COBALT

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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. Some analysts estimate that rechargeable batteries are now the leading use 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.

In 2004, 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 2004. 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.

In 2004, world demand for cobalt reportedly 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 (Inco Ltd., 2005, p. 17). U.S. reported consumption of cobalt was greater than that of 2003. The overall trend in cobalt prices was downward.

Salient U.S. and world cobalt statistics for 2004 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

During fiscal year 2004 (October 1, 2003, through September 30, 2004), the Defense National Stockpile Center (DNSC), U.S. Department of Defense, held one long-term negotiated cobalt sale and periodically offered cobalt under a basic ordering agreement (BOA). Cobalt was awarded under the BOA each month. During the fiscal year, the DNSC sold 1,920 metric tons (t) of cobalt cathode, granules, and rondelles valued at $70.5 million (table 2). This represented 71% of the 2,720-t (6-million-pound) maximum allowed for sale under the fiscal year 2004 Annual Materials Plan (AMP). As of the end of the fiscal year, 46 t of cobalt had been sold but not shipped from the stockpile. The AMP for fiscal year 2005 (October 1, 2004, through September 30, 2005) maintained the maximum allowable sale of cobalt at 2,720 t (U.S. Department of Defense, 2005, p. 6, 8, 55).

During calendar year 2004, the DNSC made BOA awards each month except October and November. During this period, the DNSC sold 987 t of cobalt cathode, granules, and rondelles valued at $47.5 million. On December 31, the total uncommitted cobalt inventory held by the DNSC was 2,340 t, all of which was authorized for disposal.

The U.S. Public Health Service, U.S. Department of Health and Human Services, announced that it intended to review cobalt-tungsten carbide hardmetals (cemented carbides) for possible inclusion in the 12th edition of the "Report on Carcinogens" (RoC), which was scheduled to be published in 2006. The RoC 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. Hardmetals were nominated for review on the basis of human cancer studies on the hardmetal manufacturing industry that showed an association between exposure to hardmetals and lung cancer (Public Health Service, 2004).

The Agency for Toxic Substances and Disease Registry, U.S. Department of Health and Human Services (2004), announced the availability of an updated toxicological profile on cobalt.

Production

With the exception of negligible amounts of byproduct cobalt produced from mining operations in Missouri and Montana, the United States did not mine or refine cobalt in 2004. For example, minor amounts of cobalt present in the ores mined for platinum-group metals at the Stillwater Complex of southern Montana were recovered from converter matte at Stillwater Mining Co.'s refinery and sold as a byproduct.

Formation Capital Corp. worked on mine permitting and the final feasibility study for its Idaho Cobalt Project. The project entailed developing cobalt-copper-gold deposits in the Idaho Cobalt Belt in Lemhi County and retrofitting an acid pressure leach plant in Big Creek, ID, to refine cobalt concentrates. The retrofitted plant 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 hoped to begin mine development in 2005 and forecast the first production of refined cobalt in 2007 (Formation Capital Corp., 2004, p. 10; 2005§[1]).

PolyMet Mining Corp. worked on project permitting and a final feasibility study for its NorthMet project. The NorthMet

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

polymetallic deposit, which is in the Duluth Complex of northeastern Minnesota, could be mined by open pit methods. Ore would be treated at the nearby Cliffs-Erie mill and concentrator to produce bulk concentrates, some of which would be processed in a new hydrometallurgical plant using the company's PlatSol technology. PolyMet planned to produce the following products: copper cathode, a nickel-cobalt hydroxide containing 7,800 t/yr of nickel and 375 t/yr of cobalt, and a concentrate of platinum-group metals and gold. PolyMet hoped to begin commercial production in early 2008 (PolyMet Mining Corp., 2005, p. 2, 23-28).

Kennecott Minerals Co. evaluated the potential of developing a small underground nickel-copper mine northwest of Marquette, MI, on the Yellow Dog Plains. During the year, Kennecott performed exploration drilling to define the shape of the ore body and worked on environmental baseline studies. The Eagle deposit had an estimated resource of 5 million metric tons (Mt) grading 3.68% nickel, 3.06% copper, and 0.1% cobalt, with small amounts of gold, palladium, and platinum (Kennecott Exploration Co., 2004; Kennecott Minerals Co., 2004).

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.

Umicore announced that it planned to build a new recycling unit at its facility in Arab, AL (n.v. Umicore, s.a., 2005, p. 8).

Consumption

U.S. apparent consumption for 2004, as calculated from net imports, consumption from purchased scrap, and changes in Government and industry stocks, was nearly the same as that calculated for 2003 (table 1). Although net imports and consumption of scrap were higher in 2004 than in 2003, shipments from the NDS were lower than those in 2003 and there was a buildup of industry stocks by yearend.

U.S. reported consumption of cobalt in 2004 was 11% higher than that for 2003. As compared with 2003, metallurgical industries consumed 11% more cobalt, and the cobalt consumption for chemical uses was 13% higher. 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, decreased from a high of $27.00 to $29.00 per pound in mid-January to a low of $15.25 to $15.75 per pound in late November, and then rebounded to $18.75 to $19.50 per pound by yearend. The Platts annual average U.S. spot cathode price for 2004 was $23.93 per pound, more than double that of 2003 (table 1). Trends in the 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 $23.27 per pound, and the annual average of weekly prices for Russian cobalt was $22.86 per pound. Sales prices for 99.8% cobalt cathode reported by WMC Resources Ltd. ranged from $15.75 to $29.50 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 2004, net import reliance as a percentage of apparent consumption was 77%. Because there was no measurable U.S. primary cobalt production in 2004, this indicates that 77% of U.S. cobalt supply was from imports and stock releases of primary cobalt and 23% was from scrap, which would have been generated domestically or imported.

In 2004, the United States imported 8% more cobalt than it did in 2003 (tables 4, 5). On the basis of cobalt content, 10 countries supplied 94% of U.S. imports of unwrought cobalt and cobalt in chemicals. Russia was the leading supplier, followed by Norway, Canada, Belgium, Finland, China, Zambia, Australia, the United Kingdom, and Japan. Compared with those of 2003, cobalt imports from Australia, Belgium, Canada, China, Japan, and Zambia increased, and imports from Finland, Norway, Russia, and the United Kingdom decreased.

In 2004, the United States imported 75 t, gross weight, of unwrought cobalt alloys valued at $3.2 million. Five countries supplied most of these materials—China (29%), Congo (Kinshasa) (22%), Germany (16%), Japan (15%), and the United Kingdom (13%). The United States imported 1,020 t, gross weight, of cobalt waste and scrap valued at $10.9 million. Seven countries supplied nearly 90% of this material—the United Kingdom (38%), Germany (17%), Ireland (10%), Austria (9%), Canada (7%), Japan (5%), and France (4%). The United States also imported 230 t, gross weight, of wrought cobalt and cobalt articles valued at $15.4 million. The leading suppliers of these materials were the United Kingdom (44%),

Zambia (17%), Canada (13%), France (11%), Japan (8%), and Belgium (6%).

U.S. exports of unwrought cobalt and cobalt contained in chemicals decreased by 8% compared with those of 2003. As listed in table 6, 90% of the cobalt metal and chemical exports was shipped to eight countries—Belgium, Canada, Germany, Ireland, Japan, Mexico, Sweden, and the United Kingdom. The remainder was shipped to 38 other countries.

Exports also included 1,150 t, gross weight, of wrought metal and cobalt articles valued at $48.4 million. Eighty-five percent of these materials was sent to 9 countries—France (26%), the United Kingdom (18%), Japan (12%), Germany (8%), Belgium and Canada (5% each), India and the Republic of Korea (4% each), and Taiwan (3%). The remainder was shipped to 44 other countries.

World Industry Structure

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 Ltd.) processed lateritic ore imported from Indonesia, New Caledonia, and the Philippines at its Yabulu nickel-cobalt refinery in Townsville, Queensland, and produced 1,900 t of cobalt as cobalt oxide hydroxide, 6% more than the 1,800 t produced in 2003. In March, BHP Billiton approved the construction of a nickel-cobalt laterite mine and front-end acid leaching plant at Ravensthorpe on the southern coast of Western Australia and an expansion of 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 would supply as much as 50,000 t/yr of nickel and 1,400 t/yr of cobalt in nickel-cobalt hydroxide, with the first shipment in 2007 (Cobalt Development Institute, 2005b; BHP Billiton, 2004§).

WMC produced cobalt in intermediate nickel-cobalt mixed sulfide at its Kwinana nickel refinery in Western Australia. The refinery processed matte from WMC's Kalgoorlie smelter, which was produced from nickel sulfide concentrates from ores mined in Western Australia by WMC and other companies. WMC'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 on its Web site. In 2004, WMC sold 593 t of cobalt, significantly less than the 886 t sold in 2003. WMC also sold nickel concentrates, matte, and mixed sulfide. During the fourth quarter, WMC announced that it was developing a low-pressure leach process to treat low-grade ores from Mt. Keith and Yakabindie (WMC Resources Ltd., 2005a, p. 17, 28).

Minara Resources Ltd. produced 1,979 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, a slight decrease from the 2,039 t produced in 2003. Production was impacted by an unplanned shutdown owing to heavy flooding in February, a planned shutdown in April to install equipment under a capital works program, and various maintenance repairs (Minara Resources Ltd., 2004, p. 4; 2005, p. 3; Cobalt Development Institute, 2005b).

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. commissioned its nickel sulfide mine and concentrator in the East Kimberly District of Western Australia and began shipping concentrates in early September. All production from the mine was to be processed by Jinchuan Group Ltd. under a life-of-mine concentrate sales agreement. Mine output was forecast to be 7,500 t/yr of nickel, 3,600 t/yr of copper, and 370 t/yr of cobalt. By mid-January 2005, concentrates containing a total of 166 t of cobalt had been shipped (Sally Malay Mining Ltd., 2004a, p. 5-9; 2004b).

Fox Resources Ltd. reopened the Radio Hill nickel sulfide mine and concentrator near Karratha in Western Australia and produced 49 t of cobalt in concentrates by yearend. Fox had a 3-year agreement to ship approximately 35,000 t/yr of nickel-copper concentrates, containing approximately 170 t/yr of cobalt, to Jinchuan Group Ltd.'s operations in Gansu Province, China. In addition, Fox began to study the feasibility of processing the nearby Sholl nickel sulfide deposits by heap leaching (Fox Resources Ltd., 2004, 2005).

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 and OMG in Finland to be refined.

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).

Compass Resources NL evaluated various options for a reduced cost startup of its Browns lead-copper-cobalt-nickel project in the Northern Territory. The company decided to proceed with detailed development planning on a project that would treat oxide ores by agitated sulfuric acid leaching to recover 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 planned to decide on whether to proceed with the project in mid-2005 and hoped to begin production in 2006 (Compass Resources NL, 2004; 2005§).

LionOre Mining International Ltd. purchased the Bulong nickel laterite plant from the receivers and managers of Bulong Operations Pty. Ltd. and Bulong Nickel Pty. Ltd. and renamed it Avalon. During the year, LionOre studied the feasibility of converting the plant, which is near Kalgoorlie, to treat nickel sulfide ores by using the company's Activox medium-temperature, medium-pressure oxidation process (LionOre Mining International Ltd., 2005, p. 8, 46).

Sherlock Bay Nickel Corp. Ltd. studied the feasibility of developing the Discovery and Symonds nickel sulfide

deposits approximately 120 kilometers (km) east of Karratha in northwest Western Australia. Pacific Ore Technology (Australia) Ltd. (a subsidiary of Titan Resources Ltd.) agreed to provide Sherlock Bay with a license to use its BioHeap bacterial leaching process for the project. Sherlock Bay was considering expected initial production from the project to average 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).

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 (2005b), Umicore's 2004 cobalt refinery production was 2,947 t, 73% more than the 1,704 t produced in 2003. 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; Leduc and Fort Saskatchewan, Alberta, Canada; Guangzhou and Shanghai, China; Cheonan, Republic of Korea; and Subic, Philippines.

Botswana.—LionOre installed and operated a demonstration plant that used the Activox process to treat concentrates from the Phoenix Mine at its Tati Nickel Mining Co. (Proprietary) Ltd. operations and produce nickel metal, copper metal, and cobalt carbonate. Information generated from the demonstration plant was to be included in a study of the feasibility of establishing a full-scale plant at the mine (LionOre Mining International Ltd., 2004; 2005, p. 17-18).

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 and planned to increase the cobalt capacity to 1,450 t/yr in 2005 (Ferraz, 2004).

Companhia Vale do Rio Doce (CVRD) studied the economic and technical feasibility of developing the Niquel do Vermelho laterite deposits in the Carajas mineral province, Para State. CVRD was considering a high-pressure acid leaching process to produce 45,000 t/yr of nickel cathode and 2,000 t/yr of cobalt, with startup during the second half of 2007 (Companhia Vale do Rio Doce, 2005).

Cameroon.—Geovic Cameroon S.A. studied the feasibility of developing a cobalt-rich low-nickel laterite deposit in Est Province. Geovic was considering producing 7,500 t/yr of cobalt and 4,700 t/yr of nickel by treating an upgraded cobalt concentrate with an atmospheric pressure sulfurous acid leaching; cobalt and nickel could be precipitated as an intermediate mixed sulfide product or upgraded by solvent extraction to produce cobalt and nickel oxides. The company hoped to start production during 2008 at initial rates of 4,000 t/yr of cobalt and 2,300 t/yr of nickel (Geovic, Ltd., 2005; 2004§).

Canada.—Falconbridge produced 565 t of cobalt in concentrate from its Sudbury, Ontario, mines; 400 t of cobalt in concentrate from its Raglan Mine in Quebec; and 70 t of cobalt in concentrate from its Montcalm Mine northwest of Timmins, Ontario. Nickel-copper matte produced at the Sudbury smelter was refined at the company's Nikkelverk refinery in Norway. In 2004, this matte contained 1,840 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. The custom feed was primarily nickel-copper-cobalt secondary materials (scrap) and nickel concentrates (Falconbridge Ltd., 2005, p. 15-21).

Inco produced 1,562 t of cobalt in 2004, significantly more than its production in 2003, which was adversely affected by a strike and problems in bringing output back up to planned levels following the strike. 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 (48%); nickel sulfide ores from company mines in Manitoba (32%); and purchased feedstocks, including nickel sulfide concentrates from the Sudbury Joint Venture [FNX Mining Co. (75%) and Dynatec Corp. (25%)] and Jubilee Mines NL's Cosmos nickel project and LionOre's Emily Ann Mine in Western Australia (20%) (FNX Mining Co. Inc., 2004, p. 4; Jubilee Mines NL, 2004, p. 9; Cobalt Development Institute, 2005b; Inco Ltd., 2005, p. 17, 19; LionOre Mining International Ltd., 2005, p. 26).

Inco continued to construct the Voisey's Bay nickel-copper-cobalt sulfide mine and concentrator in northeastern Labrador, completed the minipilot plant work on the hydrometallurgical process, and began to build a hydrometallurgical demonstration facility in Argentia. Progress during the year allowed Inco to advance the project schedule by 6 months. The company planned to begin mining in May 2005 and producing concentrates in August. The demonstration plant in Argentia was to be ready to test the first shipment of concentrates arriving from Voisey's Bay in November, and metal production was expected to begin in early 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 (Inco Ltd., 2005, p. 2, 45; Voisey's Bay Nickel Co., 2005).

The Fort Saskatchewan refinery of the Sherritt International Corp.-General Nickel Co. S.A. joint venture produced 3,325 t of cobalt as metal powder and briquettes in 2004, 6% more than the 3,141 t produced in 2003. Most of the feed was in the form of nickel-cobalt mixed sulfides from the joint-venture's operations at Moa Bay, Cuba. As a result of a United States embargo on imports of products originating from Cuba, nickel and cobalt produced by Sherritt cannot be sold to customers in the United States. Sherritt and General Nickel continued to discuss a proposed expansion of their nickel-cobalt operations (Sherritt International Corp., 2005, p. 26-29).

Fortune Minerals Ltd. began a bankable feasibility study on developing the NICO gold-cobalt-bismuth deposit 160 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 an acid-leach pressure-oxidation process, and approximately 1,200 to 1,500 t/yr of cobalt as carbonate or cathode would be produced (Fortune Minerals Ltd., 2004, 2005).

China.—China's production of refined cobalt increased significantly in 2004. Production estimates of 9,000 t made

China the world's leading producer of refined cobalt. This cobalt, which was in the form of metal, metal powders, and compounds, was produced from domestically mined and imported raw materials and was for domestic use and export. In 2004, there were approximately 26 companies with refining capacity of more than 100 t/yr of cobalt, resulting in a total Chinese cobalt refinery capacity of approximately 15,000 t/yr. Chinese imports of cobalt-bearing raw materials have increased significantly in recent years. The majority of these imports have been from Africa, most of which probably originated from Congo (Kinshasa). One analyst estimated that the cobalt content of Chinese "ore and concentrate" imports in 2004 was 11,487 t (Aidong, 2004; Aidong and Yang, 2005; Tomlinson, 2005).

The number of Chinese cobalt refiners and processors was reported to be approximately 50 (Aidong, 2004). The leading refiners were Jinchuan Group Ltd., Umicore, and Ganzhou Cobalt & Tungsten Co., Ltd., listed in order of estimated 2004 refined cobalt production. Jinchuan produced an estimated 2,200 t of cobalt as cathode and other products in 2004. The company has been steadily increasing its refinery capacity and planned for cobalt production to more than double to 4,500 t/yr in 2005. 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 nickel-cobalt feeds imported from Australia and elsewhere (China Metal Market, 2001, p. 13; Fox Resources Ltd., 2004; Jinchuan Group Ltd., 2004; Metal Bulletin, 2004b; Sally Malay Mining Ltd., 2004a, p. 9; WMC Resources Ltd., 2005b, p. 29).

Umicore refined cobalt-bearing materials in south-central China. Some of the cobalt from the refinery was processed into cobalt metal powders at Umicore's plant in Shanghai. In late 2003, Umicore acquired a 40% stake in Guangzhou Hongsheng Metallurgical and Chemical Co., a cobalt processor with a capacity of 1,000 t/yr of cobalt. In 2004, the plant was renamed Ganzhou Yi Hao Industries and its cobalt refining capacity was expanded (Gellens, 2002, p. 7-8; n.v. Umicore s.a., 2005, p. 8).

Ganzhou, which produced cobalt cathode, metal powders, oxides, and salts at Ganzhou, Jiangxi Province, had the capacity to refine 1,000 t/yr of cobalt (Ganzhou Cobalt & Tungsten Co., Ltd., undated§).

Congo (Kinshasa).—According to the Cobalt Development Institute (2005b), La Générale des Carrières et des Mines (Gécamines) produced only 735 t of refined cobalt in 2004. The record-low production was a reflection of ongoing problems in Congo (Kinshasa).

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.

High cobalt prices and increased demand from China resulted in a significant increase in the artisanal mining and export of cobalt-rich ores containing the mineral heterogenite. Some of the heterogenite was processed at plants within Congo (Kinshasa) prior to export, but most was not. Much of the unprocessed heterogenite was exported without Government approval (Global Witness, 2004, p. 9-23; Tomlinson, 2005).

The Costamin Resources (a joint venture between Congo Stars Mining Co. and a private Canadian company) mined heterogenite by artisanal methods from its Pumpi concession east of Kolwezi (Costamin Resources, undated§).

The Big Hill smelter at Lubumbashi, which was operated by Société pour le Traitement de la Terril de Lubumbashi (a joint venture between Gécamines, OMG, and S.A. Groupe George Forrest) was out of service for several weeks in October to make repairs following an electrical malfunction. The smelter processed stockpiled slag to produce a cobalt-copper alloy, which was shipped to OMG's Kokkola refinery (OM Group, Inc., 2004).

The Chemaf S.P.R.L. plant in Lubumbashi treated cobalt-rich ores by direct leaching with sulfuric acid followed by carbonation with soda ash and reportedly produced at a rate of 30 metric tons per month of cobalt contained in carbonate. Chemaf planned to increase the plant capacity from 500 t/yr to 3,000 t/yr of cobalt as carbonate (Chemaf S.P.R.L., undated§).

Adastra Minerals Inc. (formerly named America Mineral Fields, Inc.), the Government of Congo (Kinshasa), and Gécamines completed the agreements necessary to establish Kingamyambo Musonoi Tailings s.a.r.l. and begin developing the Kolwezi Tailings Project. Adastra awarded a contract for a definitive feasibility study on a processing plant with initial production levels of approximately 30,000 t/yr of copper and 5,500 t/yr of cobalt and the potential to double production in the future. In addition, Adastra signed a memorandum of understanding with Umicore regarding a long-term cobalt offtake agreement and assistance with cobalt marketing, the metallurgical process, and plant commissioning. Adastra hoped to make a go-ahead decision on the project in 2006 (Adastra Minerals Inc., 2004; 2005, p. 14-16, 23-25, 36-37).

Central African Mining & Exploration Company plc and Enterprises Swanepoel SARL formed Casmin SPRL, a joint venture to develop cobalt opportunities in Congo (Kinshasa). Casmin began building a processing plant at Kambove with an initial capacity of 1,200 t/yr of cobalt, although the company planned to increase the capacity to approximately 2,900 t/yr in the near future. Production was expected to begin in 2005 (Central African Mining & Exploration Company plc, 2004).

Metorex Ltd. reached an agreement with the Government of Congo (Kinshasa), Gécamines, and Sentinelle Global Investments (Proprietary) Ltd. to mine and process a high-grade copper-cobalt ore body at Ruashi and copper-cobalt oxide minerals stockpiled at Ruashi and Etoile. The project would be developed in two phases. For phase I, Metorex planned to build a flotation plant at Ruashi to treat the stockpiles. The resulting concentrates would be refined in Zambia at a company-owned solvent extraction-electrowinning (SX-EW) plant, which was to be retrofitted to produce approximately 8,000 t/yr of copper metal and 1,200 t/yr of cobalt as a salt. In phase II, Metorex would mine the ore body and process the ores onsite at an

expanded flotation plant and newly constructed acid leaching-SX-EW refinery to produce an estimated 40,000 t/yr of copper metal and 3,000 t/yr of cobalt metal (Metorex Ltd., 2004b).

Africo Resources Ltd. began a feasibility study on developing the Kalukundi copper-cobalt deposit approximately 65 km northeast of Kolwezi. Africo held an option to acquire a 75% interest in the deposit, which contained an inferred resource of 16.9 Mt, grading 3.03% copper and 0.66% cobalt as oxides (Rubicon Minerals Corp., 2004).

KGHM Polska Miedź planned to build a copper-cobalt processing plant in Congo (Kinshasa) to treat ores from the Kimpe deposit. In addition, the President of Poland and the Chairman of the People's Republic of China signed a letter of intent on a strategic partnership for the exploration and exploitation of copper-cobalt deposits in Congo (Kinshasa) and Zambia (Metal Bulletin, 2004a; President of Poland, 2004§).

Tenke Mining Corp. and Phelps Dodge Exploration Corp. negotiated with Gécamines and officials from the Government of Congo (Kinshasa) on the Tenke Fungurume project, which remained under force majeure (Tenke Mining Corp., 2005).

Kinross Forrest Ltd. (75%) and Gécamines (25%) formed a joint venture to rehabilitate and operate the Kamoto Mine west of Kolwezi. The joint venture's 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. Kinross Forrest was to deliver a feasibility study to Gécamines within 8 months after the joint venture received all required regulatory approvals (Balloch Resources Ltd., 2005).

Industrial Copper Systems Ltd., a Canadian supplier of copper products, planned to build a small copper-cobalt processing plant in Congo (Kinshasa). The plant was to use a process based on Electrometals Technologies Ltd.'s electrowinning cell technology to produce copper and cobalt metal and chemicals. Initially, the company would build a small plant with a capacity of 88 t/yr of cobalt and 114 t/yr of copper. Soon thereafter, the plant's capacity would be increased to 1,260 t/yr of cobalt and 1,630 t/yr of copper, and it could be further increased in stages. The company had financial assistance from the Canadian International Development Agency for the project (Chisholm and others, 2004a, p. 5, 18; b, p. 3, 7, 17).

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, in 2004, produced mixed sulfides containing 33,534 t of nickel and cobalt, a 5% increase from the 32,042 t produced in 2003. All of the mixed sulfides produced at Moa were sent to the joint venture's Fort Saskatchewan refinery in Canada. Sherritt and General Nickel continued to discuss a proposed expansion of their nickel-cobalt operations (Sherritt International Corp., 2005, p. 26, 29).

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 China (McCutcheon, 2003, p. 38.44). Nickel and cobalt of Cuban origin cannot be imported into the United States because of a United States embargo on imports from Cuba.

Cuban and Chinese mining and finance officials signed agreements to finish construction of the Las Camariocas nickel plant and to explore and develop nickel-cobalt resources at San Felipe (Resource Investor, 2004§).

Finland.—OMG's Kokkola Chemicals Oy refinery processed cobalt-bearing materials from Australia, the Big Hill smelter and the Luiswishi Mine in Congo (Kinshasa), and elsewhere. The company's production of cobalt metal powders, briquettes, oxides, and compounds was 7,893 t, similar to that produced in 2003 (Cobalt Development Institute, 2005b).

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 (2005b), cobalt production in India more than doubled as compared with production in 2003. Three companies refined cobalt from imported raw materials—Conic Metals Ltd., Nicomet Industries Ltd., and Rubamin Ltd.

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 WMC in Australia and P.T. Inco in Indonesia. 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 the Coral Bay Nickel Corp. plant in the Philippines (Metal Bulletin, 2002).

Madagascar.—Dynatec Corp. studied the feasibility of developing the Ambatovy nickel laterite deposit, 130 km east of Antananarivo. Dynatec planned to transport ore slurry by pipeline from the mine site to a proposed pressure acid leach plant and metals refinery near the Port of Toamasina. Following an initial ramp-up period, production during the first 10 years of operation was forecast to average 58,900 t/yr of nickel metal powder and 5,350 t/yr of cobalt metal powder. The deposit had proven and probable reserves totaling 125 Mt, grading 1.04% nickel and 0.099% cobalt, plus additional low-grade material that would sustain a project life of 27 years (Dynatec Corp., 2005, p. 4-19).

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. The study was considering a high-grade underground mine, a relatively small open pit operation, and a processing plant that would produce an estimated 50,000 t/yr of copper cathode, 2,100 t/yr of cobalt as carbonate or cathode, and 23,000 t/yr of zinc sulfate. In late 2004, Baja completed a preliminary pilot-plant-scale evaluation of an oxidation leaching-reduction leaching-SX-EW process on ore from Boleo (Baja Mining Corp., 2005; Greenslade, 2005§).

Morocco.—Cie. de Tifnout Tiranimine (CTT) mined cobalt-arsenic deposits at Bou Azzer and produced concentrates. The company refined the concentrates and tailings generated by past mining at Bou Azzer to produce cobalt cathode. In 2004, CTT

began operating a pilot-scale unit for the production of cobalt oxide and investigated the production of other cobalt chemicals. In addition, the company explored for new cobalt resources in Bou Azzer (Cie. de Tifnout Tiranimine, 2001; Groupe ONA, 2005, p. 24).

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 completed a comprehensive review of its Goro nickel-cobalt laterite project in southern New Caledonia and decided to proceed with developing 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. Inco, three Provinces of New Caledonia, and the French Government's Bureau de Recherches Géologiques et Minières (BRGM) entered into a letter of understanding covering the Provinces' acquisition of BRGM's shares in the project. Inco also reached an agreement in principle with Sumitomo and Mitsui & Co. Ltd. regarding their purchase of a 21% interest in the project and their right to offtake nickel and cobalt. Inco planned to remobilize for construction in early 2005 and expected that initial production would begin in late 2007 (Inco Ltd., 2004, p. 23, 24; Sumitomo Metal Mining Co., Ltd., 2004b).

Norway.—Falconbridge's production of cobalt at its Nikkelverk refinery increased 3% as compared with production in 2003. During 2004, 17% of the cobalt produced at Nikkelverk originated from Falconbridge mines in Canada, and 83% originated from custom feeds. The custom feed included matte from Botswana, which Falconbridge processed under a long-term agreement with BCL Ltd. (Falconbridge Ltd., 2005, p. 21-22).

Papua New Guinea.—China Metallurgical Construction Group Corp. and Highlands Pacific Ltd. began discussions on establishing a joint venture to develop the Ramu nickel-cobalt laterite project in Madang Province. The project [owned by Highlands Pacific (68.5%) and the Papua New Guinea Government's Mineral Resources Development Co. (31.5%)] was to use pressure acid leaching technology to produce 32,800 t/yr of nickel cathode and 3,200 t/yr of cobalt cathode (Papua New Guinea Department of Mining, 2004, p. 4, 20-21; Highlands Pacific Ltd., 2005, p. 5-6).

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, Rio Tuba Nickel Mining Corp., Mitsui & Co., Ltd., and Sojitz Corp.) completed construction and began commissioning a plant that would use pressure acid leaching technology to process low-grade lateritic ores stockpiled at the Rio Tuba nickel mine on Palawan Island. All of the mixed nickel-cobalt sulfide intermediate product produced by the plant, 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 (Sumitomo Metal Mining Co., Ltd. 2004a).

Russia.—According to the Cobalt Development Institute (2005b), OJSC MMC Norilsk Nickel, which was Russia's leading cobalt producer, produced 4,524 t of cobalt in 2004, slightly less than the 4,654 t produced in 2003. 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, 2004c; Astafiev, 2005, p. 6).

Mechel OAO's Yuzhuralnickel refinery at Orsk in the Ural Mountains processed nickel ores from the Sakhara and Buruktal mines. Cobalt in the ores was incorporated into the ferronickel produced (Mechel OAO, undated a§, b§).

South Africa.—Cobalt was mined as a byproduct from six platinum-group metal mines and one nickel mine (Harding, 2004). 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. [formerly Anglovaal Mining Ltd. (Avmin)] 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 partners were considering a base-metals plant with the capacity to produce 16,000 t/yr of nickel cathode, 7,200 t/yr of copper cathode, and 950 t/yr of cobalt salts. In recent years, sales of cobalt in nickel concentrates have been approximately 60 t/yr to 80 t/yr (African Rainbow Minerals Ltd., 2004; 2005; Anglovaal Mining Ltd., 2004, p. 281-289).

Umicore South Africa Pty. decided to sell its cobalt plant in Roodepoort. The plant treated low-grade cobalt-containing residues to produce cobalt compounds (Metal Bulletin, 2005).

Spain.—Rio Narcea Gold Mines, Ltd. started to commission its Aguablanca open pit nickel sulfide mine and processing plant in Badajoz Province near the boundaries of Huelva and Sevilla Provinces in southwestern Spain. Commercial production of copper-nickel-platinum-group-metal concentrate, containing an estimated 150 t/yr of cobalt, was expected to begin in early 2005 (Rio Narcea Gold Mines, Ltd., 2004, p. 6-7; 2005).

Turkey.—European Nickel PLC entered into a strategic alliance with BHP Billiton to develop a heap-leach process for nickel laterite ore from its Çaldağ deposit in western Turkey. As part of the agreement, BHP Billiton could take up to 80% of the nickel-cobalt mixed hydroxide produced from the project. European Nickel began a bankable feasibility study and successfully operated a large-scale heap-leach trial on the ore. The company expected to begin commercial production in 2007. At full operation, 15,000 t/yr of nickel and 800 t/yr of cobalt would be produced (European Nickel PLC, 2004a, b).

Uganda.—In May, Kasese Cobalt Co. restarted production from its cobalt refinery in southwestern Uganda. The refinery recovers cobalt from stockpiled pyrite concentrates by using a

bacterial leaching and electrowinning process. During the year, MFC Bancorp Ltd. distributed its cobalt assets, including its interest in Kasese, into Blue Earth Refineries Inc. of Hong Kong (Blue Earth Refineries Inc., 2005).

Uganda Gold Mining Ltd. signed an agreement with Kilembe Mines Ltd. to undertake an exploration program and begin a feasibility study on reopening the Kilembe copper-cobalt mine in western Uganda (Uganda Gold Mining Ltd., 2004).

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 2,022 t of cobalt metal at its Nkana cobalt refinery, approximately the same as it produced in 2003. Most of the cobalt originated from the company's Nkana underground copper-cobalt mine (Cobalt Development Institute, 2005b).

Chambishi Metals plc [owned by J&W Holding AG (90%) and ZCCM Investments Holdings plc (10%)] produced 3,769 t of cobalt metal at its Chambishi cobalt refinery, an 18% decrease from the 4,570 t produced in 2003. The refinery's main feed materials were metal-bearing solutions from the company's COSAC smelter and matte leach facility, which recovered cobalt and copper from slag stockpiled at Nkana, and concentrates from other mining companies in the Copperbelt, which it toll refined. The decrease in production was attributed to a decrease in availability of concentrates. In June, J&W subsidiary Luanshya Copper Mines Plc restarted operations at the Baluba copper-cobalt mine (Metal Bulletin, 2004d; Cobalt Development Institute, 2005b).

Konkola Copper Mines plc [owned by Vedanta Resources plc (51%), Zambia Copper Investments Ltd. (28.4%), and ZCCM Investments Holdings plc (20.6%)] mined copper ores from its Nchanga and Konkola operations, but reportedly ceased producing cobalt, owing to a depletion of cobalt resources at the Nchanga open pit (Platts Metals Week, 2004).

Copper-cobalt ore produced from Metorex's Chibuluma West Mine was processed at the company's Chibuluma South concentrator, and the concentrates were sold to Mopani (Metorex Ltd., 2004a, p. 15).

Equinox Resources Ltd. worked towards developing its Lumwana project in Zambia's North-Western Province. The project comprised two copper-cobalt-gold deposits, which could be mined by conventional open pit methods. Production would be in the form of copper concentrates, which would be transported offsite for smelting and refining. Later, if economic conditions warranted, a roast-leach-electrowin refinery could be built onsite to produce copper cathode, cobalt powder, and sulfuric acid (Equinox Resources Ltd., 2005, p. 7-9).

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 and power generation, catalysts 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, 2003; n.v. Umicore, s.a., 2004; Falconbridge Ltd., 2005, p. 42; Yamamoto, 2005).

World production of refined cobalt is also expected to continue to increase. Some 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. The first production from the larger of the new projects, in terms of cobalt output, is not expected to begin before 2006 or 2007. 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, has been sold, however. As of August 31, 2005, only 1,580 t of uncommitted cobalt remained in the NDS, which represented about 1 year's supply at the current rate of disposal.

Many analysts predict that the balance between cobalt supply and demand could be tight in the next few years (Cobalt Development Institute, 2005a). Tomlinson (2005) predicted that in the short term, cobalt demand would be constrained by supply. He stated that in the past few years, supply had been strongly supported by the export of cobalt intermediates from Congo (Kinshasa) to high-cost refineries in China. Future cobalt prices would have to remain high enough to continue to support this necessary Chinese production, but not so high as to initiate an industry-wide effort to substitute cobalt in batteries. From January through June 2005, the trend in average prices for cobalt cathode was downward, with a high of $19.50 per pound in January and a low of $13.05 per pound in June. Average prices during July through September ranged from $14.75 to $16.75 per pound.

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TABLE 1
SALIENT COBALT STATISTICS[1]

(Metric tons, cobalt content, unless otherwise specified)

	2000	2001	2002	2003	2004
United States:					
Consumption:					
Reported	8,980	9,540	7,880 r	7,590 r	8,450
Apparent	11,700 r	11,800	9,830 r	10,000	9,920
Imports for consumption	8,770	9,410	8,450	8,080	8,720
Exports	2,630	3,210	2,080	2,710	2,500
Stocks, December 31:					
Industry[2]	753 r	809 r	858 r	649 r	719
U.S. Government[3]	10,200	7,200 e	6,680	4,290	2,660
Price, metal[4] dollars per pound	15.16	10.55	6.91	10.60	23.93
World, production:[e]					
Mine	37,900 r	47,900 r	50,700 r	48,700 r	52,400
Refinery	36,000 r	39,600 r	41,700 r	43,800 r	49,100

[e]Estimated. [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]Annual 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 SHIPMENTS[1]

(Metric tons, cobalt content)

	2003	2004
Sales:		
Fiscal year[2]	2,060	1,920
Calendar year	2,820	987
Shipments:[3]		
Fiscal year[2]	1,930	2,220
Calendar year	2,380	1,630

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

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

[3]Calculated 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)

	2003	2004
Consumption by end use:		
Steels	565	722
Superalloys	3,400	3,650
Alloys, excludes steels and superalloys:		
Magnetic alloys	282 r	396
Other alloys[3]	632	627
Cemented carbides[4]	662	765
Chemical and ceramic uses	1,980	2,230
Miscellaneous and unspecified	63	63
Total	7,590 r	8,450
Consumption by form:		
Chemical compounds, organic and inorganic[5]	1,940	2,040
Metal	3,520 r	4,110
Purchased scrap	2,130 r	2,300
Total	7,590 r	8,450
Stocks, December 31:[6]		
Chemical compounds, organic and inorganic[5]	214	223
Metal	378 r	379
Purchased scrap	57 r	117
Total	649 r	719

rRevised.

[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 tool 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]

	2003			2004		
	Gross weight (metric tons)	Cobalt content[2] (metric tons)	Value (thousands)	Gross weight (metric tons)	Cobalt content[2] (metric tons)	Value (thousands)
Metal[3]	6,700	6,700	$135,000	7,250	7,250	$311,000
Oxides and hydroxides	1,370	983	23,000	1,300	934	45,100
Other forms:						
Acetates	294	71	1,600	230	55	2,550
Carbonates	231	106	2,700	453	208	10,300
Chlorides	106	26	866	327	82	3,220
Sulfates	716	193	3,180	705	190	6,030
Grand total	9,410	8,080	166,000	10,300	8,720	378,000

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

[2]Estimated from gross weights.

[3]Unwrought cobalt, excluding alloys and waste and scrap.

Source: U.S. Census Bureau.

TABLE 5

U.S. IMPORTS FOR CONSUMPTION OF COBALT, BY COUNTRY[1]

	Metal[2]			Oxides and hydroxides			Other forms[3]			Total		
Country of origin	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)
2003:												
Australia	298	298	$5,040	--	--	--	--	--	--	298	298	$5,040
Belgium	325	325	7,290	537	387	$9,900	17	4	$121	880	717	17,300
Brazil	262	262	4,780	--	--	--	4	2	42	266	264	4,820
Canada	508	508	9,440	--	--	--	--	--	--	508	508	9,430
China	161	161	3,440	128	92	1,560	46	13	297	335	267	5,300
Congo (Kinshasa)	178	178	2,820	--	--	--	--	--	--	178	178	2,820
Finland	582	582	13,600	381	274	5,720	832	255	5,150	1,800	1,110	24,500
France	31	31	1,430	38	27	1,350	--	--	--	69	58	2,780
Germany	29	29	489	2	1	173	--	--	--	31	31	662
India	--	--	--	--	--	--	50	14	195	50	14	195
Japan	128	128	3,320	--	--	--	60	15	597	189	144	3,910
Korea, Republic of	28	28	317	--	--	--	--	--	--	28	28	317
Morocco	20	20	353	--	--	--	--	--	--	20	20	353
Norway	1,770	1,770	36,500	--	--	--	--	--	--	1,770	1,770	36,500
Philippines	--	--	--	--	--	--	111	35	766	111	35	766
Russia	1,640	1,640	32,000	--	--	--	--	--	--	1,640	1,640	32,000
South Africa	103	103	1,540	26	18	301	--	--	--	129	121	1,840
Sweden	22	22	601	--	--	--	6	2	13	28	24	615
Uganda	5	5	66	--	--	--	--	--	--	5	5	66
United Kingdom	17	17	403	250	180	3,950	203	51	1,110	470	248	5,470
Zambia	555	555	9,920	--	--	--	--	--	--	555	555	9,920
Other	37 r	37 r	1,520 r	3	2	57	17	5	49	57 r	44 r	1,630 r
Total	6,700	6,700	135,000	1,370	983	23,000	1,350	396	8,350	9,410	8,080	166,000
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	589
Canada	1,120	1,120	36,900	1	1	45	--	--	--	1,130	1,130	37,000
China	429	429	18,400	188	135	4,660	462	136	5,250	1,080	701	28,300
Congo (Kinshasa)	16	16	712	--	--	--	--	--	--	16	16	712
Finland	357	357	19,600	361	260	12,300	733	257	11,800	1,450	874	43,800
France	56	56	3,570	24	18	1,280	--	--	--	81	74	4,850
Germany	33	33	1,550	5	4	202	--	--	--	38	37	1,760
India	--	--	--	--	--	--	171	46	1,370	171	46	1,370
Japan	164	164	9,460	(6)	(6)	13	57	14	772	221	178	10,200
Korea, Republic of	71	71	1,620	--	--	--	--	--	--	71	71	1,620
Norway	1,420	1,420	65,200	--	--	--	--	--	--	1,420	1,420	65,200

See footnontes at end of table.

TABLE 5—Continued

U.S. IMPORTS FOR CONSUMPTION OF COBALT, BY COUNTRY[1]

	Metal[2]			Oxides and hydroxides			Other forms[3]			Total		
Country of origin	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)
2004—Continued:												
Philippines	--	--	--	--	--	--	83	27	$758	83	27	$758
Russia	1,630	1,630	$79,800	--	--	--	--	--	--	1,630	1,630	79,800
South Africa	110	110	3,270	--	--	--	--	--	--	110	110	3,270
Sweden	8	8	315	--	--	--	--	--	--	8	8	315
Uganda	50	50	2,110	--	--	--	--	--	--	50	50	2,110
United Kingdom	12	12	579	240	173	$7,940	155	41	1,930	407	226	10,400
Zambia	618	618	27,700	--	--	--	--	--	--	618	618	27,700
Other	11	11	347	27	19	1,020	53	14	153	92	45	1,520
Total	7,250	7,250	311,000	1,300	934	45,100	1,720	536	22,100	10,300	8,720	378,000

[r]Revised. -- 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; includes cobalt cathode and cobalt metal powder; may include intermediate products of cobalt metallurgy.

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

[4]Estimated from gross weights.

[5]Customs value.

[6]Less than ½ unit.

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

TABLE 6

U.S. EXPORTS OF COBALT IN 2004, BY COUNTRY[1, 2]

	Metal[3]		Oxides and hydroxides		Acetates		Chlorides		Total	
Country of destination	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)
Argentina	15	$524	4	$97	--	--	--	--	18	$621
Belgium	804	45,300	17	331	62	$269	--	--	831	45,900
Brazil	2	134	4	95	61	864	--	--	19	1,090
Canada	216	4,140	37	1,430	138	1,160	67	$700	292	7,430
China	34	295	1	21	--	--	--	--	35	316
France	23	1,110	--	--	--	--	--	--	23	1,110
Germany	140	3,300	(6)	11	--	--	--	--	140	3,310
Ireland	292	6,090	--	--	--	--	--	--	292	6,090
Japan	266	9,750	169	9,090	--	--	--	--	387	18,800
Korea, Republic of	20	788	--	--	19	234	--	--	25	1,020
Mexico	13	500	52	1,650	295	2,060	1	18	121	4,230
Netherlands	27	651	(6)	11	--	--	--	--	27	662
Spain	2	125	--	--	16	86	--	--	5	210
Sweden	70	1,570	--	--	--	--	--	--	70	1,570
Tunisia	16	338	--	--	--	--	--	--	16	338
Ukraine	10	57	--	--	--	--	--	--	10	57
United Kingdom	105	2,530	16	375	--	--	(6)	3	116	2,900
Venezuela	(6)	3	17	625	--	--	--	--	12	628
Other	56	2,180	8	95	8	89	--	--	63	2,360
Total	2,110	79,400	324	13,800	598	4,770	68	720	2,500	98,700

-- 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 value.

[5]Estimated from gross weights.

[6]Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 7
WORLD ANNUAL COBALT REFINERY CAPACITY, DECEMBER 31, 2004[1, 2]

(Metric tons, cobalt content)

Country	Capacity
Australia[e]	4,950
Belgium	1,200
Brazil[e]	1,200
Canada	5,300
China[e]	15,000
Congo (Kinshasa)	17,600
Finland	10,000
France	600
India[e]	550
Japan	600
Morocco[e]	1,600
Norway	4,800
Russia[e]	8,000
South Africa[e]	1,000
Uganda	720
Zambia	9,700
Total	82,800

[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 powders, oxides, and/or salts.

TABLE 8

COBALT: WORLD MINE PRODUCTION, BY COUNTRY[1, 2]

(Metric tons, cobalt content)

Country[3]	2000	2001	2002	2003	2004[e]
Australia[e, 4]	5,600	6,300 [r]	6,700	6,900	6,700
Botswana[5]	308	325	269	294 [r]	223 [6]
Brazil[e]	900	1,100	1,200	1,300	1,400
Canada[7]	5,298	5,326	5,148	4,327 [r]	5,197 [6]
China[e]	90	150	1,000	700 [r]	800
Congo (Kinshasa)[e, 8]	11,000	15,000	14,500	12,000	16,000
Cuba[9]	2,852 [r]	3,417 [r]	3,384 [r]	3,465 [r]	3,580 [6]
Kazakhstan[e, 10]	300	300	300	300	300
Morocco[11]	967 [r]	1,242	1,453 [r]	1,391 [r]	1,600
New Caledonia[e, 12]	1,200	1,400	1,400	1,400	1,400
Norway[e, 11]	100	100	100	--	--
Russia[e]	4,000	4,600	4,600	4,800	4,700
South Africa[e]	580	560 [r]	520 [r]	400	460
Zambia[e, 13]	4,600	8,000	10,000	11,300	10,000
Zimbabwe[14]	79	95	87	79 [r]	59 [6]
Total[e]	37,900 [r]	47,900 [r]	50,700 [r]	48,700 [r]	52,400

[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 18, 2005. 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, Indonesia, the Philippines, Poland, 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.

[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, in metric tons, was estimated to be as follows: 2000—5,200 (revised); 2001—6,200 (revised); 2002—6,800 (revised); 2003—7,300 (revised); and 2004—7,000.

[5]Reported cobalt content of pelletized nickel-copper matte.

[6]Reported figure.

[7]Assay 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: 2000—2,022; 2001—2,112; 2002—2,065; 2003—1,842 (revised); and 2004—2,126.

[8]Cobalt content of concentrates, tailings, and slags. Includes the following estimates, in metric tons, of illegal production by artisanal miners: 2000—1,000; 2001-02—2,000; 2003—4,000; and 2004—7,000.

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

[10]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 1,400 metric tons (2000-04).

[11]Cobalt content of concentrates.

[12]Quantities 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.

[13]Cobalt content of concentrates and slags.

[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]	2000	2001	2002	2003	2004
Australia, metal, metal powder, oxide hydroxide[e]	2,610	3,470	3,700	3,840	3,880
Belgium, metal powder, oxide, hydroxide[4]	1,110	1,090	1,135	1,704	2,947
Brazil, metal	792	889	960	1,097	1,155
Canada, metal, metal powder, oxide	4,364	4,378	4,625	4,233	5,144
China, metal, metal powder, oxide, salts[e, 5]	1,200 [r]	1,470 [r]	1,840 [r]	4,580 [r]	8,000
Congo (Kinshasa), metal[6]	4,320	4,071	3,000 [e]	1,200 [e]	735
Finland, metal powder and salts[7]	7,700	8,100	8,200	7,990	7,893
France, chloride	204	199	176	181	199
India, metal and salts	206	250	270	255	545
Japan, metal	311	350	354	379	429
Morocco, metal	1,207 [r]	1,341 [r]	1,354	1,431 [r]	1,593
Norway, metal	3,433	3,314	3,994	4,556	4,670
Russia, unspecified[e, 8]	4,400	5,000	5,100	5,500	5,400
South Africa, metal powder and sulfate	397	373	352 [r]	271	309
Uganda, metal	420	634	450 [e]	--	436
Zambia, metal	3,342	4,657	6,144	6,620	5,791
Total[e]	36,000 [r]	39,600 [r]	41,700 [r]	43,800 [r]	49,100

[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 18, 2005. 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 and Poland may produce some cobalt, but information is inadequate to make reliable estimates of production.

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

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

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

[7]Production reported by OM Group, Inc.; may include production from outside Finland that is not otherwise included in this table.

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