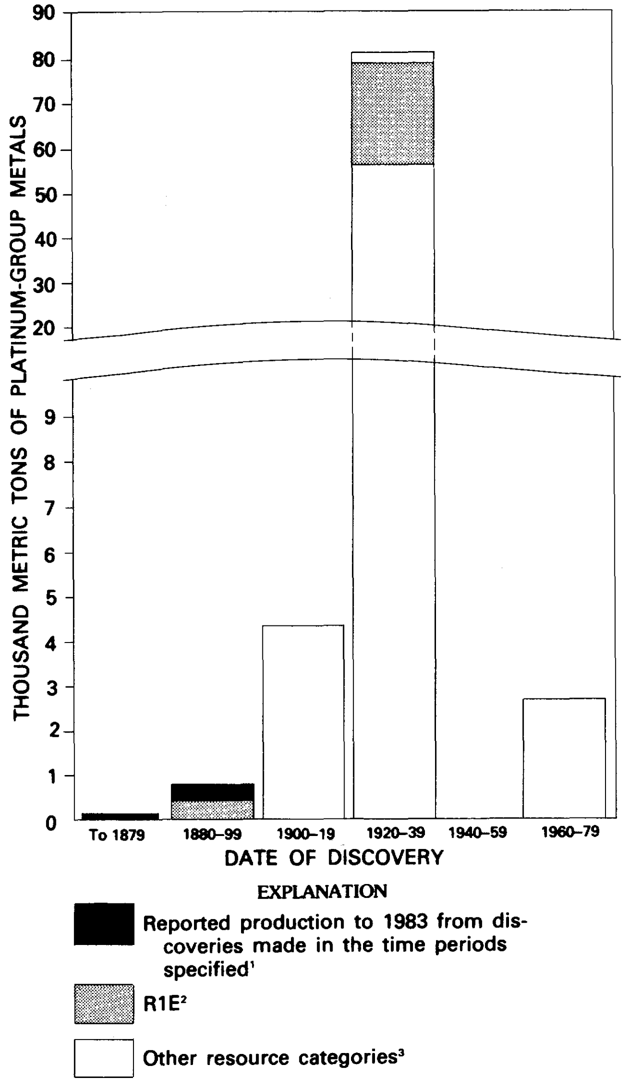


FIGURE 4.—Platinum-group-metal resources in the world's major deposits and districts according to their date of discovery. If the year of discovery was not reported, year of first production was used instead. Years of discovery are listed in table 9 of Part II.

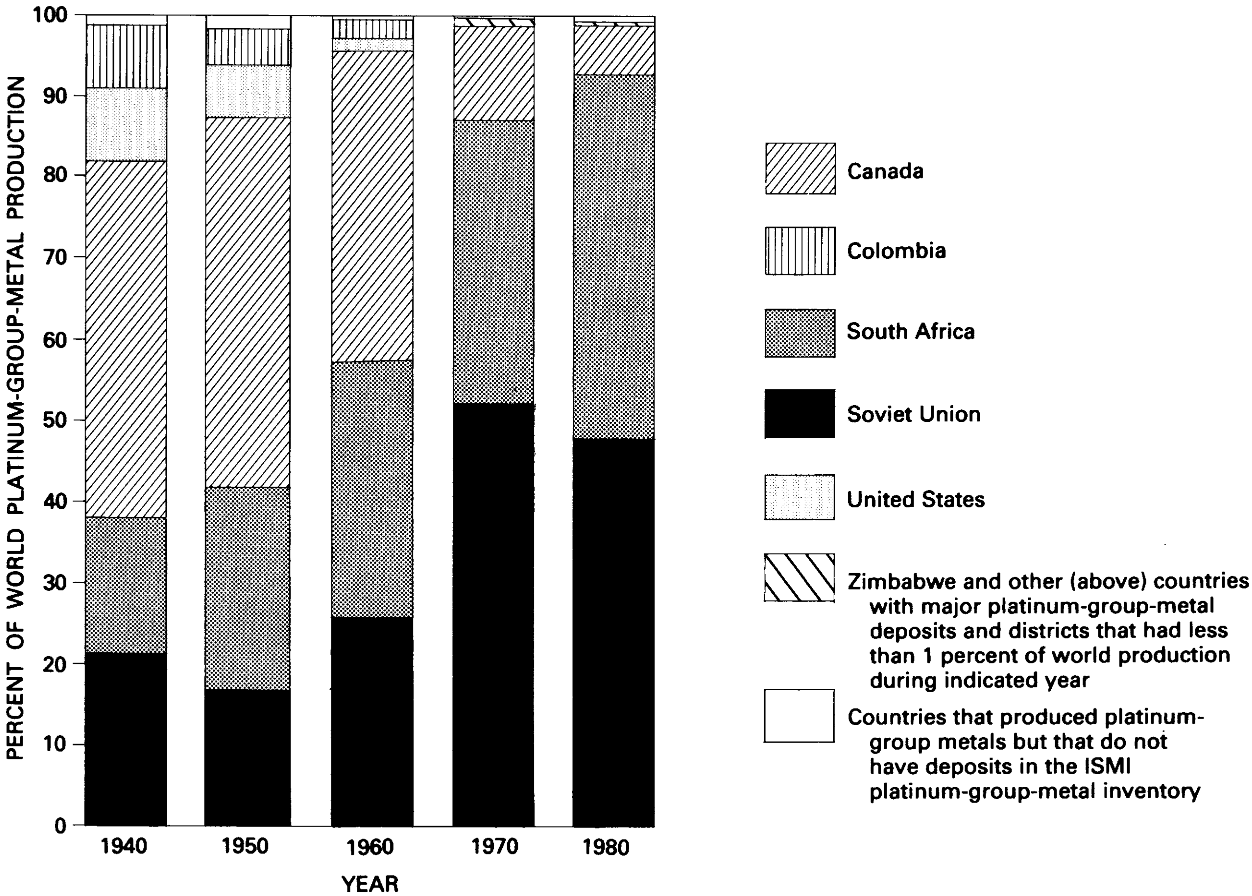


FIGURE 5.—Proportions of total world mine production of platinum-group metals accounted for by countries having major deposits and districts in the ISMI platinum-group-metal inventory, selected years 1940–80. Reported production (U.S. Bureau of Mines, 1943–83) for countries listed in table 5.

TABLE 5.—*Estimated cumulative and annual mine production of platinum-group metals for each country having major platinum-group-metal deposits or districts*

[Figures are in metric tons of contained platinum-group metals; numbers in parentheses denote production ranking of country]

Country	Cumulative production[1] 1735–1983		Annual production[1] 1983	
Soviet Union	2,110	(1)	112	(1)
South Africa	1,420	(2)	80.9	(2)
Canada	550	(3)	5.2	(3)
Colombia	115	(4)	.6	(4)
United States	39.8	(5)	.2	(5)
Zimbabwe	.8	(6)	.1	(6)

[1]Cumulative production calculated from reported production (U.S. Bureau of Mines, 1927–34, 1933–84; Quiring, 1962). Data for all countries for all years are not always available. Production for 1983 is from Loebenstein, 1984, p. 694.

included in table 7, 45 percent are not being mined at present and 55 percent are mined underground.

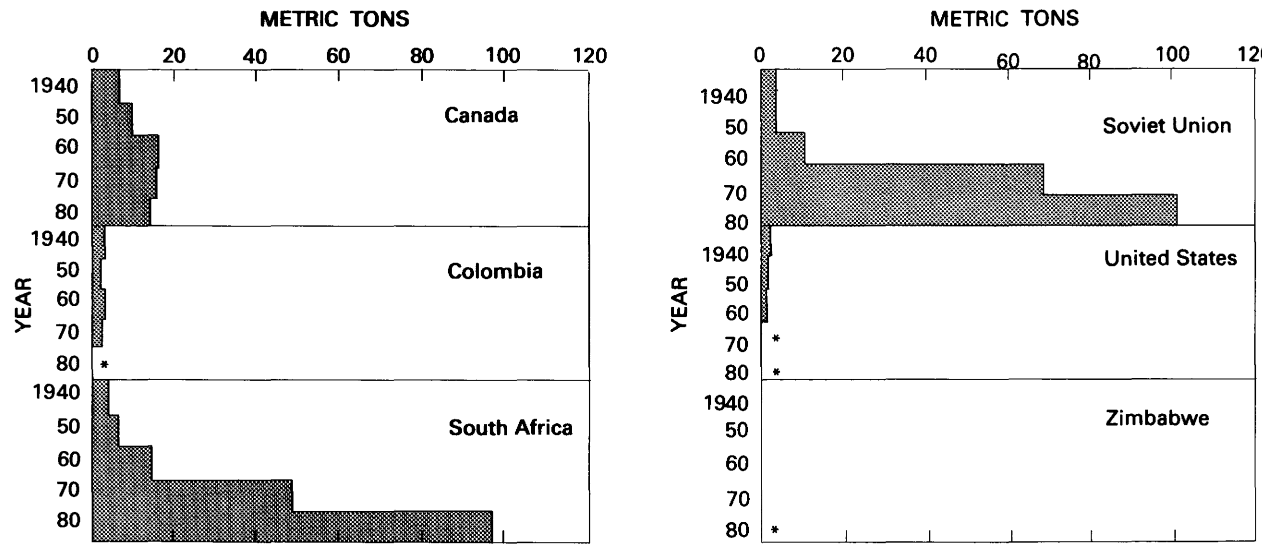
TABLE 6.—*Estimated cumulative and annual mine production of platinum-group metals by economic class for countries having major platinum-group-metal deposits or districts*

[Figures are in metric tons; numbers in parentheses denote production ranking of economic class. Figures may not add to totals shown due to rounding]

Economic class[1]	Cumulative production 1735–1983[2]	Annual production 1983[2]
Lower middle-income	116 (4)	.75 (4)
Upper middle-income	1,420 (2)	80.9 (2)
Industrial market	590 (3)	5.4 (3)
Eastern European nonmarket	2,110 (1)	112 (1)
Total	4,240	199

[1]Based principally on GNP per capita and, in some instances, on other distinguishing economic characteristics (World Bank, 1985, p. 174–175). Countries where major platinum-group-metal deposits or districts occur are, by class: lower middle-income economies—Colombia, Zimbabwe; upper middle-income economies—South Africa; industrial market economies—Canada, United States; eastern European nonmarket economies—Soviet Union. Two economic classes, low-income economies and high-income oil exporters, are not listed because those countries do not have identified major platinum-group-metal deposits. See figure 3.

[2]Reported production from countries in indicated economic class (U.S. Bureau of Mines, 1927–34, 1933–84; Quiring, 1962). Production for 1983 is from Loebenstein, 1984, p. 694.



*Reported mine production of less than 600 kilograms

FIGURE 6.—Platinum-group-metal mine production in countries having major deposits and districts in the ISMI platinum-group-metal inventory, selected years 1940–80. Reported mine production (U.S. Bureau of Mines, 1943–84) for those countries listed in table 5.

In studies of the structure of industrial markets, one way of measuring market concentration is to focus directly on observable dimensions, such as number of suppliers. The market concentration ratio, defined as a percentage of total industry sales or output contributed by the largest firms (Scherer, 1970, p. 50–51), can be applied to countries as well. Figure 7 shows the four-country and eight-country concentration ratios for 1913 and 1980 production of several nonfuel mineral commodities. By these measures, platinum-group metals (reported as platinum in 1913) ranked high among those mineral commodities controlled by a few producing countries in 1913. This concentration of platinum-group-metal production declined only slightly from 1913 to 1980 based on both the four-country ratio and the eight-country ratio.

In 1913, Russia, Colombia, and Australia were the major suppliers of platinum-group metals (USGS, 1921, p. 48), while in 1980 the Soviet Union and South Africa supplied over 90 percent of the world's platinum-group metals.

Present and probable future production of platinum-group metals from the major deposits included in the International Strategic Minerals

TABLE 7.—*Platinum-group-metal resources in the world's major deposits and districts, listed by mining method and economic class of country*

[Resources are those in the R1 and R2 categories (fig. 1). N.r.=None reported. Figures are metric tons of contained platinum-group metals. Figures may not add to totals shown due to rounding]

Economic class[1]	Mining method			
	Surface	Underground	Surface and underground	Not mined
Lower middle-income	N.r.	N.r.	N.r.	4,320
Upper middle-income	N.r.	37,900	N.r.	34,100
Industrial market	N.r.	2,960	N.r.	N.r.
Eastern European nonmarket	N.r.	6,250	N.r.	N.r.
Total	N.r.	47,100	N.r.	38,400

[1]Based principally on GNP per capita and, in some instances, other distinguishing economic characteristics (World Bank, 1985, p. 174–175). Countries where major platinum-group-metal deposits or districts occur are, by class: lower middle-income economies—Colombia, Zimbabwe; upper middle-income economies—South Africa; industrial market economies—Canada, United States; eastern European nonmarket economies—Soviet Union. Two economic classes, low-income economies and high-income oil exporters, are not listed because those countries do not have identified major platinum-group-metal deposits. See figure 3.

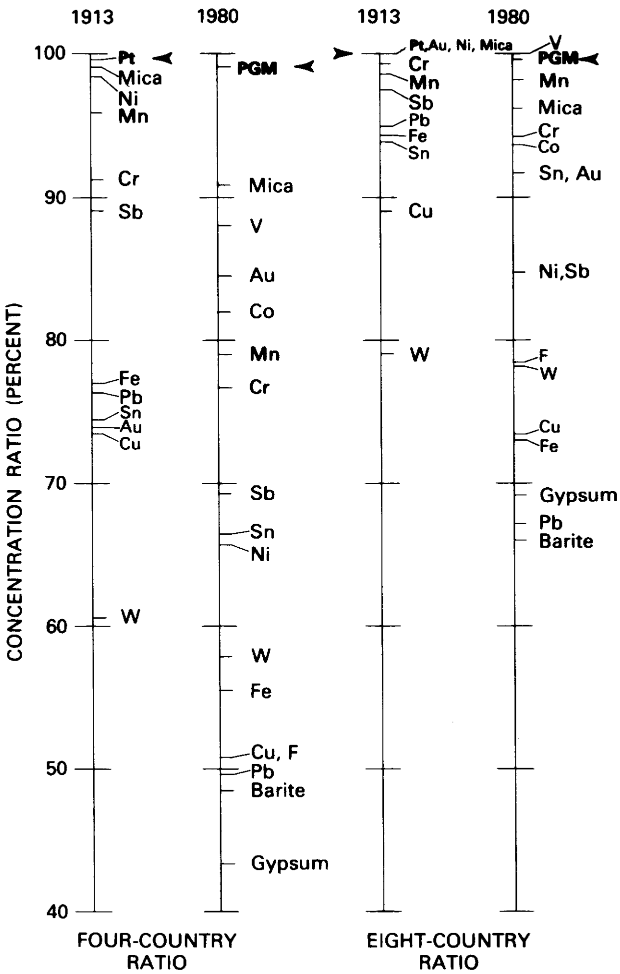


FIGURE 7.—Concentration ratios for selected nonfuel mineral commodity production in 1913 and 1980. The ratios are percent of total world production for the indicated commodities, designated by chemical-element symbols (PGM for platinum-group metals), for the four or eight countries with the largest reported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

Inventory are shown on the map in figure 8. Present major producers (such as Sudbury district, Noril'sk-Talnakh district, and the Bushveld Complex) will probably continue to be significant producers through the year 2020. The recent cessation of production from placer deposits in Upper San Juan and Atrato Rivers district of Colombia will probably be compensated for by production from the Stillwater Complex. The Great Dyke, although shown in figure 8 as a nonproducer or an insignificant producer, may also compensate for the loss of production in Colombia. An analysis by Anstett and others (1982) suggests that the price of platinum would have to quadruple before mining in the Great Dyke could begin.

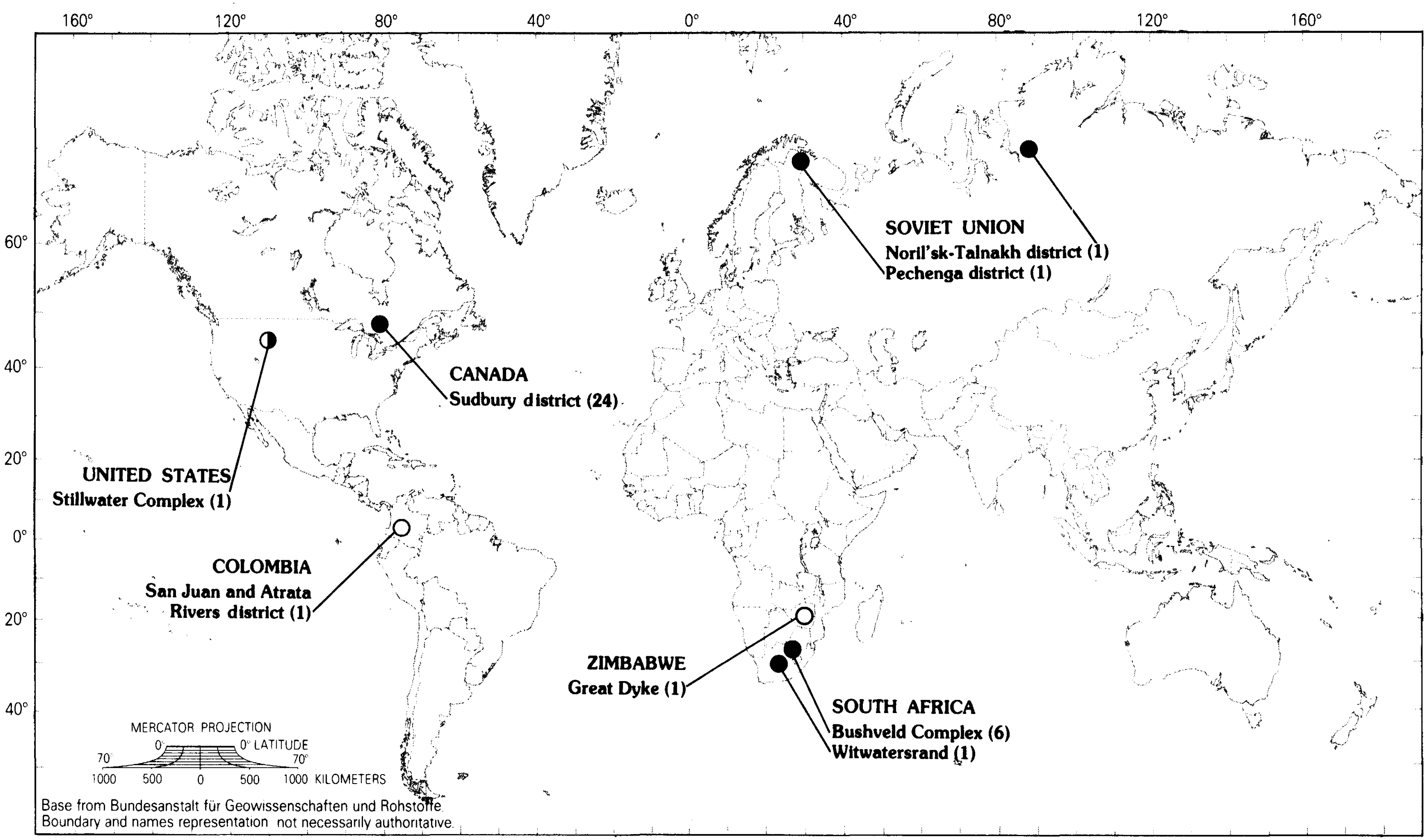
The Penikat Layered Intrusion in Finland (table 1) is reported to contain platinum-group-metal mineralization of the Merensky Reef-type (Alapieti and Lahtinen, 1985). Layered mafic and ultramafic intrusions similar to this one have been identified in other countries and have as yet not been explored thoroughly for platinum-group-metal deposits. Such discoveries and new exploration have been encouraged by the rapid expansion of published geologic and geochemical information on platinum-group-metal deposits and the development of precise, rapid analytical techniques in the last decade. It is possible that discoveries such as the Penikat occurrence and future discoveries of other Merensky Reef-type deposits could change the present platinum-group-metal supply structure by the year 2020.

CONCLUSIONS

At present, platinum-group-metal supply is dominated by mines in South Africa and the Soviet Union. Worldwide demand is increasing because of current or pending emission-control legislation that necessitates platinum-based catalysts in gasoline-powered vehicles. Development and potential use of fuel cells could add to this demand. Continuing exploration and development of Merensky Reef-type mineralization in the Stillwater Complex, Montana, and the potential discovery of other deposits of this type could dramatically change the supply situation evolving by 2020.

PART II—SELECTED INVENTORY INFORMATION FOR PLATINUM-GROUP-METAL DEPOSITS AND DISTRICTS

Tables 8 and 9 contain information from the International Strategic Minerals Inventory record forms for platinum-group-metal deposits and districts. Only selected items of information about the location and geology (table 8) and mineral production and resources (table 9) of the deposits are listed here; some of this information has been abbreviated.



EXPLANATION

- ● Producer in 1985; probably a significant producer in 2020
- ◑ No production in 1985; probably a significant producer in 2020
- ○ No production in 1985; probably an insignificant producer or no production by 2020

FIGURE 8.—Major platinum-group-metal deposits and districts, their present production status, and their probable production status in 2020.

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

TABLE 8.—*Selected geologic and location information from ISMI records for platinum-group-metal deposits and districts*

Abbreviations used throughout this table include:

———, Not reported on the ISMI record form
PGM, Platinum-group metals
Ma, Million years

Host rock includes some or all of the following items (separated by semicolons): main host rock type, formation name, and host rock age.

Age abbreviations and prefix:

Quaternary	QUAT	Proterozoic	PROT
Triassic	TRI	Archean	ARCH
Carboniferous	CARB	Precambrian	PREC
Devonian	DEV	Early	E

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

Atokite	ATKT	Iridosmine	IDSM	Pentlandite	PNLD
Bornite	BRNT	Kotulskite	KTSK	Plagioclase	PLGC
Braggite	BRGT	Laurite	LART	Platinum-group metals	PGM
Chalcopyrite	CLCP	Mackinawite	MCKN	Polydymite	PLDM
Chromite	CRMT	Magnetite	MGNT	Pyrite	PYRT
Clinopyroxene	CLPX	Marcasite	MRCS	Pyrrhotite	PYTT
Cobaltite	CBLT	Merenskyite	MRSK	Quartz	QRTZ
Cooperite	COPR	Michenerite	MCNR	Sperrylite	SPRL
Cubanite	CBNT	Millerite	MLRT	Sphalerite	SPLR
Gersdorffite	GRDF	Moncheite	MNCH	Uraninite	URNN
Gold	GOLD	Olivine	OLVN	Violarite	VOLR
Heazlewoodite	HZLD	Orthopyroxene	ORPX	Vysotskite	VSSK
Ilmenite	ILMN	Osmiridium	OSMR	Zvyagintsevite	ZVGS
Insizwaite	INZW	Paolovite	PLVT		

Site name	Latitude, Longitude	Deposit type	Host rock	Age of mineralization	Tectonic setting	Local environment	Principal mineral assemblages	Comments	Reference
CANADA									
East mine (Sudbury district (Ontario)-Falconbridge Ltd.).	46°35′N., 80°47′W.	Magmatic, gabbroic, Sudbury-type.	Gabbro-norite; Sudbury nickel irruptive; EPROT (1,849.5±3 Ma).	EPROT, final emplacement after nickel irruptive.	Intracratonic intrusion triggered by impact of meteorite.	Penecontemporaneous fault cutting basal contact of intrusion.	PYTT, PNLD, CLCP, PYRT; minor MGNT, GRDF, VOLR, MRCS. PGM minerals probably similar to those in Inco mines at Sudbury; see Creighton mine.	Ore body parallel to, but distinct from, Falconbridge mine ore body.	Pye and others (1984).
Falconbridge mine (Sudbury district (Ontario)-Falconbridge Ltd.).	46°35′N., 80°48′W.	do	do	EPROT, slightly before or after nickel irruptive (1,849 Ma).	do	Penecontemporaneous fault cutting basal contact of irruptive.	PYTT, PNLD, CLCP, PYRT; minor MGNT, GRDF, VOLR, MRCS. PGM minerals probably similar to those at Creighton mine.	Consists of a sheet of massive and breccia-sulfide occupying a nearly vertical fault zone.	Do.

Fecunis-North mine (Sudbury district (Ontario)-Falconbridge Ltd.).	46°39′N., 81°21′W.	-------- do --------	"Granite breccia"; probably Sudbury sublayer; EPROT.	------ do -----	---- do ----	Footwall breccia below the base of Sudbury nickel irruptive.	PYTT, PNLD, CLCP. PGM minerals probably similar to those in Inco mines at Sudbury; see Creighton mine.	Ore body mainly in granite breccia.	Do.
Fraser mine (Sudbury district (Ontario)-Falconbridge Ltd.).	46°40′N., 81°21′W.	-------- do --------	---------- do ---------	------ do -----	---- do ----	---	PYTT, PNLD, CLCP, PYRT: minor MGNT, GRDF, VOLR, MRCS. PGM minerals probably similar to those at Creighton mine.	Deposit may consist of copper-rich footwall veins.	Do.
Lockerby mine (Sudbury district (Ontario)-Falconbridge Ltd.).	46°26′N., 81°20′W.	-------- do --------	Sudbury sublayer; EPROT.	------ do -----	---- do ----	---	------- do ------	No published geologic information.	Do.
Onaping-Craig mine (Sudbury district (Ontario)-Falconbridge Ltd.).	46°38′N., 81°23′W.	-------- do --------	Probably "granite breccia"; Sudbury sublayer; EPROT.	------ do -----	---- do ----	---	------- do ------	Ore body forms a sheet lying within the footwall gneiss.	Do.
Strathcona mine (Sudbury district (Ontario)-Falconbridge Ltd.).	46°40′N., 81°20′W.	-------- do --------	"Granite breccia"; probably Sudbury sublayer; EPROT.	------ do -----	---- do ----	Sudbury sublayer intrusion at base of nickel irruptive.	PYTT, PNLD, CLCP; also minor PYRT, CBNT. PGM minerals probably similar to those in Inco mines at Sudbury, see Creighton mine.	Ore body consists of three zones: gabbro-norite, granite breccia, and gneiss.	Do.

TABLE 8.—*Selected geologic and location information from ISMI records for platinum-group-metal deposits and districts*—Continued

Site name	Latitude, Longitude	Deposit type	Host rock	Age of mineralization	Tectonic setting	Local environment	Principal mineral assemblages	Comments	Reference
				CANADA—continued					
Clarabelle No. 2 open pit (Sudbury district (Ontario)-Inco Ltd.).	46°31′N., 81°04′W.	Magmatic, gabbroic, Sudbury-type.	Xenolithic gabbro-norite; Sudbury sublayer; EPROT.	EPROT, slightly before or after nickel irruptive (1,849 Ma).	Intracratonic intrusion triggered by impact of meteorite.	Sudbury sublayer intrusion at base of nickel irruptive.	PYTT, PNLD, CLCP. For a description of PGM minerals in Inco mines at Sudbury, see Creighton mine.	Xenolithic gabbro-norite contains sulfides which increase with depth.	Pye and others (1984).
Coleman mine (Sudbury district (Ontario)-Inco Ltd.).	46°41′N., 81°20′W.	-------- do --------	"Leucocratic breccia"; Sudbury sublayer; EPROT.	---	---- do ----	---	------- do ------	Ore body is an extension of Strathcona ore body.	Do.
Copper Cliff North mine (Sudbury district (Ontario)-Inco Ltd.).	46°30′N., 81°04′W.	-------- do --------	Quartz diorite; Copper Cliff.	EPROT, slightly before or after nickel irruptive (1,849 Ma).	---- do ----	Apophysis (offset) of the sublayer intrusion at base of the nickel irruptive.	PYTT, CLCP, PNLD, PYRT. For a description of PGM minerals in Inco mines at Sudbury, see Creighton mine.	Ore bodies consist of near-vertical sheets or pipes.	Do.
Copper Cliff South mine (Sudbury district (Ontario)-Inco Ltd.).	46°28′N., 81°05′W.	-------- do --------	----------- do ----------	------ do -----	---- do ----	-------- do --------	------- do ------	---- do ----	Do.
Crean Hill mine (Sudbury district (Ontario)-Inco Ltd.).	46°26′N., 81°21′W.	-------- do --------	"Greenstone breccia"; Sudbury sublayer; EPROT.	------ do -----	---- do ----	Probably part of the sublayer intrusion at base of the nickel irruptive.	PYTT, PNLD, CLCP. For a description of PGM minerals in Inco mines at Sudbury, see Creighton mine.	"Greenstone breccia" is probably xenolithic mineralized gabbro-norite of the sublayer.	Do.

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.	------ do -----	---- do ----	Sudbury sublayer intrusion at base of the nickel irruptive.	Inco mines Sudbury: MCNR, SPRL; less common MNCH (North Range only), MRSK; small amounts of Pt, Pd, and Rh in CBLT, GRDF.	---	Do.
Frood mine (Sudbury district (Ontario)-Inco Ltd.).	46°32′N., 81°00′W.	Magmatic, gabbroic, Sudbury-type.	Quartz diorite; Frood-Stobie offset; EPROT.	------ do -----	---- do ----	Apophysis ("offset") of the Sudbury sublayer intrusion at base of the nickel irruptive.	PYTT, PNLD, CLCP; PGM and Ni arsenide minerals are unusually abundant. For a description of PGM minerals in Inco mines at Sudbury, see Creighton mine.	"Offset" is a downward-wedging body of quartz diorite.	Do.
Garson mine (Sudbury district (Ontario)-Inco Ltd.).	46°34′N., 80°52′W.	-------- do --------	Gabbro-norite; Sudbury nickel irruptive; EPROT (1,849.5±3 Ma).	EPROT, final emplacement after nickel irruptive.	Intracratonic intrusion triggered by impact of meteorite.	Penecontemporaneous fault cutting basal contact of intrusion.	PYTT, PNLD, CLCP, GRDF. For a description of PGM minerals in Inco mines at Sudbury, see Creighton mine.	About 80 percent of ore is massive and breccia sulfides along branching fault zones.	Do.
Levack mine (Sudbury district (Ontario)-Inco Ltd.).	46°39′N., 81°23′W.	-------- do --------	"Leucocratic breccia"; Sudbury sublayer; EPROT.	EPROT, slightly before or after nickel irruptive (1,849 Ma).	---- do ----	Sudbury sublayer intrusion (at base of the nickel irruptive and underlying footwall breccia).	PYTT, PNLD, CLCP. For a description of PGM minerals in Inco mines at Sudbury; see Creighton mine.	About 70 percent of ore is disseminated sulfides in a leucocratic breccia.	Do.

TABLE 8.—*Selected geologic and location information from ISMI records for platinum-group-metal deposits and districts*—Continued

Site name	Latitude, Longitude	Deposit type	Host rock	Age of mineralization	Tectonic setting	Local environment	Principal mineral assemblages	Comments	Reference
				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.	---	Intracratonic intrusion triggered by impact of meteorite.	---	PYTT, PNLD, CLCP. For a description of PGM minerals in Inco mines at Sudbury; see Creighton mine.	Probably a typical North Range-type deposit like Levack and Strathcona ore bodies.	Pye and others (1984).
Little Stobie mine (Sudbury district (Ontario)-Inco Ltd.).	46°33′N., 81°00′W.	-------- do --------	Xenolithic gabbro-norite; Sudbury sublayer; EPROT.	EPROT, slightly before or after nickel irruptive (1,849 Ma).	---- do ----	Sudbury sublayer intrusion at base of the nickel irruptive.	PYTT, PNLD, CLCP, minor PYRT, MGNT, ILMN. For a description of PGM minerals in Inco mines at Sudbury, see Creighton mine.	Little published geologic information.	Do.
McCreedy West mine (Sudbury district (Ontario)-Inco Ltd.).	46°38′N., 81°24′W.	-------- do --------	"Leucocratic breccia"; Sudbury sublayer; EPROT.	------ do -----	---- do ----	Footwall breccia and sulfide veins below the sublayer intrusion at base of the nickel irruptive.	PYTT, PNLD, CLCP. For a description of PGM minerals in Inco mines at Sudbury, see Creighton mine.	Similar to Strathcona ore body.	Do.
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.	------ do -----	---- do ----	Sudbury sublayer intrusion at base of the nickel irruptive.	PYTT, PNLD, CLCP, minor PYRT, MGNT. For a description of PGM minerals in Inco mines at Sudbury, see Creighton mine.	Xenoliths are peridotite, gabbro, and metavolcanic rocks.	Do.

Stobie mine (Sudbury district (Ontario)-Inco Ltd.).	46°32′N., 81°00′W.	Magmatic, gabbroic, Sudbury-type.	Quartz diorite; Frood-Stobie "offset"; EPROT.	------ do -----	---- do ----	Apophysis ("offset") of the Sudbury sublayer intrusion at the base of the nickel irruptive.	PYTT, PNLD, CLCP. For a description of PGM minerals in Inco mines at Sudbury, see Creighton mine.	Common ore body with Frood mine.	Do.
Totten mine (Sudbury district (Ontario)-Inco Ltd.).	46°23′N., 81°28′W.	-------- do --------	Quartz diorite; Worthington "offset"; EPROT.	------ do -----	---- do ----	-------- do -------	For a description of PGM minerals in Inco mines at Sudbury, see Creighton mine.	Presumed to be similar to Frood-Stobie ore body.	Do.
Pipe No. 2 open pit (Thompson Nickel Belt (Manitoba)).	55°30′N., 98°09′W.	Magmatic, stratiform, disseminated.	Serpentinized peridotite; EPROT.	EPROT, 2,320 ±30 Ma based on Pb isotopes in nickel sulfide ore.	PROT supracrustal sequence near margin of ARCH craton.	Ultramafic sill emplaced in metasedimentary sequence.	PYTT, PNLD, PYRT, VOLR; no information on PGM minerals.	Ore is found in serpentinite lens which occupies west limb of a tight, steeply plunging fold.	Peredery and others (1982).
Thompson mine (Thompson Nickel Belt (Manitoba)).	55°43′N., 97°51′W.	-------- do --------	"Biotite schist"; Thompson metasedimentary band; EPROT.	------ do -----	---- do ----	-------- do -------	PYTT, PNLD, PYRT, CLCP; no information on PGM minerals.	Irregular, continuous sulfide layer (containing ultramafic inclusions) within folded biotite schist; intensely deformed and metamorphosed.	Do.

TABLE 8.—*Selected geologic and location information from ISMI records for platinum-group-metal deposits and districts*—Continued

Site name	Latitude, Longitude	Deposit type	Host rock	Age of mineralization	Tectonic setting	Local environment	Principal mineral assemblages	Comments	Reference
COLOMBIA									
San Juan and Atrato Rivers district.	05°42′N., 76°39′W.	Placer	Alluvium; QUAT	QUAT	Outerfold of Colombian Andes.	River placers	GOLD, PGM alloys.	Placers occur in a 300-km belt along the flank of the West Cordillera with Quibdo near center.	Wokittel (1961).
SOUTH AFRICA									
Merensky Reef: Eastern Bushveld (Bushveld Complex).	24°19′S., 29°50′E.	Magmatic, stratiform, massive.	Pyroxenite; Merensky Reef, Dwars River Subsuite, Rustenburg Layered Suite; EPROT (2,095±24 Ma).	EPROT (2,095 ±24 Ma).	Intracratonic	Plutonic	CLCP, PNLD, PYRT, PYTT; COPR, BRGT, LART, SPRL, MNCH, PLVT, ATKT.	Independent platinoid minerals are quite rare; PGM are commonly associated with base-metal sulfides.	Schwellnus and others (1976).
Merensky Reef: Western Bushveld (Bushveld Complex).	25°40′S., 27°15′E.	do	Pyroxenite; Merensky Reef, Schildpadnest Subsuite, Rustenburg Layered Suite; EPROT (2,095±24 Ma).	do	do	do	PNLD, PYTT, CLCP; SPRL, COPR, LART, BRGT, Pt-Fe alloy; PYRT, CBNT, MCKN.	---	Coetzee (1976).
Platreef (Bushveld Complex).	23°57′S., 28°54′E.	Magmatic, stratiform, massive and disseminated.	Pyroxenite; Platreef, Grasvally norite-anorthosite, Rustenburg Layered Suite; EPROT (2,095 ±24 Ma).	do	do	do	PYTT, PNLD, CLCP; COPR, BRGT.	Unaltered igneous rocks are uneconomic, but relatively high concentrations of PGM are in serpentinized zones.	Gain and Mostert (1982).

UG2 chromitite layer: Eastern Bushveld (Bushveld Complex).	24°40′S., 30°00′E.	Magmatic, strati-form, massive.	Chromitite; UG2 chromi-tite layer, Dwars River Subsuite, Rustenburg Layered Suite; EPROT (2,095±24 Ma).	------ do -----	---- do ----	-------- do --------	CRMT, ORPX, PLGC; LART, COPR, BRGT, Pt-Rh-Cu sul-fide, Pt-Pb-Cu sulfide, Pt-Fe alloy, Pd-Cu alloy, Pd-Pb alloy, Pd-Hg alloy; PNLD, CLCP, PYTT, PYRT.	UG2 occurs 145 to 370 m be-low Merensky Reef.	McLaren and DeVilliers (1982).
UG2 chromitite layer: Western Bushveld (Bushveld Complex).	25°42′S., 27°30′E.	-------- do --------	Chromitite; UG2 chromi-tite layer, Schildpadnest Subsuite, Rustenburg Layered Suite; EPROT (2,095±24 Ma).	------ do -----	---- do ----	-------- do --------	CRMT, ORPX, PLGC; LART, COPR, BRGT, Pt-Ir-Rh-Cu sulfide, Pt-Pb-Cu sulfide, Pt-Fe alloy, Pd-Cu alloy, Pd-Pb al-loy, Pd-Hg alloy; PNLD, CLCP, PYTT, PYRT.	Dips 8 to 30° toward center of Bushveld Complex.	Vermaak and von Gruene-waldt (1981).
Volspruit de-posit (Bushveld Complex).	24°22′S., 28°57′E.	Magmatic, strati-form, dissemi-nated.	Pyroxenite; Volspruit py-roxenite, Zoetveld Sub-suite, Rustenburg Lay-ered Suite; EPROT (2,095±24 Ma).	------ do -----	---- do ----	-------- do --------	PYTT, PNLD, CLCP, CBNT.	Average thickness of mineral-ized zone 5 to 6 m; depth of cover 3 m.	Hulbert and von Gruene-waldt (1982).
Witwatersrand	26°10′S., 28°00′E.	Placer, continental, fossil.	Conglomerate; Witwater-srand Supergroup; EPROT (2,500 Ma).	PROT (2,500, 2,300, 2,000 Ma).	Intracratonic	Clastic sedimentary facies.	QRTZ, PYRT, GOLD, URNN, OSMR, IDSM, SPRL, various PGM alloys.	Osmium and iridium are main PGM present; Au/PGM ranges from 100 to 8,000.	Feather (1976).

TABLE 8.—*Selected geologic and location information from ISMI records for platinum-group-metal deposits and districts*—Continued

Site name	Latitude, Longitude	Deposit type	Host rock	Age of mineralization	Tectonic setting	Local environment	Principal mineral assemblages	Comments	Reference
SOVIET UNION									
Noril'sk-Talnakh district.	69°20′N., 88°08′E.	Magmatic, gabbroic, intercontinental rift zone.	Tholeiitic basalt; Siberian traps; TRI.	TRI	Intercontinental rift zone.	Magmatic sulfides separated from gabbroic liquids and formed ores concentrated in sills along Noril'sk-Kharaelakh fault system.	PYTT, CLCP, MGNT, BRNT, MCKN, MRCS, MLRT, PLDM, SPLR, HZLD, BRGT, VSSK, ZVGS, INZW, KTSK, COPR, MCNR, PLVT, MNCH.	Gabbroic to basaltic magmas assimilated sulfur from DEV-CARB evaporites which caused precipitation of magmatic sulfides rich in Cu-Ni-PGM.	Genkin and others (1981).
Pechenga district.	69°20′N., 29°44′E.	Magmatic, gabbroic, stratiform, massive and disseminated.	Serpentinite; Pechenga series; PROT.	---	Fault in PREC shield.	Sulfides separated in mafic magmas.	PYTT, PNLD, CLCP; PYRT; MGNT; VOLR.	Over 20 deposits in district.	Smirnov (1977).
UNITED STATES									
J–M Reef deposit (Stillwater Complex).	43°23′N., 109°53′W.	Magmatic, stratiform, Merensky Reef-type, disseminated.	Harzburgite-olivine cumulate; Stillwater Complex, 05B; ARCH (2,700–2,900 Ma).	---	Stable PREC craton.	Layered mafic intrusion.	PYTT, PNLD, CLCP, BRGT, COPR, KTSK, MNCH, Pt-Fe alloy, PLGC, CLPX, ORPX, OLVN.	J–M reef is 1 to 3 m thick and extends for 40 km. It is distinguished by 0.5 to 1.0 percent sulfide minerals which contain PGM minerals.	Todd and others (1982).

				ZIMBABWE					
Great Dyke	19°00′S., 30°15′E.	Magmatic, stratiform, Merensky Reef-type, disseminated.	Feldspathic pyroxenite; Pyroxenite Band No. 1; ARCH (2,532±89 Ma).	---	Stable craton.	Layered mafic intrusion.	PYTT, PNLD, CLCP, SPRL, COPR.	The Great Dyke is 500 km long covering 7,500 km^2 and is comprised of 6 concave layers 6 km wide and extending to 3,000 m depth.	Worst (1960).

TABLE 9.—*Selected production and mineral-resource information from ISMI records for platinum-group metal deposits and districts*

Abbreviations used throughout this table include:

---, Not reported on the ISMI record form
PGM, Platinum-group metals
g/t, Grams per metric ton

Abbreviations for *mining method:* S, surface; U, underground; N, not yet producing.

Annual production includes some or all of the following items (separated by semicolons): production in 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).

Cumulative production includes some or all of the following items (separated by semicolons): production in metric tons of material mined (unless other processing stage is indicated); grade of reported material; and years for reported cumulative production.

Resources includes, for various resource categories, some or all of the following items (separated by semicolons): resource in metric tons; U.N. resource classification (United Nations Economic and Social Council, 1979; 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-place grades are usually reported. Dilution in the mill feed grades may be about 15 percent for underground mining.

Site name	Year of discovery	Mining method	Year of first production	Elements of economic interest	Annual production	Cumulative production	Resources	Comments
				CANADA				
East mine (Sudbury district (Ontario)-Falconbridge Ltd.).	1949	U	1953	Ni, Cu, PGM, Au, Ag, Co, Se, Te.	See Falconbridge mine.	See Falconbridge mine.	r1E (see Falconbridge mine).	---
Falconbridge mine (Sudbury district (Ontario)-Falconbridge Ltd.).	1916	U	1930	Ni, Cu, PGM, Au, Ag, Co, Se, Te.	2,498,000; 1.3 percent Ni, 1.0 percent Cu, 0.04 percent Co, 0.45 g/t PGM; 1979–83.	78,248,000; 1.5 percent Ni, 0.8 percent Cu, 0.45 g/t PGM; 1952–83.	66,769,000; r1E; 1.51 percent Ni, 1.1 percent Cu, 0.45 g/t PGM; 1983.	Production and resources for all Falconbridge operations in Sudbury district (Ontario); Falconbridge mine closed after June 1984 rock burst.
Fecunis-North mine (Sudbury district (Ontario)-Falconbridge Ltd.).	1964	U	1965	Ni, Cu, PGM, Au, Ag, Co, Se, Te.	See Falconbridge mine.	See Falconbridge mine.	r1E (see Falconbridge mine).	---
Fraser mine (Sudbury district (Ontario)-Falconbridge Ltd.).	Pre-1970	U	1981	Ni, Cu, PGM, Au, Ag, Co, Se, Te.	------ do ------	------ do ------	-------- do --------	---
Lockerby mine (Sudbury district (Ontario)-Falconbridge Ltd.).	1919	U	1975	Ni, Cu, PGM, Au, Ag, Co, Se, Te.	------ do ------	------ do ------	-------- do --------	Believed to be an extension of Crean Hill No. 2 deposit.

Onaping-Craig mine (Sudbury district (Ontario)-Falconbridge Ltd.).	1942	U	1961	Ni, Cu, PGM, Au, Ag, Co, Se, Te.	------ do ------	------ do ------	-------- do --------	Operation suspended indefinitely Sept. 1982.
Strathcona mine (Sudbury district (Ontario)-Falconbridge Ltd.).	1951	U	1962	Ni, Cu, PGM, Au, Ag, Co, Se, Te.	------ do ------	------ do ------	-------- do --------	PGE+Au about 0.4 g/t, of which Pt=50 percent, Pd=40 percent, Os+Rh+Ru=5 percent, and Au=5 percent.
Clarabelle No. 2 open pit (Sudbury district (Ontario)-Inco Ltd.).	1883	S	1979	Ni, Cu, PGM, Au, Ag, Co, Se, Te.	See Creighton mine.	See Creighton mine.	r1E (see Creighton mine).	---
Coleman mine (Sudbury district (Ontario)-Inco Ltd.).	Pre-1964	U	1971	Ni, Cu, PGM, Au, Ag, Co, Se, Te.	------ do ------	------ do ------	-------- do --------	Last production in 1982.
Copper Cliff North mine (Sudbury district (Ontario)-Inco Ltd.).	Pre-1960	U	1967	Ni, Cu, PGM, Au, Ag, Co, Se, Te.	------ do ------	------ do ------	-------- do --------	Last production in 1978.
Copper Cliff South mine (Sudbury district (Ontario)-Inco Ltd.).	Pre-1967	U	1970	Ni, Cu, PGM, Au, Ag, Co, Se, Te.	------ do ------	------ do ------	-------- do --------	---
Crean Hill mine (Sudbury district (Ontario)-Inco Ltd.).	Pre-1905	U	1905	Ni, Cu, PGM, Au, Ag, Co, Se, Te.	------ do ------	------ do ------	-------- do --------	Placed on standby in 1978.

TABLE 9.—*Selected production and mineral-resource information from ISMI records for platinum-group metal deposits and districts*—Continued

Site name	Year of discovery	Mining method	Year of first production	Elements of economic interest	Annual production	Cumulative production	Resources	Comments
CANADA—continued								
Creighton mine (Sudbury district (Ontario)-Inco Ltd.).	1900	U	1901	Ni, Cu, PGM, Au, Ag, Co, Se, Te.	7,107,707; 1.37 percent Ni, 1.27 percent Cu, 0.7–1.0 g/t PGM; 1979–83.	438,250,000; 1.25 percent Ni, 1.04 percent Cu, 0.02 percent Co, 4.11 g/t Ag, 0.026 g/t Au, 0.7-1.0 g/t PGM; 1950–83.	360,000,000; r1E; 1.24 percent Ni, 1.06 percent Cu, 0.05 percent Co, 0.7 to 1.0 g/t PGM; 1983.	Production and resources for all Inco operations in Sudbury district (Ontario), Thompson mines (Manitoba), and for Shebandowan mine.
Frood mine (Sudbury district (Ontario)-Inco Ltd.).	1884	U	1889	Ni, Cu, PGM, Au, Ag, Co, Se, Te.	See Creighton mine.	See Creighton mine.	r1E (see Creighton mine).	---
Garson mine (Sudbury district (Ontario)-Inco Ltd.).	1891	U	1908	Ni, Cu, PGM, Au, Ag, Co, Se, Te.	------ do ------	------ do ------	-------- do --------	---
Levack mine (Sudbury district (Ontario)-Inco Ltd.).	1888	U	1914	Ni, Cu, PGM, Au, Ag, Co, Se, Te.	------ do ------	------ do ------	-------- do --------	---
Levack East mine (Sudbury district (Ontario)-Inco Ltd.).	Pre-1970	U	None	Ni, Cu, PGM, Au, Ag, Co, Se, Te.	None	None	-------- do --------	---
Little Stobie mine (Sudbury district (Ontario)-Inco Ltd.).	1885	U	1902	Ni, Cu, PGM, Au, Ag, Co, Se, Te.	See Creighton mine.	See Creighton mine.	-------- do --------	---
McCreedy West mine (Sudbury district (Ontario)-Inco Ltd.).	Pre-1939	U	1973	Ni, Cu, PGM, Au, Ag, Co, Se, Te.	------ do ------	------ do ------	-------- do --------	---

Murray mine (Sudbury district (Ontario)-Inco Ltd.).	1883	S, U	1889	Ni, Cu, PGM, Au, Ag, Co, Se, Te.	------ do ------	------ do ------	-------- do --------	Last production 1971 (on standby).
Stobie mine (Sudbury district (Ontario)-Inco Ltd.).	1884	U	1887	Ni, Cu, PGM, Au, Ag, Co, Se, Te.	------ do ------	------ do ------	-------- do --------	---
Totten mine (Sudbury district (Ontario)-Inco Ltd.).	1885	U	1966	Ni, Cu, PGM, Au, Ag, Co, Se, Te.	------ do ------	------ do ------	-------- do --------	Last production in 1972.
Pipe No. 2 open pit (Thompson Nickel Belt (Manitoba)).	1959	S	1970	Ni, Cu, Co, PGM, Au, Ag, Se, Te.	------ do ------	------ do ------	-------- do --------	Last production in 1984.
Thompson mine (Thompson Nickel Belt (Manitoba)).	1956	U	1967	Ni, Cu, Co, PGM, Au, Ag, Se, Te.	------ do ------	------ do ------	-------- do --------	Resources and production for Thompson Nickel Belt mines are included with Inco's figures for Creighton mine. Thompson mines account for 10 percent of Inco's PGM + Au produced annually.
				COLOMBIA				
San Juan and Atrato Rivers district.	Prehistoric	S	Early 1500's.	PGM, Au	0.516 (PGM in products); 1983.	115 (PGM in products); through 1983.	---	World's first platinum-group-metal production; it has been estimated that only half of Colombian PGM production is traded on the free market.

TABLE 9.—*Selected production and mineral-resource information from ISMI records for platinum-group metal deposits and districts*—Continued

Site name	Year of discovery	Mining method	Year of first production	Elements of economic interest	Annual production	Cumulative production	Resources	Comments
				SOUTH AFRICA				
Merensky Reef: Eastern Bushveld (Bushveld Complex).	1924	U	1969	PGM, Ni, Co, Cu.	Proprietary data	Proprietary data	345.664 (contained PGM); R1E; 5.4 g/t PGM, 0.24 percent Ni, 0.1 percent Cu, 3.6 g/t Co; 1984. 2,573.940 (contained PGM); R1S; 5.4 g/t PGM, 0.24 percent Ni, 0.1 percent Cu, 3.6 g/t Co; 1984. 6,284.998 (contained PGM); R2S; 5.4 g/t PGM, 0.24 percent Ni, 0.1 percent Cu, 3.6 g/t Co; 1984.	Average thickness of reef is 0.3 m; independent platinoid minerals are rare.
Merensky Reef: Western Bushveld (Bushveld Complex).	1924	U	1920's	PGM, Ni, Co, Cu.	------ do ------	------ do ------	5,543.062 (contained PGM); R1E; 5.1 g/t PGM, 0.2 percent Ni, 0.1 percent Cu, 3 g/t Co; 1984. 5,494.527 (contained PGM); R2S; 5.1 g/t PGM, 0.2 percent Ni, 0.1 percent Cu, 3 g/t Co; 1984.	Mining methods are under revision to achieve greater productivity at greater depths and increased ventilation requirements.
Platreef (Bushveld Complex).	1924	N	None	Ni, Cu, PGM, Co.	None	None	1,644.971 (contained PGM); R1E; 5 g/t PGM, 0.3 percent Ni, 0.2 percent Cu, 4 g/t Co; 1984.	Only deposit in Bushveld Complex where Ni and Cu are economically more important than platinum-group metals.

							9,775.241 (contained PGM); R1S; 5 g/t PGM, 0.3 percent Ni, 0.2 percent Cu, 4 g/t Co; 1984.	
							5,177.391 (contained PGM); R2S; 5 g/t PGM, 0.3 percent Ni, 0.2 percent Cu, 4 g/t Co; 1984.	
UG2 chromitite layer: Eastern Bushveld (Bushveld Complex).	1924	N	None	PGM, Ni, Co, Cu.	------ do ------	------ do ------	3,826.079 (contained PGM); R1S; 7.4 g/t PGM, 0.09 percent Ni, 0.04 percent Cu, 1.4 g/t Co; 1984. 13,667.897 (contained PGM); R2S; 7.4 g/t PGM, 0.09 percent Ni, 0.04 percent Cu, 1.4 g/t Co; 1984.	Well investigated area with large resources but no production in the near future.
UG2 chromitite layer: Western Bushveld (Bushveld Complex).	1924	U	1970's	PGM, Ni, Co, Cu.	Proprietary data	Proprietary data	9,068.948 (contained PGM); R1E; 5.6 g/t PGM, 0.09 percent Ni, 0.03 percent Cu, 0.8 g/t Co; 1984. 8,591.106 (contained PGM); R2S; 5.6 g/t PGM, 0.09 percent Ni, 0.03 percent Cu, 0.8 g/t Co; 1984.	UG2 chromitite layer is 0.15 m thick.
Volspruit deposit (Bushveld Complex).	1924	N	None	PGM, Ni	None	None	---	No production planned in the near future.
Witwatersrand	1892	U	1922	Au, U, PGM	Proprietary data	Proprietary data	Proprietary data	---

TABLE 9.—*Selected production and mineral-resource information from ISMI records for platinum-group metal deposits and districts*—Continued

Site name	Year of discovery	Mining method	Year of first production	Elements of economic interest	Annual production	Cumulative production	Resources	Comments
				SOVIET UNION				
Noril'sk-Talnakh district.	1920	U	---	Ni, Cu, Co, Pt, Pd, Rh, Ru, Os, Ir.	17,800,000; 3.8 g/t PGM; 1977.	169,700,000; 3.8 g/t PGM; through 1980.	128,100,000; R1E; 3.8 g/t PGM, 2.2 percent Ni; 1980. 6220 (contained PGM); R1E; 1979.	Production and resources include Noril'sk, Oktyabr'skiy, Talnakh, and Tamyr deposits.
Pechenga district	1937	U	---	Cu, Ni, Se, Te, Au, Ag, PGM.	2,025,000; 2.5 g/t PGM, 1 percent Ni; 1977.	26,000,000; 2.5 g/t PGM, 1 percent Ni through 1981.	10,000,000; R1E; 2.5 g/t PGM, 1 percent Ni; 1981.	Kola Peninsula accounts for 8 to 10 percent of Soviet platinum-group-metal production; production calculated using PGM grade of 3 g/t.
				UNITED STATES				
J–M Reef deposit (Stillwater Complex).	1973	U	1987 projected.	PGM, Cu, Ni	297,000; 20 g/t; 1987 (projected), with about 86 percent recovery.	None	130,000,000; R1M; 20 g/t Pt+Pd (Pd/Pt=3.5); 1984.	Resource estimate based on 42 km length, 1.83 m width, 600 m depth, and rock density of 2.87 g/cm^3.
				ZIMBABWE				
Great Dyke	1918	N	None	PGM, Ni, Cu	None	None	4,320 (contained PGM); R1M; 3.1 to 5 g/t PGM, 0.25 percent Ni, 0.25 percent Cu; 1982.	As of 1985 there are no major platinum-group-metal mining operations in the Great Dyke.

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