COBALT

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Cobalt is a strategic and critical metal used in many diverse industrial and military applications. The largest use of cobalt is in superalloys, which are used to make parts for gas turbine aircraft engines. Cobalt is also used to make magnets; corrosion- and wear-resistant alloys; high-speed steels; cemented carbides (also called hardmetals) and diamond tools; catalysts for the petroleum and chemical industries; drying agents for paints, varnishes, and inks; ground coats for porcelain enamels; pigments; battery electrodes; steel-belted radial tires; and magnetic recording media.

The United States is the world's largest consumer of cobalt. With the exception of negligible amounts of byproduct cobalt produced as intermediate products from some mining operations, the United States did not mine or refine cobalt in 1998. The U.S. Government maintained significant quantities of cobalt metal in the National Defense Stockpile (NDS) for military, industrial, and essential civilian use during a national emergency. Since 1993, sales of excess cobalt from the NDS have contributed to U.S. and world supplies.

World refined cobalt production continued to increase in 1998. Because no new sources of refined cobalt came into production, the increase was from existing producers. The annual rate of growth in world demand for refined cobalt decreased, primarily as a result of the economic recession in Asia and inventory reductions by consumers. The increase in availability, combined with a slowdown in demand, resulted in a significant decrease in cobalt prices, particularly during the second half of the year (Cobalt Development Institute, 1999; Hawkins, 1999). The decrease in cobalt prices, as well as those of copper and nickel, resulted in delays in or postponements of various mining and refining projects that had been planning to produce cobalt. Certain projects in the Democratic Republic of the Congo [Congo (Kinshasa)] were also negatively affected by the ongoing civil war in that country.

Salient U.S. and world cobalt statistics for 1998 and the previous 4 years are listed in table 1. With the exception of prices and reported production from foreign countries, all quantity and value data in this report have been rounded to three significant digits. Totals and percentages were calculated from unrounded numbers.

Legislation and Government Programs

The Defense Logistics Agency (DLA) held monthly sealed-bid cobalt offerings during fiscal year 1998 (October 1, 1997, through September 30, 1998). During the fiscal year, the DLA sold 2,510 metric tons (t) of cobalt valued at nearly $102 million (table 2). This equaled 92% of the 2,720-t (6-million-pound) maximum allowed for sale under the 1998 Annual Materials Plan (AMP). The value of the cobalt sold represented 22% of the total value of all materials sold from the NDS that year. Cobalt has been the top selling material in terms of total dollar value for 4 of the 6 years since cobalt sales began. The AMP for fiscal year 1999 (October 1, 1998, through September 30, 1999) set the maximum allowable sale of cobalt at 2,720 t.

The DLA held 12 monthly cobalt offerings during calendar year 1998 and sold 1,950 t of cobalt valued at $77 million. On December 31, the total uncommitted cobalt inventory held by the DLA was 14,600 t, all of which was authorized for eventual disposal.

In August, the U.S. Environmental Protection Agency (EPA) issued a final rule that added spent hydrotreating and hydrorefining catalysts to a list of hazardous wastes under the Resource Conservation and Recovery Act. As a result of the ruling, these materials will be subject to management and treatment standards and to emergency notification requirements for releases of hazardous substances to the environment. The EPA's decision to classify these materials as hazardous was based on risks associated with their benzene and arsenic contents and on their potential to ignite spontaneously. In response to industry concern regarding the impact that the ruling might have on current catalyst regeneration, metal reclaiming, and recycling activities, the EPA stated that the decision was based primarily on the results of the risk assessment and that the potential impact of the decision on current (1998) catalyst-treatment practices was not a central issue in the decision (U.S. Environmental Protection Agency, 1998, p. 42110-42111, 42118-42121, and 42154-42158).

Production

With the exception of negligible amounts of byproduct cobalt produced from some mining operations, the United States did not mine or refine cobalt in 1998. The U.S. Department of the Interior's Minerals Management Service (1999) reported sales of 44 t of cobalt valued at $101,000 from Federal lands in Missouri in 1998. Cobalt is present in the ores mined for platinum-group metals at the Stillwater Complex of southern Montana. At the Stillwater Mining Co.'s metallurgical complex in Columbus, MT, converter matte from the precious metals smelter was processed at the base metals refinery. Nickel-copper-cobalt sulfate solution from the refinery was sold to Westaim Corp. of Edmonton, Alberta, Canada. In 1998, Stillwater Mining began construction of a nickel-copper refining circuit as part of an expansion of the base metal refinery (Stillwater Mining Co., 1999, p. 9).

Formation Capital Corp., of Vancouver, British Columbia, Canada, received the results of a prefeasibility study on its Sunshine copper-cobalt-gold project in Lemhi County, ID. The study was based on proven and probable reserves of 975,000 t (diluted) grading 0.687% cobalt, 0.686% copper, 0.020 ounce of gold per ton, and an inferred resource of 1.4 million metric tons (Mt) (diluted) grading 0.628% cobalt, 0.525% copper, and 0.017 ounce of gold per ton. Ore from two deposits would be mined by using either underground drift-and-fill or cut-and-fill methods. A 10% cobalt concentrate and a 28% copper concentrate would be produced by flotation. The cobalt concentrate would be processed at a hydrometallurgical plant to be built offsite, and the copper concentrate would be processed by an existing copper smelter. The study recommended working towards a final feasibility study to be completed in 2000, with construction on the project to begin in 2001 (Formation Capital Corp., 1998).

PolyMet Mining Corp. (formerly Fleck Resources Ltd.) of Golden, CO, conducted a drilling program on its 100%-owned Dunka Road deposit in northeastern Minnesota. The deposit occurs in the Duluth Complex, a large layered mafic intrusion that contains copper, nickel, cobalt, platinum-group metals, gold, and silver. Reverse circulation chips of average minable grade generated during the drilling program were crushed, ground, and subjected to flotation to produce a bulk sulfide concentrate, which will be used for metallurgical testing. PolyMet was considering two hydrometallurgical processing technologies for the Dunka Road concentrate—pressure oxidation leaching and bacterial leaching (PolyMet Mining Corp., 1999).

Chrome Corp. of America, a subsidiary of Boulder Group NL of Chatswood, New South Wales, Australia, and Johanna Minerals Inc. formed the Black Rock joint venture to locate and develop mineral deposits in which platinum-group metals are either principal products or significant coproducts. The joint venture had a lease agreement over two nickel-copper sulfide deposits adjacent to Stillwater Mining's platinum-group metal mining operations in southern Montana. During the year, Black Rock made arrangements for a study on the economics of mining and processing the sulfides by bacterial leaching, solvent extraction, and electrowinning to produce nickel, copper, cobalt, and a sludge containing platinum-group metals (Boulder Group NL, 1998a, p. 4-6; b).

U.S. processors made cobalt chemicals and cobalt metal powders from cobalt metal and/or cobalt-bearing scrap. U.S. Geological Survey (USGS) data on chemical and metal powder production and shipments were derived from a monthly voluntary survey of U.S. cobalt processors. Five of the seven cobalt processors on this survey provided data. Estimates were made for plants for which data were not provided. In 1998, U.S. processors produced 2,230 t of cobalt oxide and hydroxide, inorganic cobalt compounds, and organic cobalt compounds, a 26% increase from the revised 1,770 t produced in 1997. Because this figure includes production of intermediate forms, it does not represent net production. Shipments are defined as sales, transfers, or consumption to make end-use products, such as paint driers and catalysts. In 1998, shipments by U.S. processors included 2,490 t of cobalt oxide and hydroxide, inorganic cobalt compounds, and organic cobalt compounds, a 20% increase from revised 2,070 t shipped in 1997. Two processors made extra-fine cobalt metal powder in the United States. Carolmet Cobalt Products, a division of Union Minière Inc., made cobalt metal powder from imported metal at its Laurinburg, NC, plant. Osram Sylvania Inc. made cobalt metal powder from scrap in Towanda, PA. Production and shipments of cobalt metal powder are withheld to avoid disclosing company proprietary data.

U.S. cobalt supply included secondary cobalt from alloy scrap, cemented carbide scrap, and spent catalysts. In 1998, spent petroleum catalysts were treated by at least three companies. Gulf Chemical & Metallurgical Corp. of Freeport, TX, produced a nickel-cobalt alloy for sale to nickel refiners. OMG Apex, Inc., in St. George, UT, produced cobalt chemicals from secondary feedstocks, including spent catalysts. The CRI-MET plant in Braithwaite, LA, a partnership between subsidiaries of Cyprus Amax Minerals Co. and CRI International, Inc., produced a nickel-cobalt "concentrate." This plant was expected to close by the end of 1999, following the commissioning of a new spent-catalyst-processing plant in Louisiana. The new plant will be jointly operated by CRI International and Strategic Minerals Corp., of Danbury, CT (Ryan's Notes, 1998a). During the year, Chrome Corp. of America worked toward acquiring Dakota Catalyst Inc.'s plant in Williston, ND (Boulder Group NL, 1998a). This plant, which formerly produced fused alumina and a metal alloy containing nickel, cobalt, molybdenum, and vanadium from spent catalysts, closed in May 1997 because of financial constraints and environmental and legal problems.

Consumption

Apparent consumption for 1998 (as calculated from net imports, consumption from purchased scrap, and changes in Government and industry stocks) was slightly higher than that calculated for 1997 (table 1). The increase was primarily because of an increase in scrap consumption in 1998. Reduced levels of cobalt imports were counterbalanced by an increase in shipments from the NDS. An increase in cobalt exports was counterbalanced by a drawdown in industry stocks.

Reported consumption was derived by the USGS from voluntary surveys of U.S. operations. Most of the data on cobalt chemical uses were obtained from the cobalt processors survey. A second survey covered a broad range of metal-consuming companies, such as superalloy, magnetic alloy, and tungsten carbide producers. For this survey, more than 100 cobalt consumers were canvassed on a monthly or annual basis. Reported consumption and stocks data in tables 1 and 3 contain estimates to account for nonrespondents.

U.S. reported consumption for 1998 was slightly higher than that for 1997. As a whole, metallurgical industries consumed approximately the same amount of cobalt in 1998 and 1997. On an industry-by-industry basis, consumption to make steels and magnetic alloys was lower in 1998, consumption to make cemented carbides and other alloys was higher in 1998, and consumption to make superalloys was basically the same during the past 2 years. Total reported cobalt consumption in

chemical uses increased by 12% in 1998 (table 3).

Prices

Cobalt prices decreased significantly in 1998. The average of weekly high and low prices for U.S. spot cathode (minimum of 99.8% cobalt), as reported by Platt's Metals Week, began the year at $25.50 per pound. The average price slowly decreased to $24.00 per pound in June, then decreased more rapidly during the second half of the year. By the end of December, the average of U.S. spot cathode prices had dropped to $10.50 per pound, the lowest since 1990. Platt's average annual U.S. spot cathode price for 1998 was $21.43 per pound, down by 8% from that of 1997 (table 1).

Platt's prices for Zambian cobalt (minimum 99.6% cobalt) and Russian cobalt (minimum 99.3% cobalt) also decreased during the second half of 1998. The decrease in prices was attributed to a steady supply of cobalt combined with consumer destocking. As the price fell during the second half of the year, consumers chose to draw down stocks rather than make purchases in a falling market (Searle, 1999). Additional factors cited as contributing to the price decrease included a decrease in demand by the superalloy industry; a decrease in demand from Asia; a decrease in nickel prices, which prompted nickel producers to sell more cobalt; and producers battling for market share (French, 1999).

The reference price, set by African producers La Générale des Carrières et des Mines (Gécamines) of Congo (Kinshasa) and Zambia Consolidated Copper Mines Ltd. (ZCCM) in 1995, remained unchanged at $27.50 per pound. Little, if any, cobalt has been sold on a producer price basis in recent years (Metal Bulletin, 1999c).

Foreign Trade

Eight countries supplied 94% of U.S. imports of unwrought cobalt and cobalt in chemicals. Norway was the leading supplier, followed by Finland, Canada, Zambia, Russia, Congo (Kinshasa), the United Kingdom, and Belgium. In 1998, the United States imported 9% less cobalt than it did in 1997. Compared with those of 1997, cobalt imports from Belgium, Canada, and the United Kingdom increased; imports from Congo (Kinshasa), Finland, Russia, and Zambia decreased; and imports from Norway were basically unchanged. (See tables 4-5.)

In 1998, the United States imported 315 t, gross weight, of unwrought cobalt alloys valued at $11.6 million. Seven countries supplied 99% of these materials—Belgium (39%), Japan (24%), the United Kingdom (20%), Canada and Congo (Kinshasa) (5% each), Sweden (4%), and France (2%). The United States imported 857 t, gross weight, of cobalt matte, waste, and scrap, valued at $10.8 million. Eight countries supplied 97% of these materials—Japan (22%), Finland (20%), Germany (17%), the United Kingdom (14%), Belgium and the Netherlands (8% each), Canada and France (4% each). The United States also imported 217 t, gross weight, of wrought cobalt and cobalt articles valued at $11.3 million. The leading suppliers of these materials were the United Kingdom (36%), Japan (34%), Canada (10%), France and Germany (6% each), and Belgium (4%).

U.S. exports of unwrought cobalt and cobalt contained in chemicals increased by 7% compared with those of 1997. As listed in table 6, more than 80% of the cobalt metal and chemical exports was shipped to nine countries—Belgium, Brazil, Canada, China, Finland, France, Mexico, the Netherlands, and the United Kingdom. The remainder was shipped to 34 other countries.

Exports also included 667 t, gross weight, of wrought metal and cobalt articles valued at $33.9 million. More than 80% of these materials was sent to eight countries—Finland (22%), Belgium (13%), the United Kingdom (12%), the Netherlands (11%), Canada (8%), Germany and India (7% each), and Italy (4%). The remainder was shipped to 29 other countries.

World Review

World refined cobalt production increased to a record level in 1998. Although progress in the production of cobalt from new sources was made during the year, the increase in 1998 refinery production was solely from existing operations. As a result of construction underway on new refineries in Australia and Uganda in 1998, 6,900 metric tons per year (t/yr) will be added to world cobalt refinery capacity. This would be an increase of more than 10% above capacity at yearend 1998 (table 7). As discussed below, several of the companies building new refineries planned to increase their capacity in the future, and many additional projects planned by these and other companies were in preconstruction stages.

The Cobalt Development Institute (CDI) reported a 19% increase in cobalt availability to 33,400 t in 1998 from 28,100 t in 1997. Cobalt availability is estimated by the CDI from refinery production by CDI members and nonmembers (excluding Russia), imports from the Commonwealth of Independent States (CIS) to other countries, and releases from the NDS and other stockpiles. The CDI estimated apparent world demand for refined cobalt (excluding internal demand by the CIS) as approximately 30,000 t, slightly higher than that of 1997. The CDI cautioned, however, that actual world demand was probably significantly higher, because apparent demand does not take inventory reductions into account (Cobalt Development Institute, 1999; Hawkins, 1999).

Australia.—During the 12-month period ending June 30, 1998, QNI Ltd. produced 1,337 t of cobalt from its Yabulu nickel-cobalt refinery in Townsville, Queensland. This represented a 10% decrease from the 1,482 t of cobalt produced in 1997. QNI stated that cobalt production was adversely affected by operating difficulties in the refinery's leach circuit and the lower-than-usual cobalt grade of the lateritic ore processed during the second half of the fiscal year. During that period, QNI processed larger quantities of ore from Indonesia and the Philippines because of reduced ore deliveries from New Caledonia owing to local climatic and economic conditions. Beginning in March 1998, QNI converted all its cobalt sulfide to cobalt oxide hydroxide at the recently completed cobalt plant at its Yabulu refinery (QNI Ltd., 1998, p. 7-8 and 24).

During the latter part of 1998, Billiton Plc increased its

ownership in QNI to 100%. By yearend, QNI had completed modifications to the cobalt plant and increased the production rate to design capacity at target metal recovery rates and product quality. In addition, QNI installed a pilot plant at the refinery to research the possible treatment of nickel sulfide concentrates at Yabulu using bioleaching technology developed by Billiton (Billiton Plc, 1999, p. 5 and 11). Between January and December 1998, QNI produced 1,395 t of cobalt as cobalt oxide hydroxide (Cobalt Development Institute, 1999).

WMC Ltd. produced an estimated 1,280 t of cobalt in intermediate products as a byproduct of mining, smelting, and refining nickel sulfide ores in Western Australia (Matheson, 1998). The intermediate products were exported to be refined.

Outokumpu Australia Pty. Ltd. produced nickel concentrates from its Forrestania and Silver Swan operations in Western Australia. Outokumpu also received nickel concentrates from WMC's Mount Keith operation. Concentrates from these three nickel sulfide operations, containing an estimated 500 t of cobalt, were exported to Finland for treatment at Outokumpu's Harjavalta refinery (Matheson, 1998).

Centaur Mining & Exploration Ltd. progressed with its Cawse nickel-cobalt project, which is based on a laterite deposit northwest of Kalgoorlie in Western Australia. In April, Centaur began full-scale open-pit mining of the deposit. By yearend, construction and commissioning of the processing plant and associated infrastructure were completed. The plant will use pressure acid leaching, followed by precipitation of a nickel-cobalt hydroxide, releaching, solvent extraction, and then precipitation to produce cobalt sulfide and electrowinning to produce nickel cathode. In late December, Centaur began producing cobalt sulfide and planned to begin producing nickel cathode in early 1999. Production levels for the first 2 years of operation were forecast as follows: 4,800 t of nickel and 1,200 t of cobalt in the first year increasing to 8,500 t of nickel and 1,900 t of cobalt in the second year. Centaur was considering adding a cobalt refinery at Cawse to upgrade the cobalt sulfide to higher value products for the battery and chemical markets. The refinery would use N.V. Union Minière S.A. technology to produce approximately 1,000 t/yr of cobalt in chemicals (Centaur Mining & Exploration Ltd., 1998a, p. 9, 13; b; c).

Resolute Ltd. sold its Bulong nickel-cobalt project to Preston Resources NL of Perth, Western Australia. The project, which is based on a nickel laterite deposit located east of Kalgoorlie in Western Australia, will use pressure acid leaching, followed by solvent extraction and electrowinning to produce nickel cathode and cobalt cathode. Preston completed construction on the project by yearend and planned to begin producing metal in early 1999. Annual production was forecast to increase as follows: 1,400 t of nickel and 140 t of cobalt in 1999, 8,600 t of nickel and 730 t of cobalt in 2000, and 9,600 t of nickel and 1,000 t of cobalt in 2004. Preston was also planning to develop the Marlborough laterite deposit in Queensland using technology similar to that used at Bulong. A feasibility study completed on this project was based on production rates of 25,000 t/yr of nickel and 2,000 t/yr of cobalt (Metal Bulletin, 1998b, 1999b).

In March, Anaconda Nickel Ltd. began mining the Murrin Murrin laterite deposit located between Leonora and Laverton, Western Australia. Construction of Stage I of the project was completed by yearend, with various parts of the refinery complex commissioned progressively during the year. The project, which was being developed as a joint venture with Glencore International AG, will use pressure acid leaching technology and will produce nickel and cobalt metal powders. Production capacity for Stage I was to be 45,000 t/yr of nickel and 3,000 t/yr of cobalt. During the year, Anaconda committed in principle to the Stage II expansion of the project, which would increase nickel capacity to 115,000 t/yr and cobalt capacity to 9,000 t/yr. The feasibility study of Stage II was completed in August. During the year, exploration drilling identified eight sites in Papua New Guinea, Queensland, and Western Australia as potential sources of additional feed for the Murrin Murrin project (Anaconda Nickel Ltd., 1998, p. 2, 5, 11-12 and 18-19; 1999).

In addition to its work on the Murrin Murrin project, Anaconda performed metallurgical testwork on ore samples from its Mount Margaret project, which included the Marshall Pool tenements 100 kilometers northeast of Murrin Murrin. Inferred resources at Mount Margaret were reported to be 144 Mt of laterite grading 0.79% nickel and 0.05% cobalt. Anaconda was considering a refinery for this project, based on pressure acid leaching technology, with the capacity to produce 45,000 t/yr nickel and 3,000 t/yr cobalt (Anaconda Nickel Ltd., 1998, p. 3 and 15).

Calliope Metals Corp. completed a feasibility study for a nickel-cobalt refinery to be built in Gladstone, Queensland. The company planned to use pressure acid leaching technology to treat limonitic ore imported from New Caledonia. The refinery was to have the capacity to produce 20,000 t/yr of nickel and 2,000 t/yr of cobalt. As a result of low metal prices, Calliope considered building the refinery near the ore body in New Caledonia and concluded that the savings in ore transportation costs would likely outweigh an increase in capital cost to build the plant there (Metal Bulletin, 1998d).

Belgium.—Union Minière converted cobalt metal, residues, and other cobalt-bearing materials into cobalt hydroxides, metal powders, oxides, and salts at its facilities in Olen. During the year, Union Minière increased its capacity to produce cobalt oxide and added new facilities to produce submicron cobalt powders and cobalt alloy powders. These plant improvements were in response to increased demand for cobalt oxide from the rechargeable battery industry, a trend towards smaller particle-size powders by the hardmetals industry, and a desire by the diamond tool industry to reduce the cobalt content of their products (N.V. Union Minière S.A., 1998, p. 26; 1999, p. 26-27).

Brazil.—Cia. Niquel Tocantins produced cobalt cathode at its refinery in Sao Miguel Paulista, Sao Paulo State. The refinery used lateritic nickel ore from Niquelandia, Goias State, as feed (Metal Bulletin, 1998g; Platt's Metals Week, 1998).

Canada.—Falconbridge Ltd. produced 940 t of cobalt in concentrate from its Sudbury, Ontario, mines and 190 t of cobalt in concentrate from its Raglan Mine in Quebec. Nickel-copper matte produced at its Sudbury smelter was refined at the company's Nikkelverk refinery in Norway. In 1998, this matte

contained 2,130 t of cobalt; 47% of the cobalt originated from ores produced at company mines, and 53%, from custom feed materials, defined as feeds that did not originate from Falconbridge mines (Falconbridge Ltd., 1999, p. 19).

Inco Ltd. produced cobalt oxide at its Thompson, Manitoba, refinery and cobalt cathode at its Port Colborne, Ontario, refinery from feed materials originating primarily from nickel mines in Thompson and Sudbury, respectively. In 1998, Inco produced 1,740 t of cobalt, a 16% increase from the 1,500 t produced in 1997 (Cobalt Development Institute, 1999). During the year, the company progressed with its restructuring program. Following a mine-by-mine review of its Canadian operations, Inco developed new mine plans to maximize cash flow, to increase efficiency, to reduce costs, and to phase out production from higher cost mines (Inco Ltd., 1999, p. 6 and 10-13).

Inco's development of its Voisey's Bay nickel-copper-cobalt-sulfide deposit in northeastern Labrador was delayed by an impasse between the company and the Province of Newfoundland and Labrador on the scope of the project. Inco originally planned to build a smelter/refinery complex in Argentia, Newfoundland, to process concentrates from Voisey's Bay. As a result of declining metal prices, higher capital cost estimates, and delays in underground exploration, Inco revised its proposal by limiting the initial project to a mine and mill complex at Voisey's Bay. Under the new proposal, concentrates from Voisey's Bay would be shipped to existing company operations in Manitoba and Ontario for smelting and refining. In July, the Provincial Government rejected Inco's revised proposal and suspended negotiations with the company. Negotiations between Inco and the Provincial Government had not resumed by yearend. In spite of this impasse, the environmental review process for the mine and mill complex continued, Federal and Provincial Governments reached an agreement in principle with the Labrador Inuit Association regarding Inuit land claims in the Province, and Inco continued its exploration program, increasing the total reserves and resources to 124 Mt by the end of the year (Inco Ltd., 1999, p. 20-21).

Sherritt International Corp.'s Fort Saskatchewan, Alberta, refinery produced a record 2,645 t of cobalt in 1998, an 18% increase from the 2,248 t produced in 1997. The increase in production was attributed, in part, to continuing improvement in operating parameters and the installation of an additional cobalt reduction autoclave in late 1997 (Sherritt International Corp., 1999, p. 6 and 20). Most of the feed for the refinery was in the form of nickel-cobalt mixed sulfides from Moa Nickel S.A. of Moa Bay, Cuba. As a result of a U.S. embargo on imports of products originating from Cuba, nickel and cobalt produced by Sherritt cannot be sold to U.S. customers.

In October, Cobatec Inc. suspended operations and filed for bankruptcy protection, with the hope that it would be able to restructure its finances, and then expand its hydrometallurgical cobalt refinery in North Cobalt, Ontario (Cobatec Inc., 1998). Cobatec's efforts to refinance were unsuccessful. In early 1999, the plant was taken over by creditors and put up for sale (Metal Bulletin, 1999e). Prior to closure, the plant produced cobalt carbonate from Cuban nickel-cobalt sulfide precipitates.

Canmine Resources Corp. continued developing its Werner Lake cobalt project in southwestern Ontario-southeastern Manitoba. The project is based on a Precambrian calcic cobalt skarn, from which cobalt would be produced as a primary product. By September, construction of a 300-metric-ton-per-day mill at Werner Lake was 75% complete, and Canmine had decided to build a hydrometallurgical plant to convert the mill's concentrates to cobalt carbonate. Canmine planned to commission the carbonate plant in July 1999 at an initial production rate of 250 to 300 t/yr of contained cobalt (Ellwood, 1998). During the year, Canmine acquired Red Engine Exploration Ltd. and consolidated the assets of the two companies, which included the Werner Lake cobalt project and other joint-venture cobalt and nickel projects in Manitoba and Ontario (Canmine Resources Corp., 1998).

China.—An estimated 1,200 t of cobalt metal and chemicals was produced from domestic and imported raw materials (Cobalt Development Institute, 1999). At Jinchuan, Gansu Province, cobalt metal was produced as a byproduct of nickel from the refining of domestic nickel sulfide ores. The Ganzhou cobalt refinery in Jiangxi Province produced cobalt metal and salts from cobalt arsenide concentrates imported from Morocco. Minor amounts of cobalt were produced at other refineries in China.

Congo (Kinshasa).—Gécamines continued to focus its resources on cobalt production to benefit from the high price of cobalt relative to that of copper. In recent years, the company's strategy has included closing nonprofitable mines and concentrators, recovering cobalt from stockpiled intermediate materials, developing small-scale cobalt-rich mines, and processing certain cobalt-rich ores by direct leaching to increase cobalt recovery (Swana, 1998). In the near term, the company planned to continue to develop small-scale mines, to rehabilitate the large Kamoto Mine, and to refurbish metallurgical equipment in the refineries. In the longer term, Gécamines planned to increase production from open-pit mines, to start production from joint-venture projects, and to exploit new mine sites (Lenge, 1998).

In 1998, Gécamines and L'Enterprise Générale Malta Forrest S.P.R.L. (EGMF) produced copper-cobalt concentrates from backfill at the Luiswishi Mine. The concentrates were shipped to OM Group, Inc.'s Kokkola refinery in Finland (Mabiola, 1999; OM Group, Inc., 1999, p. 3). EGMF also operated the Kasombo 2 project with Gécamines in partnership with Union Minière (Mabiola, 1999). Ridgepointe Overseas Developments Ltd., registered in the British Virgin Islands, produced cobalt from the Kababankola Mine near Likasi (Block, 1998), and KGHM Polska Miedz S.A., of Lubin, Poland, continued its operations at the Kimpe deposit (Metal Bulletin, 1998c).

Gécamines, OM Group, and S.A. Groupe George Forrest continued with a smelter construction project at Lubumbashi. The smelter will be used to upgrade slags stockpiled at Lubumbashi to a cobalt-copper alloy, which will be shipped to the Kokkola refinery. The project was scheduled for completion by 2000. The stockpile was expected to supply the smelter for 20 years at a production rate of 5,000 t/yr of contained cobalt (OM Group, Inc., 1997; 1999, p. 3).

Beginning in early 1998, a consortium of international

mining companies, comprised of Anglo American Corp. of South Africa Ltd., Billiton, Iscor Ltd., of Pretoria, South Africa, and others negotiated with Gécamines on a project to rehabilitate the mines and plants in Gécamines' Kolwezi Group West. This mining area consists of four open-pit mines, two concentrators, and two refineries with a production capacity of approximately 350,000 t/yr of copper and 15,000 t/yr of cobalt (Iscor Ltd., 1998b, p. 19). The status of the negotiations was not known at yearend.

In September, Ridgepointe signed an agreement with Gécamines and the Government of Congo (Kinshasa) to manage and rehabilitate the copper-cobalt operations in Gécamines' Central Group. The agreement established Central Mining Group Corp. S.P.R.L., with Ridgepoint holding an 80% interest and Gécamines holding 20% (Mining Journal, 1998b).

East Asia Gold Corp., of Spokane, WA, signed agreements with Gécamines and COMIEX-Congo S.A.R.L. to buy a 55% interest in two copper-cobalt properties. East Asia agreed to provide bankable feasibility studies and arrange financing for the Mukondo deposit, south of the Tenke Fungurume concessions and west of the Kakanda Mine, and the former Luishia Mine, northwest of Lubumbashi (East Asia Gold Corp., 1998).

In early August, military factions dissatisfied with the new Government of Congo (Kinshasa) began a rebellion that continued into 1999. Political uncertainty resulting from the conflict combined with low metal prices delayed the progress of the following copper-cobalt projects being developed as joint ventures with Gécamines:

- In February, Gécamines and Iscor signed an agreement for the rehabilitation of the Kamoto Mine. This mine had been a significant source of Gécamines' copper and cobalt ores before it suffered a major collapse in 1990. Iscor planned to increase production from the mine within 3 to 4 years to a level that would yield approximately 70,000 t/yr of copper and 5,000 t/yr of cobalt. In October, the agreement was ratified by the Government of Congo (Kinshasa) (Iscor Ltd., 1998a), but in early 1999, Iscor announced that it would not begin the rehabilitation project until political stability was assured (Metal Bulletin, 1999d).

- International Panorama Resource Corp. of Vancouver, British Columbia, Canada, investigated ways to lower the costs on the Kakanda tailings project, which it was to develop as a joint venture with Gécamines. By April, International Panorama had determined that the project would still be economic with a smaller plant and decided to proceed with a plant designed to produce approximately 1,500 t/yr of cobalt and 14,000 t/yr of copper (International Panorama Resource Corp., 1998). This project was delayed by the uncertain political situation (Mabiola, 1999).

- Tenke Mining Corp. of Vancouver worked on a feasibility study on the development of copper-cobalt deposits at Tenke and Fungurume. The Tenke Fungurume concessions, located between the towns of Kolwezi and Likasi in the Shaba Province's copper belt, were owned by Tenke Mining (55%) and Gécamines (45%) under a joint-venture agreement. In December, Tenke Mining and BHP Copper, a division of Broken Hill Proprietary Co. Ltd., entered into an agreement under which BHP could acquire a majority stake in the project in exchange for funding some of the development costs. The ongoing civil war prevented Tenke Mining from completing its feasibility study, and as a result, the company declared a force majeure on the project in early 1999 (Tenke Mining Corp., 1998, 1999).

- America Mineral Fields Inc. and Anglo American reached an agreement on a project to recover copper and cobalt from flotation tailings accumulated during past production at Kolwezi. Congo Mineral Development Ltd. was formed to develop the project and would be held equally by each joint-venture partner. In October, Congo Mineral Development signed a joint-venture agreement with Gécamines regarding the project. Under the agreement, ownership of the Kolwezi tailings project would be transferred to a new company, KMT S.A.R.L., which would be 60% owned by Congo Mineral Development and 40% owned by Gécamines. At yearend, Anglo American was awaiting approval from the Reserve Bank of South Africa for a transfer of funds to Gécamines, the president of Congo (Kinshasa) had not ratified the project, and Congo Mineral Development had not started work on the feasibility study (America Mineral Fields Inc., 1999, p. 1; Metal Bulletin, 1999a).

- As part of two joint-venture agreements with Gécamines, First Quantum Minerals Ltd. of Vancouver completed preliminary feasibility studies on the recovery of cobalt and copper from tailings dumps located at Kolwezi and Likasi. First Quantum systematically drilled and sampled four tailings dumps to estimate the tonnage and copper and cobalt contents of each dump. Metallurgical testwork was performed on composite samples from the drilling programs. The Likasi project included tailings dumps from past operations at Panda and from the Shituru hydrometallurgical refinery. First Quantum projected that a plant processing 1 million tons per year of Panda tailings could yield 13,500 t/yr of copper and 1,487 t/yr of cobalt. The Kolwezi project included Kingamiambo sulfide tailings from the Kolwezi concentrator and tailings from the Luilu hydrometallurgical refinery. This project would be developed after the Likasi project because it would require a more-complex metallurgical process to recover the metals. Following completion of the studies, First Quantum decided to suspend its development activities in Congo (Kinshasa) until the political situation had stabilized (First Quantum Minerals Ltd., 1999, p. 1 and 8-9).

Côte d'Ivoire.—Falconbridge continued to evaluate hydrometallurgical processes to treat nickel laterite ores from western Côte d'Ivoire (Falconbridge Ltd., 1999, p. 28).

Cuba.—Moa Nickel mined nickel-cobalt laterites at Moa Bay and produced mixed sulfides containing 27,066 t of nickel and cobalt, a slight increase from the 26,512 t produced in 1997 and a new production record for the fourth consecutive year

(Sherritt International Corp., 1999, p. 6 and 20). The mixed sulfides produced at Moa were refined by The Cobalt Refinery Co. Inc. in Fort Saskatchewan, Alberta, Canada. Moa Nickel and The Cobalt Refinery Co. are part of Metals Enterprise, which was jointly owned by Sherritt and General Nickel Co. S.A. Nickel and cobalt of Cuban origin cannot be imported into the United States because of a U.S. embargo on imports from Cuba.

WMC finalized its agreements with state-owned Commercial Caribbean Nickel S.A. on a joint-venture project to evaluate the possibility of developing the Pinares de Mayari West nickel laterite deposit in Holguín Province. A 3-year evaluation period was established to do environmental, metallurgical, and engineering studies that would result in a feasibility study. During the year, WMC researched pressure acid leaching processes for the Pinares ores (WMC Ltd., 1999, p. 29).

In February QNI concluded a joint-venture agreement with Geominera S.A., Cuba's mining investment company, on the San Felipe nickel laterite project in the Camaguey Province. QNI had a 75% share in the project and will be the project operator with responsibility for the exploration and feasibility work. Initial drilling results on approximately one-third of the target area indicate a thickness of about 10 meters with nickel grades of approximately 1.4% and low cobalt values (QNI Ltd., 1998, p. 26). By year's end, QNI had started preliminary work on a metallurgical process for the ore.

Finland.—OM Group produced 5,250 t of cobalt in cobalt metal powders, oxides, and salts, 5% more than the 5,000 t produced in 1997 (Cobalt Development Institute, 1999). The Kokkola Chemicals Oy refinery processed cobalt-bearing materials from Australia, Congo (Kinshasa), Finland, Russia, and elsewhere. In October, OM Group purchased copper-cobalt concentrates containing approximately 4,000 t of cobalt from ZCCM (OM Group, Inc., 1998, 1999).

Outokumpu produced cobalt metal powder at its Harjavalta nickel refinery. Raw materials for the nickel refinery were imported from Western Australia and elsewhere.

Indonesia.—State-owned P.T. Aneka Tambang (Antam) exported lateritic nickel ore to QNI's Yabulu refinery in Queensland, Australia, for processing. Several companies worked with Antam on projects to explore and develop Indonesia's nickel-cobalt laterite resources. QNI worked on a study for a potential nickel and cobalt refinery that would use laterites from Halmahera and Obi Islands. Weda Bay Minerals Inc. of Vancouver explored nickel laterites on Halmahera Island and completed a project evaluation study that proposed a plant with initial production rates of 30,000 t/yr of nickel and 1,300 t/yr of cobalt (Weda Bay Minerals Inc., 1998). BHP World Minerals, a division of Broken Hill Proprietary, studied the feasibility of developing a lateritic nickel prospect on Gag Island.

Japan.—Sumitomo Metal Mining Co., Ltd., produced electrolytic cobalt, cobalt oxide, and cobalt salts as a byproduct of nickel at its Niihama nickel refinery in Ehime Prefecture. Sumitomo's 1998 metal production was 25% higher than that of 1997.

Madagascar.—Phelps Dodge Mining Co., of Phoenix, AZ, completed a feasibility study on the Ambatovy nickel-cobalt laterite deposit located east of the capital city of Antananarivo in central Madagascar. Detailed drilling defined a resource of 210 Mt of ore at a grade of 1.1% nickel and 0.1% cobalt. The study concluded that in spite of the ore's favorable metallurgical characteristics, the project would not be economical at current nickel prices (Phelps Dodge Corp., 1999, p. 23).

Mexico.—International Curator Resources Ltd. of Vancouver investigated the Boleo copper-cobalt deposit near Santa Rosalia, Baja California. A prefeasibility study completed in September 1997 recommended an open-pit mine with production rates of 49,000 t/yr of copper, 16,600 t/yr of zinc, and 3,500 t/yr of cobalt (International Curator Resources Ltd., 1997). By yearend 1998, a full feasibility study on the Boleo project had been completed. It concluded that the project was not economic under current market conditions and that further evaluation of the deposit should be delayed until metal prices improve (International Curator Resources Ltd., 1999).

Morocco.—Cie. de Tifnout-Tiranimine produced cobalt concentrates and cobalt metal. Cobalt concentrates from the Bou-Azzer Mine were exported to China for refining. Cobalt tailings from past mining operations at Bou-Azzer were pretreated at a plant near the mine and then refined to cathode at a plant near the Guemassa Mine (M'Hamdi, 1996).

New Caledonia.—Lateritic nickel ore was exported to QNI's Yabulu refinery for processing. Nickel matte from Société Métallurgique Le Nickel's Doniambo smelter was sent to Eramet-SLN's refinery in Sandouville-LeHavre, France, where it was refined into nickel cathode, nickel chloride, and cobalt chloride.

Inco worked on its Goro nickel-cobalt laterite project in southern New Caledonia. The project is based on laterite deposits with potentially minable resources in excess of 200 million dry metric tons averaging 1.60% nickel and 0.17% cobalt. Inco has identified 47 Mt of proven and probable reserves in an initial mining zone that could supply a commercial plant for 20 years. During 1998, Inco worked on constructing an integrated pilot plant to test the proprietary pressure acid leaching-solvent extraction process it developed to treat Goro laterites. The pilot plant was scheduled to begin operation in August 1999. By 2000, Inco planned to make a decision on whether to build a commercial plant with an initial capacity of 27,000 t/yr of nickel and 2,700 t/yr of cobalt. The project was 85% owned by Inco, with the remainder owned by Bureau de Recherches Géologiques et Minières, a French Government agency (Inco Ltd., 1999, p. 19-20).

Eramet-SLN and QNI completed a joint feasibility study for a nickel-processing plant to be built in the northern province of New Caledonia (Eramet Group, 1999, p. 21). The study concluded that the plant would not be economically viable at projected nickel prices. The proposed plant would have treated lateritic ores from SLN's mines by using the hydrometallurgical process used at QNI's Yabulu refinery. The nickel-cobalt carbonate produced at the New Caledonian plant would then have been further refined at Eramet's Sandouville refinery and QNI's Yabulu refinery.

Norway.—In 1998, Falconbridge produced a record 3,851 t of cobalt at its Nikkelverk refinery, a 13% increase compared

with the previous year. Feedstock for the refinery was in the form of matte from the company's smelter in Sudbury, Canada, BCL Ltd. in Botswana, and elsewhere. Nearly three-quarters of the cobalt produced at Nikkelverk originated from custom feeds, which were defined as feeds that did not originate at Falconbridge mines. To process larger volumes of custom feed, Falconbridge increased the cobalt capacity of the refinery to 4,500 t/yr (Falconbridge Ltd., 1999, p. 2 and 19-20).

During 1998, Falconbridge introduced a new cobalt product to the market. It is 99.8% cobalt metal in cathode form with extra sulfur added to improve solubility. Falconbridge built a 500-t/yr-capacity plant at the Nikkelverk refinery to produce the new product, which will be marketed to the chemical industry (Ryan's Notes, 1998b).

Papua New Guinea.—Highlands Pacific Ltd. completed a feasibility study on its 65%-owned Ramu River nickel-cobalt laterite project. The study estimated a mine life of 20 years on the basis of the current (1998) ore reserves, with a possible extension to more than 35 years based on the resource base. The project would have production rates of 33,000 t/yr of nickel metal and 3,200 t/yr of cobalt in the form of pure cobalt sulfate, with initial metal production at the end of 2001 (Highlands Pacific Ltd., 1999). Nord Pacific Ltd. owned the remaining 35% of the project, which is located in the Mandang region of Papua New Guinea (Nord Pacific Ltd., 1998).

Philippines.—Lateritic nickel ore from the Philippines was exported to QNI's Yabulu refinery for refining.

As part of the rehabilitation of the Nonoc nickel-cobalt refinery in Surigao del Norte, Nonoc Island, Philnico Mining and Industrial Corp. decided to convert the refinery from an ammonia leach process to a pressure acid leach process. The change will require the purchase of new process equipment and was expected to result in a delay in the start of operations until mid-2001. By yearend, an environmental review of the project was underway (Metal Bulletin, 1998f).

Russia.—Russian cobalt continued to contribute to Western supply in 1998. Nickel and cobalt production in Russia involves a complex flow of ores, flotation concentrates, precipitates, and mattes between various production sites. The main feed materials were domestic nickel-copper sulfide ores, nickel laterite ores from Kazakhstan and Russia, and imported nickel- and cobalt-bearing secondary materials. Refined cobalt was produced at four locations—Norilsk Nickel Joint Stock Co. refineries at Monchegorsk on the Kola Peninsula and Norilsk in Siberia, the Ufaleynickel Joint Stock Co. refinery at Verkhniy Ufaley in the Ural Mountains, and the Yuzhuralnickel Joint Stock Co. refinery at Orsk, also in the Ural Mountains (Roskill Information Services Ltd., 1995, p. 11-15).

In 1998, Russian cobalt production was 86% of that of 1997 (Interfax Mining & Metals Report, 1999c). The Ufaleynickel and the Yuzhuralnickel refineries suffered from problems with supplies of feedstock (Metal Bulletin, 1998h, i). Norilsk Nickel produced most of Russia's cobalt. The company's production of metallic cobalt increased by 6.9% in 1998 compared with that of 1997 (RAO Norilsk Nickel, 1999).

During the year, Norilsk's Severonickel refinery in Murmansk stopped processing ore from the company's Siberian operations (RAO Norilsk Nickel, 1999). The company planned to produce more cobalt from scrap at Severonickel in the future (Interfax Mining & Metals Report, 1999a). Work continued on the installation of a 200-t/yr cobalt salts facility at Severonickel. The facility was designed to convert the intermediate "concentrate" currently produced by the refinery to cobalt carbonate (Interfax Mining & Metals Report, 1999b). At year's end, Norilsk merged its subsidiaries in the Murmansk region into a holding company named Kola Mining and Metallurgical Co. (Metal Bulletin, 1998e).

South Africa.—Two South African companies produced refined cobalt as a byproduct of domestic platinum mining and refining—Impala Platinum Ltd. produced cobalt metal powder, and Rustenburg Base Metal Refiners Pty. Ltd. produced cobalt sulfate. The Nkomati joint venture between Anglovaal Mining Ltd. (Avmin) and Anglo American produced 109 t of cobalt in concentrates from the Nkomati nickel sulfide mine in Mpumalanga Province (Anglovaal Mining Ltd., 1999). Union Mineral Concentrators Pty., a Union Minière subsidiary, produced cobalt compounds from low-grade cobalt-containing residues in Roodepoort, near Johannesburg.

Uganda.—Banff Resources Ltd., of Vancouver continued construction on its Kasese cobalt project. This project entailed building a refinery to recover cobalt from stockpiled pyrite concentrates at the Kilembe copper mine in southwestern Uganda. The refinery will use bioleaching followed by solvent extraction and electrowinning to produce 1,000 t/yr of cobalt cathode. As part of the project, Banff was also building a hydroelectrical powerplant. During the year, unseasonable rains, delays in deliveries of parts and supplies, disruptions from rebel activity in the region, and unforeseen quantities of rock in the water diversion canal for the powerplant led to project delays. Banff planned to start power production from the hydroelectrical plant and to begin building up the bacterial biomass in early 1999. Commissioning of the solvent extraction and electrowinning circuits was planned for spring of 1999, with the first cobalt production scheduled for May (Banff Resources Ltd., 1998).

Zambia.—During calendar year 1998, cobalt production was 5,011 t, a 27% increase from the 3,949 t produced in 1997. Production in 1998 included ZCCM production and production by ZCCM for Binani Industries Ltd. and Avmin (Cobalt Development Institute, 1999).

Roan Antelope Mining Corp. produced copper and cobalt from the Baluba and the Luanshya Mines. The company had been formed by Binani in 1997 when it acquired the mines as part of ZCCM's privatization program. Binani awarded a contract for a feasibility study of the Muliashi North project. If developed, this mine and refinery project was forecast to produce 30,000 t/yr of copper and 450 t/yr of cobalt (Buchanan, 1998).

Crew Development Corp. of Vancouver worked to improve the life span and profitability of the Chibuluma West Mine, which it had acquired from ZCCM in October 1997. The mine produced approximately 8,000 t/yr of copper and 150 t/yr of cobalt, which were concentrated, smelted, and refined at ZCCM's Nkana division (Crew Development Corp., 1998).

In September, Avmin acquired a 90% interest in the

Chambishi cobalt and acid plants and the Nkana slag dump from ZCCM. ZCCM retained a 10% interest in Avmin's newly formed subsidiary Chambishi Metals PLC. Avmin planned to improve recovery rates and product qualities at the Chambishi cobalt plant, which toll treats concentrates for ZCCM's Nchanga and Nkana divisions and for Roan Antelope Mining. In addition, Avmin began design and engineering studies for a smelter and matte leach facility to be added to the Chambishi cobalt plant to treat the Nkana slag. Avmin planned to commission the new facility by early 2001. Following commissioning, production levels from the Chambishi cobalt plant were forecast to be 2,500 t/yr of cobalt from concentrates and between 2,000 and 4,000 t/yr of cobalt from slag (Chambishi Metals PLC, 1998; Anglovaal Mining Ltd., 1999).

In March, Colossal Resources Corp. announced that it was temporarily suspending operations at its cobalt-slag-processing plant in Kabwe. During the closure, Colossal planned to reengineer the plant to improve the quality of the cobalt alloy product (Mining Journal, 1998a). As a result of low metal prices during the year, Colossal decided to discontinue the cobalt processing project and to dispose of its assets in Zambia and South Africa (Colossal Resources Corp., 1998).

ZCCM continued negotiations on privatizing its remaining assets. In late May, Noranda Mining and Exploration, Inc., of Toronto, Canada, and Phelps Dodge announced that they were withdrawing from the Kafue Consortium, which had been negotiating with ZCCM for its Nchanga and Nkana divisions. Avmin and the Commonwealth Development Corp., of London, United Kingdom, the remaining members, withdrew their bids the following month (Metal Bulletin, 1998a). The Nchanga division was ZCCM's largest producer of copper and cobalt. Cobalt concentrates from Nchanga were treated at ZCCM's two cobalt refineries in the Nkana division. Thus, this privatization package represented about two-thirds of ZCCM's total copper production and all its refined cobalt output (Noranda Mining and Exploration, Inc., 1997).

In March, Falconbridge withdrew from the Konkola project, leaving Ango American's Zambia Copper Investments Ltd. (ZCI) as the remaining company from that consortium (Falconbridge Ltd., 1998). Anglo American continued its negotiations with ZCCM and signed a memorandum of understanding to buy 80% of the Konkola, Nchanga, and Nkana assets in early 1999. A final agreement on the acquisition would not be signed until certain conditions were met, including the following: ZCI must form a consortium of partners, including a "substantial mining partner," raise financing, and confirm its due diligence on the assets (Platt's Metals Week, 1999).

Outlook

World cobalt production is expected to continue to increase over the medium to long term, although in the near term, production may decline from the record level reached in 1998. Decreases in production are possible from Congo (Kinshasa) as a result of the ongoing civil war, from Russia as a result of technical problems at Severonickel and supply problems at Ufaleynickel, and from Zambia as a result of delays in privatizing the major production units of ZCCM (Searle, 1999; Southwood and Gray, 1999). In contrast, production from other sources, including Australian laterites and Ugandan concentrates which began in 1999, is expected to increase in coming years.

Another component of world supply is U.S. Government sales of cobalt from the NDS. Offers of NDS cobalt are expected to continue at the rate set each year under the AMP until the amount authorized for disposal has been sold. If current (fiscal year 1999) AMP levels are maintained and the amount of cobalt sold each year is close to the AMP level, then the NDS cobalt sales program could extend into 2004.

Demand for cobalt in any given year depends on world economic conditions and the performance of various consuming industries. In the near term, demand from Asia may continue to be suppressed by the economic recession in that region (Hawkins, 1999), and demand from the superalloy industry may be reduced because of production cutbacks by Boeing Co., a leading aircraft manufacturer (Southwood and Gray, 1999). In the medium to long term, however, Western world demand for cobalt is expected grow at a rate of 3% to 5% per year (Kielty, 1998; Southwood and Gray, 1999), and world cobalt supply is expected to grow at a rate faster than that of demand.

After continuously decreasing during 1998, the price of cobalt bottomed out in the middle of January 1999. The average of weekly high and low prices for U.S. spot cathode reported by Platt's Metals Week reached a low of $8.50 per pound in mid-January, 1999, then rapidly increased to $19 per pound by mid-February. The rapid rise in price has been attributed to the withdrawal of cobalt sellers from the market (Hawkins, 1999) and to the market's realization that significant amounts of cobalt would not be available from the new Australian producers in the short term, and that a major cobalt trading firm had become the sales agent for most of the cobalt from Congo (Kinshasa) and Zambia (Searle, 1999).

References Cited

America Mineral Fields Inc., 1999, 1998 annual report: London, America Mineral Fields Inc., 24 p.

Anaconda Nickel Ltd., 1998, Corporate report 1998: Perth, Australia, Anaconda Nickel Ltd., 28 p.

———1999, Quarterly report for the period ended December 31, 1998: Perth, Australia, Anaconda Nickel Ltd., 6 p.

Anglovaal Mining Ltd., 1999, Interim report for the half-year ended December 31, 1998: Johannesburg, Anglovaal Mining Ltd., 17 p.

Banff Resources Ltd., 1998, Banff Resources announces first quarter results: Toronto, Banff Resources Ltd. press release, December 2, 2 p.

Billiton Plc, 1999, Interim results for the half year to 31 December 1998: London, Billiton Plc press release, March 1, 22 p.

Block, Robert, 1998, Congo names Zimbabwean head of mining concern: Wall Street Journal, November 9, p. A20.

Boulder Group NL, 1998a, Annual report 1998: Chatswood, Australia, Boulder Group NL, 37 p.

———1998b, Report for quarter ended 31 December, 1998: Chatswood, Australia, Boulder Group NL, 4 p.

Buchanan, Sandra, 1998, Slow progress for Zambian copper: Metal Bulletin Monthly, no. 335, November, p. 16-23.

Canmine Resources Corp., 1998, Canmine completes acquisition of joint venture partner: London, Ontario, Canada, Canmine Resources Corp. press release, December 1, 1 p.

Centaur Mining & Exploration Ltd., 1998a, Annual report 1998: South Melbourne, Australia, Centaur Mining & Exploration Ltd., 90 p.

———1998b, Report for the quarter ended 30 September 1998: South Melbourne, Australia, Centaur Mining & Exploration Ltd., 11 p.
———1998c, Report for the quarter ended 31 December 1998: South Melbourne, Australia, Centaur Mining & Exploration Ltd., 7 p.
Chambishi Metals PLC, 1998, New chairman appointed for Chambishi Metals PLC: Lusaka, Zambia, Chambishi Metals PLC press release, September 23, 1 p.
Cobalt Development Institute, 1999, Statistics review 1998: Cobalt News, no. 2, April, p. 12-13.
Cobatec Inc., 1998, Cobatec statement—Bankruptcy protection: Toronto, Cobatec Inc. press release, October 2, 1 p.
Colossal Resources Corp., 1998, [Untitled]: Vancouver, Canada, Colossal Resources Corp. press release, December 8, 1 p.
Crew Development Corp., 1998, 1998 annual report: Vancouver, Canada, Crew Development Corp., 35 p.
East Asia Gold Corp., 1998, Bonanza-grade copper-cobalt mine in Africa: Toronto, East Asia Gold Corp. press release, November 2, 3 p.
Ellwood, Edward, 1998, A strategic perspective from one end of the value chain, *in* Cobalt Development Institute Mini Conference, Boston, MA, September 18, 1998, Proceedings: London, Cobalt Development Institute, 9 p.
Eramet Group, 1999, Annual report 1998: Paris, Eramet Group, 41 p.
Falconbridge Ltd., 1998, Falconbridge withdraws from Konkola consortium: Toronto, Falconbridge Ltd. press release, March 25, 1 p.
———1999, Annual report 1998: Toronto, Falconbridge Ltd., 53 p.
First Quantum Minerals Ltd., 1999, 1998 annual report: Vancouver, Canada, First Quantum Minerals Ltd., 32 p.
Formation Capital Corp., 1998, Positive cobalt project pre-feasibility study: Vancouver, Canada, Formation Capital Corp. press release, October 14, 1 p.
French, Nick, 1999, Cobalt in turmoil, *in* Metals Day in Pittsburgh, Pittsburgh, PA, May 3, 1999, Proceedings: Pittsburgh, Phoenixx International Resources, 9 p.
Hawkins, Michael, 1999, Cobalt, *in* Steel industry metals annual review supplement: Mining Journal, v. 333, no. 8543, August 6, p. 82-83.
Highlands Pacific Ltd., 1999, Activities report for the quarter ended 31 December, 1998: Brisbane, Queensland, Australia, Highlands Pacific Ltd., 10 p.
Inco Ltd., 1999, 1998 annual report: Toronto, Inco Ltd., 80 p.
Interfax Mining & Metals Report, 1999a, Norilsk Nickel's Kola subsidiaries reduce nickel output: Interfax Mining & Metals Report, v. 8, issue 30 (384), July 16-22, p. 9-10.
———1999b, Norilsk Nickel subsidiary Severonikel raises output: Interfax Mining & Metals Report, v. 8, issue 5 (360), January 29, p. 8.
———1999c, Russian nonferrous metal production in 1998: Interfax Mining & Metals Report, v. 8, issue 7 (362), February 12, p. 17.
International Curator Resources Ltd., 1997, Quarterly report for the six months ended September 30, 1997: Vancouver, Canada, International Curator Resources Ltd., 7 p.
———1999, Quarterly report for the nine months ended December 31, 1998: Vancouver, Canada, International Curator Resources Ltd., 8 p.
International Panorama Resource Corp., 1998, International Panorama decides upon plant size: Vancouver, Canada, International Panorama Resource Corp. press release, April 21, 1 p.
Iscor Ltd., 1998a, Iscor agreement with Gecamines ratified by DRC government: Pretoria, Iscor Ltd. press release, October 29, 1 p.
———1998b, 1998 annual report: Pretoria, Iscor Ltd., 88 p.
Kielty, E.R., 1998, Cobalt—Where it's at, *in* Nickel, Stainless Steel, Specialty Metals Roundtable, Pittsburgh, PA, October 15, 1998, Proceedings: Washington, DC, Institute of Scrap Recycling Industries, Inc., 14 p.
Lenge, M.M., 1998, Cobalt production—Gecamines, *in* Ryan's Notes Annual Ferroalloys Conference, Boca Raton, FL, October 25-27, 1998, Proceedings: Pelham, NY, Ryan's Notes, 12 p.
Mabiola, Yenga, 1999, Democratic Republic of Congo, *in* Africa annual review supplement: Mining Journal, v. 333, no. 8538, July 2, p. 83.
Matheson, P.J., 1998, Cobalt in Australia 1993 to 2003—A review and forecast, *in* The Cobalt Conference, Toronto, May 27-28, 1998, Proceedings: London, Cobalt Development Institute, 11 p.
Metal Bulletin, 1998a, Avmin, CDC pull out of Zambian bid: Metal Bulletin, no. 8285, June 11, p. 3.
———1998b, Bulong project on track for first production next month: Metal Bulletin, no. 8333, December 7, p. 6.
———1998c, DRC troubles not affecting mining: Metal Bulletin, no. 8304, August 24, p. 3.
———1998d, New Caledonia preferred site for Calliope plant: Metal Bulletin, no. 8275, May 7, p. 5.
———1998e, Norilsk Nickel merges Kola plants: Metal Bulletin, no. 8327, November 16, p. 13.
———1998f, Plunging nickel prices change Nonoc rehabilitation plans: Metal Bulletin, no. 8310, September 17, p. 6.
———1998g, Tocantins cuts output forecast: Metal Bulletin, no. 8284, June 8, p. 5.
———1998h, Ufaleynikel tries to keep up with the pace: Metal Bulletin, no. 8295, July 16, p. 5.
———1998i, Yuzhuralnickel continues to struggle: Metal Bulletin, no. 8290, June 29, p. 3.
———1999a, Anglo-AMF in $130M pact for Kolwezi tailings: Metal Bulletin, no. 8346, January 28, p. 4.
———1999b, Bulong set to be in full production by end 2000: Metal Bulletin, no. 8361, March 22, p. 9.
———1999c, Industry sceptical about return of African producer price: Metal Bulletin, no. 8380, May 31, p. 3 and 11.
———1999d, Iscor's plans for Kamoto held up by DRC war: Metal Bulletin, no. 8350, February 11, p. 5.
———1999e, Shuttered Cobatec plant put up for sale by creditors: Metal Bulletin, no. 8350, February 11, p. 6.
M'Hamdi, Jamal-Iddine, 1996, The future of cobalt in Morocco, *in* Cobalt Industry Restructuring, New York, September 9-11, 1996, Proceedings: Gorham, ME, Gorham/Intertech Consulting, 11 p.
Mining Journal, 1998a, Kabwe suspended: Mining Journal, v. 330, no. 8470, March 6, p. 187.
———1998b, New chief for Gécamines: Mining Journal, v. 331, no. 8507, November 20, p. 401-2.
Noranda Mining and Exploration, Inc., 1997, An international consortium bids for ZCCM assets: Toronto, Noranda Mining and Exploration, Inc., press release, March 3, 1 p.
Nord Pacific Ltd., 1998, Nord Pacific announces feasibility results for Ramu nickel-cobalt project: Albuquerque, NM, Nord Pacific Ltd., press release, November 17, 2 p.
N.V. Union Minière S.A., 1998, Annual report 1997: Brussels, N.V. Union Minière S.A., 103 p.
———1999, Annual report 1998: Brussels, N.V. Union Minière S.A., 105 p.
OM Group, Inc., 1997, Cobalt slag smelter agreement signed: Cleveland, OH, OM Group, Inc., press release, June 25, 1 p.
———1998, OMG buys cobalt concentrate: Cleveland, OH, OM Group, Inc., press release, October 5, 1 p.
———1999, OM Group, Inc. 1998 annual report: Cleveland, OH, OM Group, Inc., 16 p.

Phelps Dodge Corp., 1999, Annual report 1998: Phoenix, Phelps Dodge Corp., 70 p.
Platt's Metals Week, 1998, Tocantins cuts nickel output: Platt's Metals Week, v. 69, no. 12, March 23, p. 10.
———1999, Anglo agrees to buy ZCCM assets, still needs partner: Platt's Metals Week, v. 70, no. 4, January 25, p. 1 and 13.
PolyMet Mining Corp., 1999, PolyMet retains Lakefield Research for POX metallurgical tests—Reports on accomplishments in 1998: Golden, CO, PolyMet Mining Corp. press release, February 8, 2 p.
QNI Ltd., 1998, Annual report 1998: Brisbane, Australia, QNI Ltd., 79 p.
RAO Norilsk Nickel, 1999, Norilsk Nickel announces its 1998 results: Moscow, RAO Norilsk Nickel press release, June 18, 7 p.
Roskill Information Services Ltd., 1995, Cobalt in the CIS: London, Roskill Information Services Ltd., 32 p.
Ryan's Notes, 1998a, CRI-MET will shut its Port Nickel, LA, catalyst recovery plant: Ryan's Notes, v. 4, no. 42, October 19, p. 3.
———1998b, Falconbridge is doing final testing: Ryan's Notes, v. 4, no. 2, January 12, p. 3.
Searle, Peter, 1999, 1998 was indeed a remarkable year, but..., *in* The Cobalt Conference, London, May 26-27, 1999, Proceedings: London, Cobalt Development Institute, 8 p.
Sherritt International Corp., 1999, Annual report 1998: Toronto, Sherritt International Corp., 42 p.
Southwood, Malcolm, and Gray, Paul, 1999, Cobalt, *in* Commodities focus, quarterly review, June 1999: London, J.B. Were & Son Ltd., p. 72-77.
Stillwater Mining Co., 1999, Form 10-K—fiscal year ended December 31, 1998: Securities and Exchange Commission, 62 p.
Swana, M.K., 1998, Cobalt from Congo—Past—Present—Future, *in* The Cobalt Conference, Toronto, May 27-28, 1998, Proceedings: London, Cobalt Development Institute, 15 p.
Tenke Mining Corp., 1998, Tenke agreement with BHP Copper: Vancouver, Canada, Tenke Mining Corp. press release, December 16, 1 p.
———1999, Tenke Mining—Force majeure declared: Vancouver, Canada, Tenke Mining Corp. press release, February 23, 1 p.
U.S. Environmental Protection Agency, 1998, Hazardous waste management system; identification and listing of hazardous waste: Federal Register, v.

63, no. 151, August 6, p. 42110-42189.
U.S. Minerals Management Service, 1999, Mineral revenue collections—January-December 1998: Denver, U.S. Minerals Management Service, p. 18.
Weda Bay Minerals Inc., 1998, Weda Bay nickel-cobalt project Halmahera Island: Vancouver, Canada, Weda Bay Minerals Inc. press release, May 20, 2 p.
WMC Ltd., 1999, Annual report 1998—Concise: Melbourne, Australia, WMC Ltd., 52 p.

SOURCES OF INFORMATION

U.S. Geological Survey Publications

Cobalt. Ch. in Metal prices in the United States through 1998. U.S. Geological Survey Special Publication, 1999.

Cobalt. Ch. in Mineral Commodity Summaries, annual.[1]

Cobalt. Ch. in Minerals Yearbook, annual.[1]

Cobalt. Ch. in United States mineral resources, U.S. Geological Survey Professional Paper 820, 1973.

Cobalt. Mineral Industry Surveys, monthly.[1]

Recycling—Metals. Ch. in Minerals Yearbook, annual.[1]

International Strategic Minerals Inventory summary report—Cobalt, U.S. Geological Survey Circular 930-F, 1987.

[1]Prior to January 1996, published by the U.S. Bureau of Mines.

Other

American Metal Market, daily.

Cobalt. Ch. in Mineral facts and problems. U.S. Bureau of Mines Bulletin 675, 1985.

Cobalt Development Institute (United Kingdom).

Company annual reports.

Defense Logistics Agency, Defense National Stockpile Center.

Engineering and Mining Journal, monthly.

Federal Register, daily.

Interfax International Ltd., Mining & Metals Report, weekly.

Metal Bulletin (London), semiweekly and monthly.

Mining Journal (London), weekly, Metals & Minerals Annual Review, Mining Annual Review.

Platt's Metals Week, weekly.

Roskill Information Services Ltd. (London).

Ryan's Notes, weekly.

Strategic and critical materials report to the Congress, U.S. Department of Defense.

The materials flow of cobalt in the United States. U.S. Bureau of Mines Information Circular 9350, 1993.

TABLE 1
SALIENT COBALT STATISTICS 1/

(Metric tons cobalt content unless otherwise specified)

	1994	1995	1996	1997	1998
United States:					
Consumption:					
Reported	7,500 r/	7,590 r/	7,990 r/	8,910 r/	9,180
Apparent	8,730 r/	8,970 r/	9,380 r/	11,200 r/	11,500
Imports for consumption	6,780	6,440	6,710	8,430	7,670
Exports	1,360	1,300	1,660	1,570	1,680
Stocks, December 31:					
Industry 2/	913 r/	822 r/	794 r/	763 r/	750
U.S. Government 3/	22,300	20,700	18,700	17,100	14,700
Price, metal, per pound:					
Average U.S. spot cathode 4/	$24.66	$29.21	$25.50	$23.34	$21.43
Yearend producer 5/	$25.00	$27.50	$27.50	$27.50	$27.50
World production:					
Mine	18,000 r/	24,400 r/	26,200 r/	27,100 r/	26,300 e/
Refinery	20,000 r/	23,300 r/	25,600 r/	27,000 r/	30,900 e/

e/ Estimated. r/ Revised.

1/ Data are rounded to three significant digits, except prices.

2/ Stocks held by cobalt processors and consumers.

3/ Defense Logistics Agency. Includes material committed for sale pending shipment.

4/ Prices are annual averages reported by Platt's Metals Week.

5/ Price established by La Générale des Carrières et des Mines and Zambia Consolidated Copper Mines Ltd.

TABLE 2
U.S. GOVERNMENT NATIONAL DEFENSE STOCKPILE
SALES AND SHIPMENTS 1/

(Metric tons cobalt content)

	1997	1998
Sales:		
Fiscal year 2/	1,060	2,510
Calendar year	1,680	1,950
Shipments:		
Fiscal year 2/	1,440	2,580
Calendar year	1,620	2,310

1/ Data are rounded to three significant digits.

2/ Twelve-month period ending September 30 of year stated.

Source: Defense Logistics Agency.

TABLE 3
U.S. REPORTED CONSUMPTION AND STOCKS OF COBALT 1/ 2/

(Metric tons cobalt content)

	1997	1998
Consumption by end use:		
Steel:		
Stainless and heat resisting	38	38
Tool	112	96
Superalloys	4,170 r/	4,110
Alloys (excludes steels and superalloys):		
Magnetic alloys	879 r/	771
Other alloys 3/	342	421
Cemented carbides 4/	789	844
Chemical and ceramic uses:		
Catalysts	734	W
Driers in paints or related usage	556	W
Ground coat frit	490	W
Pigments	201	W
Miscellaneous and unspecified 5/	602 r/	2,900
Total	8,910 r/	9,180
Consumption by form:		
Chemical compounds (organic and inorganic) 6/	1,980 r/	1,860
Metal	4,190 r/	4,240
Purchased scrap	2,750 r/	3,080
Total	8,910 r/	9,180
Stocks, December 31: 7/		
Chemical compounds (organic and inorganic) 6/	206	306
Metal	419	356
Purchased scrap	138 r/	89
Total	763 r/	750

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous and unspecified."

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Includes estimates.

3/ Includes nonferrous alloys, welding materials, and wear-resistant alloys.

4/ Includes diamond bit matrices, cemented and sintered carbides, and cast carbide dies or parts.

5/ Includes feed or nutritive additive, full-alloy steel, glass decolorizer, and mill products made from metal powder.

6/ Includes oxides.

7/ Stocks held by cobalt processors and consumers.

TABLE 4
U.S. IMPORTS FOR CONSUMPTION OF COBALT, BY FORM 1/

(Metric tons, unless otherwise specified)

		1997	1998
Metal: 2/			
Gross weight		7,070	6,450
Cobalt content 3/		7,070	6,450
Value	thousands	$328,000	$284,000
Oxides and hydroxides:			
Gross weight		1,130	1,210
Cobalt content 3/		815	868
Value	thousands	$42,800	$41,500
Other forms:			
Acetates:			
Gross weight		208	231
Cobalt content 3/		50	55
Value	thousands	$2,480	$2,460
Carbonates:			
Gross weight		54	18
Cobalt content 3/		25	8
Value	thousands	$658	$419
Chlorides:			
Gross weight		68	22
Cobalt content 3/		17	6
Value	thousands	$872	$292
Sulfates:			
Gross weight		1,670	1,040
Cobalt content 3/		450	281
Value	thousands	$15,100	$10,400
Total:			
Gross weight		10,200	8,970
Cobalt content 3/		8,430	7,670
Value	thousands	$390,000	$339,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Unwrought cobalt, excluding alloys and waste and scrap.
3/ Estimated from gross weights.

Source: Bureau of the Census, minor adjustments by the U.S. Geological Survey.

TABLE 5
U.S. IMPORTS FOR CONSUMPTION OF COBALT, BY COUNTRY 1/

Country of origin	Metal 2/			Oxides and hydroxides			Other forms 3/			Total		
	Gross weight (metric tons)	Cobalt content 4/ (metric tons)	Value (thou-sands)	Gross weight (metric tons)	Cobalt content 4/ (metric tons)	Value (thou-sands)	Gross weight (metric tons)	Cobalt content 4/ (metric tons)	Value (thou-sands)	Gross weight (metric tons)	Cobalt content 4/ (metric tons)	Value (thou-sands)
1997:												
Australia	--	--	--	5	4	$116	--	--	--	5	4	$116
Belgium	97	97	$6,820	287	207	11,500	41	10	$570	426	315	18,900
Brazil	131	131	5,530	--	--	--	2	1	26	133	131	5,550
Canada	949	949	45,400	--	--	--	17	8	397	966	957	45,800
Congo (Kinshasa) 5/	618	618	27,100	--	--	--	--	--	--	618	618	27,100
Finland	917	917	42,700	481	347	16,400	1,790	479	16,600	3,190	1,740	75,700
France	47	47	4,070	28	20	1,910	--	--	--	75	68	5,980
Germany	87	87	5,610	2	1	152	(6/)	(6/)	4	89	88	5,760
Japan	17	17	855	11	8	683	(6/)	(6/)	4	28	25	1,540
Mexico	--	--	--	--	--	--	4	2	76	4	2	76
Morocco	55	55	2,460	--	--	--	--	--	--	55	55	2,460
Netherlands	--	--	--	12	9	529	--	--	--	12	9	529
Norway	1,920	1,920	89,000	--	--	--	--	--	--	1,920	1,920	89,000
Russia	950	950	39,600	12	9	356	33	15	185	996	974	40,100
South Africa	98	98	4,410	(6/)	(6/)	9	4	1	50	102	99	4,470
Spain	1	1	56	4	3	135	--	--	--	5	4	190
United Kingdom	71	71	3,600	287	207	10,800	105	26	1,220	463	303	15,700
Zambia	1,110	1,110	50,900	--	--	--	--	--	--	1,110	1,110	50,900
Other	2	2	118	2	1	84	(6/)	(6/)	3	4	4	205
Total	7,070	7,070	328,000	1,130	815	42,800	2,000	542	19,200	10,200	8,430	390,000
1998:												
Belgium	222	222	10,900	226	163	8,960	--	--	--	448	385	19,800
Brazil	110	110	3,760	--	--	--	--	--	--	110	110	3,760
Canada	1,090	1,090	48,900	--	--	--	16	7	364	1,100	1,090	49,300
China	27	27	1,190	57	41	1,470	2	1	25	86	69	2,690
Congo (Kinshasa) 5/	494	494	20,200	--	--	--	--	--	--	494	494	20,200
Finland	596	596	27,800	448	323	14,800	1,190	317	12,000	2,240	1,240	54,600
France	36	36	3,480	41	29	2,380	1	(6/)	25	78	66	5,880
Germany	58	58	3,480	3	2	218	(6/)	(6/)	8	61	60	3,710
Japan	36	36	1,870	4	3	159	1	1	21	41	40	2,050
Luxembourg	--	--	--	--	--	--	2	1	19	2	1	19
Netherlands	--	--	--	3	3	105	(6/)	(6/)	3	4	3	107
Norway	1,890	1,890	84,000	--	--	--	--	--	--	1,890	1,890	84,000
Russia	690	690	27,200	--	--	--	--	--	--	690	690	27,200
South Africa	44	44	1,660	(6/)	(6/)	11	2	(6/)	3	46	44	1,670
Switzerland	30	30	1,280	--	--	--	--	--	--	30	30	1,280
United Kingdom	103	103	4,160	422	304	13,400	94	24	1,110	620	431	18,700
Zambia	1,020	1,020	44,400	--	--	--	--	--	--	1,020	1,020	44,400
Other	--	--	--	1	(6/)	32	1	(6/)	2	1	1	34
Total	6,450	6,450	284,000	1,210	868	41,500	1,310	351	13,600	8,970	7,670	339,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Unwrought cobalt, excluding alloys and waste and scrap.
3/ Includes cobalt acetates, cobalt carbonates, cobalt chlorides, and cobalt sulfates.
4/ Estimated from gross weights.
5/ Formerly Zaire.
6/ Less than 1/2 unit.

Source: Bureau of the Census, minor adjustments by the U.S. Geological Survey.

TABLE 6
U.S. EXPORTS OF COBALT IN 1998, BY COUNTRY 1/ 2/

Country of destination	Metal 3/		Oxides and hydroxides		Acetates		Chlorides		Total	
	Gross weight (metric tons)	Value 4/ (thou-sands)	Gross weight (metric tons)	Value 4/ (thou-sands)	Gross weight (metric tons)	Value 4/ (thou-sands)	Gross weight (metric tons)	Value 4/ (thou-sands)	Cobalt content 5/ (metric tons)	Value 4/ (thou-sands)
Australia	21	$459	26	$490	--	--	--	--	40	$949
Belgium	266	14,400	--	--	--	--	(6/)	$8	266	14,400
Brazil	15	488	36	967	99	$1,010	2	23	65	2,490
Canada	149	4,880	54	1,330	52	399	1	12	200	6,610
Chile	--	--	25	365	--	--	--	--	18	365
China	79	684	2	13	--	--	--	--	81	698
Colombia	(6/)	5	4	95	29	102	--	--	10	202
Finland	125	4,140	20	250	--	--	--	--	140	4,390
France	98	3,350	--	--	--	--	--	--	98	3,350
Germany	49	2,380	2	74	--	--	--	--	50	2,450
Hong Kong	24	181	(6/)	4	--	--	--	--	24	186
Japan	31	1,040	36	993	--	--	--	--	57	2,030
Korea, Republic of	3	114	(6/)	13	13	442	1	10	6	580
Mexico	16	922	67	2,130	449	1,760	1	13	172	4,820
Netherlands	133	4,220	190	3,460	--	--	--	--	270	7,690
Sweden	25	1,540	(6/)	5	--	--	--	--	25	1,540
Taiwan	2	104	7	71	15	168	5	76	11	419
United Kingdom	58	3,140	4	91	(6/)	3	--	--	61	3,230
Other	41	1,370	59	922	8	110	(6/)	6	86	2,410
Total	1,140	43,400	533	11,300	664	3,990	10	149	1,680	58,900

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ In addition to the materials listed, the United States exports cobalt ores and concentrates and wrought cobalt and cobalt articles.
3/ Includes unwrought cobalt, powders, waste and scrap, and mattes and other intermediate products of cobalt metallurgy.
4/ Free alongside ship (f.a.s.) value.
5/ Estimated from gross weight.
6/ Less than 1/2 unit.

Source: Bureau of the Census, minor adjustments by the U.S. Geological Survey.

TABLE 7
WORLD ANNUAL COBALT REFINERY CAPACITY
DECEMBER 31, 1998 1/ 2/

(Metric tons cobalt content)

Country	Capacity
Australia	2,000
Belgium	1,200
Brazil	500
Canada	4,700
China e/	1,500
Congo (Kinshasa) 3/	17,000
Finland e/	10,600
France	300
Japan	480
Morocco	300
Norway	4,500
Russia e/	8,000
South Africa e/	1,500
United States 4/	900
Zambia	5,000
Total	58,500

e/ Estimated.
1/ Data are rounded to three significant digits; may not add to total shown.
2/ Refinery products include cobalt metal, metal powder, oxides, and/or salts.
3/ Formerly Zaire.
4/ Standby capacity.

TABLE 8
COBALT: WORLD MINE PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons, cobalt content)

Country 3/	1994	1995	1996	1997	1998 e/
Australia e/ 4/	2,300	2,500	2,800	3,000	3,300
Botswana 5/	225	271	408 r/	334	335
Brazil e/	400	400	400	400	400
Canada 6/	4,265	5,339	5,714	5,709 r/	6,039 7/
China e/	270	980	190	200 r/	210
Congo (Kinshasa) e/ 8/ 9/	826	1,647 7/	2,000	3,500	1,500
Cuba 10/	972	1,591	2,011	2,082	2,200
Kazakhstan e/ 11/	300	300	300	300	300
Morocco 9/	419	537	565	714 r/	287 7/
New Caledonia e/ 12/	1,000 r/	1,100 r/	1,100 r/	1,000 r/	1,000
Russia e/	3,000	3,500	3,300	3,300	3,200
South Africa e/	358	288	350	450 r/	450
Zambia 9/ 13/	3,600	5,908	6,959 r/	6,043 r/	7,000
Zimbabwe e/	100	80	95	100 r/	90
Total	18,000 r/	24,400 r/	26,200 r/	27,100 r/	26,300

e/ Estimated. r/ Revised.

1/ World totals and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through June 8, 1999. Figures represent recoverable cobalt content of ores, concentrates, or intermediate products from copper, nickel, platinum, or zinc operations. Morocco was the only country where cobalt was mined as a primary product.

3/ In addition to the countries listed, Bulgaria, Germany, India, Indonesia, the Philippines, and Poland are known to produce ores that contain cobalt, but information is inadequate for reliable estimates of output levels. Other copper-, nickel-, platinum-, or zinc-producing nations may also produce ores containing cobalt as a byproduct component, but recovery is small or nil.

4/ Figures represent quantities of cobalt contained in intermediate or refined metallurgical products (cobalt sulfide, cobalt oxide hydroxide, nickel-cobalt sulfide, nickel concentrate, and nickel matte) produced from Australian and imported ores. Cobalt content of lateritic nickel ore, nickel concentrate, and zinc concentrate originating in Australia was estimated as follows, in metric tons: 1994--1,200; 1995--1,300; 1996--1,400; 1997--1,600; and 1998--1,800.

5/ Reported cobalt content of pelletized nickel-copper matte.

6/ Figures represent the assay content of cobalt in concentrates produced. The cobalt content of all products derived from ores of Canadian origins, including cobalt oxide shipped to the United Kingdom for further processing and nickel-copper matte shipped to Norway for refining, was reported as follows, in metric tons: 1994--1,846; 1995--2,016; 1996--2,150; 1997--2,168 (revised); and 1998--2,324.

7/ Reported figure.

8/ Formerly Zaire.

9/ Cobalt content of concentrates.

10/ Determined from reported nickel-cobalt content of sulfide production.

11/ Figures represent estimated cobalt content of only those ores from which it is assumed cobalt is recovered. Cobalt content of total ores mined is assumed to be as follows, in metric tons: 1994--1,394 and 1995-98--1,400.

12/ Figures represent quantities of cobalt contained in intermediate or refined metallurgical products (cobalt chloride, cobalt oxide hydroxide, and cobalt sulfide) produced from New Caledonian ores exported to Australia and France. Cobalt content of total ores mined is estimated as follows, in metric tons: 1994--9,700; 1995--12,000; 1996--12,200; 1997--13,600; and 1998--12,900.

13/ Fiscal year beginning April 1 of that stated. Cobalt content ore milled was as follows, in metric tons: 1994--6,747; 1995--8,849; 1996--10,087 (revised); 1997--8,178 (revised); and 1998--10,000 (estimated).

TABLE 9
COBALT: WORLD REFINERY PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons, cobalt content)

Country 3/	1994	1995	1996	1997	1998
Australia: Oxide hydroxide	--	--	--	617 r/	1,395
Belgium: Metal powder, oxide, hydroxide e/	1,000	1,200	1,200	1,200	1,200
Brazil: Metal	165 r/	166 r/	193 r/	266 r/	364
Canada: Metal (including metal powder) and oxide	2,971	3,259 r/	3,601	3,792 r/	4,357
China: Metal e/	200	240	230	470 r/	480
Congo (Kinshasa): Metal 4/ 5/	2,439 r/	3,422 r/	3,540 r/	2,808	4,490
Finland: Metal powder and salts	3,000	3,610	4,160	5,000	5,250
France: Chloride	146	161	174	159	172
Japan: Metal	161	227	258	264	329
Morocco: Metal	--	--	80 r/	220 r/	230
Norway: Metal	2,823	2,804	3,098	3,417	3,851
Russia: Unspecified e/	4,340	4,450	4,200	4,100	3,500
South Africa: Metal powder and sulfate	258	190	244 r/	316 r/	296
Zambia: Metal 6/	2,482	3,577	4,612 r/	4,403 r/	5,011
Total	20,000 r/	23,300 r/	25,600 r/	27,000 r/	30,900

e/ Estimated. r/ Revised.

1/ World totals and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through June 18, 1999. Figures represent cobalt refined from ores, concentrates, or intermediate products and do not include production of downstream products from refined cobalt.

3/ In addition to the countries listed, Germany, India, and Slovakia may produce cobalt, but available information is inadequate to make reliable estimates of production.

4/ Congo (Kinshasa) was formerly Zaire.

5/ Excludes production of cobalt in white alloy, matte, and slag that would require further refining.

6/ Fiscal years beginning April 1 of that stated.