USGS
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2006 Minerals Yearbook

COBALT

U.S. Department of the Interior
U.S. Geological Survey

April 2008

COBALT

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World production of refined cobalt in 2006 was nearly equal to that of 2005. The United States did not mine or refine cobalt in 2006. 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.

According to the Cobalt Development Institute, world demand (consumption and stock increases) for cobalt decreased slightly compared with that of 2005. European apparent demand was slightly lower than that of 2005, and Chinese apparent demand was adversely affected by the limited availability of raw material. U.S. apparent consumption of cobalt was lower than that of 2005, primarily because of lower shipments from the NDS. Cobalt prices rapidly increased late in the year, and the U.S. spot price briefly exceeded $30 per pound at the end of November. The last time that this price was more than $30 per pound was in late 1995 through early 1996 (Cobalt Development Institute, 2007a).

Salient U.S. and world cobalt statistics for 2006 and the previous 4 years are listed in table 1.

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 resulted in a significant increase in the use of cobalt to make battery electrodes, such that on a global basis, the battery industry began to use more cobalt than the superalloy industry. 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

In December 2005, the Defense National Stockpile Center (DNSC), U.S. Department of Defense, suspended cobalt sales while it determined whether the metal was needed by the military. The moratorium on sales was lifted in April (Defense National Stockpile Center, 2006b; Platts Metals Week, 2006a).

During fiscal year 2006 (October 1, 2005, through September 30, 2006), DNSC sold 200 metric tons (t) of cobalt cathode, granules, and rondelles valued at $6.1 million under a basic ordering agreement (BOA) (table 2). This represented 7% of the 2,720-t (6-million-pound) maximum allowed for sale under the fiscal year 2006 Annual Materials Plan (AMP). At the end of the fiscal year, 106 t of cobalt had been sold but not shipped from the stockpile. The AMP for fiscal year 2007 (October 1, 2006, through September 30, 2007) was reduced to 1,590 t (3.5 million pounds) (Defense National Stockpile Center, 2006a; U.S. Department of Defense, 2007, p. 5, 11, 58).

During calendar year 2006, DNSC sold 256 t of cobalt valued at $9.3 million under the BOA. On December 31, the total uncommitted cobalt inventory held by the DNSC was 1,250 t of cobalt cathode.

Production

With the exception of negligible amounts of byproduct cobalt produced from lead and platinum-group metal (PGM) operations, the United States did not mine or refine cobalt in 2006.

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.

In 2006, 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 in Minnesota, and Kennecott Minerals Co.'s Eagle project in Michigan.

Formation received the preliminary draft environmental impact statement on its Idaho cobalt project and submitted a final mine plan of operation to the permitting agencies. The company planned to develop an underground cobalt-copper-gold mine and mill complex in the Idaho Cobalt Belt in Lemhi County, and retrofit its hydrometallurgical refinery in Big Creek, ID, to refine the cobalt concentrates. The refinery was to have the capacity to produce more than 1,600 metric tons per year (t/yr) of cobalt as high-grade cathode (99.9% cobalt); cobalt compounds could also be produced. Formation expected to complete the bankable feasibility study and receive mine permits in 2007, then commence construction so that production could begin in late 2008 (Formation Capital Corp., 2007, p. 2, 13, 17-18, 23, 26, 29).

PolyMet received the results of a definitive feasibility study that confirmed the economic and technical viability of its NorthMet project. The project entailed open pit mining of the NorthMet polymetallic deposit in the Duluth Complex of northeastern Minnesota. A bulk concentrate produced at the nearby Cliffs-Erie mill and concentrator would be processed in a new hydrometallurgical plant using the company's PlatSol technology. Products would include copper cathode, either a nickel-cobalt mixed hydroxide or separate hydroxides, and a precipitate of PGMs and gold. During the first 5 years of a 20-year mine life, approximately 330 t/yr of cobalt would be produced. PolyMet planned to begin mine production in mid-2008 and metal production by late 2008, pending receipt of

operating permits and project financing (PolyMet Mining Corp., 2006a, p. 2-4; 2006b).

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 seven U.S. cobalt processors. Information from this survey was used to prepare the statistics on cobalt consumption and stocks in table 3. 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 until the plant's closure late in the year. 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 (n.v. Umicore, s.a., 2006, p. 4-5).

Environment

The International Programme on Chemical Safety, which was a cooperative program of the World Health Organization, the International Labour Organization, and the United Nations Environment Programme, published a summary of scientific information concerning the potential effects of cobalt and inorganic cobalt chemicals on human health and/or the environment (Kim and others, 2006, p. 1).

Consumption

U.S. apparent consumption for 2006, as calculated from net imports, consumption from purchased scrap, and changes in Government and industry stocks, was 6% lower than that of 2005 (table 1). Net imports and consumption of scrap were about the same in both years, but shipments from the NDS were lower in 2006 than those of 2005.

U.S. reported consumption of cobalt in 2006 was approximately equal to that of 2005. Compared with consumption in 2005, metallurgical industries consumed about the same amount of cobalt, and the cobalt consumption for chemical uses was 6% 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, 65 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

The annual average U.S. spot price for cathode (minimum of 99.8% cobalt), as reported by Platts Metals Week, was $17.22 per pound for 2006, up by 8% from that of 2005 (table 1). For most of the year, the price was fairly stable and between $12.75 and $20.50 per pound. In late November, it rapidly increased to a high of $31.00 per pound, following two events that resulted in consolidating some large sectors of the cobalt market—Xstrata plc acquired Falconbridge Ltd., and ultimately awarded the marketing of its cobalt to Swiss trading firm Glencore International AG (which has partial ownership of cobalt-producing operations in Australia and Zambia), and OJSC MMC Norilsk Nickel agreed to supply OM Group, Inc. (OMG) with most of its cobalt production (Ryan's Notes, 2006). The price retreated by yearend to a range of $26.00 to $27.00 per pound. 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 $16.36 per pound, and the annual average of weekly prices for Russian cobalt was $15.98. Sales prices for 99.8% cobalt cathode reported by BHP Billiton ranged from $12.50 to $30.00 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 2006, net import reliance as a percentage of apparent consumption was 82%. Because there was no measurable U.S. primary cobalt production in 2006, this indicates that 82% of U.S. cobalt supply was from imports and stock releases of primary cobalt and 18% was from domestic or imported scrap.

In 2006, the United States imported 5% more cobalt than it did in 2005 (tables 4, 5). Ten countries supplied more than 90% of U.S. imports. Russia was the leading supplier, followed by Norway, China, Canada, Finland, Zambia, Belgium, Australia, Brazil, and Morocco. Compared with those of 2005, cobalt imports from Australia, Canada, China, and Russia increased, and imports from Belgium, Brazil, Finland, Morocco, Norway, and Zambia decreased.

In 2006, the United States imported 34 t, gross weight, of unwrought cobalt alloys valued at $1.3 million. Five countries supplied most of these materials—Australia (60%), Belgium (14%), Japan (10%), the United Kingdom (5%), and Canada (4%). The United States imported 726 t, gross weight, of cobalt waste and scrap valued at $9.4 million. Seven countries supplied most of this material—the United Kingdom (46%), Ireland (17%), Germany (10%), Canada (8%), Japan (6%), and France and Tunisia (4% each). The United States also imported 238 t, gross weight, of wrought cobalt and cobalt articles valued at $18.6 million. The leading suppliers of these materials were the

United Kingdom (47%), Canada (13%), Germany (12%), and Japan and France (11% each).

U.S. exports of unwrought cobalt and cobalt contained in chemicals increased by 17% compared with those of 2005. As listed in table 6, more than 90% of the cobalt metal and chemical exports was shipped to nine countries—Belgium, Canada, Finland, France, Germany, Ireland, Japan, Mexico, and the United Kingdom. The remainder was shipped to 40 other countries.

Exports also included 1,980 t, gross weight, of wrought metal and cobalt articles valued at $90.4 million. Ninety percent of these materials was sent to 10 countries—France (19%); the United Kingdom (15%); Ireland and Japan (11% each); Belgium and Germany (10% each); Canada, China, and Switzerland (4% each); and the Republic of Korea (3%). The remainder was shipped to 41 other countries.

World Review

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 approximately one-half of world cobalt production in 2006 (Cobalt Development Institute, 2006; 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.

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 1,300 t of cobalt as cobalt oxide hydroxide compared with 1,400 t produced in 2005. During the year, the company worked on its Ravensthorpe nickel-cobalt laterite mine and acid leaching plant in Western Australia and on expanding the Yabulu refinery to accommodate nickel-cobalt mixed hydroxide product from Ravensthorpe. The expanded refinery was to have the capacity to produce 3,500 t/yr of cobalt. At yearend, the Yabulu expansion was essentially complete, the Ravensthorpe construction was nearly 80% complete and mine operations had commenced. The revised target for first metal production was the first quarter of 2008 (BHP Billiton, 2007a, p. 14; 2007b).

BHP Billiton's Nickel West operation 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 Xstrata Nickel (formerly Falconbridge) 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 matte (BHP Billiton, undated).

Minara Resources Ltd. produced 2,096 t of cobalt as metal powder and briquettes from its Murrin Murrin nickel-cobalt laterite pressure-acid leaching operation east of Leonora, Western Australia, 20% more than the 1,750 t produced in 2005. Problems with the operation's acid plant were addressed during the year. In addition, Minara built and began commissioning a demonstration plant to recover nickel and cobalt by heap leaching stockpiled ore reject material. The plant was to provide a second feed source to the Murrin Murrin refinery at a rate of approximately 2,000 t/yr of nickel and 150 t/yr of cobalt (Minara Resources Ltd., 2007).

OMG shipped intermediate nickel-cobalt carbonate produced from its Cawse plant, northwest of Kalgoorlie, Western Australia, to its plant at Harjavalta, Finland, for refining. The Cawse plant had the capacity to produce carbonate containing 375 to 440 t/yr of cobalt. In late 2006, OMG agreed to sell its nickel assets to Norilsk (discussed in more detail in the "Finland" section of this report). The sale included the Cawse plant and OMG's share in MPI Nickel Pty. Ltd., which operated the Black Swan and Silver Swan nickel sulfide mines (OJSC MMC Norilsk Nickel, 2006a; 2006b).

Sally Malay Mining Ltd. mined nickel sulfide ores in Western Australia and produced concentrates containing 389 t of cobalt, which were shipped to Jinchuan Group Ltd.'s operations in China under a life-of-mine sales agreement. Early in the year, Sally Malay ramped up production from its underground operations after suspending mining from its open pit following a wall slippage (Sally Malay Mining Ltd., 2006a,b; 2007).

Fox Resources Ltd. ceased underground operations at its Radio Hill nickel-copper sulfide mine near Karratha, Western Australia, and placed the mine on care-and-maintenance status. Fox supplied Jinchuan with nickel and copper concentrates from Radio Hill under a 3-year offtake agreement that was signed in 2004. The company planned to restart underground mining at Radio Hill in 2007 (Fox Resources Ltd., 2006, p. 8; 2007).

Western Areas NL began mining the Flying Fox Mine at its Forrestania nickel project in Western Australia; nickel sulfide ore from Forrestania was committed to LionOre Mining International Ltd. Cobalt-bearing nickel sulfide concentrates produced from several operations in Australia were exported to Inco Ltd. in Canada. Zinifex Ltd. shipped zinc concentrates produced at its Century Mine in northern Queensland to the Budel smelter in the Netherlands, where cobalt was recovered as filter cake (Zinifex Budel BV, undated).

Allegiance Mining NL signed an offtake agreement with Jinchuan for nickel sulfide concentrates to be produced from its Avebury project in Tasmania. By early 2007, Allegiance was producing and stockpiling development ore in anticipation of mill startup by late 2007. At full production, Avebury was expected to produce 8,500 t/yr of nickel in concentrate grading

more than 20% nickel and 0.4% cobalt (Allegiance Mining NL, 2006, p. 11; 2007, p. 2, 8).

Compass Resources NL received government approvals to develop its Browns oxide project near Darwin, Northern Territory. The project comprised mining oxidized copper-cobalt-nickel ores from the Browns deposit and processing them by sulfuric acid leaching followed by solvent extraction-electrowinning (SX-EW) to produce 10,000 t/yr of copper cathode and a mixed carbonate containing 1,000 t/yr of cobalt and 700 t/yr of nickel. Compass moved the mill and SX-EW plant from the Cawse operation in Western Australia to the project site, and began refurbishing them. The company planned to begin mining and commission the plant in 2007. During the year, Hunan Nonferrous Metals Corp. Ltd. agreed to establish joint ventures with Compass to develop the oxide project, develop a sulfide project, and explore for metals in the Northern Territory (Compass Resources NL, 2007a, p. 4-7; 2007b).

LionOre continued to study the feasibility of converting their Avalon plant to treat nickel sulfide ores from the Honeymoon Well deposit in Western Australia using the company's Activox hydrometallurgical process (LionOre Mining International Ltd., 2007, p. 3).

Gladstone Pacific Nickel Ltd. studied the feasibility of building a high-pressure acid-leach plant and refinery at the port city of Gladstone in Queensland. The leaching plant would process nickel laterite ores imported from New Caledonia and elsewhere and ores mined and delivered by slurry pipeline from its Marlborough laterite deposits. Initial production was to include 4,800 t/yr of cobalt metal briquettes from a blend of Marlborough and New Caledonian ores. The complex would be expanded as needed. During the year, Gladstone signed a preliminary agreement with Société des Mines de la Tontouta (SMT) for ore from existing SMT mines and the right to participate in the development of a new mine. Gladstone estimated that production could begin in late 2010, assuming that funding arrangements are made and the remaining government approvals are obtained (Gladstone Pacific Nickel Ltd., 2006, inside front cover and p. 4-14).

Australasian Resources Ltd. (formerly Sherlock Bay Nickel Corp. Ltd.) studied various options for reducing the amount of fresh acid needed to treat the low-grade disseminated nickel sulfide ores from the Discovery and Symonds nickel sulfide deposits in Western Australia. Australasian was considering using 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; Australasian Resources Ltd., 2007).

Ivanplats Syerston Pty. Ltd. began preliminary construction of an open pit mine at its Syerston nickel-cobalt laterite project near Fifield, New South Wales. The project would include a processing plant to produce 53,000 t/yr of nickel-cobalt mixed sulfide (New South Wales Government, 2005, Australian Broadcasting Corp., 2006).

Havilah Resources NL and Heilongjiang Resources Ltd. formed a joint venture to study the feasibility of developing the Mutooroo copper-cobalt sulfide deposit west of Broken Hill, South Australia. The partners hoped to find sufficient reserves to produce 20,000 t/yr of copper and 2,000 t/yr of cobalt from an open pit mine (Havilah Resources NL, 2006; 2007).

Metals Finance Corp. and Metallica Minerals Ltd. studied the feasibility of the Lucky Break project west of Townsville, Queensland. The project would use heap and vat leaching to recover approximately 1,600 t/yr of nickel from lateritic ore and was expected to begin producing intermediate nickel carbonate in late 2008. Development of this project was expected to provide information for Metallica to develop the larger NORNICO heap-leach operation northwest of Townsville (Metallica Minerals Ltd., 2007, p. 23).

Belgium.—Umicore converted cobalt metal, residues, and other cobalt-bearing materials into a wide range of cobalt specialty products, including metal powders, hydroxides, oxides, salts, and compounds. According to the Cobalt Development Institute (2007b), Umicore's 2006 cobalt refinery production was 2,840 t, 14% less than the 3,298 t produced in 2005. This production took place at plants in Olen, Belgium, and Ganzhou, China. In addition, Umicore produced specialty cobalt products at processing plants in Arab, AL, and Laurinburg, NC, in the United States; Guarulhos, Brazil; Fort Saskatchewan, Alberta, Canada; Shanghai, China; and Cheonan, Republic of Korea.

Botswana.—LionOre completed a bankable feasibility study and decided to proceed with its Activox project at the Tati Nickel Mining Co. (Proprietary) Ltd. operation. The company planned to construct a dense media separation plant at Tati's Phoenix Mine, build a refinery that would use its Activox hydrometallurgical process, and develop the Selkirk Mine. The refinery was to produce an estimated 22,000 t/yr of nickel cathode, as well as copper cathode and cobalt carbonate, beginning in 2009 (LionOre Mining International Ltd., 2006, p. 3, 21-22; 2007, p. 1, 3).

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.

Companhia Vale do Rio Doce (CVRD) sought the necessary licenses 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 (Companhia Vale do Rio Doce, 2007a, p. 44, 52).

Mirabela Nickel Ltd. studied the feasibility of the Santa Rita nickel sulfide project near Salvador, Bahia State. The company was considering an open pit mine with a conventional mineral flotation plant. Production was expected to be 17,000 t/yr of nickel in concentrate with a target composition of 12% to 14% nickel, 3.5% copper, and 0.35% cobalt. Mirabela hoped to complete a bankable feasibility study and mine permitting in 2007 and commissioning in late 2008 (Mirabela Nickel Ltd., 2007, p. 2, 4, 9, 20).

Cameroon.—Geovic Mining Corp. began a final feasibility study on its Nkamouna project in Est Province. Nkamouna is one of seven cobalt-rich low-nickel laterite deposits that Geovic was considering for development. Ore from open pit mines would be processed to form a coarse cobalt-rich concentrate of the mineral absolane, which would be treated by atmospheric acid leaching-solvent extraction to produce cobalt and nickel

oxides. Annual production was forecast to be 3,300 t/yr of cobalt and 2,700 t/yr of nickel. The company planned to improve and expand project infrastructure during 2007 and start major construction in 2008, so that production could begin in 2009 (Geovic Mining Corp., 2007a, p. 5, 29-30; 2007b).

Canada.—Inco Ltd. was acquired by CVRD and in early 2007 became a wholly owned subsidiary named CVRD Inco Ltd. Inco produced 2,040 t of refined cobalt in 2006, 23% more than the 1,660 t produced in 2005. The production was in the form of cathode from the company's Port Colborne, Ontario, refinery and cobalt oxide and hydrate from its Thompson, Manitoba, refinery. The cobalt originated from nickel sulfide ores from company mines at Sudbury, Ontario; Thompson; and Voisey's Bay in northeastern Labrador; and purchased feedstocks, including nickel sulfide ore from FNX Mining Co. Inc.'s Sudbury operations and nickel sulfide concentrates from Jubilee Mines NL's Cosmos nickel project and LionOre's Emily Ann Mine, both in Western Australia. Voisey's Bay became the company's main source of cobalt in 2006. CVRD reported the following distribution of sources for its cobalt production: Ontario, 633 t (1,378 t in 2005); Manitoba, 415 t (282 t in 2005); Voisey's Bay, 680 t (0 t in 2005); and external sources, 312 t (0 t in 2005) (Companhia Vale do Rio Doce, 2007b).

During the year, Inco increased the cobalt capacity of its Thompson refinery from 400 t/yr to 1,000 t/yr to accommodate the higher cobalt grades of the Voisey's Bay concentrates. As part of the expansion, Inco was able to eliminate the calcining step from the process and began producing cobalt hydrate for direct sale (Jebbink and others, 2006).

Voisey's Bay Nickel Co. Ltd. (an Inco subsidiary) announced that it was considering an alternative site near Long Harbour, Newfoundland, for its commercial processing plant. The company continued to evaluate the viability of using a hydrometallurgical process for Voisey's Bay concentrates. If the hydrometallurgical process was selected, the plant would have a design capacity of 2,460 t/yr of cobalt cathode. If not, the concentrates would be smelted to produce matte prior to being processed, and the plant's cobalt capacity would be reduced to 900 t/yr of cathode. A decision on which type of plant would be built was scheduled for the end of 2008, so that construction could begin in early 2009 and production by early 2012 (Voisey's Bay Nickel Co. Ltd., 2006, p. 3-4, 12-14).

Xstrata acquired Falconbridge and transferred its nickel assets into a new business unit named Xstrata Nickel. In 2006, the company produced 697 t of cobalt in concentrates from its Sudbury mines (900 t in 2005) and 486 t of cobalt in concentrate from its Raglan Mine in Quebec (448 t in 2005). Nickel-copper matte containing 2,367 t of cobalt was produced at the company's Sudbury smelter and refined at its Nikkelverk refinery in Norway. Some of the cobalt originated from ores produced at company mines and some originated from custom feed materials, which were primarily nickel concentrates and nickel-copper-cobalt secondary materials (scrap). In 2006, custom feed included nickel sulfide ores mined in Ontario by First Nickel Inc. and palladium concentrates from North American Palladium Ltd.'s Lac des Iles Mine in northern Ontario. Xstrata began construction on a new recycling plant at its Sudbury smelter to increase its ability to process nickel-cobalt catalysts and lithium ion and nickel metal hydride batteries. Xstrata planned to work closely with CVRD Inco to optimize efficiencies between both companies' operations in the Sudbury basin (Xstrata plc, 2007a, p. 5, 58; 2007b).

The Fort Saskatchewan refinery of the joint venture of Sherritt International Corp. and General Nickel Co. S.A. produced 3,311 t of cobalt as metal powder and briquettes in 2006, slightly less than the 3,391 t produced in 2005. Approximately 84% of the cobalt was from nickel-cobalt mixed sulfides from the joint venture's operations at Moa Bay, Cuba; the remainder was from purchased feed materials. Sherritt and General Nickel completed the basic engineering for the expansion of their nickel-cobalt operations in Canada and Cuba and agreed to execute the expansion in three phases (discussed in more detail in the "Cuba" section of this report). 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., 2007, p. 40, 42).

FNX Mining Company Inc. mined nickel sulfide ore from its McCreedy West Mine in Sudbury containing 38 t of cobalt (45 t in 2005); the ore was processed by CVRD Inco. Liberty Mines Inc. began mining nickel sulfide ores from its Redstone Mine southeast of Timmins, Ontario, and shipped concentrates to Jilin Jien Nickel Industry Company Ltd. in China (FNX Mining Company Inc., 2007, p. 43; Liberty Mines Inc., 2007, p. 8).

Fortune Minerals Ltd. studied the feasibility of developing the NICO gold-cobalt-bismuth deposit northwest of Yellowknife, Northwest Territories. Fortune planned to mine the deposit by open pit and underground methods and then use mineral flotation to produce gold-bearing bismuth and cobalt concentrates. The cobalt concentrate would be processed onsite by pressure acid leaching, ion exchange purification, and electrowinning to produce 1,475 t/yr of cobalt cathode. During the year, the feasibility study was modified to take advantage of the full capacity of the mill purchased for the project, and a bulk sampling program was conducted to obtain ores for large-scale pilot plant tests. Fortune planned to proceed with the environmental assessment and permitting so that production could begin in 2010 (Fortune Minerals Ltd., 2007a, p. 5, 19; 2007b).

Canadian Royalties Inc. began a feasibility study on its Raglan South nickel project in Nunavik, Quebec. The company was considering a mining and milling operation to produce copper and nickel sulfide concentrates. An average of 425 t/yr of cobalt would be produced during the first 4 years of operation (Canadian Royalties Inc., 2007, p. 12).

Blue Earth Refineries Inc. decided to sell its interest in 36569 Yukon Inc., which owned the cobalt refinery in Lorrain Township, Ontario, previously owned by Canmine Resources Corp. Blue Earth had determined that there was not a suitable source cobalt feedstock for the refinery at a reasonable cost (Blue Earth Refineries Inc., 2007, p. 11).

China.—China's production of refined cobalt was estimated to be approximately 15,200 t, which made it the world's leading producer. In 2006, only about 4% of China's cobalt production originated from domestic mines. The remainder was from imports (69%), stockpiled raw materials (15%), and scrap (12%). Most of the imported raw materials were from Congo (Kinshasa). China's imports of cobalt ores and concentrates

decreased in 2006 compared with those of 2005, but its imports of semirefined materials increased. One analyst estimated that China imported 17,179 t of cobalt contained in ores, concentrates, and semirefined materials in 2006, up from 16,820 t in 2005. China's cobalt production was in the form of metal, metal powders, and compounds, and was made for domestic use and export. Since 2001, Chinese cobalt consumption has grown by an average annual rate of 22%. The growth was driven primarily by consumption by the battery industry, which represented nearly one-half of Chinese cobalt consumption in 2006. To meet its need for cobalt raw materials, the Chinese cobalt industry was expected to make full use of its domestic resources, increase recycling of cobalt-bearing scrap, and develop new supply channels in Africa and elsewhere (Li, 2007, p. 3-4, 11; Searle, 2007, p. 7, 9-11; Shao and Xu, 2007).

The number of Chinese cobalt refiners was reported to be more than 30. The leading four refiners were Jinchuan, Zhejiang Galico Cobalt & Nickel Material Co., Ltd., Ganzhou Yi Hao Umicore Industries, and Zhejiang Huayou Cobalt Nickel Materials Co., Ltd., listed in descending order of 2006 estimated cobalt production. Jinchuan produced 6,300 t of cobalt as cathode and other products in 2006. The company has been steadily increasing its refinery capacity at Jinchang, Gansu Province, and planned for cobalt production to reach 10,000 t in 2008. Some of Jinchuan's cobalt production was from domestic nickel-copper-cobalt sulfide ores mined and refined at Jinchang and some was from other nickel or cobalt feeds. Jinchuan refined cobalt carbonates produced in China from imported cobalt concentrates; nickel-copper concentrates from Australia, GobiMin Inc.'s mines in the Hami region of northwestern China, and Spain; and nickel matte from BHP Billiton. During the year, Jinchuan reportedly commissioned a copper-cobalt smelter in Congo (Kinshasa), considered investing in the Nonoc nickel plant in the Philippines, and signed offtake agreements for nickel concentrates from future production from the Avebury project in Australia and the Munali project in Zambia (Yongjun, 2005; Cobalt Development Institute, 2006; Metal Bulletin, 2006b, 2007a; Metal-Pages, Ltd., 2006; Xu, 2006, p. 2; Shao and Xu, 2007).

Congo (Kinshasa).—According to the Cobalt Development Institute (2007b), La Générale des Carrières et des Mines (Gécamines) produced only 550 t of refined cobalt in 2006. Congo (Kinshasa) continued to supply the world with significant quantities of cobalt in ores, concentrates, and semirefined materials. Some of the country's cobalt mine production has been from copper-cobalt ores mined by traditional methods, but a large portion has been gathered by tens of thousands of artisanal miners hand-picking cobalt-rich ores containing the mineral heterogenite. These ores were sold to middlemen or trading houses, and exported, primarily to China and India. Some of the heterogenite was processed into cobalt carbonate or 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. As discussed in the "China" section of this report, in 2006, total cobalt exports from Congo (Kinshasa) to China increased compared with those of 2005; exports of unprocessed ores and concentrates decreased and exports of cobalt semirefined materials increased (Searle, 2007, p. 7, 9-10).

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. The concentrates 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) and Gécamines (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.

Democratic Republic of Congo Copper and Cobalt Project S.a.r.l. (DCP) (a joint venture of Nikanor PLC subsidiary Global Enterprises Corporate Ltd. and Gécamines) restarted mining cobalt-rich Kananga and Tilwezembe copper mines, refurbished the Kolwezi concentrator, and began producing copper-cobalt concentrate. The joint venture also worked on a project to redevelop the Kamoto Oliviera Virgule (KOV) open pit mine and build a major new SX-EW refinery. Detailed engineering for the refinery, which was to have the capacity to produce 250,000 t/yr of copper cathode and 27,500 t/yr of cobalt in hydroxide, was largely completed, and dewatering of the flooded mine was initiated. DCP hoped to begin production of refined metal by the end of 2009. Discussions regarding funding for the project were ongoing at yearend (Nikanor PLC, 2007, p. 1-7).

The Big Hill smelter at Lubumbashi (operated as a joint venture between Gécamines, OMG, and S.A. Groupe George Forrest) processed stockpiled slag to produce a cobalt-copper alloy, which was sold to OMG's Kokkola refinery. In 2006, the smelter produced alloy containing 4,300 t of cobalt, up from the 2,259 t produced in 2005 (George Forrest International S.A., 2006; Metal Bulletin, 2007b).

Other smelters capable of producing cobalt-bearing alloys included Gécamines' Fonderie Electrique de Panda, M.A.D.S.A.'s Four Electrique Luilu Cobalt (FELCO) project, and smelters built by Feza Mining SPRL (a joint venture between Comide SPRL and Wanbao Resources Corp.) and Jinchuan (Feza Mining SPRL, 2006; Metal Bulletin, 2006b-c).

Chemaf S.P.R.L. produced cobalt carbonate at its plant in Lubumbashi from ores extracted at the nearby Etoile Mine. Central African Mining & Exploration Company plc (CAMEC) began heap leaching operations at its newly constructed Luita cobalt carbonate plant at Kambove. The plant had an initial capacity of 1,400 t/yr of contained cobalt but was to be expanded to 6,000 t/yr by the end of March 2008 and to 12,000 t/yr by yearend 2008. In addition, CAMEC planned to install an SX-EW facility at Luita to produce cobalt cathode. Numerous other cobalt carbonate plants reportedly were being built in Congo (Kinshasa) by various Chinese organizations (Central African Mining & Exploration Company plc, 2006, p. 5; Cobalt Development Institute, 2006).

Metorex Ltd. began operating phase 1 of its Ruashi project by commissioning the concentrator and processing copper-cobalt oxide minerals stockpiled by Gécamines from past mining operations at Ruashi and Etoile. The resulting concentrates were refined in Zambia at Metorex's Sable Zinc refinery (as discussed in the "Zambia" section of this report). During the year, Metorex

completed a feasibility study on phase 2 of the project, which would entail mining the Ruashi ore body by open pit methods and processing the ores onsite at an expanded concentrator and newly constructed acid leaching-SX-EW refinery. The company decided to fast track construction of phase 2, which was to produce an estimated 3,500 t/yr of cobalt contained in cobalt hydroxide (Metorex Ltd., 2006).

First Quantum Minerals Ltd. acquired Adastra Minerals Inc. and its Kolwezi Tailings Project, which involved the recovery of copper and cobalt from oxide tailings produced from past operations at Gécamines' Kolwezi concentrator. First Quantum was considering the construction of a processing plant with an initial production level 5,800 t/yr of cobalt, which could be expanded to 17,400 t/yr. The company planned to complete a detailed engineering study and capital estimate in 2007 (First Quantum Minerals Ltd., 2007, p. 27).

Africo Resources Ltd. completed a feasibility study on developing the Kalukundi copper-cobalt deposit east of Kolwezi. The deposit would be mined by open pit methods; concentrates from the mill would be treated by leaching and SX-EW and produce 4,200 t/yr of cobalt cathode. Africo held an option to acquire a 75% interest in the Kalukundi project; the remaining 25% was held by Gécamines (Africo Resources Ltd., 2007, p. 2-11).

Tenke Mining Corp. worked on updating a feasibility study on the Tenke Fungurume project, northwest of Lubumbashi. Ore would be mined from several open pits and processed by an agitated leaching process. The project was being designed so that production could be expanded from the initial level of approximately 115,000 t/yr of copper cathode and 8,000 t/yr of cobalt as hydroxide or metal. Tenke Fungurume was owned by Phelps Dodge Corp., Tenke Mining, and Gécamines. By yearend, Phelps Dodge had conditionally approved its development and earthwork activity had commenced; production was to begin in late 2008 or early 2009 (Phelps Dodge Corp., 2007, p. 17; undated; Tenke Mining Corp., 2007).

Kamoto Copper Company SARL (a joint venture between Katanga Mining Ltd. and Gécamines) worked to rehabilitate the Kamoto/Dima mining complex west of Kolwezi, which included the large underground Kamoto copper-cobalt mine, 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 over 4 years with cobalt production forecast to begin in 2008 and increase incrementally as follows: 2,000 t in 2008, 5,200 t in 2009, 9,000 t in 2010, and 106,000 t in 2011 and beyond (Katanga Mining Ltd., 2007, p. 2, 6).

KGHM Polska Miedź S.A. decided not to build a hydrometallurgical processing plant in Congo (Kinshasa) to treat copper-cobalt ores from the Kimpe deposit. KGHM's decision was based on the amount of investment that would have been required and the small size of the deposit, which would have been exhausted within 5 years at the planned production rate (KGHM Polska Miedź S.A., 2006).

Cuba.—Moa Nickel S.A. (part of the 50-50 joint venture between Sherritt and General Nickel) mined nickel-cobalt laterites at Moa Bay, Holguin Province, and produced mixed sulfides containing 29,855 t of nickel and cobalt, 10% less than the 33,006 t produced in 2005. All the mixed sulfides were sent to the joint venture's Fort Saskatchewan refinery in Canada. Moa Nickel began construction on the first phase of an expansion project, which was to increase capacity by 4,000 t/yr of nickel-cobalt mixed sulfides, and was scheduled to be commissioned by yearend 2007. Construction of the second phase, which was to increase capacity by an additional 9,000 t/yr of nickel-cobalt mixed sulfides, was to begin in mid-2007 (Sherritt International Corp., 2007, p. 39, 42).

Unión del Níquel S.A. mined lateritic ores and produced nickel-cobalt mixed sulfides in Holguin Province at the Ernesto Che Guevara Mining and Metallurgical Combine at Punta Gorda. 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 materials (scrap). The company's production of cobalt metal powders, briquettes, oxides, and compounds was 5% higher than that of 2005 (Geological Survey of Finland, 2007; OM Group, Inc., undated).

In late 2006, OMG agreed to sell its nickel refining operations in Harjavalta and up to 11.1% of its holding in the Talvivaara project in the Kainuu District to Norilsk. Other assets included in the sale are discussed in the "Australia" section of this report. Following the sale, Norilsk was to enter into 5-year agreements to supply to OMG up to 2,500 t/yr cobalt metal, up to 2,500 t/yr cobalt contained in cobalt hydroxide concentrate, and up to 1,500 t/yr cobalt contained in cobalt sulfate solution (OJSC MMC Norilsk Nickel, 2006b).

Talvivaara Mining Company Ltd. studied the feasibility of establishing open pit mines in two polymetallic sulfide deposits in eastern Finland and recovering nickel, zinc, copper, and cobalt with bioheapleaching technology. An estimated 1,200 t/yr cobalt could be produced as nickel-cobalt mixed sulfide beginning in late 2008 (Talvivaara Mining Company Ltd., 2007, p. 4).

Vulcan Resources Ltd. studied the feasibility of developing its Kylylahti polymetallic deposit in eastern Finland. Vulcan planned to mine the deposit by underground methods, and treat the ore by flotation to produce a copper-gold concentrate and a polymetallic bulk sulfide concentrate. The polymetallic concentrate would be sent to a roaster in Siilinjarvi, and the resulting calcine would be treated in an adjacent leaching plant to be built by Vulcan. Copper sulfate, nickel-cobalt mixed hydroxide, and zinc sulfide were the likely products from the leaching plant. Vulcan planned to begin mining in early 2009. During the first 6 years of the 12-year mine life, the average production of cobalt in concentrate was expected to be 1,330 t/yr (Cowden, 2007, p. 3, 16; Vulcan Resources Ltd., 2007, p. 7).

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 (2007b), India's cobalt production decreased slightly from that of 2005. Nicomet Industries Ltd. and Rubamin Ltd. were the leading producers. India relied on imports of heterogenite from

Congo (Kinshasa) as its cobalt feed material (Agrawal, Porwal, and Koppiker, 2006).

Indonesia.—Eramet S.A. acquired Weda Bay Minerals Inc. and began evaluating its Halmahera nickel-cobalt laterite project. Prefeasibility studies by Weda Bay forecast production to be 60,000 t/yr of nickel and 5,000 t/yr of cobalt. Eramet was considering a new hydrometallurgical process developed at its Trappes research center to recover nickel and cobalt from the ore, and hoped to begin production by 2013 (Eramet S.A., 2007, p. 10-11).

Japan.—Sumitomo Metal Mining Co., Ltd. produced electrolytic cobalt as a byproduct of nickel at its Niihama nickel refinery in Ehime Prefecture. Cobalt production nearly doubled in 2006 as a result of an increase in nickel-cobalt mixed sulfide feed from the Coral Bay Nickel Corp. plant in the Philippines. The refinery also processed nickel matte from P.T. Inco in Indonesia.

Korea, Republic of.—The Government reportedly planned to build a stockpile of 14 metals, including cobalt. The amount of each metal was to be equivalent to that imported during a 2-month period (Shinhye, 2006).

Madagascar.—Dynatec Corp. updated a 2005 feasibility study on the Ambatovy nickel laterite project, east of Antananarivo. The study confirmed the potential for an open pit mining operation and ore preparation plant; a 220-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 mixed sulfide product; and a metals refinery for the production of cobalt and nickel metal powders. The project would have the capacity to produce 5,600 t/yr of cobalt. By yearend, the Government of Madagascar had issued the environmental permit for the project. Dynatec planned to begin construction in mid-2007. The project was owned by Dynatec, Sumitomo Corp., and Korea Resources Corp. (Dynatec Corp., 2007).

Mexico.—Baja Mining Corp. studied the feasibility of developing the Boleo copper-cobalt-zinc deposit near Santa Rosalia, Baja California Sur. Baja was considering underground mining supplemented by production from small open pits. The operation would include a hydrometallurgical refinery that would produce 3,100 t/yr of cobalt as cathode. During the year, Baja received the environmental impact manifest for the project from the Mexican Government. The company planned to fast-track development so that copper production could begin in 2009; cobalt production would follow (Baja Mining Corp., 2007, p. 3, 5, 8, 11).

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. In 2006, CTT began construction on a project to produce cobalt oxide. The company also planned to increase its cobalt production capacity by 10% to 20% in 2007 (Akalay, 2006; Groupe ONA, 2007, p. 41).

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 nickel products and cobalt chloride were produced.

Construction continued on the Goro nickel-cobalt laterite project in southern New Caledonia. The project comprised an integrated mining and pressure acid leaching-solvent extraction 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. After acquiring Inco, CVRD reviewed the project and planned changes to reduce environmental, operational, and technological risks. First production from Goro was expected in early 2009. At yearend, the project was owned by CVRD, Sumic Nickel Netherlands b.v. (a joint venture between Sumitomo and Mitsui & Co., Ltd.), and Société de Participation Minière du Sud Calédonien SAS (Companhia Vale do Rio Doce, 2007a, p. 28, 44).

Norway.—Xstrata Nickel's production of cobalt at its Nikkelverk refinery was slightly lower than that of 2005. The cobalt originated from Xstrata Nickel mines in Canada and custom feeds, which included matte from Botswana processed under a long-term agreement with BCL Ltd. (Xstrata plc, 2007b).

Papua New Guinea.—China Metallurgical Construction Group Corp. (MCC) began preconstruction of the Ramu nickel-cobalt laterite project in Madang Province under a joint-venture agreement with Highlands Pacific Ltd. The project was to produce 3,200 t/yr of cobalt as cathode or an intermediate product using pressure acid leaching technology. Permitting and development approvals were in place. MCC hoped to begin project commissioning by mid-2009, subject to securing funding and commencing construction (Highlands Pacific Ltd., 2007, p. 13-14).

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, Mitsui & Co., Ltd., Sojitz Corp., and Rio Tuba Nickel Mining Corp.) processed stockpiled low-grade nickel laterite ores at its high-pressure acid-leaching plant at the Rio Tuba Mine on Palawan Island. All the plant's nickel-cobalt mixed sulfide production was refined by Sumitomo in Japan. The joint venture finalized a plan to double Coral Bay's production capacity to 20,000 t/yr of nickel and 1,400 t/yr of cobalt. A duplicate plant to be built adjacent to the existing plant was targeted to begin production in 2009 (Sumitomo Metal Mining Co., Ltd., 2006).

Russia.—According to the Cobalt Development Institute (2007b), Norilsk, Russia's leading source of cobalt, produced 4,759 t of cobalt, nearly the same amount as the 4,748 t produced in 2005. Norilsk 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 Verkhniy Ufaley in the Ural Mountains. Norilsk's agreements to purchase OMG's nickel refining operation in Finland and to supply OMG with various cobalt products are discussed in the "Finland" section of this report.

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 nine PGM mines and one nickel mine (Harding, 2006). 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 studied the feasibility of using the Activox process for the expansion of the Nkomati nickel sulfide mine in Mpumalanga Province. The expansion would increase cobalt output to 950 t/yr of cobalt carbonate. In recent years, sales of cobalt in nickel concentrates have been 70 to 80 t/yr (Anglovaal Mining Ltd., 2004, p. 282; LionOre Mining International Ltd., 2005; 2007, p. 4; African Rainbow Minerals Ltd., 2007, p. 41).

Independence Platinum Ltd. was formed to commercially develop Mintek's ConRoast smelter process for PGM sulfide concentrates and use Atomaer (RSA) Pty. Ltd.'s leaching process to recover base metals. Independence planned to establish smelting and base-metals refining facilities using these two processes to treat concentrates from junior South African resource companies. One of the benefits of the combined technologies was an anticipated two-fold increase in cobalt recoveries (Phillips, Jones, and Cramer, 2006).

Spain.—Rio Narcea Gold Mines, Ltd. produced nickel-copper concentrate from its Aguablanca open pit nickel sulfide mine and processing plant in Badajoz Province, which it sold to Jinchuan under a long-term sales agreement. At planned production rates, concentrates were expected to contain approximately 200 t/yr of cobalt (Rio Narcea Gold Mines, Ltd., 2005, p. 6).

Turkey.—European Nickel PLC began to develop the infrastructure for its Çaldağ project in western Turkey. The project entailed mining nickel laterite ores and processing them by acid heap leaching followed by precipitation to produce nickel-cobalt mixed hydroxides. European Nickel planned to build the first ore heap by July 2007, complete construction of the precipitation plant, and begin producing mixed hydroxides by early 2008. At full operation in 2009, 1,200 t/yr of cobalt would be produced in mixed hydroxides. BHP Billiton exercised its option to purchase all of the project's output (European Nickel PLC, 2006, p. 10, 16-18, 25, 27).

Uganda.—Kasese Cobalt Co. Ltd. produced cobalt cathode from stockpiled pyrite concentrates using a bacterial leaching-SX-EW process at its cobalt refinery in southwestern Uganda. Kasese increased its production rate to 60 t/yr of cobalt, which was the plant's expected capacity (Blue Earth Refineries Inc., 2007, p. 14).

Vietnam.—Asian Mineral Resources Ltd. undertook predevelopment activities and worked on obtaining a mining license for the Ban Phuc nickel sulfide deposit west of Hanoi in Son La Province. The company planned to develop an underground mine and produce a nickel-copper flotation concentrate containing an average of approximately 110 t/yr of cobalt (Ausenco International Pty. Ltd., 2005, p. 1, 58; Asian Mineral Resources Ltd., 2007, p. 7-8).

Zambia.—Mopani Copper Mines Plc produced 1,438 t of cobalt metal at its Nkana cobalt refinery, 19% less than the 1,744 t produced in 2005. Most of the cobalt originated from the company's Nkana underground copper-cobalt mine (Cobalt Development Institute, 2007b).

Chambishi Metals plc produced 3,227 t of cobalt metal at its Chambishi refinery, a 12% decrease from the 3,648 t produced in 2005. Production was limited by difficulties in sourcing feed. The refinery's main feed materials were slag from a stockpile at Nkana and concentrates from Luanshya Copper Mines Plc's Baluba copper-cobalt mine. Chambishi was also able to process purchased raw materials, such as alliage blanc, concentrates, and heterogenite (Brown, 2006; Metal Bulletin, 2006a; Cobalt Development Institute, 2007b).

Konkola Copper Mines Plc (KCM) 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 concentrate from KCM's copper operations was sold to Chambishi Metals for refining; cobalt-bearing slag from the company's Nkana Smelter was stockpiled for future reclamation. KCM reportedly canceled its plan to resume cobalt production (Platts Metals Week, 2006b; Konkola Copper Mines Plc, undated a, b).

Metorex commissioned its Sable copper electrowinning plant near Kabwe and began processing purchased ore and copper-cobalt concentrates produced at the company's Ruashi operations in Congo (Kinshasa). The plant was expected to produce approximately 1,000 t/yr of cobalt as carbonate, which would be expanded to 3,500 t/yr during phase 2 of the Ruashi project (as discussed in the "Congo (Kinshasa)" section of this report). In 2006, the plant produced 53 t of cobalt (Metorex Ltd., 2006, 2007).

Albidon Ltd. completed a feasibility study on the Enterprise deposit at its Munali nickel project in southern Zambia. The company planned to build an underground mine and produce a nickel sulfide concentrate containing more than 400 t/yr of cobalt. Albidon signed an offtake agreement with Jinchuan for all the nickel concentrates produced during the life of the project. Albidon began work at the mine site and planned to commission the concentrator in 2008 (Albidon Ltd., 2006a, b, p. 1-3).

Zimbabwe.—Bindura Nickel Corp. worked to improve the capacity and extend the lives of its Shangani and Trojan nickel sulfide mines. The company was constructing a new concentrator at Trojan and was considering an expansion of its nickel refinery. Cobalt hydroxide is one of the refinery's products (Mwana Africa PLC, 2007, p. 5, 7, 10).

Outlook

World demand for cobalt is expected to continue to increase in coming years. Industries that could show significant increases in cobalt consumption include superalloys for civil aviation, power generation, and flue gas desulfurization equipment; catalysts for producing 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 use by the battery sector is being dampened, however, by substitution of cobalt by other, less expensive metals. Preliminary data for the first half of 2007 indicate that global apparent demand was slightly greater than that during the first half of 2006 (Cobalt Development Institute, 2007a; 2008; Searle, 2007, p. 16, 24).

World production of refined cobalt is also expected to continue to increase. Many producers plan to increase production and/or capacity levels at existing operations, and numerous new nickel and copper-cobalt projects and one primary cobalt project are in progress. The first significant new production, in terms of cobalt output, is scheduled to begin in 2008. Additional new production is expected in following years. In addition to production, recycled cobalt and NDS inventory releases will continue to contribute to supply, although much of the cobalt from the NDS has been sold. At yearend 2007, only 676 t of uncommitted cobalt remained.

Some analysts predict that the balance between available cobalt supplies and consumer demand could be tight in the short term. Growth in consumption could be constrained by tight supplies of raw materials until the output from new projects begins and ramps up (Searle, 2007, p. 5, 20, 24; Cobalt Development Institute, 2008).

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TABLE 1
SALIENT COBALT STATISTICS[1]

(Metric tons, cobalt content, unless otherwise specified)

	2002	2003	2004	2005	2006
United States:					
Consumption:					
Reported	8,270 r	8,030 r	8,990 r	9,150 r	9,270
Apparent	9,830	10,000	9,950 r	11,800 r	11,100
Imports for consumption	8,450	8,080	8,720	11,100	11,600
Exports	2,080	2,710	2,500	2,440	2,850
Stocks, December 31:					
Industry[2]	858	649	690 r	705 r	711
U.S. Government[3]	6,680	4,290	2,660	1,550	1,290
Price, metal[4] dollars per pound	6.91	10.60	23.93	15.96	17.22
World, production:[e]					
Mine	52,200 r	52,700 r	58,400 r	63,500 r	67,500
Refinery	40,800	43,800	49,100	54,900	55,000

[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)

	2005	2006
Sales:		
Fiscal year[2]	1,120	200
Calendar year	880	256
Shipments:[3]		
Fiscal year[2]	893	341
Calendar year	1,110	260

[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)

	2005	2006
Consumption by end use:		
Steels	857	700
Superalloys	4,140	4,180
Alloys, excludes steels and superalloys:		
Magnetic alloys	343 r	386
Other alloys[3]	227	224
Cemented carbides[4]	762 r	796
Chemical and ceramic uses	2,760 r	2,920
Miscellaneous and unspecified	63	63
Total	9,150 r	9,270
Consumption by form:		
Chemical compounds, organic and inorganic[5]	2,570 r	2,760
Metal	4,550	4,500
Purchased scrap	2,030	2,010
Total	9,150 r	9,270
Stocks, December 31:[6]		
Chemical compounds, organic and inorganic[5]	209	196
Metal	386 r	387
Purchased scrap	110 r	129
Total	705 r	711

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]

	2005			2006		
	Gross weight (metric tons)	Cobalt content[2] (metric tons)	Value (thousands)	Gross weight (metric tons)	Cobalt content[2] (metric tons)	Value (thousands)
Metal[3]	9,350	9,350	$312,000	9,950	9,950	$302,000
Oxides and hydroxides	1,310	943	35,100	1,180	847	29,400
Other forms:						
Acetates	260	62	2,250	536	129	3,520
Carbonates	985	453	15,300	1,010	465	15,100
Chlorides	189	47	1,480	63	16	683
Sulfates	762	206	5,750	717	194	4,920
Grand total	12,900	11,100	372,000	13,500	11,600	356,000

[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)
2005:												
Australia	313	313	$10,300	--	--	--	--	--	--	313	313	$10,300
Belgium	393	393	12,700	495	357	$14,200	42	19	$714	930	768	27,600
Brazil	305	305	9,770	--	--	--	--	--	--	305	305	9,770
Canada	818	818	30,200	(6)	(6)	4	--	--	--	818	818	30,200
China	576	576	20,500	155	111	3,440	767	282	8,460	1,500	970	32,400
Congo (Kinshasa)	25	25	780	--	--	--	--	--	--	25	25	780
Finland	687	687	25,200	296	213	7,350	743	289	9,780	1,730	1,190	42,400
France	24	24	1,550	34	24	1,620	1	(6)	23	59	49	3,190
Germany	8	8	411	1	1	151	--	--	--	9	9	561
India	23	23	695	--	--	--	370	100	2,720	393	123	3,410
Japan	218	218	9,650	10	7	502	--	--	--	228	225	10,200
Korea, Republic of	24	24	413	--	--	--	--	--	--	24	24	413
Morocco	342	342	10,300	--	--	--	--	--	--	342	342	10,300
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
2006:												
Australia	449	449	12,500	--	--	--	--	--	--	449	449	12,500
Belgium	254	254	7,900	360	259	9,460	62	20	610	676	533	18,000
Brazil	265	265	7,930	--	--	--	17	7	245	282	272	8,180
Canada	967	967	29,500	--	--	--	--	--	--	967	967	29,500
China	1,210	1,210	36,800	235	169	4,800	339	134	3,740	1,780	1,510	45,400
Congo (Kinshasa)	31	31	744	--	--	--	--	--	--	31	31	744
Finland	268	268	9,980	347	250	8,530	985	381	12,000	1,600	899	30,500
France	14	14	936	30	22	1,280	--	--	--	44	36	2,220
Germany	17	17	821	5	4	370	--	--	--	22	21	1,190
India	27	27	705	--	--	--	339	92	1,980	366	118	2,690
Japan	202	202	6,240	1	(6)	35	5	1	51	208	204	6,330
Korea, Republic of	12	12	125	--	--	--	36	9	299	48	20	424
Morocco	257	257	7,490	--	--	--	--	--	--	257	257	7,490

See footnotes 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)
2006—Continued:												
Norway	2,230	2,230	$66,900	--	--	--	--	--	--	2,230	2,230	$66,900
Philippines	--	--	--	--	--	--	49	20	$963	49	20	963
Russia	2,630	2,630	79,900	--	--	--	--	--	--	2,630	2,630	79,900
South Africa	73	73	2,060	--	--	--	272	65	1,390	345	138	3,460
Sweden	4	4	132	--	--	--	--	--	--	4	4	132
Uganda	133	133	3,760	--	--	--	--	--	--	133	133	3,760
United Kingdom	26	26	640	194	140	$4,880	213	70	2,840	433	236	8,360
Zambia	885	885	26,800	--	--	--	--	--	--	885	885	26,800
Other	(6)	(6)	37	4	3	76	10	4	160	14	7	273
Total	9,950	9,950	302,000	1,180	847	29,400	2,330	803	24,200	13,500	11,600	356,000

-- Zero.

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

[2]Unwrought cobalt, excluding alloys and waste and scrap; 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.

TABLE 6

U.S. EXPORTS OF COBALT IN 2006, 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	22	$734	--	--	--	--	--	--	22	$734
Belgium	498	18,500	--	--	184	$655	--	--	542	19,200
Brazil	1	109	--	--	19	114	--	--	6	222
Canada	348	4,150	123	$2,330	63	621	49	$519	464	7,620
China	6	249	--	--	10	90	--	--	9	339
Finland	127	1,050	--	--	--	--	--	--	127	1,050
France	82	1,770	--	--	--	--	--	--	82	1,770
Germany	93	3,960	1	10	--	--	--	--	94	3,970
India	24	875	--	--	25	113	--	--	30	988
Indonesia	--	--	--	--	4	35	--	--	1	35
Ireland	183	4,990	--	--	--	--	1	20	183	5,010
Italy	14	2,700	--	--	--	--	--	--	14	2,700
Jamaica	--	--	1	8	28	34	--	--	7	42
Japan	318	14,900	907	22,900	8	67	--	--	973	37,800
Korea, Republic of	3	232	--	--	6	53	1	17	5	302
Mexico	36	523	26	624	124	883	(6)	3	85	2,030
Netherlands	21	423	12	270	--	--	(6)	5	30	698
Singapore	12	610	13	279	--	--	--	--	22	889
Spain	25	191	--	--	--	--	--	--	25	191
Taiwan	1	76	--	--	3	28	--	--	2	104
Thailand	31	1,510	--	--	--	--	--	--	31	1,510
Trinidad and Tobago	--	--	1	6	1	5	(6)	5	1	16
United Kingdom	61	1,550	2	38	--	--	1	14	62	1,600
Venezuela	--	--	11	379	6	12	--	--	9	391
Other	26	1,360	1	15	1	9	--	--	26	1,380
Total	1,930	60,500	1,100	26,800	482	2,720	53	582	2,850	90,600

-- 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, 2006[1, 2]

(Metric tons, cobalt content)

Country	Capacity
Australia[e]	4,500
Belgium	1,500
Brazil[e]	1,200
Canada	5,900
China[e]	25,000
Congo (Kinshasa)[e, 3]	15,000
Finland	10,000
France	600
India	1,560
Japan[e]	1,000
Morocco[e]	1,650
Norway	5,200
Russia[e]	6,000
South Africa[e]	750
Uganda	720
Zambia	8,200
Total	88,800

[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.

[3]Refurbishment necessary to achieve stated capacity.

TABLE 8

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

(Metric tons, cobalt content)

Country[3]	2002	2003	2004	2005	2006[e]
Australia[e, 4]	6,800 [r]	7,300 [r]	7,000 [r]	7,200 [r]	7,400
Botswana[5]	269	294	223	326 [r]	303 [6]
Brazil	1,099	1,097	1,236	1,225 [r]	1,200
Canada[7]	5,148	4,327	5,060	5,767 [r]	6,976 [p, 6]
China[e]	1,000	700	1,260	2,100 [r]	2,300
Congo (Kinshasa)[e, 8]	14,600 [r]	14,800 [r]	20,200 [r]	24,500 [r]	28,000
Cuba[9]	3,442	3,274	3,554	3,768 [r]	3,800
Kazakhstan[e, 10]	300	300	300	300	300
Morocco[11]	1,453	1,391	1,600 [e]	1,600 [e]	1,500
New Caledonia[12]	2,780 [r]	2,602 [r]	2,726 [r]	1,769 [r]	1,900
Norway[e, 11]	100	--	--	--	--
Russia[e]	4,600	4,800	4,700	5,000	5,100
South Africa[e]	520	400	460	400	400
Zambia[e, 13]	10,000	11,300	10,000	9,300	8,000
Zimbabwe[14]	99	79	59	281 [r]	290
Total	52,200 [r]	52,700 [r]	58,400 [r]	63,500 [r]	67,500

[e]Estimated. [p]Preliminary. [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, 2007. Figures represent recoverable cobalt content of ores, concentrates, or intermediate products from cobalt, copper, nickel, platinum, or zinc operations.

[3]In 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.

[4]Cobalt content of lateritic nickel ore, nickel concentrate, and zinc concentrate originating in Australia. Quantities of cobalt contained in intermediate or refined metallurgical products produced from Australian and imported ores, in metric tons, was estimated to be as follows: 2002—6,700; 2003—6,900; 2004—6,700; 2005—6,000; and 2006—6,900.

[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: 2002—2,065; 2003—1,842; 2004—2,085; 2005—2,391 (revised); and 2006—2,793.

[8]Cobalt content of concentrates, tailings, and slags.

[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 (2002-06).

[11]Cobalt content of concentrates.

[12]Cobalt content of limonitic nickel laterite ores mined. 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, in metric tons, was estimated to be as follows: 2002–04—1,400; 2005—1,200; and 2006—1,500.

[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]	2002	2003	2004	2005	2006
Australia, metal, metal powder, oxide hydroxide[e]	3,700	3,840	3,880	3,150	4,000 [e]
Belgium, metal powder, oxide, hydroxide[4]	1,135	1,704	2,947	3,298	2,840
Brazil, metal	960	1,097	1,155	1,136	902
Canada, metal, metal powder, oxide	4,625	4,233	5,144	5,090 [r]	5,180 [p]
China, metal, metal powder, oxide, salts[e, 5]	1,840	4,580	8,000	12,700	12,700 [e]
Congo (Kinshasa), metal[6]	2,149	1,200 [e]	735	600	550
Finland, metal powder and salts[7]	8,240	7,989	7,893	8,171	8,582
France, chloride	176	181	199	280	256
India, metal and salts	270	255	545	1,220	1,184
Japan, metal	354	379	429	471	920
Morocco, metal	1,354	1,431	1,594	1,613	1,405
Norway, metal	3,994	4,556	4,670	5,021	4,927
Russia, unspecified[e, 8]	5,100	5,500	5,400	5,800	5,900 [e]
South Africa, metal powder and sulfate	352	271	309	268	267
Uganda, metal	450 [e]	--	436	638	674
Zambia, metal	6,144	6,620	5,791	5,422	4,665
Total	40,800	43,800	49,100	54,900	55,000

[e]Estimated. [p]Preliminary. [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, 2007. 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 the Geological Survey of Finland.

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