



2005 Minerals Yearbook

COBALT

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By Kim B. Shedd

Domestic survey data and tables were prepared by Jo-Ann S. Sterling, statistical assistant, and the world production tables were prepared by Linder Roberts, international data coordinator.

In 2005, world production of refined cobalt increased, primarily as a result of a significant increase in production from China. The United States did not mine or refine cobalt in 2005. However, a small number of mining operations produced negligible amounts of byproduct cobalt as intermediate products. Since 1993, sales of excess cobalt from the National Defense Stockpile (NDS) have contributed to U.S. and world supplies.

World demand for cobalt increased as a result of an increase in cobalt demand from the aerospace and land-based gas turbine industries and growth of cobalt use in rechargeable batteries and catalysts. U.S. apparent consumption of cobalt was greater than that of 2004. The overall trend in cobalt prices was downward, signifying that the supply of cobalt was more than sufficient to meet demand (Inco Ltd., 2006b, p. 18; Searle, 2006; Cobalt Development Institute and World Bureau of Metal Statistics, undated[§]).

Salient U.S. and world cobalt statistics for 2005 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.

Cobalt is a strategic and critical metal used in many diverse commercial, industrial, and military applications. Historically, the leading use of cobalt has been in superalloys, which are used to make parts for gas turbine engines. In recent years, rapid growth in the rechargeable battery industry has resulted in a significant increase in the use of cobalt to make battery electrodes, such that now, on a global basis, the battery and superalloy industries consume similar amounts of cobalt. Cobalt is also used to make airbags in automobiles; catalysts for the petroleum and chemical industries; cemented carbides (also called hardmetals) and diamond tools; corrosion- and wear-resistant alloys; drying agents for paints, varnishes, and inks; dyes and pigments; ground coats for porcelain enamels; high-speed steels; magnetic recording media; magnets; and steel-belted radial tires.

Legislation and Government Programs

During fiscal year 2005 (October 1, 2004, through September 30, 2005), the Defense National Stockpile Center (DNSC), U.S. Department of Defense, periodically offered cobalt under a basic ordering agreement (BOA). Cobalt was awarded each month except October and November. The DNSC sold 1,120 metric tons (t) of cobalt cathode, granules, and rondelles valued at \$37 million (table 2). This represented 41% of the 2,720-t (6-million-pound) maximum allowed for sale under the fiscal year 2005 Annual Materials Plan (AMP). As of the end of the fiscal year, 239 t of cobalt had been sold but not shipped from the stockpile. The

AMP for fiscal year 2006 (October 1, 2005, through September 30, 2006) maintained the maximum allowable sale of cobalt at 2,720 t (U.S. Department of Defense, 2006, p. 5, 8, 12, 56, 62).

During calendar year 2005, the DNSC made BOA awards each month except December. During this period, the DNSC sold 880 t of cobalt valued at \$26.9 million. On December 31, the total uncommitted cobalt inventory held by the DNSC was 1,480 t of cobalt cathode. Although the DNSC had authority to sell the remaining cobalt inventory, the agency suspended sales in December until it determined whether the cobalt was needed by the military (Platts Metals Week, 2006).

The Public Health Service released the 11th edition of the "Report on Carcinogens," a document that lists all substances that are either known to be human carcinogens or may reasonably be anticipated to be human carcinogens and to which a significant number of persons residing in the United States are exposed. Cobalt sulfate was listed as reasonably anticipated to be a human carcinogen based on sufficient evidence of carcinogenicity in experimental animals (Public Health Service, 2005, 2005[§]).

Production

With the exception of negligible amounts of byproduct cobalt produced from lead, platinum-group metal (PGM), and zinc operations, the United States did not mine or refine cobalt in 2005. Cobalt-bearing nickel sulfate produced from Stillwater Mining Co.'s PGM mining and refining operations in southeastern Montana was sold to several companies. Some of southeastern Missouri's lead ores contained minor amounts of cobalt. Big River Zinc Corp.'s refinery in Sauget, IL, recovered cobalt from zinc sulfide concentrates mined in southeastern Missouri, Tennessee, and overseas. Zinc refining operations at Sauget were scheduled to cease in early 2006 (Korea Zinc Co., Ltd., 2006, p. 6; Big River Zinc Corp., undated a[§], b[§]).

In 2005, there were three U.S. mine projects in the feasibility and permitting stages of development that planned to produce cobalt—Formation Capital Corp.'s Idaho cobalt project, PolyMet Mining Corp.'s NorthMet project, and Kennecott Minerals Co.'s Eagle project.

Formation planned to develop an underground cobalt-copper-gold mine and mill complex in the Idaho Cobalt Belt in Lemhi County, ID, and retrofit its hydrometallurgical refinery in Big Creek, ID, to refine the cobalt concentrates produced. The retrofitted refinery was to have the capacity to produce approximately 1,500 metric tons per year (t/yr) of cobalt as cathode and/or cobalt compounds. Formation expected to receive final permits for the mine during the last quarter of 2006 or the first quarter of 2007 and hoped to complete mine construction and begin production approximately 1 year after receiving the permits (Formation Capital Corp., 2004, p. 10; 2006, p. 2).

[§]References that include a section mark (§) are found in the Internet References Cited section.

PolyMet planned to mine the NorthMet polymetallic deposit in the Duluth Complex of northeastern Minnesota by open pit methods. Ore would be treated at the nearby Cliffs-Erie mill and concentrator to produce a bulk concentrate, which would be processed in a new hydrometallurgical plant using the company's PlatSol technology. PolyMet would produce copper cathode, either a nickel-cobalt-zinc hydroxide or cobalt, nickel, and zinc hydroxides, and a precipitate of PGMs and gold. At a production rate of 25,000 metric tons per day of ore, approximately 375 t/yr of cobalt could be produced. PolyMet hoped to begin commercial production in mid 2008 (PolyMet Mining Corp., 2005, p. 20; 2006, p. 8, 13; Dreisinger and others, 2006, p. 18-19).

Kennecott planned to develop a small underground nickel-copper mine in the Eagle deposit in the Yellow Dog Plains area northwest of Marquette, MI. The company would crush ore at the mine site and then send the crushed ore to an offsite processor. The Eagle deposit was a high-grade magmatic sulfide with indicated and inferred resources totaling 4 million metric tons (Mt) grading 3.57% nickel, 2.91% copper, 0.10% cobalt, and 0.28 grams per metric ton (g/t) gold (Foth & Van Dyke and Associates, Inc., 2006, p. 1, 17).

U.S. processors made cobalt chemicals and cobalt metal powders from refined cobalt materials and/or cobalt-bearing scrap. U.S. Geological Survey (USGS) data on chemical and metal powder production, shipments, and stocks were derived from a monthly voluntary survey of U.S. cobalt processors. Information from this survey was used to prepare the statistics on cobalt consumption and stocks in table 3. Five of the seven cobalt processors on this survey provided data. Estimates were made for plants for which data were not provided. Two processors made extra-fine cobalt metal powder in the United States. Carolmet Cobalt Products (a division of n.v. Umicore s.a.) made cobalt metal powder from cobalt metal at its Laurinburg, NC, plant. Osram Sylvania Inc. produced cobalt metal powder as a byproduct of tungsten recovered from cemented carbide scrap in Towanda, PA. Production and shipments of cobalt metal powder are withheld to avoid disclosing company proprietary data. In 2005, Umicore set up a new recycling unit at its facility in Arab, AL (n.v. Umicore, s.a., 2006, p. 4).

Consumption

U.S. apparent consumption for 2005, as calculated from net imports, consumption from purchased scrap, and changes in Government and industry stocks, was 20% greater than that calculated for 2004 (table 1). The increase in consumption was met primarily by an increase in imports.

U.S. reported consumption of cobalt in 2005 was approximately equal to that of 2004. Compared with 2004, metallurgical industries consumed 3% more cobalt, and the cobalt consumption for chemical uses was 8% lower. 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 cemented carbide, magnetic alloy, and superalloy producers. For this survey, nearly 70 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.

Prices

U.S. spot price ranges for cathode (minimum of 99.8% cobalt), as reported by Platts Metals Week, generally trended downward during the year. The highest price, at a range of \$19.25 to \$19.75 per pound, was reported in mid-January, and the lowest price, at a range of \$12.05 to \$13.30 per pound, was reported in early November. The annual average U.S. spot cathode price for 2005 was \$15.96 per pound, down by 33% from that of 2004 (table 1). Trends in Platts' prices for Zambian cobalt (minimum 99.6% cobalt) and Russian cobalt (minimum 99.3% cobalt) were similar to those for U.S. spot cathode. The annual average of weekly prices for Zambian cobalt was \$15.06 per pound, and the annual average of weekly prices for Russian cobalt was \$14.62. Sales prices for 99.8% cobalt cathode reported by BHP Billiton ranged from \$12.10 to \$19.25 per pound.

Foreign Trade

Net import reliance as a percentage of apparent consumption is used to measure the adequacy of current domestic production to meet U.S. demand. Net import reliance was defined as imports minus exports plus adjustments for Government and industry stock changes. Releases from stocks, including shipments from the NDS, were counted as part of import reliance, regardless of whether they were imported or produced in the United States. In 2005, net import reliance as a percentage of apparent consumption was 83%. Because there was no measurable U.S. primary cobalt production in 2005, this indicates that 83% of U.S. cobalt supply was from imports and stock releases of primary cobalt and 17% was from scrap, which would have been generated domestically or imported.

The following discussion of cobalt imports is based on cobalt contained in metal, including metal powder, and chemicals. In 2005, the United States imported 27% more cobalt than it did in 2004 (tables 4, 5). Ten countries supplied 91% of U.S. imports. Norway was the leading supplier, followed by Russia, Finland, China, Zambia, Canada, Belgium, Morocco, Australia, and Brazil. Compared with those of 2004, cobalt imports from Brazil, China, Finland, Morocco, Norway, Russia, and Zambia increased, and imports from Australia, Belgium, and Canada decreased.

In 2005, the United States imported 101 t, gross weight, of unwrought cobalt alloys valued at \$2.7 million. Five countries supplied most of these materials—Norway (39%), the United Kingdom (38%), Japan (13%), China (5%), and Germany (3%). The United States imported 815 t, gross weight, of cobalt waste and scrap valued at \$7.9 million. Eight countries supplied most of this material—the United Kingdom (20%), Canada and Ireland (17% each), France (13%), Germany (11%), India (7%), and Austria and Japan (6% each). The United States also imported 256 t, gross weight, of wrought cobalt and cobalt articles valued at \$17.7 million. The leading suppliers of these materials were the United Kingdom (59%), Japan (10%), Canada (9%), Germany (8%), and Australia and France (6% each).

U.S. exports of unwrought cobalt and cobalt contained in chemicals decreased by 3% compared with those of 2004. As listed in table 6, more than 90% of the cobalt metal and chemical exports was shipped to nine countries—Belgium,

Canada, France, Germany, Ireland, Japan, Mexico, Singapore, and the United Kingdom. The remainder was shipped to 39 other countries.

Exports also included 2,340 t, gross weight, of wrought metal and cobalt articles valued at \$91.8 million. More than 90% of these materials was sent to 9 countries—the United Kingdom (26%), Belgium (24%), France (15%), Japan (9%), Germany (8%), Ireland (3%), and Canada, the Republic of Korea, and Switzerland (2% each). The remainder was shipped to 48 other countries.

World Industry Structure

Historically, most of the world's cobalt was produced as a byproduct of copper, nickel, or other metals. Until recently, Morocco was identified as the only country where cobalt was produced as the principal (primary) product of a mining operation. The artisanal mining of the cobalt mineral heterogenite in Congo (Kinshasa), which has increased since the late 1990s, should be considered primary cobalt production. The recovery of cobalt from previously stockpiled intermediate materials (for example, slags) could be classified either as primary production, in that the materials are processed primarily to recover the cobalt, or as byproduct production, because the materials were originally produced as a byproduct of copper mining and refining. Thus, the percentage of cobalt produced as a primary product will depend on how the production is categorized, but may have represented more than one-half of world cobalt production in 2005 (Cobalt Development Institute, 2006a; Searle, 2006).

Refinery capacity by country is listed in table 7. Plants that processed 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.

World Review

Australia.—QNI Pty. Ltd. (a subsidiary of BHP Billiton) processed lateritic ore imported from Indonesia, New Caledonia, and the Philippines at its Yabulu nickel-cobalt refinery in Townsville, Queensland, and produced 1,400 t of cobalt as cobalt oxide hydroxide, 26% less than the 1,900 t produced in 2004. During the year, the company worked on building a nickel-cobalt laterite mine and front-end acid leaching plant at Ravensthorpe on the southern coast of Western Australia and expanding the Yabulu refinery to accommodate the intermediate material produced from Ravensthorpe. The expanded refinery was to have the capacity to produce 76,000 t/yr of nickel and 3,500 t/yr of cobalt. It would continue to process imported lateritic ore, but Ravensthorpe was to supply as much as 50,000 t/yr of nickel and 1,400 t/yr of cobalt in nickel-cobalt mixed hydroxide. The first shipment of mixed hydroxide was scheduled for the second quarter of 2007, and the first nickel metal production from the expanded Yabulu refinery was scheduled for the third quarter of 2007 (Cobalt Development Institute, 2006c; BHP Billiton, 2006, 2004§).

In August, BHP Billiton acquired WMC Resources Ltd. and renamed the former WMC nickel producing assets Nickel West. Nickel West produced cobalt in intermediate nickel-cobalt mixed sulfide at its Kwinana nickel refinery in Western Australia.

The refinery processed matte from Nickel West's Kalgoorlie smelter, which was produced from nickel sulfide concentrates from ores mined in Western Australia by Nickel West and other companies. Nickel West's mixed sulfide was refined in Norway by Falconbridge Ltd. under a tolling agreement, and the resulting cobalt cathode was offered for sale by WMC Resources Marketing Ltd. on BHP Billiton's Web site. Nickel West also sold nickel concentrates and matte (BHP Billiton, undated§).

Minara Resources Ltd. produced 1,750 t of cobalt as metal powder and briquettes from its Murrin Murrin nickel-cobalt laterite pressure-acid leaching operation east of Leonora in Western Australia, 12% less than the 1,979 t produced in 2004. Production was impacted by a planned 3-week plant-wide shutdown, delays in restarting the hydrogen sulfide plant after planned shutdowns, and a failure in the acid plant. While continuing to work on improving plant performance at Murrin Murrin, Minara decided to build a demonstration plant to recover nickel and cobalt by heap leaching stockpiled ore reject material. The plant's capacity was to be 2,000 t/yr of nickel and 120 t/yr of cobalt (Cobalt Development Institute, 2006c; Minara Resources Ltd., 2006, p. 6-7, 27).

OM Group, Inc. (OMG) shipped intermediate nickel hydroxide produced from its Cawse plant, northwest of Kalgoorlie in Western Australia, to Finland for refining. Output from the plant, which used pressure acid leaching to treat lateritic ore, was expected to supply approximately 8,000 t/yr of nickel to Harjavalta and 800 t/yr of cobalt to Kokkola (OM Group, Inc., 2001; Reuters Ltd., 2002).

Sally Malay Mining Ltd. mined nickel sulfide ores in the East Kimberly District of Western Australia and produced concentrates containing 426 t of cobalt. The concentrates were shipped to Jinchuan Group Ltd. under a life-of-mine sales agreement (Sally Malay Mining Ltd., 2005a, b).

Fox Resources Ltd. mined nickel sulfide ores from the Radio Hill Mine near Karratha in Western Australia and shipped concentrates to Jinchuan Group Ltd.'s operations in Gansu Province, China. Fox studied the feasibility of using the BioHeap bacterial oxidation heap-leaching process to treat disseminated nickel sulfide ores from Radio Hill and the nearby Sholl nickel sulfide deposit (Fox Resources Ltd., 2005, p. 9, 19).

In addition to the production discussed above, cobalt-bearing nickel sulfide concentrates produced from several operations in Australia were exported to Inco Ltd. in Canada, as discussed in the "Canada" portion of the "World Review" section of this report. WMC's contract to supply nickel sulfide concentrates from its Mt. Keith operations to OMG in Finland expired in March (WMC Resources Ltd., 2005, p. 28).

Zinifex Ltd. shipped zinc concentrates produced at its Century Mine in northern Queensland to the Budel smelter in the Netherlands, where approximately 25 t of cobalt was recovered as filter cake (Bowyer, 2003).

Allegiance Mining NL completed a feasibility study on an underground mine and concentrator at its Avebury nickel project in western Tasmania. Allegiance planned to begin production in 2007 at an initial rate of 28,800 t/yr of nickel sulfide concentrates grading more than 20% nickel and 0.4% cobalt. At yearend, Allegiance was in the final stages of negotiation with a potential partner that would provide financial and technical support and buy the concentrates (Allegiance Mining NL, 2006, p. 6, 11).

Compass Resources NL purchased the solvent extraction plant and much of the electrowinning plant that had been installed at the Cawse nickel laterite operation in Western Australia. These purchases allowed the company to decide to fast-track develop its Browns Oxide project in the Northern Territory, subject to final permits and funding. The company planned to use agitated sulfuric acid leaching followed by solvent extraction-electrowinning (SX-EW) to produce 10,000 t/yr of copper cathode, 1,000 t/yr of cobalt as a chemical precipitate, and 700 t/yr of nickel as a chemical precipitate (Compass Resources NL, 2005, 2006).

LionOre Mining International Ltd. studied the feasibility of converting the company's Avalon plant to treat nickel sulfide ores from the Honeymoon Well deposit in Western Australia by using the company's Activox hydrometallurgical process (LionOre Mining International Ltd., 2006, p. 9).

Gladstone Pacific Nickel Ltd. studied the feasibility of developing a nickel laterite mine at Marlborough and a high-pressure acid-leach refinery at the deepwater port city of Gladstone in Queensland. The company was considering developing the project in three stages. Stage I would produce approximately 30,000 t/yr of nickel metal briquettes and 1,400 t/yr of cobalt metal briquettes solely from Marlborough ore. Stage II production (60,000 t/yr of nickel and 3,800 t/yr of cobalt) would be supplemented by high-grade nickel laterite ore imported from the southwest Pacific region (Indonesia, New Caledonia, Papua New Guinea, the Philippines, and Solomon Islands). Stage III production (124,000 t/yr of nickel and 9,900 t/yr of cobalt) would be primarily from imported ore. Gladstone hoped to have the construction for stage I completed in 2009 (Gladstone Pacific Nickel Ltd., 2005§).

Sherlock Bay Nickel Corp. Ltd. reviewed a 2004 bankable feasibility study on developing the low-grade disseminated nickel sulfide ores from the Discovery and Symonds nickel sulfide deposits in Western Australia. The company determined that additional work was necessary to update the study, which evaluated the use of BioHeap bacterial leaching to produce approximately 8,500 t/yr of nickel, 1,200 t/yr of copper, and 100 t/yr of cobalt (Sherlock Bay Nickel Corp. Ltd., 2004, p. 9-13; 2005).

In mid-2004, Ivanplats Syerston Pty. Ltd. acquired the Syerston nickel-cobalt laterite project near Fifield in New South Wales from Black Range Minerals Ltd. Ivanplats proposed several modifications to the project, including an increase in the ore processing rate and the removal of the metals refinery from the processing plant. As modified, the project would produce 53,000 t/yr of nickel-cobalt mixed sulfide (New South Wales Government, 2005§).

Belgium.—Umicore converted cobalt metal, residues, and other cobalt-bearing materials into a wide range of cobalt specialty products, including metal powders, oxides, salts, and compounds. According to the Cobalt Development Institute (2006c), Umicore's 2005 cobalt refinery production was 3,298 t, 12% more than the 2,947 t produced in 2004. This production took place in plants in Olen, Belgium; south-central China; and Roodepoort, South Africa. In addition, Umicore produced specialty cobalt products at processing plants in Arab, AL, and Laurinburg, NC, in the United States; Leduc and Fort Saskatchewan, Alberta, Canada; Guangzhou and Shanghai, China; Subic, Philippines; and Cheonan, Republic of Korea.

Botswana.—LionOre decided to commercialize its Activox hydrometallurgical process by developing projects at the

Honeymoon Well deposit in Australia, the Nkomati joint venture in South Africa, and the Tati Nickel Mining Co. (Proprietary) Ltd. operation in Botswana. The first full-scale Activox refinery was to be built at Tati. LionOre planned to complete a feasibility study by the end of June 2006, so that it could begin construction in 2007 and commercial production in 2009. The refinery would produce an estimated 25,000 t/yr of nickel cathode as well as copper cathode and cobalt carbonate (LionOre Mining International Ltd., 2006, p. 8-12).

Brazil.—Cia. Niquel Tocantins (CNT) produced cobalt cathode at its refinery in Sao Miguel Paulista, Sao Paulo State, from lateritic nickel-cobalt ore mined from Niquelandia, Goias State. CNT has gradually expanded the refinery's capacity during the past few years.

Companhia Vale do Rio Doce (CVRD) approved the investment to develop the Niquel do Vermelho laterite deposits in the Carajas region of Para State. CVRD planned to build a high-pressure acid leaching plant with the capacity to produce 46,000 t/yr of nickel cathode and 2,800 t/yr of cobalt cathode. The project was expected to have a commercial life of 40 years, with production beginning in late 2008 (Companhia Vale do Rio Doce, 2005).

Canada.—Falconbridge produced 525 t of cobalt in concentrate from its Sudbury, Ontario, mines and 354 t of cobalt in concentrate from its Raglan Mine in Quebec. Nickel-copper matte produced at the Sudbury smelter was refined at the company's Nikkelverk refinery in Norway. In 2005, this matte contained 2,423 t of cobalt; 36% of the cobalt originated from ores produced at company mines, and 64% from custom feed materials, defined as feeds that did not originate from Falconbridge mines. The custom feed was primarily nickel-copper-cobalt secondary materials (scrap) and nickel concentrates. Some of the concentrates originated from nickel sulfide ores mined in Ontario by Canadian Arrow Mines Ltd. and First Nickel Inc. Falconbridge also processed some palladium concentrates containing minor amounts of cobalt from North American Palladium Ltd.'s Lac des Iles Mine in northern Ontario (Falconbridge Ltd., 2006, p. 22, 49-51).

According to the Cobalt Development Institute (2006c), Inco produced 1,563 t of cobalt in 2005, essentially the same amount as it produced in 2004. Approximately 85% of Inco's production was cathode from the company's Port Colborne, Ontario, refinery, and 15% was oxide from its Thompson, Manitoba, refinery. The cobalt originated from nickel sulfide ores from company mines at Sudbury (57%); nickel sulfide ores from company mines in Manitoba (19%); and purchased feedstocks (24%), including nickel sulfide ore from FNX Mining Co. Inc.'s Sudbury operations, nickel sulfide concentrates from Jubilee Mines NL's Cosmos nickel project and LionOre's Emily Ann Mine in Western Australia, and palladium concentrates from North American Palladium. In preparation for treating concentrates from Voisey's Bay, Inco worked on a project to double the cobalt capacity of its Thompson refinery (Inco Ltd., 2006a, p. 11, 24; 2006b, p. 18, 20, 56).

Inco completed construction of its Voisey's Bay nickel-copper-cobalt-sulfide mine and concentrator in northeastern Labrador and began commercial production. Shipments of nickel concentrates to Inco's Ontario and Manitoba operations began in November. The company expected to produce approximately 1,100 t of cobalt from Voisey's Bay nickel concentrates in 2006. When fully operational, production from Voisey's Bay was expected to

be 50,000 t/yr of nickel in concentrates containing 7,000 t/yr of copper and 2,300 t/yr of cobalt as well as 32,000 t/yr of copper in concentrates. In October, Inco completed construction and began operating a demonstration plant in Argentia, Newfoundland. The demonstration plant was for testing hydrometallurgical processes on Voisey's Bay concentrates. Inco planned to build and begin operating a commercial processing facility in the Province by the end of 2011. Once the commercial facility was operational, it would treat all of the concentrates from Voisey's Bay and produce finished nickel and cobalt products by using hydrometallurgical processing technologies, or if hydrometallurgical processing did not prove to be technically or economically feasible, by using conventional technologies (Inco Ltd., 2006b, p. 18, 48).

The Fort Saskatchewan refinery of the joint venture of Sherritt International Corp. and General Nickel Co. S.A. produced 3,391 t of cobalt as metal powder and briquettes in 2005, slightly more than the 3,325 t produced in 2004. Eighty-nine percent of the cobalt was from nickel-cobalt sulfides from the joint venture's operations at Moa Bay, Cuba; the remainder was from feed materials purchased from four suppliers. Sherritt and General Nickel agreed to expand their nickel-cobalt operations in Canada and Cuba. Construction at Fort Saskatchewan was to begin during the third quarter of 2006 so that commissioning could begin by the third quarter of 2008. As a result of a United States embargo on imports of products originating from Cuba, cobalt and nickel produced by Sherritt cannot be sold to customers in the United States (Sherritt International Corp., 2006, p. 3, 23, 26-27).

FNX produced nickel sulfide ore from its McCreedy West Mine containing 45 t of cobalt, compared with 36 t in 2004. The ore was processed by Inco (FNX Mining Co. Inc., 2006).

Fortune Minerals Ltd. studied the feasibility of developing the NICO gold-cobalt-bismuth deposit, 160 kilometers (km) northwest of Yellowknife in the Northwest Territories. Fortune was considering mining the deposit by open pit and underground methods and then producing gold-bismuth and gold-cobalt sulfide concentrates by mineral flotation. The gold-cobalt concentrate would be processed onsite by a hydrometallurgical process; 1,200 to 1,500 t/yr of cobalt cathode would be produced by SX-EW. During the year, Fortune conducted mini-pilot-plant tests of the proposed process and entered into an agreement to purchase the mill from Newmont Canada Ltd.'s Golden Giant Mine. Fortune planned to move the mill from its location at Hemlo, Ontario, and use it for processing the ores from the NICO deposit (Fortune Minerals Ltd., 2005; 2006, p. 4, 14).

Blue Earth Refineries Inc. held a 49.2% interest in 36569 Yukon Inc., which owned the cobalt refinery in Lorrain Township, Ontario, previously owned by Canmine Resources Corp. During the year, Blue Earth determined that the availability of cobalt feedstock for the refinery was very limited. As a result, the company was considering the following options for the refinery: using it to participate in the future gas-to-liquid catalyst market, dismantling and relocating it to South Africa where it would be closer to a supply of cobalt feedstock, using it to recover metals from waste, or selling it (Blue Earth Refineries Inc., 2005, p. 16-18).

China.—China's production of refined cobalt was estimated to be 15,178 t, which made it the world's leading producer. Only about 10% of China's cobalt production was from domestic mines. The remainder was from imported raw materials, most of

which was heterogenite ores from Congo (Kinshasa). One analyst estimated that China imported 15,926 t of cobalt contained in ore and concentrate in 2005; cobalt-bearing matte and scrap were also imported. The cobalt produced was in the form of metal, metal powders, and compounds, and was made for domestic use and export. Since 1998, Chinese cobalt consumption has grown by an average annual rate of 20%. The growth was driven primarily by consumption by the battery industry, which represented more than one-half of Chinese cobalt consumption in 2005 (Aidong, 2006, p. 3, 5, 14-15; Cobalt Development Institute, 2006a; Searle, 2006).

The number of Chinese cobalt refiners and processors was reported to be approximately 50. The leading three refiners were Jinchuan Group Ltd., Ganzhou Yi Hao Umicore Industries, and Zhejiang Huayou Cobalt Nickel Materials Co., Ltd., listed in descending order of 2005 refined cobalt production. Jinchuan reportedly produced 4,500 t of cobalt as cathode and other products in 2005. The company has been steadily increasing its refinery capacity and planned for cobalt production to reach 6,000 t in 2006 and 10,000 t in 2008. Some of Jinchuan's cobalt production was from domestic nickel-copper-cobalt sulfide ores mined and refined at Jinchang, Gansu Province, and some was from other nickel or cobalt feeds. Jinchuan purchased cobalt carbonates produced in China from imported cobalt concentrates and nickel-copper concentrate from GobiMin Inc.'s mines in the Hami region of northwestern China. The company imported nickel-copper concentrates from Fox Resources and Sally Malay in Australia, nickel-copper concentrates from Rio Narcea Gold Mines Ltd. in Spain, and nickel matte from BHP Billiton's Nickel West operations in Australia. During the year, Jinchuan considered investments in the Nonoc nickel plant in the Philippines, the Avebury nickel project in Australia, and a copper-cobalt smelter project in Congo (Kinshasa) (Aidong, 2004, 2006, p. 3; Cobalt Development Institute, 2006a; Ryan's Notes, 2006; Li, 2005§).

Umicore announced plans to double the cobalt refining capacity at its Ganzhou Yi Hao Industries plant in Jiangxi Province. Following this increase, Umicore's combined cobalt refining capacity from plants in Belgium and China would be more than 5,000 t/yr (n.v. Umicore s.a., 2005, p. 4).

Congo (Kinshasa).—According to the Cobalt Development Institute (2006c), La Générale des Carrières et des Mines (Gécamines) produced only 600 t of refined cobalt in 2005. Although its production of refined cobalt has been very low in recent years, Congo (Kinshasa) has continued to supply the world with significant quantities of cobalt in raw and semirefined materials, such as ore concentrates, carbonate, and copper-cobalt alloys. Large quantities of cobalt-rich ores containing the mineral heterogenite have been hand-picked by tens of thousands of artisanal miners, sold to middlemen or trading houses, and exported, primarily to China and India. Some of the heterogenite was processed into cobalt carbonate or cobalt-rich alliage blanc (an alloy of cobalt, copper, and iron) at plants within Congo (Kinshasa) prior to export, but most was not, and much of the unprocessed heterogenite was exported illegally. In 2005, high copper prices and the availability of localized high-grade copper ores resulted in a shift by some artisanal miners to gather copper-rich malachite ores and a shift by some smelters to produce copper products. Other factors that could affect future cobalt mining in Congo (Kinshasa) included decreasing heterogenite ore grades, higher freight rates

and lower availability of trucks, political desire to reduce artisanal mining and the direct export of cobalt ores, and an increased interest by international mining companies to develop projects in Congo (Kinshasa) (Metal Bulletin, 2005b; Grant, 2006; Global Witness, 2006, p. 4-5, 13, 15, 17).

Kababankola Mining Co. S.P.R.L. (KMC) mined copper-cobalt ores from open pit operations in Gécamines' Central Group and processed the ores at the nearby Kakanda concentrator, which it operated under lease from Gécamines. Concentrates from KMC's mining operations were either exported or toll-treated at Gécamines' Shituru refinery in Likasi. KMC was a joint venture between Tremalt Ltd. (a private company based in the British Virgin Islands) (80%) and Gécamines (20%) (Kababankola Mining Co. S.P.R.L., undated a§, b§).

Gécamines and L'Enterprise Générale Malta Forrest S.P.R.L. produced copper-cobalt concentrates from the Luiswishi Mine, which were sold under a long-term supply contract to OMG.

The Big Hill smelter at Lubumbashi, which was operated by Société pour le Traitement du Terril de Lubumbashi (a joint venture between Gécamines, OMG, and S.A. Groupe George Forrest), processed stockpiled slag to produce a cobalt-copper alloy containing 17% to 19% cobalt, which was sold to OMG's Kokkola refinery. In 2005, the smelter was shut down for approximately 4 months for scheduled maintenance and production improvements. During the year, the smelter produced alloy containing 2,259 t of cobalt, down from the 2,894 t produced in 2004 (OM Group, Inc., 2006, p. 5; George Forrest International S.A., 2006§).

Feza Mining SPRL (a joint venture between Comide SPRL and Wanbao Resources Corp.) built a smelter in Likasi with the capacity to produce 1,000 t/yr of cobalt in copper-cobalt alloy. Other smelters producing cobalt-bearing alloys included Gécamines' Fonderie Electrique de Panda and M.A.D.S.A.'s Four Electrique Luilu Cobalt (FELCO) project (Metal Bulletin, 2006; Feza Mining SPRL, 2006a§, b§).

Chemaf S.P.R.L. produced cobalt carbonate at its plant in Lubumbashi from ores extracted from the nearby Etoile Mine. In 2005, the company increased the plant's capacity to 4,000 t/yr of contained cobalt. Central African Mining & Exploration Company plc (CAMEC) began commissioning its newly constructed cobalt carbonate plant at Kambove. The plant had an initial capacity of 1,400 t/yr of contained cobalt, which could be doubled at a later time. Numerous other cobalt carbonate plants reportedly were being built in Congo (Kinshasa) by various Chinese organizations (Central African Mining & Exploration Company plc, 2006; Cobalt Development Institute, 2006a; Chemaf S.P.R.L., undated§).

Metorex Ltd. began constructing phase I of its Ruashi project. For this phase, Metorex was moving the flotation plant from its South African O'Okiep copper operation to Ruashi, and reconfiguring it to treat copper and cobalt oxide minerals stockpiled by Gécamines from past mining operations at Ruashi and Etoile. The resulting concentrates were to be refined in Zambia at Metorex's Sable Zinc refinery (as discussed in the "Zambia" portion of the "World Review" section of this report). During the year, Metorex worked on a feasibility study for phase II of the project, which would entail mining the Ruashi ore body by open pit methods and processing the ores onsite at an expanded flotation plant and newly constructed acid leaching-SX-EW refinery. An estimated 40,000 t/yr of copper metal

and 3,000 t/yr of cobalt metal would be produced from phase II. The Congo (Kinshasa) operating company for the project was Ruashi Mining SPRL, which was 80%-owned by Ruashi Holdings (Pty.) Ltd. (a subsidiary of Metorex Ltd.) and 20% by Gécamines (Metorex Ltd., 2004, 2005, p. 5, 18-19).

Adastra Minerals Inc. continued to study the feasibility of proceeding with the Kolwezi Tailings Project, which involved the recovery of copper and cobalt from oxide tailings produced from past operations at Gécamines Kolwezi concentrator. In August, Congo (Kinshasa)'s Ministry of Mines approved the project's environmental adjustment plan; this was the official endorsement that project development could proceed. The feasibility study was based on a processing plant with initial production levels of approximately 30,000 t/yr of copper and 5,500 t/yr of cobalt. Adastra expected to complete the feasibility study and make a go-ahead decision on the project in 2006. At yearend, ownership of Kingamyambo Musonoi Tailings s.a.r.l., the company that held the tailings exploration permit for the project, was 65% Congo Mineral Development Ltd. (a wholly owned subsidiary of Adastra), 12.5% Gécamines, 10% Industrial Development Corp. of South Africa Ltd., 7.5% International Finance Corp., and 5% Government of Congo (Kinshasa) (Adastra Minerals Inc., 2006, p. 17, 22-25).

Africo Resources Ltd. studied the feasibility of developing the Kalukundi copper-cobalt deposit, which is approximately 65 km northeast of Kolwezi. Africo held an option to acquire a 75% interest in the deposit, which contained a measured and indicated resource of 12.2 Mt, grading 2.45% copper and 0.61% cobalt and an additional inferred resource of 15.0 Mt grading 2.63% copper and 0.58% cobalt (Rubicon Minerals Corp., 2006, p. 36-37).

KGHM Polska Miedź S.A. evaluated a project to build a hydrometallurgical processing plant in Congo (Kinshasa) to treat copper-cobalt ores from the Kimpe deposit. The company expected to decide on whether to proceed with the project in 2006 (KGHM Polska Miedź S.A., 2006, p. 12, 17).

Tenke Mining Corp. received formal approval from Gécamines and the Government of Congo (Kinshasa) for the development of the Tenke Fungurume project. Following receipt of the approval, Phelps Dodge Corp. exercised its option to acquire a controlling interest in the project, and the force majeure, which had been in place since 1999, was lifted. Tenke Fungurume, which is approximately 175 km northwest of Lubumbashi, has been described as the largest undeveloped high-grade copper-cobalt project in the world. The companies hoped to update a previous feasibility study on the project by mid-2006, so that production could begin in late 2008 or early 2009. Initial production would be 110,000 t/yr of copper metal and 8,800 t/yr of cobalt in various forms, depending on market demand. At yearend, ownership of the project was 57.75% Phelps Dodge, 24.75% Tenke Mining Corp., and 17.5% Gécamines (Tenke Mining Corp., 2006, p. 3-9; Phelps Dodge Corp., 2006§).

Kamoto Copper Company SARL [a joint venture between Kinross Forrest Ltd. (75%) and Gécamines (25%)] studied the feasibility of rehabilitating Gécamines' Kamoto Mine and associated facilities west of Kolwezi. The assets included the mine, which is a large underground copper-cobalt mine that has had only limited production since it suffered a major collapse in 1990, various open pit oxide resources, the Kamoto concentrator, and the Luilu copper and cobalt refinery. The joint

venture planned to restore the mines and facilities incrementally over a period of years, maintaining existing equipment and process flow sheets unless it was determined that the equipment was beyond repair or that new process technology would offer sufficient advantages (du Plessis and Heili, 2005, p. 1.7-1.8).

Privately owned Global Enterprises Corporate Ltd. (GEC) reportedly studied the feasibility of reopening the Kamoto Oliviera Virgule (KOV) open pit mine in a joint venture with Gécamines (75% GEC and 25% Gécamines). The KOV Mine, which flooded after Gécamines ceased production there, had been a significant past producer of copper and cobalt (Metal Bulletin, 2005c).

Industrial Copper Systems Ltd. (ICS) installed a pilot-scale copper-cobalt processing plant south of Gécamines' Shituru refinery. The plant, which was designed to produce metal and chemicals by using a process based on Electrometals Technologies Ltd.'s electrowinning cell technology, began production in June. ICS hoped to acquire the rights from Gécamines to process the nearby Panda tailings (Industrial Copper Systems Ltd., 2005§).

Cuba.—Moa Nickel S.A. [part of the joint venture between Sherritt (50%) and General Nickel (50%)] mined nickel-cobalt laterites at Moa Bay in Holguin Province and produced mixed sulfides containing 33,006 t of nickel and cobalt, a slight decrease from the 33,534 t produced in 2004. All of the mixed sulfides were sent to the joint venture's Fort Saskatchewan refinery in Canada. Sherritt and General Nickel agreed to expand production at Moa Bay to 49,000 t/yr of nickel-cobalt sulfides. Construction was to begin during the second quarter of 2006 so that commissioning could begin by the second quarter of 2008. General Nickel was to ensure the granting of concessions for ore reserves for 25 years of production at the new rate (Sherritt International Corp., 2006, p. 3, 23, 26).

Unión del Níquel S.A. also mined and refined nickel-cobalt laterites in Holguin Province. Nickel-cobalt mixed sulfides produced at the Ernesto Che Guevara Mining and Metallurgical Combine at Punta Gorda were exported to Jinchuan in China (McCutcheon, 2004, p. 38.45-38.46). Nickel and cobalt of Cuban origin cannot be imported into the United States because of a United States embargo on imports from Cuba.

Finland.—OMG's Kokkola Chemicals Oy refinery recovered cobalt from cobalt-copper alloy from the Big Hill smelter in Congo (Kinshasa), cobalt solution from the company's Harjavalta nickel refinery, and other materials, including low-grade ores and concentrates, sulfides, metallic feeds, and secondary (scrap) materials. The company's production of cobalt metal powders, briquettes, oxides, and compounds was 8,171 t, 4% higher than the 7,893 t produced in 2004 (Geological Survey of Finland, 2006§; OM Group, Inc., undated§).

Vulcan Resources Ltd. began to study the feasibility of developing its Kylylahti copper-cobalt-nickel-gold deposit, which is 24 km from Outokumpu in eastern Finland. Kylylahti had a resource of 7.4 Mt grading 1.0% copper, 0.2% cobalt, 0.2% nickel, and 0.6 g/t gold (Vulcan Resources Ltd., 2006).

France.—The Eramet Group produced cobalt chloride at its refinery at Sandouville near Le Havre. Feed for the refinery was nickel matte imported from Eramet subsidiary Le Nickel SLN's Doniambo smelter in New Caledonia.

India.—According to the Cobalt Development Institute (2006c), India's cobalt production more than doubled as compared with

that of 2004. Nicomet Industries Ltd. and Rubamin Ltd. were the leading producers. During the year, Nicomet increased the capacity of its plant in Cuncolim, Goa State, to 90 metric tons per month of cobalt (1,080 t/yr of cobalt), and Rubamin expanded the capacity of its Halol plant near Vadodara, Gujarat State, to 500 t/yr cobalt. India relies on imports of heterogenite from Congo (Kinshasa) as its cobalt feed material (Metal Bulletin, 2005d; Agrawal, Porwal, and Koppiker, 2006; Rubamin Ltd., 2005§).

Indonesia.—State-owned PT Antam Tbk exported lateritic nickel-cobalt ore to QNI's Yabulu refinery in Australia. Antam and other companies worked on projects to explore and develop Indonesia's nickel-cobalt laterite resources.

Japan.—Sumitomo Metal Mining Co., Ltd. produced electrolytic cobalt as a byproduct of nickel production at its Niihama nickel refinery in Ehime Prefecture. The Niihama refinery processed nickel matte from P.T. Inco in Indonesia and nickel-cobalt mixed sulfide from the Coral Bay Nickel Corp. plant in the Philippines; Sumitomo's long-term contract with WMC for nickel matte expired in March. Sumitomo planned to increase the capacity of Niihama to approximately 45,000 t/yr of nickel and 1,100 t/yr of cobalt to accommodate the output from Coral Bay (Metal Bulletin, 2002; WMC Resources Ltd., 2005, p. 29; Cobalt Development Institute, 2006c).

Madagascar.—Dynatec Corp. completed a feasibility study on developing the Ambatovy nickel laterite deposit, which is 130 km east of Antananarivo. The study confirmed the potential for an open pit mining operation, including an ore preparation plant; a 195-km pipeline to transport slurried ore to a pressure acid leaching plant, which would be built near the Port of Toamasina and produce an intermediate nickel-cobalt sulfide product; and a metals refinery for the production of cobalt and nickel metal powders. The project would have the capacity to produce 60,000 t/yr of nickel and 5,600 t/yr of cobalt during a 27-year life. At yearend, project partners Dynatec (75%) and Sumitomo (25%) were in discussion with other parties interested in joining the project (Dynatec Corp., 2006, p. 7-9, 12).

Mexico.—Baja Mining Corp. studied the feasibility of developing the Boleo copper-cobalt-zinc deposit near Santa Rosalia on the east coast of the Baja California Peninsula. Baja was considering underground mining using continuous mining machines, supplemented by production from open pits during some years. The operation would include a hydrometallurgical processing plant that would produce up to 50,000 t/yr of copper cathode, 10,000 t/yr of zinc as sulfate, 2,000 t/yr of cobalt as carbonate or cathode, and possibly 35,000 to 65,000 t/yr of manganese as carbonate. During the year, Baja began trial underground mining to test the mechanized mining method at Boleo and collect geotechnical and operational information for mine design (Baja Mining Corp., 2006).

Morocco.—Cie. de Tifnout Tiranimine (CTT) mined cobalt-arsenic deposits at Bou Azzer and produced concentrates. At its Guemassa hydrometallurgical complex north of Marrakech, CTT refined the concentrates and cobalt hydroxides produced from tailings generated by past mining at Bou Azzer and produced cobalt cathode. The company planned to increase its production capacity by 10% to 20% in 2007 (Akalay, 2006).

New Caledonia.—Lateritic nickel-cobalt ore was exported to QNI's Yabulu refinery for processing. Nickel matte from Le

Nickel SLN's Doniambo smelter was sent to Eramet's refinery in Sandouville, France, where it was refined into nickel cathode, nickel chloride, and cobalt chloride, listed in decreasing order of magnitude.

Inco began construction of its Goro nickel-cobalt laterite project in southern New Caledonia. The project comprised an integrated mining and pressure acid leaching-solvent extraction processing facility with a planned capacity of approximately 60,000 t/yr of nickel as oxide and 4,300 to 5,000 t/yr of cobalt as carbonate. At yearend, ownership of Goro was as follows: Inco (71%), Sumic Nickel Netherlands b.v. (a joint venture between Sumitomo and Mitsui & Co., Ltd.) (21%), and Société de Participation Minière du Sud Calédonien SAS (8%). Inco expected to begin production at Goro in late 2007 (Inco Ltd., 2006b, p. 50-52).

Norway.—Falconbridge's production of cobalt at its Nikkelverk refinery increased by 7% compared with production in 2004. During 2005, 20% of the cobalt produced at Nikkelverk originated from Falconbridge mines in Canada, and 80% originated from custom feeds. The custom feed included matte from Botswana, which Falconbridge processed under a long-term agreement with BCL Ltd. (Falconbridge Ltd., 2006, p. 21-23).

Papua New Guinea.—China Metallurgical Construction Group Corp. (MCC) exercised its option to take an 85% interest in the Ramu nickel-cobalt laterite project in Madang Province. Under the joint-venture agreement with Highlands Pacific Ltd., MCC would be responsible for project financing, would manage and operate the project, and would have the right to purchase all of the project's future production. The feasibility study and subsequent updates were based on pressure acid leaching technology to produce 32,800 t/yr of nickel cathode and 3,200 t/yr of cobalt as cathode or an intermediate product during a 20-year life, with the potential to increase mine life by an additional 15 to 20 years. Permitting and development approvals were in place for the project. MCC planned to begin construction in 2006 (Highlands Pacific Ltd., 2006, p. 2, 15-16).

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

Coral Bay Nickel Corp. [a joint venture between Sumitomo (54%), Mitsui & Co., Ltd. and Sojitz Corp. (18% each), and Rio Tuba Nickel Mining Corp. (10%)] began commercial production from its high-pressure acid-leaching plant at the Rio Tuba nickel mine on Palawan Island and was producing at capacity by yearend. The plant used stockpiled low-grade laterite ores as feed material. All of the plant's nickel-cobalt mixed sulfide intermediate product, containing approximately 10,000 t/yr of nickel and 700 t/yr of cobalt, was to be refined at Sumitomo's Niihama nickel refinery in Japan. During the year, Coral Bay Nickel studied the feasibility of doubling the plant's capacity (Sumitomo Metal Mining Co., Ltd. 2005; Manila Bulletin Online, 2005§).

Russia.—According to the Cobalt Development Institute (2006c), OJSC MMC Norilsk Nickel, which was Russia's leading cobalt producer, produced 4,748 t of cobalt, 5% more than the 4,524 t produced in 2004. Norilsk Nickel conducted nickel-copper sulfide mining and refining at Norilsk on the Taimyr Peninsula and at Monchegorsk on the Kola Peninsula. Cobalt from ores mined at Norilsk was refined at Norilsk operations; cobalt from ores mined on the Kola Peninsula was toll refined by OJSC Ufaleynickel at its refinery at Verkhniy

Ufaley in the Ural Mountains. Norilsk was considering a change from this tolling arrangement to producing high-grade cobalt at its Kola operation (Metal Bulletin, 2004; Astafiev, 2005, p. 6).

Ufaleynickel planned to increase its nickel and cobalt production levels in 2006 by processing oxide nickel ore mined from its Serov field and by modernizing its hydrometallurgical plant (Interfax International Ltd., 2006).

South Africa.—Cobalt was mined as a byproduct from six PGM mines and one nickel mine (Harding, 2005). Two companies produced refined cobalt as a byproduct of platinum refining. Rustenburg Base Metal Refiners Pty. Ltd. (a subsidiary of Anglo American plc) produced cobalt sulfate at its refinery near Rustenburg, Northwest Province, and Impala Platinum Ltd. produced cobalt metal powder at its base-metals refinery near Springs, Gauteng Province. Some of the cobalt produced by Impala was recovered from concentrates produced at the Mimosa platinum mine in Zimbabwe.

African Rainbow Minerals Ltd. and LionOre formed a joint venture to study the feasibility of using the Activox process in the expansion of the Nkomati nickel sulfide mine in Mpumalanga Province. The expanded operation would produce an estimated 16,500 t/yr of nickel cathode, 7,900 t/yr of copper cathode, 950 t/yr of cobalt carbonate, plus palladium and platinum during a 16-year mine life. In recent years, sales of cobalt in nickel concentrates have been 80 to 100 t/yr (Anglovaal Mining Ltd., 2004, p. 281-289; LionOre Mining International Ltd., 2005; African Rainbow Minerals Ltd., 2006, p. 39).

Umicore discontinued operations at its cobalt plant in Roodepoort during the June quarter. The plant had treated low-grade cobalt-containing residues to produce cobalt compounds (n.v. Umicore s.a., 2006, p. 5).

Spain.—Rio Narcea Gold Mines, Ltd. began commercial production of copper-nickel-PGM concentrate from its Aguablanca open pit nickel sulfide mine and processing plant in Badajoz Province near the boundaries of Huelva and Sevilla Provinces in southwestern Spain. At planned production rates, the concentrates were expected to contain approximately 200 t/yr of cobalt (Rio Narcea Gold Mines, Ltd., 2005, p. 6; 2006).

Turkey.—European Nickel PLC demonstrated the viability of processing nickel laterite ores by acid heap leaching and completed a feasibility study on its Çaldağ deposit in western Turkey. Depending on the availability of financing, European Nickel planned to start building a full-scale leaching plant during the first half of 2006, begin mining and building the first ore heap by late 2006, and begin producing nickel-cobalt mixed hydroxide in 2007. At full operation, production was expected to be 21,400 t/yr of nickel and 1,000 t/yr of cobalt in mixed hydroxide. BHP Billiton has worked with European Nickel on the project and has an offtake agreement with the company for some of the mixed hydroxide (European Nickel PLC, 2005).

Uganda.—Kasere Cobalt Co. Ltd. (75% Blue Earth Refineries Inc. and 25% Kilembe Mines Ltd.) produced cobalt cathode from stockpiled pyrite concentrates by using a bacterial leaching-SX-EW process at its cobalt refinery in southwestern Uganda. Uganda Gold Mining Ltd. began an exploration program and feasibility study on reopening the Kilembe copper-cobalt mine in western Uganda. The study was considering various alternatives for treating concentrates produced from

Kilembe, including the use of the Kasese refinery (Blue Earth Refineries Inc., 2005, p. 13; Uganda Gold Mining Ltd., 2005).

Vietnam.—Asian Mineral Resources Ltd. completed a feasibility study on developing the Ban Phuc nickel sulfide deposit, which is approximately 160 km west of Hanoi in Son La Province. Asian Mineral Resources planned to mine the deposit by underground methods and produce a nickel-copper flotation concentrate, containing an average of approximately 110 t/yr of cobalt during the mine's 6-year life (Ausenco International Pty. Ltd., 2005, p. 1, 58).

Zambia.—Mopani Copper Mines Plc [owned by Glencore International AG (73.1%), First Quantum Minerals Ltd. (16.9%), and ZCCM Investments Holdings plc (10%)] produced 1,744 t of cobalt metal at its Nkana cobalt refinery, 12% less than the 2,022 t produced in 2004. The decrease in production was attributed to a decrease in the availability of cobalt concentrates in Zambia. Most of the cobalt originated from the company's Nkana underground copper-cobalt mine. Mopani anticipated that, as a result of increasing its copper production, the company's cobalt production would be 2,000 to 2,500 t/yr by 2007 (Cobalt Development Institute, 2006a, c).

Chambishi Metals plc [owned by J&W Holding AG (90%) and ZCCM Investments Holdings (10%)] produced 3,648 t of cobalt metal at its Chambishi cobalt refinery, a 3% decrease from the 3,769 t produced in 2004. The refinery's main feed materials were slag from a stockpile at Nkana and concentrates from J&W subsidiary Luanshya Copper Mines Plc's Baluba copper-cobalt mine. Chambishi also processed purchased raw materials, such as alliage blanc, concentrates, and heterogenite. During the year, Chambishi's cobalt production was limited by delays in refurbishing the Baluba Mine, which resulted in a decrease in the availability of concentrates (Metal Bulletin, 2005a; Brown, 2006; Cobalt Development Institute, 2006c).

Konkola Copper Mines plc (KCM) [owned by Vedanta Resources plc (51%), Zambia Copper Investments Ltd. (28.4%), and ZCCM Investments Holdings (20.6%)] mined copper ores from its Nchanga and Konkola operations. KCM ceased cobalt production in 2004 owing to a depletion of cobalt resources at the Nchanga open pit. Cobalt-bearing slag from the company's Nkana Smelter was stockpiled for future reclamation (Konkola Copper Mines plc, undated\$).

Metorex's Chibuluma West Mine ceased operations in March. Copper-cobalt ore from the mine had been processed at the company's Chibuluma South concentrator, and the concentrates had been sold to Mopani. During the year, Metorex worked on refurbishing its Sable Zinc leaching and electrowinning plant near Kabwe. The company was adding a solvent extraction unit and expanding the plant so that it could produce approximately 10,000 t/yr of copper metal and 1,000 t/yr of cobalt as carbonate. Metorex planned to begin processing copper-cobalt concentrates produced at its Ruashi operations in Congo (Kinshasa) in 2006 (Metorex Ltd., 2005, p. 5, 17-19; 2006).

TEAL Exploration & Mining Inc. studied the feasibility of developing the Mwambashi copper project in a joint venture with Korea Zinc Corp. The Mwambashi project is about 35 km from Kitwe and had an estimated indicated mineral resource of 8.6 Mt containing 2.43% copper and 0.066% cobalt. TEAL was considering open pit mining the oxidized minerals in the upper

portion of the deposit, possibly followed by underground mining (Verbeek and others, 2005, p. 9, 14).

Albidon Ltd. studied the feasibility of developing the Enterprise nickel sulfide deposit at its Munali nickel project in southern Zambia. The deposit's indicated and inferred resource estimate was 6.93 Mt grading 1.4% nickel, 0.2% copper, 0.08% cobalt, and 1.0 g/t PGMs. Albidon hoped to begin producing nickel concentrates from Munali in 2007 (Albidon Ltd., 2005).

Outlook

World demand for cobalt is expected to continue to increase in coming years. Industries that could show significant increases in cobalt demand include superalloys for civil aviation, power generation, and flue gas desulfurization equipment; catalysts for the production of chemicals used to make polyethylene terephthalate and for gas-to-liquid production of synthetic liquid fuels; and rechargeable batteries for portable electronic devices and hybrid electric vehicles. Some of the increase in demand from the battery sector is being dampened, however, by substitution of cobalt with other, less expensive metals (Cobalt Development Institute, 2006b).

World production of refined cobalt is also expected to continue to increase. Many producers plan to increase their production and/or capacity levels at existing operations, and various new nickel and copper-cobalt projects and a primary cobalt project are in progress. Production in 2006 will include cobalt refined from Voisey's Bay concentrates, although some of that production may replace declining production from Inco's other operations in Canada. The next production from the larger of the new projects, in terms of refined cobalt output, is not expected before late 2007 (Cobalt Development Institute, 2006a, b; Searle, 2006). In addition to production, recycled cobalt and NDS inventory releases will continue to contribute to supply. Much of the cobalt from the NDS, which has been a significant source of supply for more than a decade, however, has been sold. As of July 31, 2006, only 1,470 t of uncommitted cobalt remained in the NDS, which represented about 1 year's supply at the current rate of disposal.

Some analysts predict that the balance between cobalt supply and demand could be tight in the next few years. The near-term increase in demand will be met primarily from existing producers, including materials exported from Congo (Kinshasa) to China (Cobalt Development Institute, 2006b). Searle (2006) stated that there continues to be a risk for cobalt demand to be constrained by supply. He predicted that future cobalt prices would have to remain above \$12 per pound through 2010 in order for exports of cobalt materials from Congo (Kinshasa) to continue. From January through July 2006, the price of cobalt cathode reported by Platts Metals Week remained in the \$12.75 to \$16.15 per pound range.

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TABLE 1
 SALIENT COBALT STATISTICS¹

(Metric tons, cobalt content, unless otherwise specified)

| | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---------------------|---------------------|---------------------|---------------------|--------|
| United States: | | | | | |
| Consumption: | | | | | |
| Reported | 9,540 | 7,880 | 7,590 | 8,450 | 8,430 |
| Apparent | 11,800 | 9,830 | 10,000 | 9,920 | 11,900 |
| Imports for consumption | 9,410 | 8,450 | 8,080 | 8,720 | 11,100 |
| Exports | 3,210 | 2,080 | 2,710 | 2,500 | 2,440 |
| Stocks, December 31: | | | | | |
| Industry ² | 809 | 858 | 649 | 719 | 664 |
| U.S. Government ³ | 7,200 ^e | 6,680 | 4,290 | 2,660 | 1,550 |
| Price, metal ⁴ dollars per pound | 10.55 | 6.91 | 10.60 | 23.93 | 15.96 |
| World, production:^e | | | | | |
| Mine | 44,800 ^r | 50,600 ^r | 50,800 ^r | 57,100 ^r | 57,900 |
| Refinery | 38,700 ^r | 40,800 ^r | 43,800 | 49,100 | 54,900 |

^eEstimated. ^rRevised.

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

²Stocks held by cobalt processors and consumers.

³Defense National Stockpile Center. Includes material committed for sale pending shipment.

⁴Annual average U.S. spot price for minimum 99.8% cobalt cathode reported by Platts Metals Week.

TABLE 2
 U.S. GOVERNMENT NATIONAL DEFENSE STOCKPILE
 SALES AND SHIPMENTS¹

(Metric tons, cobalt content)

| | 2004 | 2005 |
|-------------------------------|-------|-------|
| Sales: | | |
| Fiscal year ² | 1,920 | 1,120 |
| Calendar year | 987 | 880 |
| Shipments:³ | | |
| Fiscal year ² | 2,220 | 893 |
| Calendar year | 1,630 | 1,110 |

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

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

³Calculated from yearend inventory levels.

Source: Defense National Stockpile Center.

TABLE 3
U.S. REPORTED CONSUMPTION AND STOCKS OF COBALT^{1,2}

(Metric tons, cobalt content)

| | 2004 | 2005 |
|--|-------|-------|
| Consumption by end use: | | |
| Steels | 722 | 857 |
| Superalloys | 3,650 | 4,140 |
| Alloys, excludes steels and superalloys: | | |
| Magnetic alloys | 396 | 337 |
| Other alloys ³ | 627 | 227 |
| Cemented carbides ⁴ | 765 | 763 |
| Chemical and ceramic uses | 2,230 | 2,040 |
| Miscellaneous and unspecified | 63 | 63 |
| Total | 8,450 | 8,430 |
| Consumption by form: | | |
| Chemical compounds, organic and inorganic ⁵ | 2,040 | 1,860 |
| Metal | 4,110 | 4,550 |
| Purchased scrap | 2,300 | 2,030 |
| Total | 8,450 | 8,430 |
| Stocks, December 31: ⁶ | | |
| Chemical compounds, organic and inorganic ⁵ | 223 | 209 |
| Metal | 379 | 383 |
| Purchased scrap | 117 | 72 |
| Total | 719 | 664 |

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

²Includes estimates.

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

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

⁵Includes oxides.

⁶Stocks held by cobalt processors and consumers.

TABLE 4
U.S. IMPORTS FOR CONSUMPTION OF COBALT, BY FORM¹

| | 2004 | | | 2005 | | |
|-----------------------|-------------------------------|--|----------------------|-------------------------------|--|----------------------|
| | Gross weight (metric tons) | Cobalt content ² (metric tons) | Value (thousands) | Gross weight (metric tons) | Cobalt content ² (metric tons) | Value (thousands) |
| Metal ³ | 7,250 | 7,250 | \$311,000 | 9,350 | 9,350 | \$312,000 |
| Oxides and hydroxides | 1,300 | 934 | 45,100 | 1,310 | 943 | 35,100 |
| Other forms: | | | | | | |
| Acetates | 230 | 55 | 2,550 | 260 | 62 | 2,250 |
| Carbonates | 453 | 208 | 10,300 | 985 | 453 | 15,300 |
| Chlorides | 327 | 82 | 3,220 | 189 | 47 | 1,480 |
| Sulfates | 705 | 190 | 6,030 | 762 | 206 | 5,750 |
| Grand total | 10,300 | 8,720 | 378,000 | 12,900 | 11,100 | 372,000 |

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

²Estimated from gross weights.

³Unwrought cobalt, excluding alloys and waste and scrap.

Source: U.S. Census Bureau.

TABLE 5
U.S. IMPORTS FOR CONSUMPTION OF COBALT, BY COUNTRY¹

| Country of origin | Metal ² | | | Oxides and hydroxides | | | | Other forms ³ | | | | Total | | |
|--------------------|-------------------------------|--|-----------------------------------|-------------------------------|--|-----------------------------------|-------------------------------|--|-----------------------------------|-------------------------------|--|-------------------------------|--|-----------------------------------|
| | Cobalt content ⁴ | | Value ⁵ (thousands) | Cobalt content ⁴ | | Value ⁵ (thousands) | Cobalt content ⁴ | | Value ⁵ (thousands) | Cobalt content ⁴ | | Gross weight (metric tons) | Cobalt content ⁴ (metric tons) | Value ⁵ (thousands) |
| | Gross weight (metric tons) | Cobalt content ⁴ (metric tons) | | Gross weight (metric tons) | Cobalt content ⁴ (metric tons) | | Gross weight (metric tons) | Cobalt content ⁴ (metric tons) | | Gross weight (metric tons) | Cobalt content ⁴ (metric tons) | | | |
| 2004: | | | | | | | | | | | | | | |
| Australia | 448 | 448 | \$18,600 | -- | -- | -- | -- | -- | -- | -- | 448 | 448 | \$18,600 | |
| Belgium | 668 | 668 | 20,200 | 451 | 325 | \$17,700 | -- | -- | -- | -- | 1,120 | 992 | 37,900 | |
| Brazil | 16 | 16 | 585 | -- | -- | -- | (6) | (6) | \$5 | 17 | 16 | 16 | 589 | |
| Canada | 1,120 | 1,120 | 36,900 | 1 | 1 | 45 | -- | -- | -- | 1,130 | 1,130 | 1,130 | 37,000 | |
| China | 429 | 429 | 18,400 | 188 | 135 | 4,660 | 462 | 136 | 5,250 | 1,080 | 701 | 701 | 28,300 | |
| Congo (Kinshasa) | 16 | 16 | 712 | -- | -- | -- | -- | -- | -- | 16 | 16 | 16 | 712 | |
| Finland | 357 | 357 | 19,600 | 361 | 260 | 12,300 | 733 | 257 | 11,800 | 1,450 | 874 | 874 | 43,800 | |
| France | 56 | 56 | 3,570 | 24 | 18 | 1,280 | -- | -- | -- | 81 | 74 | 74 | 4,850 | |
| Germany | 33 | 33 | 1,550 | 5 | 4 | 202 | -- | -- | -- | 38 | 37 | 37 | 1,760 | |
| India | -- | -- | -- | -- | -- | -- | 171 | 46 | 1,370 | 171 | 46 | 46 | 1,370 | |
| Japan | 164 | 164 | 9,460 | (6) | (6) | 13 | 57 | 14 | 772 | 221 | 178 | 178 | 10,200 | |
| Korea, Republic of | 71 | 71 | 1,620 | -- | -- | -- | -- | -- | -- | 71 | 71 | 71 | 1,620 | |
| Norway | 1,420 | 1,420 | 65,200 | -- | -- | -- | -- | -- | -- | 1,420 | 1,420 | 1,420 | 65,200 | |
| Philippines | -- | -- | -- | -- | -- | -- | 83 | 27 | 758 | 83 | 27 | 27 | 758 | |
| Russia | 1,630 | 1,630 | 79,800 | -- | -- | -- | -- | -- | -- | 1,630 | 1,630 | 1,630 | 79,800 | |
| South Africa | 110 | 110 | 3,270 | -- | -- | -- | -- | -- | -- | 110 | 110 | 110 | 3,270 | |
| Sweden | 8 | 8 | 315 | -- | -- | -- | -- | -- | -- | 8 | 8 | 8 | 315 | |
| Uganda | 50 | 50 | 2,110 | -- | -- | -- | -- | -- | -- | 50 | 50 | 50 | 2,110 | |
| United Kingdom | 12 | 12 | 579 | 240 | 173 | 7,940 | 155 | 41 | 1,930 | 407 | 226 | 226 | 10,400 | |
| Zambia | 618 | 618 | 27,700 | -- | -- | -- | -- | -- | -- | 618 | 618 | 618 | 27,700 | |
| Other | 11 | 11 | 347 | 27 | 19 | 1,020 | 53 | 14 | 153 | 92 | 45 | 45 | 1,520 | |
| Total | 7,250 | 7,250 | 311,000 | 1,300 | 934 | 45,100 | 1,720 | 536 | 22,100 | 10,300 | 8,720 | 8,720 | 378,000 | |
| 2005: | | | | | | | | | | | | | | |
| Australia | 313 | 313 | 10,300 | -- | -- | -- | -- | -- | -- | 313 | 313 | 313 | 10,300 | |
| Belgium | 393 | 393 | 12,700 | 495 | 357 | 14,200 | 42 | 19 | 714 | 930 | 768 | 768 | 27,600 | |
| Brazil | 305 | 305 | 9,770 | -- | -- | -- | -- | -- | -- | 305 | 305 | 305 | 9,770 | |
| Canada | 818 | 818 | 30,200 | (6) | (6) | 4 | -- | -- | -- | 818 | 818 | 818 | 30,200 | |
| China | 576 | 576 | 20,500 | 155 | 111 | 3,440 | 767 | 282 | 8,460 | 1,500 | 970 | 970 | 32,400 | |
| Congo (Kinshasa) | 25 | 25 | 780 | -- | -- | -- | -- | -- | -- | 25 | 25 | 25 | 780 | |
| Finland | 687 | 687 | 25,200 | 296 | 213 | 7,350 | 743 | 289 | 9,780 | 1,730 | 1,190 | 1,190 | 42,400 | |
| France | 24 | 24 | 1,550 | 34 | 24 | 1,620 | 1 | (6) | 23 | 59 | 49 | 49 | 3,190 | |
| Germany | 8 | 8 | 411 | 1 | 1 | 151 | -- | -- | -- | 9 | 9 | 9 | 561 | |
| India | 23 | 23 | 695 | -- | -- | -- | 370 | 100 | 2,720 | 393 | 123 | 123 | 3,410 | |
| Japan | 218 | 218 | 9,650 | 10 | 7 | 502 | -- | -- | -- | 228 | 225 | 225 | 10,200 | |
| Korea, Republic of | 24 | 24 | 413 | -- | -- | -- | -- | -- | -- | 24 | 24 | 24 | 413 | |
| Morocco | 342 | 342 | 10,300 | -- | -- | -- | -- | -- | -- | 342 | 342 | 342 | 10,300 | |

See footnotes at end of table.

TABLE 5—Continued
U.S. IMPORTS FOR CONSUMPTION OF COBALT, BY COUNTRY¹

| Country of origin | Metal ² | | Oxides and hydroxides | | | | Other forms ³ | | | Total | | |
|-------------------|----------------------------|---|--------------------------------|----------------------------|---|--------------------------------|----------------------------|---|--------------------------------|----------------------------|---|--------------------------------|
| | Gross weight (metric tons) | Cobalt content ⁴ (metric tons) | Value ⁵ (thousands) | Gross weight (metric tons) | Cobalt content ⁴ (metric tons) | Value ⁵ (thousands) | Gross weight (metric tons) | Cobalt content ⁴ (metric tons) | Value ⁵ (thousands) | Gross weight (metric tons) | Cobalt content ⁴ (metric tons) | Value ⁵ (thousands) |
| 2005—Continued: | | | | | | | | | | | | |
| Norway | 2,670 | 2,670 | \$89,200 | -- | -- | -- | -- | -- | -- | 2,670 | 2,670 | \$89,200 |
| Philippines | -- | -- | -- | -- | -- | -- | 94 | 34 | \$1,310 | 94 | 34 | 1,310 |
| Russia | 1,700 | 1,700 | 50,700 | -- | -- | -- | -- | -- | -- | 1,700 | 1,700 | 50,700 |
| South Africa | 204 | 204 | 7,280 | 20 | 14 | \$705 | 39 | 9 | 200 | 263 | 228 | 8,190 |
| Sweden | 7 | 7 | 142 | -- | -- | -- | -- | -- | -- | 7 | 7 | 142 |
| Uganda | 60 | 60 | 2,140 | -- | -- | -- | -- | -- | -- | 60 | 60 | 2,140 |
| United Kingdom | 14 | 14 | 496 | 290 | 209 | 6,910 | 138 | 35 | 1,550 | 442 | 258 | 8,950 |
| Zambia | 936 | 936 | 29,900 | -- | -- | -- | -- | -- | -- | 936 | 936 | 29,900 |
| Other | (6) | (6) | 15 | 9 | 7 | 240 | 3 | 1 | 18 | 13 | 8 | 273 |
| Total | 9,350 | 9,350 | 312,000 | 1,310 | 943 | 35,100 | 2,200 | 769 | 24,800 | 12,900 | 11,100 | 372,000 |

-- Zero.

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

²Unwrought cobalt, excluding alloys and waste and scrap; includes cobalt cathode and cobalt metal powder; may include intermediate products of cobalt metallurgy.

³Includes cobalt acetates, cobalt carbonates, cobalt chlorides, and cobalt sulfates.

⁴Estimated from gross weights.

⁵Customs value.

⁶Less than ½ unit.

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

TABLE 6
U.S. EXPORTS OF COBALT IN 2005, BY COUNTRY^{1,2}

| Country of destination | Metal ³ | | Oxides and hydroxides | | Acetates | | Chlorides | | Total | |
|------------------------|----------------------------|--------------------------------|----------------------------|--------------------------------|----------------------------|--------------------------------|----------------------------|--------------------------------|---|--------------------------------|
| | Gross weight (metric tons) | Value ⁴ (thousands) | Gross weight (metric tons) | Value ⁴ (thousands) | Gross weight (metric tons) | Value ⁴ (thousands) | Gross weight (metric tons) | Value ⁴ (thousands) | Cobalt content ⁵ (metric tons) | Value ⁴ (thousands) |
| Belgium | 732 | \$30,300 | (6) | \$3 | 141 | \$609 | -- | -- | 766 | \$31,000 |
| Brazil | 4 | 195 | 2 | 47 | 77 | 597 | -- | -- | 24 | 839 |
| Canada | 121 | 3,550 | 103 | 1,990 | 77 | 708 | 2 | \$22 | 214 | 6,270 |
| China | 13 | 414 | -- | -- | 15 | 162 | -- | -- | 16 | 576 |
| France | 103 | 3,670 | 7 | 34 | -- | -- | -- | -- | 108 | 3,700 |
| Germany | 86 | 3,350 | -- | -- | -- | -- | -- | -- | 86 | 3,350 |
| India | 15 | 582 | -- | -- | 19 | 143 | -- | -- | 20 | 724 |
| Ireland | 232 | 6,370 | -- | -- | -- | -- | (6) | 7 | 232 | 6,380 |
| Japan | 116 | 4,670 | 516 | 11,300 | 7 | 46 | -- | -- | 489 | 16,000 |
| Korea, Republic of | 17 | 619 | -- | -- | 25 | 239 | -- | -- | 23 | 858 |
| Mexico | 13 | 488 | 52 | 844 | 305 | 972 | 2 | 28 | 124 | 2,330 |
| Portugal | -- | -- | 40 | 65 | -- | -- | -- | -- | 29 | 65 |
| Singapore | 5 | 222 | 64 | 1,540 | -- | -- | -- | -- | 50 | 1,760 |
| Spain | 12 | 89 | 2 | 68 | 20 | 166 | -- | -- | 18 | 323 |
| Taiwan | 11 | 315 | 9 | 408 | 6 | 54 | -- | -- | 19 | 777 |
| United Kingdom | 126 | 2,340 | 17 | 611 | (6) | 6 | (6) | 4 | 138 | 2,960 |
| Other | 67 | 3,370 | 17 | 221 | 7 | 59 | -- | -- | 81 | 3,650 |
| Total | 1,670 | 60,600 | 829 | 17,100 | 699 | 3,760 | 4 | 60 | 2,440 | 81,500 |

-- Zero.

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

²In addition to the materials listed, the United States exports cobalt ores and concentrates and wrought cobalt and cobalt articles.

³Includes unwrought cobalt, powders, waste and scrap, and mattes and other intermediate products of cobalt metallurgy.

⁴Free alongside ship value.

⁵Estimated from gross weights.

⁶Less than 1/2 unit.

Source: U.S. Census Bureau.

TABLE 7
WORLD ANNUAL COBALT REFINERY
CAPACITY, DECEMBER 31, 2005^{1,2}

(Metric tons, cobalt content)

| Country | Capacity |
|----------------------------------|----------|
| Australia ^c | 4,500 |
| Belgium ^c | 1,800 |
| Brazil ^c | 1,200 |
| Canada ^c | 5,300 |
| China ^c | 25,000 |
| Congo (Kinshasa) ^{e, 3} | 15,000 |
| Finland | 10,000 |
| France | 600 |
| India | 1,560 |
| Japan | 600 |
| Morocco ^c | 1,650 |
| Norway | 5,200 |
| Russia ^c | 6,000 |
| South Africa ^c | 750 |
| Uganda | 720 |
| Zambia | 8,200 |
| Total | 88,100 |

^cEstimated.

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

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

³Refurbishment necessary to achieve stated capacity.

TABLE 8
COBALT: WORLD MINE PRODUCTION, BY COUNTRY^{1, 2}

(Metric tons, cobalt content)

| Country ³ | 2001 | 2002 | 2003 | 2004 | 2005 ^c |
|----------------------------------|---------------------|---------------------|---------------------|---------------------|--------------------|
| Australia ^{c, 4} | 6,300 | 6,700 | 6,900 | 6,700 | 6,000 |
| Botswana ⁵ | 325 | 269 | 294 | 223 | 200 |
| Brazil | 1,003 ^r | 1,099 ^r | 1,097 ^r | 1,236 ^r | 1,200 |
| Canada ⁶ | 5,326 | 5,148 | 4,327 | 5,060 ^r | 5,533 ⁷ |
| China ^c | 150 | 1,000 | 700 | 1,260 ^r | 1,300 |
| Congo (Kinshasa) ^{c, 8} | 12,000 ^r | 14,500 | 14,500 ^r | 20,500 ^r | 22,000 |
| Cuba ⁹ | 3,425 ^r | 3,442 ^r | 3,274 ^r | 3,554 ^r | 3,600 |
| Kazakhstan ^{c, 10} | 300 | 300 | 300 | 300 | 300 |
| Morocco ¹¹ | 1,242 | 1,453 | 1,391 | 1,600 ^c | 1,600 |
| New Caledonia ^{c, 12} | 1,400 | 1,400 | 1,400 | 1,400 | 1,200 |
| Norway ^{c, 11} | 100 | 100 | -- | -- | -- |
| Russia ^c | 4,600 | 4,600 | 4,800 | 4,700 | 5,000 |
| South Africa ^c | 560 | 520 | 400 | 460 | 400 |
| Zambia ^{c, 13} | 8,000 | 10,000 | 11,300 | 10,000 | 9,300 |
| Zimbabwe ¹⁴ | 95 | 99 ^r | 79 | 59 | 250 |
| Total ^c | 44,800 ^r | 50,600 ^r | 50,800 ^r | 57,100 ^r | 57,900 |

^cEstimated. ^rRevised. -- Zero.

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

²Table includes data available through June 18, 2006. Figures represent recoverable cobalt content of ores, concentrates, or intermediate products from cobalt, copper, nickel, platinum, or zinc operations.

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

⁴Quantities 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, in metric tons, was estimated to be as follows: 2001—6,200; 2002—6,800; 2003—7,300; 2004—7,000; and 2005—7,100.

⁵Reported cobalt content of pelletized nickel-copper matte.

⁶Assay content of cobalt in concentrates produced. The cobalt content, in metric tons, 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 to be as follows: 2001—2,112; 2002—2,065; 2003—1,842; 2004—2,085 (revised); and 2005—2,105.

⁷Reported figure.

⁸Cobalt content of concentrates, tailings, and slags. Includes the following estimates, in metric tons, of illegal production by artisanal miners: 2001-02—2,000; 2003—4,000; 2004—7,000; and 2005—7,000.

⁹Determined from reported nickel-cobalt content of sulfide production.

¹⁰Estimated cobalt content of only those ores from which it is assumed cobalt is recovered. Cobalt content of total ores mined is assumed to be 1,400 metric tons (2001-05).

¹¹Cobalt content of concentrates.

¹²Quantities of cobalt contained in intermediate or refined metallurgical products (cobalt chloride and cobalt oxide hydroxide) produced from New Caledonian ores exported to Australia and France.

¹³Cobalt content of concentrates and slags.

¹⁴Cobalt 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 | 2001 | 2002 | 2003 | 2004 | 2005 |
|--|---------------------|---------------------|--------------------|--------------------|--------|
| Australia, metal, metal powder, oxide hydroxide ^e | 3,470 | 3,700 | 3,840 | 3,880 | 3,150 |
| Belgium, metal powder, oxide, hydroxide ⁴ | 1,090 | 1,135 | 1,704 | 2,947 | 3,298 |
| Brazil, metal | 889 | 960 | 1,097 | 1,155 | 1,136 |
| Canada, metal, metal powder, oxide | 4,378 | 4,625 | 4,233 | 5,144 | 5,079 |
| China, metal, metal powder, oxide, salts ^{e,5} | 1,470 | 1,840 | 4,580 | 8,000 | 12,700 |
| Congo (Kinshasa), metal ⁶ | 3,199 ^r | 2,149 ^r | 1,200 ^e | 735 | 600 |
| Finland, metal powder and salts ⁷ | 8,100 | 8,240 ^r | 7,989 ^r | 7,893 | 8,171 |
| France, chloride | 199 | 176 | 181 | 199 | 280 |
| India, metal and salts | 250 | 270 | 255 | 545 | 1,220 |
| Japan, metal | 350 | 354 | 379 | 429 | 471 |
| Morocco, metal | 1,341 | 1,354 | 1,431 | 1,594 ^r | 1,613 |
| Norway, metal | 3,314 | 3,994 | 4,556 | 4,670 | 5,021 |
| Russia, unspecified ^{e,8} | 5,000 | 5,100 | 5,500 | 5,400 | 5,800 |
| South Africa, metal powder and sulfate | 373 | 352 | 271 | 309 | 268 |
| Uganda, metal | 634 | 450 ^e | -- | 436 | 638 |
| Zambia, metal | 4,657 | 6,144 | 6,620 | 5,791 | 5,422 |
| Total ^e | 38,700 ^r | 40,800 ^r | 43,800 | 49,100 | 54,900 |

^eEstimated. ^rRevised. -- Zero.

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

²Table includes data available through June 18, 2006. Figures represent cobalt refined from ores, concentrates, or intermediate products and do not include production of downstream products from refined cobalt.

³In addition to the countries listed, Germany and Poland may produce some cobalt, but information is inadequate to make reliable estimates of production.

⁴Production reported by n.v. Umicore s.a.; includes production from China and South Africa that is not otherwise included in this table.

⁵Production from domestic and imported ores and concentrates; excludes production by n.v. Umicore s.a. that is included under Belgium.

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

⁷Production for 2001 reported by OM Group, Inc.; production for 2002-05 reported by the Geological Survey of Finland.

⁸Production reportedly includes metal, oxide, and salts; other forms may also have been produced.