

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 remained the world's largest consumer of cobalt (Burstow, 2000). 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 1999. 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 increased slightly in 1999. Some of the increase was from new operations in Australia and Uganda and some was from a net increase in production by existing operations. World demand for cobalt in 1999 was estimated to be similar to that in 1998 (Cobalt Development Institute, 2000). Cobalt prices fluctuated widely during the year. Annual average prices, however, continued the downward trend that began in 1996.

Salient U.S. and world cobalt statistics for 1999 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 no more than three significant digits. Totals and percentages were calculated from unrounded numbers.

Legislation and Government Programs

The Defense National Stockpile Center (DNSC), U.S. Department of Defense, held 13 sealed-bid cobalt offerings during fiscal year 1999 (October 1, 1998, through September 30, 1999). During this period, the DNSC sold 1,960 metric tons (t) of cobalt valued at nearly \$62 million (table 2). This equaled 72% of the 2,720-t (6 million pounds) maximum allowed for sale under the fiscal year 1999 Annual Materials Plan (AMP). As of the end of the fiscal year, 495 t of cobalt had been sold, but not shipped, from the stockpile (U.S. Department of Defense, 2000). The AMP for fiscal year 2000 (October 1, 1999, through September 30, 2000) maintained the

maximum allowable sale of cobalt at 2,720 t (Defense National Stockpile Center, 1999).

The DNSC held 13 cobalt offerings during calendar year 1999 and sold 2,230 t of cobalt valued at \$70 million. Two of the 13 offerings were for cobalt cathode; the remaining 11 offerings were for cobalt granules and rondelles. On December 31, the total uncommitted cobalt inventory held by the DNSC was 12,400 t, all of which was authorized for eventual disposal.

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 1999. The U.S. Minerals Management Service (2000) reported sales of 14 t of cobalt valued at \$32,000 from Federal lands in Missouri in 1999.

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 containing cobalt, copper, and nickel from the precious metals smelter was processed at the base metals refinery. Nickel-copper-cobalt sulfate solution from the refinery was shipped to Canada to be refined (Stillwater Mining Co., 2000, p. 8).

Formation Capital Corp. of Vancouver, British Columbia, Canada, continued exploring its 100%-owned cobalt-copper-gold project in Lemhi County, ID. On the basis of data from its 1999 drilling program, proven and probable reserves were increased to 1.55 million metric tons (Mt) grading 0.695% cobalt, 0.54% copper, and 0.02 ounce per metric ton gold, and proven, probable, and inferred resources were increased to 2.7 Mt at a similar grade. Formation Capital was considering a production schedule in which mining would begin in 2002 or 2003. Ore from the underground mine would be milled and then beneficiated by flotation. The cobalt concentrate produced would be treated by using a pressure acid leaching process. The project was forecast to produce approximately 1,500 metric tons per year (t/yr) of cobalt as hydroxide and oxide (Bending, 2000; Formation Capital Corp., 2000).

In April, U.S. Cobalt Inc., a Denver, CO, mineral exploration and development company, entered into an agreement with Anschutz Mining Corp. to lease with option to purchase the Madison Mine, near Fredericktown, MO. Cobalt, copper, lead, and nickel were intermittently mined there from the mid-1800's through 1961. Anschutz purchased the mine in 1979 with a plan to produce cobalt from tailings, but also explored the underground resource, performed bulk sampling, metallurgical testwork, and engineering studies. A feasibility

study was completed, but the project was postponed when the price of cobalt decreased in the early 1980's. U.S. Cobalt's agreement with Anschutz includes all exploration records, drill cores, equipment, and buildings. During the year, U.S. Cobalt completed an internal economic scoping study and a due diligence confirmation drilling program on the property. The company planned an exploration and development program to upgrade the known resource in size and definition and to complete metallurgical studies that will conclude with a prefeasibility study (Consolidated Mango Resources Ltd., 2000, p. 52-58).

PolyMet Mining Corp. of Golden, CO, continued to study the NorthMet deposit (formerly called Dunka Road) under a lease agreement with USX Corp. of Pittsburgh, PA. NorthMet occurs in the Duluth Complex of northeastern Minnesota, a large layered mafic intrusion that contains, in order of relative abundance, copper, nickel, cobalt, silver, platinum-group metals, and gold. On the basis of laboratory-scale testing, PolyMet selected pressure oxidation leaching as the hydrometallurgical process to treat sulfide concentrates from the deposit. PolyMet began an in-fill drilling program to provide information for ore reserve estimation and drill cuttings to be used to produce a bulk concentrate for pilot-plant studies of the hydrometallurgical process. In addition, PolyMet reviewed and assayed cores from drilling during the late 1960's and early 1970's, and collected baseline environmental data in support of the permitting process (PolyMet Mining Corp., 2000a, p. 1-2, 7-9; 2000b).

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 1999, U.S. processors produced 1,960 t of cobalt oxide and hydroxide, inorganic cobalt compounds, and organic cobalt compounds, a 12% decrease from the 2,230 t produced in 1998. 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 1999, shipments by U.S. processors included 2,200 t of cobalt oxide and hydroxide, inorganic cobalt compounds, and organic cobalt compounds, a 12% decrease from 2,490 t shipped in 1998. 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 cobalt 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 1999, cobalt-bearing 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 Braithwaithe, LA, which operated as a partnership between subsidiaries of Cyprus Amax Minerals Co. and CRI International, Inc., reportedly closed late in the year (Ryan's Notes, 2000). Prior to closure, the CRI-MET plant produced a nickel-cobalt "concentrate."

Consumption

Apparent consumption for 1999 (as calculated from net imports, consumption from purchased scrap, and changes in Government and industry stocks) was 7% lower than that calculated for 1998 (see table 1). Although net imports of cobalt were higher in 1999 than in 1998, the increase in net imports was smaller than the decrease in cobalt shipments from the NDS and cobalt recovered from scrap.

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 cemented 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 1999 was 8% lower than that for 1998. As a whole, metallurgical industries consumed 7% less cobalt in 1999 as compared with that of 1998. On an industry-by-industry basis, consumption to make steels and magnetic alloys was higher in 1999, and consumption to make cemented carbides, superalloys, and other alloys was lower. Total reported cobalt consumption in chemical uses decreased by 10% in 1999 as compared with that of 1998 (table 3).

Prices

In mid-January, 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, decreased to \$8.50 per pound, its lowest level since 1990. The average price then rapidly increased to \$19.00 per pound in February, decreased to \$15.63 per pound in May, then increased to an annual high of \$21.25 per pound in June. From mid-June through November, the price gradually decreased before leveling off at approximately \$14.50 per pound in late November-early December. During the second half of December, the average price increased slightly to \$14.88 per pound. Platt's average annual U.S. spot cathode price for 1999 was 17.02 per pound, down by 21% from that of 1998 (table 1).

Platt's prices for Zambian cobalt (minimum 99.6% cobalt) and Russian cobalt (minimum 99.3% cobalt) paralleled the U.S. spot cathode price. The average of weekly prices for Zambian cobalt was \$16.20 per pound, and the average of weekly prices for Russian cobalt was \$15.50 per pound.

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, 1999b), and in April 2000, Platt's Metals Week discontinued publishing this price.

In August, a new way to buy cobalt became available when WMC Ltd. began selling its metals on the Internet (WMC Ltd., 1999; see also the Australia section of this report). The Cobalt Open Sales System, at <http://www.wmc-cobalt.com/>, listed the availability and asking prices of WMC cobalt; information on sales, such as the date of the sale, amount sold, delivery date, sale price, and destination; and news items that related to the cobalt market. For the most part, the trend in sale prices of WMC cobalt was similar to that of Platt's U.S. spot cathode price. The highest sales price was \$19.95 per pound in August and the lowest prices were several sales at \$13.50 per pound in November.

In September, the Spectron Group, an independent European energy broker, announced that it was establishing an Internet trading system for cobalt (Spectron Group, 1999). Spectron planned to deal in spot market and forward sales of various grades of cobalt from a variety of sources from its website at <http://www.spectronmetals.com/>.

Foreign Trade

As shown in tables 4 and 5, in 1999, the United States imported 6% more cobalt than it did in 1998. Eight countries supplied 94% of U.S. imports of unwrought cobalt and cobalt in chemicals. Finland was the leading supplier, followed by Norway, Congo (Kinshasa), Zambia, Canada, Russia, Belgium, and the United Kingdom. Compared with those of 1998, cobalt imports from Congo (Kinshasa), Finland, and Russia increased, and imports from Belgium, Canada, Norway, the United Kingdom, and Zambia decreased.

In 1999, the United States imported 255 t, gross weight, of unwrought cobalt alloys valued at \$9.4 million. Five countries supplied more than 95% of these materials—the United Kingdom (37%), Japan (21%), Germany (18%), Belgium (12%), and Sweden (9%). The United States imported 391 t, gross weight, of cobalt matte, waste, and scrap, valued at \$4.1 million. Seven countries supplied more than 90% of these materials—the United Kingdom (40%), Germany (16%), Japan (10%), Canada and France (9% each), and Belgium and the Netherlands (5% each). The United States also imported 173 t, gross weight, of wrought cobalt and cobalt articles valued at \$9.1 million. The leading suppliers of these materials were the United Kingdom (36%), Japan (21%), Belgium (10%), Canada and France (9% each), Germany (8%), and Russia (6%).

U.S. exports of unwrought cobalt and cobalt contained in chemicals decreased by 8% compared with those of 1998. As listed in table 6, more than 80% of the cobalt metal and chemical exports was shipped to nine countries—Belgium, Brazil, Canada, France, Germany, Japan, Mexico, the Netherlands, and the United Kingdom. The remainder was shipped to 37 other countries.

Exports also included 546 t, gross weight, of wrought metal and cobalt articles valued at \$26.4 million. More than three quarters of these materials was sent to seven countries—the United Kingdom (22%), Belgium (21%), India (9%), Canada

and Germany (8% each), Singapore (6%), and France (5%). The remainder was shipped to 30 other countries.

World Review

World refined cobalt production increased slightly in 1999 as compared with that of 1998. Some of the increase in refined cobalt production was from new operations in Australia and Uganda and some was from a net increase in production by existing operations.

Refinery capacity, as listed in table 7, includes plants that produced more than 100 tons of refined cobalt in 1999. Refined cobalt can be in the form of metal, metal powder, oxides, and/or salts. Plants that reprocessed refined cobalt, that used secondary materials (scrap) as their main source of feed, or that produced a cobalt product that required further refining were not included.

Albania.—The cobalt and ferronickel plants at the Elbasan steel works were reported to be bankrupt and scheduled to be demolished (Mining Journal, 1999a).

Australia.—During the calendar year, QNI Pty. Ltd. produced 1,539 t of cobalt as cobalt oxide hydroxide at its Yabulu nickel-cobalt refinery in Townsville, Queensland. This represented a 10% increase from the 1,395 t produced in 1998 (Cobalt Development Institute, 2000). The refinery processed lateritic ore imported from Indonesia, New Caledonia, and the Philippines. In November, QNI signed a joint-venture agreement with Comet Resources NL to develop the Ravensthorpe nickel laterite project on the southern coast of Western Australia. The project will involve building a front-end pressure acid leaching plant at Ravensthorpe to produce an intermediate nickel-cobalt hydroxide that would be shipped to Yabulu for refining. QNI planned to expand the Yabulu refinery to accommodate the increase in feed material. Future production from Ravensthorpe was estimated at approximately 35,000 t/yr of nickel and 1,300 t/yr of cobalt. The Yabulu refinery capacity might be increased to 65,000 t/yr of nickel and 3,000 t/yr of cobalt (Billiton Plc, 1999).

WMC Ltd. produced an estimated 800 t of cobalt in intermediate nickel-cobalt mixed sulfide at its Kwinana nickel refinery in Western Australia (WMC Ltd., 1999). Beginning in 1999, the mixed sulfide was refined by Falconbridge Ltd. under a tolling agreement, and WMC began marketing its own cobalt cathode (see Prices section of this report). The mixed sulfide was formerly sold to Falconbridge as feedstock for its Nikkelverk refinery in Norway.

Outokumpu Australia Pty. Ltd. produced nickel concentrates from its Forresteria and Black Swan (previously named Silver Swan) operations in Western Australia. Nickel concentrates from these operations and from WMC's Mount Keith operation, containing an estimated 500 t of cobalt, were exported to Finland for treatment at the Outokumpu Harjavalta Metals Oy refinery (Matheson, 1999).

Anaconda Nickel Ltd. commissioned Stage I of the Murrin Murrin project east of Leonora in Western Australia. The Murrin Murrin refinery uses pressure acid leaching to recover cobalt and nickel from lateritic ores. During the year, Anaconda increased its resources and reserves through

acquisitions and exploration. By yearend, Anaconda's resources were estimated at 330 Mt ore grading 1.00% nickel, 0.063% cobalt, and 5.8% magnesium, and its delineated proven and probable reserves were estimated at 310 Mt ore grading 1.00% nickel and 0.064% cobalt. Anaconda produced its first nickel metal powder briquettes in May and cobalt metal powder briquettes in July. The ramp up to Stage I capacity of 45,000 t/yr of nickel and 3,000 t/yr of cobalt was delayed by mechanical and materials problems, which necessitated plant modifications. As a result, refined cobalt production during 1999 was reportedly only 83 t (Cobalt Development Institute, 2000). Anaconda decided to expand to Stage II capacity levels of 100,000 t/yr of nickel and 8,500 t/yr of cobalt by first debottlenecking Stage I to increase its production above design capacity, and then by expanding each discrete operating unit incrementally. In December, Anaconda completed and commissioned an expansion of the cobalt unit to 5,000 t/yr (Anaconda Nickel Ltd., 1999a, b, c, 2000).

During calendar year 1999, Centaur Mining & Exploration Ltd. produced approximately 575 t of cobalt as cobalt sulfide from its Cawse nickel-cobalt operation northwest of Kalgoorlie in Western Australia. The Cawse refinery processed nickel laterites by using pressure acid leaching, followed by precipitation of a nickel-cobalt hydroxide, re-leaching, solvent extraction, and then precipitation to produce cobalt sulfide and electrowinning to produce nickel cathode. At yearend, the refinery was on schedule to operate at design capacity of approximately 10,000 t/yr of nickel and 1,500 t/yr of cobalt by June 2000. Centaur increased its nickel laterite resources through joint ventures with several Australian exploration companies and a strategic alliance with Heron Resources NL. Towards the end of the year, Anaconda Nickel and Centaur formed a strategic alliance to study the feasibility of expanding Cawse's refinery capacity to not less than 40,000 t/yr of nickel and 3,000 t/yr of cobalt (Centaur Mining & Exploration Ltd., 1999, 2000). Capacity and production of cobalt sulfide from Cawse is not included in tables 7 and 9 because the sulfide is an intermediate product that is upgraded by other cobalt refiners.

Preston Resources Ltd. of Perth, Western Australia, began production of metallic cobalt and nickel from its Bulong project east of Kalgoorlie in Western Australia. The metals were recovered from nickel laterite ore by using pressure acid leaching technology, followed by solvent extraction, and then electrowinning to produce nickel cathode and cobalt cathode. By the end of December, Preston had produced 77 t of cobalt cathode, approximately 50% less than production planned for the year. Corrosion in the cobalt sulfide autoclave was cited as the reason for the reduced output. Preston arranged to market an intermediate cobalt sulfide product in 2000 to maintain revenue from cobalt production while modifying the cobalt refinery. Production from Bulong during 2000 was forecast to increase quarterly, resulting in annual totals of 8,100 t of nickel and 700 t of cobalt (Preston Resources Ltd., 2000). In October, Anaconda Nickel established a strategic alliance with Preston to study the feasibility of expanding production from the Bulong project to at least 40,000 t/yr of nickel. Under the agreement, Anaconda would manage the joint venture and market production resulting from the expansion (Anaconda Nickel

Ltd., 1999d).

Many other projects that would include cobalt production were being evaluated during the year. Some examples include Anaconda Nickel's Mount Margaret laterite project in Western Australia, Black Range Minerals NL's Syerston laterite project in New South Wales, Compass Resources NL's Browns lead-copper-cobalt-nickel sulfide project in Northern Territory, and Preston Resources' Marlborough laterite project in Queensland.

Belgium.—N.V. Union Minière S.A. converted cobalt metal, residues, and other cobalt-bearing materials into cobalt hydroxides, metal powders, oxides, and salts at its facilities in Olen. According to the Cobalt Development Institute, estimated cobalt production by Union Minière decreased by 21% in 1999 to 950 t (Cobalt Development Institute, 2000).

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. Production in 1999 increased significantly as a result of an expansion to the refinery that increased the installed capacity to 800 t/yr of cobalt (Metal Bulletin, 2000c).

Canada.—Falconbridge Ltd. produced 922 t of cobalt in concentrate from its Sudbury, Ontario, mines and 238 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 1999, this matte contained 2,414 t of cobalt; 43% of the cobalt originated from ores produced at company mines, and 57% from custom feed materials, defined as feeds that did not originate from Falconbridge mines. In 1999, custom feeds processed by the smelter were mainly nickel-copper-cobalt-bearing scrap (Falconbridge Ltd., 2000a, p. 20; 2000b, p. 15).

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 1999, Inco produced 1,420 t of cobalt in Canada from both operations, an 18% decrease from the 1,740 t produced in 1998 (Cobalt Development Institute, 2000).

Inco's development of its Voisey's Bay nickel-copper-cobalt-sulfide deposit in northeastern Labrador continued to be delayed by an impasse between the company and the Province of Newfoundland and Labrador. The Provincial Government refused to give approval for the project without a guarantee that the ores would be refined within the Province, and Inco refused to commit to building the refinery in the Province before it was proven to be technically and economically feasible. As a result of the impasse, Inco will not be able to begin construction on the mining and milling phase of the project during the year 2000. The company planned to continue exploration activities at Voisey's Bay and research and development work on a proprietary hydrometallurgical process for the ores (Inco Ltd., 2000a).

Sherritt International Corp.'s Fort Saskatchewan, Alberta, refinery produced a record 2,770 t of cobalt in 1999, a 5% increase from the 2,645 t produced in 1998. 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 (Sherritt International Corp., 2000, p. 6, 8). 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.

Canmine Resources Corp. continued to develop its Werner Lake cobalt project in southwestern Ontario-southeastern Manitoba. The Werner Lake deposit is a Precambrian calcic cobalt skarn from which Canmine would produce cobalt as a primary product. During the year, Canmine purchased a hydrometallurgical refinery in North Cobalt, Ontario. The refinery, formerly owned by Cobatec Inc., has the capacity to produce 270 t/yr of cobalt. It will be used to produce cobalt carbonate from Werner Lake concentrates and feedstocks from other sources. In February, Canmine established a long-term agreement to sell cobalt carbonate produced from the Werner Lake project to The Shepherd Chemical Co., a U.S. company with cobalt chemical plants in Cincinnati and Middletown, OH; Mirecourt, France; and Widnes, United Kingdom (Canmine Resources Corp., 1999, p. 2-4, 10-11).

China.—An estimated 1,200 t of cobalt metal and chemicals was produced from domestic and imported raw materials (Cobalt Development Institute, 2000). 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).—Central Mining Group Corp. S.P.R.L., a joint venture between Gécamines, the Government of Congo (Kinshasa), and Ridgepointe Overseas Developments Ltd., produced copper and cobalt from mines and refineries in Gécamines Central Group (Metal Bulletin, 1999a). Gécamines and L'Enterprise Generale Malta Forrest S.P.R.L. (EGMF) produced copper-cobalt concentrates from the Luiswishi Mine, which were purchased by OM Group, Inc. for its Kokkola refinery in Finland under a long-term supply contract (OM Group, Inc., 2000, p. 3). The Kasombo Mine, operated by EGMF and Gécamines in partnership with Union Minière, reportedly ceased production in early 1999 (Mining Journal, 1999b). KGHM Polska Miedz S.A., of Lubin, Poland, reportedly ceased mining at Kimpe in November. According to Metal Bulletin, the Government of Congo (Kinshasa) ordered KGHM to cease operations at Kimpe because the company and its Congolese partner Sodimico had not invested in a new smelter and metallurgical plant as obligated in the purchase agreement (Metal Bulletin, 2000a).

Gécamines, OM Group, and S.A. Groupe George Forrest continued with the "Big Hill" 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 in the fourth quarter of 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; 2000, p. 3).

Congo Mineral Developments Ltd. (CMD), a joint venture between America Mineral Fields Inc. and Anglo American Plc (formerly named Anglo American Corp. of South Africa Ltd.), continued to work on the Kolwezi tailings project. CMD

estimated that the tailings contained in the Kingamyambo and Musonoi dams, 300 kilometers northwest of Lubumbashi, represented a resource of 112.8 million tons grading 1.49% copper and 0.32% cobalt. CMD also identified mining methods, plant locations, and infrastructure requirements for the project, defined process flowsheets and completed metallurgical testwork to determine recovery rates. CMD planned to use solvent extraction-electrowinning technology to recover 75,000 t/yr of copper and 12,000 t/yr of cobalt from the tailings. Of the 12,000 t/yr cobalt, 7,000 t/yr would be refined to metal and 5,000 t/yr would be stockpiled as an intermediate material to be refined at a later time. In October, Union Minière acquired an 11% interest in America Mineral Fields, with the option to increase its investment to 20%. Later in the year, CMD announced that it had decided to proceed with an environmental impact study and a 4-month pilot-plant program. At yearend, CMD had not yet received the necessary decrees from the President of Congo (Kinshasa) to give it a clear title to the project. Following ratification by the President, ownership of the Kolwezi tailings project will be transferred to a new company, KMT S.A.R.L., which will be 60% owned by CMD and 40% owned by Gécamines (America Mineral Fields Inc., 2000, p. 1-5, 7, 10-11).

The rebellion by military factions dissatisfied with the Government of Congo (Kinshasa) that began in August 1998 continued into early 2000. Political uncertainty resulting from the ongoing civil war delayed the progress of the following joint-venture projects with Gécamines: East Asia Gold Corp.'s Mukondo and Luisha projects, First Quantum Minerals Ltd.'s copper-cobalt tailings projects at Kolwezi and Likasi, International Panorama Resource Corp.'s Kakanda copper-cobalt tailings project, Iscor Ltd.'s rehabilitation of the Kamoto Mine, Melkior Resources Inc.'s mining and exploration in the Likasi area, and Tenke Mining Corp.'s development of copper-cobalt deposits at Tenke and Fungurume. Also delayed was the Mudima consortium's feasibility study on rehabilitating the mines and plants in Gécamines' Kolwezi Group West (East Asia Gold Corp., 1999; First Quantum Minerals Ltd., September 17, 1999, Development, accessed February 22, 2000, at URL http://www.first-quantum.com/property_development.html; International Panorama Resource Corp., 2000; Iscor Ltd., 1999, p. 18; Melkior Resources Inc., 1999; Tenke Mining Corp., 1999).

Côte d'Ivoire.—Falconbridge continued to perform environmental baseline studies at its nickel-cobalt laterite project site in western Côte d'Ivoire. The company stated that hydrometallurgical exploitation of the ores was potentially viable, provided that several requirements were met, including establishing rail access to the coast. The Government of Côte d'Ivoire was investigating the possibility of developing such a railway (Falconbridge Ltd., 2000b, p. 25).

Cuba.—Moa Nickel mined nickel-cobalt laterites at Moa Bay and produced mixed sulfides containing 27,020 t of nickel and cobalt, essentially the same amount as the 27,066 t produced in 1998 (Sherritt International Corp., 2000, p. 6). 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 decided to withdraw from a joint venture with state-owned Commercial Caribbean Nickel S.A. to evaluate the possibility of developing the Pinares de Mayari West nickel laterite deposit in Holguín Province. According to WMC, the project was unlikely to provide sufficient returns to add to shareholder value (WMC Ltd., 2000).

QNI Ltd., a subsidiary of Billiton Plc, continued exploration and metallurgical test work on the San Felipe nickel laterite project in the Camaguey Province (Billiton Plc, 2000, p. 23). The project is being investigated as a joint venture with Geominera S.A., Cuba's mining investment company.

Finland.—OM Group produced 6,200 t of cobalt in cobalt metal powders, briquettes, oxides, and salts, 18% more than the 5,250 t produced in 1998 (Cobalt Development Institute, 2000). The Kokkola Chemicals Oy refinery processed cobalt-bearing materials from Australia, Congo (Kinshasa), Finland, and elsewhere. In 1999, OM Group completed investments on the refinery's solvent extraction unit, resulting in an increase in capacity to 10,000 t/yr of cobalt, and added cobalt briquettes to its product line (OM Group, Inc., 2000, p. 3, 10).

Outokumpu produced 700 t of cobalt at its Harjavalta nickel refinery (Outokumpu Oyj, 2000). Raw materials for the nickel refinery were imported from Western Australia and elsewhere. All of the cobalt produced at Harjavalta was further processed at OM Group's Kokkola refinery.

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 continued its exploration program in Indonesia (Reuters Ltd., 1999), Weda Bay Minerals Inc. of Vancouver continued with exploration activities and bench-scale metallurgical testwork on nickel laterites from Halmahera Island (Weda Bay Minerals Inc., 2000, p. 5-6), and BHP World Minerals, a division of Broken Hill Proprietary Co. Ltd., continued an exploration drilling program and studied the environmental and social impacts of developing a lateritic nickel prospect on Gag Island (Broken Hill Proprietary Co. Ltd., 1999).

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. Although not a large cobalt producing country, Japan is a significant cobalt consumer. A review of the Japanese cobalt market showed an increase in cobalt consumption from approximately 4,300 t/yr in 1990 to an estimated 7,500 t/yr in 1999. The increase in consumption was attributed to the rapid growth of cobalt to make rechargeable batteries for various devices including camcorders, cellular phones, notebook computers, and power tools. Cobalt consumption by Japanese battery manufacturers was estimated to grow from approximately 200 t to 300 t in 1990 to approximately 3,400 t in 1999 (Terada, 2000).

Mexico.—International Curator Resources Ltd. of Vancouver

continued to evaluate its Boleo project, which was based on a copper-cobalt deposit near Santa Rosalia, Baja California. As part of the evaluation, efforts were made to simplify the metallurgical process and reduce capital and operating costs. In early 2000, International Curator determined that the economic viability of developing the Boleo property was uncertain and placed the project on care and maintenance (International Curator Resources Ltd., 2000, p. 1, 4).

Morocco.—Cie. de Tifnout-Tiranimine (CTT) 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). In 1999, CTT's production of cobalt cathode was nearly twice that of 1998 (Cobalt Development Institute, 2000).

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.

In October, Inco commissioned a pilot plant at its Goro nickel-cobalt project in southern New Caledonia. The plant was built to test the proprietary pressure acid leaching-solvent extraction process that Inco developed to treat lateritic ores from Goro. Inco expected to make a decision on whether to build a commercial refinery at Goro as early as the second half of 2000. The refinery would be built in one or two stages, with a full capacity of 54,000 t/yr of nickel and 5,400 t/yr of cobalt. Initial production could begin within 3 years after construction is started. The project was 85% owned by Inco, with the remainder owned by Bureau de Recherches Géologiques et Minières, a French Government agency (Inco Ltd., 2000b).

Argosy Minerals Inc., formed by a merger of Calliope Metals Corp. and Argosy Mining Corp., continued to study the feasibility of developing the Nakety nickel-cobalt laterite deposits on the east coast of New Caledonia. The project, which would be developed as a joint venture with Société des Mines de la Tontouta and third parties, would use pressure acid leaching technology (Argosy Minerals Inc., 2000).

Norway.—In 1999, Falconbridge produced a record 4,010 t of cobalt at its Nikkelverk refinery, a 4% increase from the 3,851 t produced in 1998. The refinery processed matte from the company's smelter in Sudbury and BCL Ltd. in Botswana. Thirty percent of the cobalt produced at Nikkelverk originated from Falconbridge mines in Canada and 70% originated from custom feeds. Custom feeds were defined as feeds that did not originate at Falconbridge mines and included smelter matte and scrap (Falconbridge Ltd., 2000a, p. 20; 2000b, p. 15).

Papua New Guinea.—Highlands Pacific Ltd. proceeded with permitting and awarded an engineering, procurement, and construction contract for the Ramu River nickel-cobalt laterite project. On the basis of a feasibility study completed in 1998, the project was expected to produce 33,000 t/yr of nickel metal and 3,200 t/yr of cobalt as cobalt sulfate. In November, Nord Pacific Ltd. agreed to sell its share in the project to Orogen Minerals Ltd. Highlands Pacific and Orogen each intended to

sell some of their equity to a third party (Highlands Pacific Ltd., 1999a, b).

Philippines.—Lateritic nickel ore from the Philippines was exported to QNI's Yabulu refinery for processing (Reuters Ltd., 1999). Philnico Mining and Industrial Corp. continued to study the feasibility of converting the Nonoc nickel-cobalt refinery in Surigao del Norte, Nonoc Island, from an ammonia leach process to a pressure acid leach process (Metal Bulletin, 1999d).

Russia.—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 and nickel laterite ores, and imported nickel- and cobalt-bearing secondary materials. Refined cobalt was produced at four locations—the Norilsk Nickel Joint Stock Co. (RAO Norilsk Nickel) 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).

Russian cobalt production was 3.5% higher in 1999 than in 1998. Norilsk Nickel produced most of Russia's cobalt. The company's production of cobalt in marketable products increased by 7.6% in 1999 compared with that of 1998. During the year, Norilsk's Severonickel refinery in Murmansk began producing cobalt carbonate, and the company's Norilsk combine restarted production of cobalt sulfate (Interfax Mining & Metals Report, 1999, 2000; RAO Norilsk Nickel, 1999b, 2000).

In April, Norilsk Nickel's board of directors approved a 10-year development plan for its production units. The emphasis of the plan was to cut production costs rather than increase output. The estimated cost of implementation was between \$3 billion and \$5 billion, with capital investment to be distributed as follows: development of exploration and mining operations, 42%; infrastructure, defined as mainly energy and heating supply, 25%; metallurgical processing units, 17%; and ore beneficiation complex, 16%. As part of the plan, Norilsk intended to concentrate its nonferrous metals production in the Taimyr Peninsula of the Norilsk region, and gradually curtail metallurgical processing on the Kola Peninsula. Norilsk's plans for the nickel plants on the Taimyr Peninsula were as follows: to develop the smelting capacity of the Nadezhdinsky metallurgical works to process all of the company's nickel concentrates; close or substantially restructure the agglomeration plant and the Nikel works, where cobalt metal and nickel cathode are produced; restructure the hydrometallurgical section of Nadezhdinsky and commission a new cobalt and nickel refining complex. At Kola, the metallurgical plants would discontinue processing ore from the Norilsk region in favor of locally mined ores. The company also planned to broaden the range of cobalt salts, copper rolled products, and nickel powders produced at Kola (RAO Norilsk Nickel, 1999a, b).

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 102 t of cobalt in concentrates from the Nkomati nickel sulfide mine in Mpumalanga Province (Anglovaal Mining Ltd., 2000). Union Mineral Concentrators Pty., a Union Minière subsidiary, produced cobalt compounds from low-grade cobalt-containing residues in Roodepoort, near Johannesburg.

Uganda.—In June, Banff Resources Ltd., of Vancouver finished building its Kasese cobalt refinery in southwestern Uganda. The refinery was designed to use bacteria to leach cobalt from stockpiled pyrite concentrates. During advanced commissioning Banff determined that insufficient air dispersal to the biooxidation tanks was reducing the rate of cobalt recovery. To solve this problem, Banff began reengineering the air spargers and agitators. In late October, a manufacturing defect was found in the turbines of the hydroelectrical powerplant that had been built as part of the Kasese project. Banff planned to obtain power from the Ugandan power grid and from four diesel generators while new turbine parts were manufactured. In order to address these mechanical and manufacturing issues, Banff revised its production ramp-up schedule. By yearend, Banff had produced 77 t of cobalt cathode (Banff Resources Ltd., 1999a, b; Cobalt Development Institute, 2000).

Zambia.—During calendar year 1999, cobalt production was 3,946 t, a 21% decrease from the 5,011 t produced in 1998. This included production from ZCCM; Chambishi Metals Plc, an Avmin subsidiary; and Roan Antelope Mining Corp. (RAMC), a subsidiary of Binani Industries Ltd. (Cobalt Development Institute, 2000).

RAMC produced copper and cobalt from the Baluba and the Luanshya Mines. The company planned to develop the Muliashi North deposit as an open pit mine, with an output of 40,000 t/yr of copper and 1,400 t/yr of cobalt. RAMC hoped that earnings from Muliashi North would offset losses sustained at Luanshya and Baluba. According to press reports, RAMC operations suffered from industrial unrest and shortages of power and supplies as a result of financial problems during the year (Metal Bulletin, 1999c, 2000b; Business Day, May 31, 1999, Zambian copper mine construction to start, accessed March 21, 2000, at URL <http://www.bday.co.za/99/0531/world/w17.htm>).

Approximately 100 t of cobalt was produced from the Chibuluma West Mine. The mine is 85% owned by Metorex Ltd., a subsidiary of Crew Development Corp., and 15% owned by ZCCM (Crew Development Corp., 2000).

Chambishi Metals Plc rehabilitated, modernized, and upgraded the Chambishi cobalt plant. Production from the plant was from the toll treatment of concentrates from RAMC and ZCCM's Nchanga and Nkana divisions. In July, Chambishi Metals began construction on a new smelter and matte leach facility at the plant. The facility was scheduled to begin treating slag from the Nkana dump in late 2000. Production from slag was forecast at 4,500 t/yr of cobalt and 10,000 t/yr of copper. This would be in addition to the 2,500 t/yr of cobalt and 10,000 t/yr to 15,000 t/yr of copper produced by toll treating concentrates (Anglovaal Mining Ltd., 1999b, 2000).

In November, Avmin presented the results of a 2-year exploration program and prefeasibility study on the Konkola North prospecting area to officials from the Government of the Republic of Zambia and ZCCM. Discussions on the next phase of work were to begin after the presentation (Anglovaal Mining Ltd., 1999a).

ZCCM continued to work towards privatizing its remaining assets. In October, Zambia Copper Investments Ltd. (ZCI), a subsidiary of Anglo American, entered into an agreement with the Government of the Republic of Zambia and ZCCM. Under the agreement, ZCI and partners would acquire an 80% interest in the assets of ZCCM's Konkola division, including the Konkola Deep mining project; Nchanga division, including the Chingola refractory ore stockpiles; and Nampundwe pyrite mine. The acquisition was to be made through the formation of a new company. The new company would also have an option to acquire ZCCM's Nkana smelter and refinery, which would be managed by Anglo American during the option period. The sale was completed on March 31, 2000, with the formation of Konkola Copper Mines Plc (65% owned by ZCI, 20% by ZCCM, and 7.5% each by Commonwealth Development Corp. and the International Finance Corp.) (Anglo American Plc, 1999; Mining Journal, 2000).

In December, a consortium comprising First Quantum Minerals Ltd. and Glencore International AG entered into negotiations to acquire ZCCM's Mufulira division and certain assets of the Nkana division. The Mufulira division consists of a mine, concentrator, smelter, and refinery. The Nkana assets included in the agreement were the mines, concentrator, and cobalt plant, but not the smelter, refinery, and acid plant. On March 31, 2000, ZCCM completed the sale by transferring the assets to Mopani Copper Mines Plc, which was to be 90% owned by First Quantum and Glencore and 10% owned by ZCCM (First Quantum Minerals Ltd., 1999, 2000a, b; Mining Journal, 2000).

Outlook

World cobalt production is expected to continue to increase. Recently commissioned projects in Australia and Uganda plan to ramp up their production during the next few years and output from established producers is likely to increase from 1999 levels. In addition, there are numerous projects in the prefeasibility, feasibility, or development stage for production of cobalt in Africa, the Asia/Pacific region, and North America. In nearly all of the proposed projects in the Asia/Pacific region, cobalt would be produced as a byproduct of nickel. Progress on these projects will depend more on the nickel market than on the cobalt market.

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 2000) 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.

Future cobalt demand will dictate how much additional cobalt the market can bear. The battery and superalloy industries

continue to be cited as examples of industries that will consume increased amounts of cobalt in the future (Burstow, 2000; Kielty, 2000; Southwood and Gray, 2000). The general consensus, however, is that the increase in cobalt supply will be at a greater rate than the increase in demand, and that a resulting surplus will put downward pressure on cobalt prices. Several analysts have forecast that prices will drop to the \$6 to \$10 per pound range in 2 to 5 years (Agoos, 1999; Burstow, 2000; Searle, 2000; Southwood and Gray, 2000).

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TABLE 1
SALIENT COBALT STATISTICS 1/

(Metric tons cobalt content, unless otherwise specified)

	1995	1996	1997	1998	1999
United States:					
Consumption:					
Reported	7,590	7,990	8,910	9,130 r/	8,420
Apparent	8,970	9,380	11,200	11,500	10,700
Imports for consumption	6,440	6,710	8,430	7,670	8,150
Exports	1,300	1,660	1,570	1,680	1,550
Stocks, December 31:					
Industry 2/	822	794	763	750	739
U.S. Government 3/	20,700	18,700	17,100	14,700	13,200
Price: Metal, per pound					
Average U.S. spot cathode 4/	\$29.21	\$25.50	\$23.34	\$21.43	\$17.02
Yearend producer 5/	\$27.50	\$27.50	\$27.50	\$27.50	\$27.50
World production:					
Mine	24,500 r/	26,200	27,100	35,300 r/	29,900
Refinery	23,300	25,600	27,000	30,800 r/	31,200

r/ Revised.

1/ Data are rounded to no more than three significant digits, except prices.

2/ Stocks held by cobalt processors and consumers.

3/ Defense National Stockpile Center. 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)

	1998	1999
Sales:		
Fiscal year 2/	2,510	1,960
Calendar year	1,950	2,230
Shipments: 3/		
Fiscal year 2/	2,580	1,670
Calendar year	2,310	1,530

1/ Data are rounded to no more than three significant digits.

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

3/ Calculated from year end inventory levels.

Source: Defense National Stockpile Center.

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

(Metric tons cobalt content)

	1998	1999
Consumption by end use:		
Steels	147	154
Superalloys	4,060 r/	3,830
Alloys (excludes steels and superalloys):		
Magnetic alloys	771	794
Other alloys 3/	421	291
Cemented carbides 4/	844	755
Chemical and ceramic uses	2,830	2,530
Miscellaneous and unspecified	63 r/	64
Total	9,130 r/	8,420
Consumption by form:		
Chemical compounds (organic and inorganic) 5/	1,860	1,910
Metal	4,180 r/	3,780
Purchased scrap	3,080	2,720
Total	9,130 r/	8,420
Stocks, December 31: 6/		
Chemical compounds (organic and inorganic) 5/	306	251
Metal	356	322
Purchased scrap	89	165
Total	750	739

r/ Revised.

1/ Data are rounded to no more than 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 oxides.

6/ Stocks held by cobalt processors and consumers.

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

(Metric tons, unless otherwise specified)

	1998	1999
Metal: 2/		
Gross weight	6,450	6,800
Cobalt content 3/	6,450	6,800
Value thousands	\$284,000	\$229,000
Oxides and hydroxides:		
Gross weight	1,210	1,260
Cobalt content 3/	868	910
Value thousands	\$41,500	\$33,700
Other forms:		
Acetates:		
Gross weight	231	158
Cobalt content 3/	55	38
Value thousands	\$2,460	\$1,270
Carbonates:		
Gross weight	18	58
Cobalt content 3/	8	27
Value thousands	\$419	\$548
Chlorides:		
Gross weight	22	35
Cobalt content 3/	6	9
Value thousands	\$292	\$702
Sulfates:		
Gross weight	1,040	1,360
Cobalt content 3/	281	366
Value thousands	\$10,400	\$9,840
Total:		
Gross weight	8,970	9,670
Cobalt content 3/	7,670	8,150
Value thousands	\$339,000	\$275,000

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Unwrought cobalt, excluding alloys and waste and scrap.

3/ Estimated from gross weights.

Source: U.S. Census Bureau, 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 (thousands)	Gross weight (metric tons)	Cobalt content 4/ (metric tons)	Value (thousands)	Gross weight (metric tons)	Cobalt content 4/ (metric tons)	Value (thousands)	Gross weight (metric tons)	Cobalt content 4/ (metric tons)	Value (thousands)
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												
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
1999:												
Belgium	144	144	6,720	264	190	7,620	--	--	--	408	334	14,300
Brazil	188	188	5,300	--	--	--	--	--	--	188	188	5,300
Canada	801	801	25,200	(6/)	(6/)	5	15	7	303	815	807	25,500
China	--	--	--	30	22	687	6	2	82	36	24	769
Congo												
(Kinshasa) 5/	1,090	1,090	37,700	--	--	--	--	--	--	1,090	1,090	37,700
Finland	1,130	1,130	37,600	609	438	15,300	1,490	397	10,900	3,230	1,970	63,800
France	45	45	3,490	54	39	2,620	2	1	21	101	85	6,130
Germany	86	86	3,320	78	56	2,500	18	5	131	182	147	5,950
Japan	57	57	3,140	1	(6/)	43	(6/)	(6/)	6	58	57	3,190
Netherlands	--	--	--	--	--	--	32	8	646	32	8	646
Norway	1,550	1,550	48,800	--	--	--	--	--	--	1,550	1,550	48,800
Russia	733	733	22,900	--	--	--	(6/)	(6/)	4	733	733	22,900
South Africa	7	7	370	--	--	--	2	(6/)	14	8	7	384
United Kingdom												
Kingdom	85	85	3,030	228	164	4,900	46	20	239	359	269	8,180
Zambia	879	879	31,100	--	--	--	--	--	--	879	879	31,100
Other	(6/)	(6/)	37	(6/)	(6/)	12	--	--	--	1	1	49
Total	6,800	6,800	229,000	1,260	910	33,700	1,610	440	12,400	9,670	8,150	275,000

-- Zero.

1/ Data are rounded to no more than 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: U.S. Census Bureau, minor adjustments by the U.S. Geological Survey.

TABLE 6
U.S. EXPORTS OF COBALT IN 1999, 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	3	\$64	14	\$127	--	--	--	--	13	\$191
Belgium	562	19,400	63	1,430	--	--	30	\$651	615	21,500
Brazil	9	284	34	425	74	\$735	--	--	51	1,440
Canada	120	3,360	29	825	45	346	20	205	157	4,730
France	83	3,600	6	42	--	--	--	--	87	3,640
Germany	40	2,230	45	573	7	17	--	--	74	2,820
Greenland	--	--	15	101	--	--	--	--	11	101
Hong Kong	24	712	20	241	--	--	--	--	38	953
Italy	2	85	25	399	--	--	--	--	20	484
Japan	40	1,330	52	723	--	--	--	--	78	2,060
Korea, Republic of	6	272	12	172	--	--	(6/)	5	14	448
Mexico	6	312	26	841	98	988	1	22	48	2,160
Netherlands	23	757	61	947	--	--	--	--	68	1,700
Poland	--	--	--	--	20	62	--	--	5	62
Singapore	3	135	39	74	(6/)	6	--	--	30	214
Taiwan	9	326	18	172	--	--	1	13	22	511
Thailand	4	57	17	149	--	--	--	--	17	206
United Arab Emirates	6	280	(6/)	10	6	10	--	--	8	300
United Kingdom	116	3,880	4	249	--	--	1	12	119	4,140
Other	45	1,390	41	640	1	22	1	8	75	2,060
Total	1,100	38,400	521	8,140	253	2,180	54	916	1,550	49,700

-- Zero.

1/ Data are rounded to no more than 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: U.S. Census Bureau, minor adjustments by the U.S. Geological Survey.

TABLE 7
WORLD ANNUAL COBALT REFINERY CAPACITY
DECEMBER 31, 1999 1/ 2/

(Metric tons cobalt content)

Country	Capacity
Australia	2,000
Belgium	1,200
Brazil	800
Canada	5,100
China e/	1,500
Congo (Kinshasa) 3/	17,000
Finland	10,000
France	300
Japan	480
Morocco e/	1,000
Norway	4,500
Russia e/	8,000
South Africa e/	1,000
Zambia	5,000
Total	57,900

e/ Estimated.

1/ Data are rounded to no more than three significant digits; may not add to total shown.

2/ Refinery products include cobalt metal, metal powder, oxides, and/or salts.

3/ Formerly Zaire.

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

(Metric tons cobalt content)

Country 3/	1995	1996	1997	1998	1999 e/
Australia e/ 4/	2,500	2,800	3,000	3,300	4,100
Botswana 5/	271	408	334	335 e/	335
Brazil e/	400	400	400	400	700
Canada 6/	5,339	5,714	5,709	5,861 r/	5,324 7/
China e/	980	190	200	40 r/	100
Congo (Kinshasa) e/ 8/ 9/	1,670 r/	2,000	3,500	6,000 r/	7,000
Cuba 10/	1,591	2,011	2,082	2,200	2,160
Kazakhstan e/ 11/	300	300	300	300	300
Morocco 9/	537	565	714	287	300
New Caledonia e/ 12/	1,100	1,100	1,000	1,000	1,100
Russia e/	3,500	3,300	3,300	3,200	3,300
South Africa e/	288	350	400 r/	370 r/	380
Zambia 9/ 13/	5,908	6,959	6,037 r/	11,900 r/	4,700
Zimbabwe e/ 14/	109 r/	106 r/	126 r/	137 r/	140
Total	24,500 r/	26,200	27,100	35,300 r/	29,900

e/ Estimated. r/ Revised.

1/ World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ Table includes data available through June 23, 2000. 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, Indonesia, 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/ Quantities of cobalt contained in intermediate or refined metallurgical products 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: 1995--1,300; 1996--1,400; 1997--1,600; 1998--4,000 (revised); and 1999--7,000.

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

6/ 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: 1995--2,016; 1996--2,150; 1997--2,168; 1998--2,262 (revised); and 1999--2,015.

7/ Reported figure.

8/ Formerly Zaire.

9/ Cobalt content of concentrates.

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

11/ 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: 1995-99--1,400.

12/ 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: 1995--12,000; 1996--12,200; 1997--13,600; 1998--12,900; and 1999--12,200.

13/ Fiscal year beginning April 1 of that stated.

14/ Cobalt content of intermediate products produced in Zimbabwe from ores originating in Botswana and Zimbabwe.

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

(Metric tons, cobalt content)

Country 3/	1995	1996	1997	1998	1999 e/
Australia: Metal (including metal powder) and oxide hydroxide	--	--	617	1,395	1,700
Belgium: Metal powder, oxide, hydroxide e/	1,200	1,200	1,200	1,200	950
Brazil: Metal	166	193	266	364	630 4/
Canada: Metal (including metal powder) and oxide	3,259	3,601	3,792	4,415 r/	4,187 4/
China: Metal e/	240	230	470	410 r/	400
Congo (Kinshasa): Metal 5/ 6/	3,422	3,540	2,808	4,490	5,000
Finland: Metal powder and salts	3,610	4,160	5,000	5,250	6,200 4/
France: Chloride	161	174	159	172	181 4/
Japan: Metal	227	258	264	329	221
Morocco: Metal	--	80	220	241 r/	470
Norway: Metal	2,804	3,098	3,417	3,851	4,009 4/
Russia: Unspecified e/	4,450	4,200	4,100	3,500	3,600
South Africa: Metal powder and sulfate	190	244	318 r/	296	306 4/
Uganda: Metal	--	--	--	--	77 4/
Zambia: Metal 7/	3,577	4,612	4,403	4,837 r/	3,300
Total	23,300	25,600	27,000	30,800 r/	31,200

e/ Estimated. r/ Revised. -- Zero.

1/ World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ Table includes data available through June 23, 2000. 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/ Reported figure.

5/ Congo (Kinshasa) was formerly Zaire.

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

7/ Fiscal years beginning April 1 of that stated.