



# 2014 Minerals Yearbook

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## COBALT [ADVANCE RELEASE]

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# COBALT

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In 2014, world production of refined cobalt increased by 6% to reach a record level of 91,300 metric tons (t) (table 9). Most of the increase was from China; production increases from Finland, Japan, and Madagascar were also significant. The United States did not refine cobalt in 2014. World mine production increased by 8% to reach a record level of 123,000 t. Congo (Kinshasa) remained the leading producer of mined cobalt, supplying more than one-half of world production, followed by China, Canada, Russia, and Australia. Cobalt was mined in the United States as a byproduct of nickel and copper in Michigan and a negligible amount of byproduct cobalt was produced in an intermediate product from the mining and refining of platinum-group-metals (PGM) ore in Montana. No cobalt has been sold from the National Defense Stockpile (NDS) since 2009.

According to the Cobalt Development Institute (2015a), preliminary data indicate that in 2014, world apparent consumption of cobalt increased by about 6,000 t, or about 8%, to approximately 81,000 t. Cobalt prices generally trended upward during the year, resulting in annual averages greater than those of 2013. Salient U.S. and world cobalt statistics for 2010–14 are listed in table 1.

Cobalt is a metal used in numerous diverse commercial, industrial, and military applications. On a global basis, the leading use of cobalt is in rechargeable battery electrodes. Superalloys, which are used to make parts for gas turbine engines, are another major use for cobalt. Other metallurgical uses for cobalt include cemented carbides (also called hardmetals) and diamond tools, controlled-expansion and corrosion- and wear-resistant alloys, high-speed and maraging steels, and magnets. With regard to other chemical uses, cobalt is used to make animal feed additives; catalysts for chemical, petroleum, and other industries; drying agents for inks, paints, and varnishes; dyes and pigments; glass decolorizers; ground coats for porcelain enamels; humidity indicators; magnetic recording media; rubber adhesion promoters for steel-belted radial tires; and vitamin B12.

## Legislation and Government Programs

Defense Logistics Agency Strategic Materials (DLA Strategic Materials), U.S. Department of Defense, did not sell or ship cobalt during 2014. The program under which cobalt sales were authorized expired in 2011 and had not been reauthorized. For the first time in more than 20 years, DLA Strategic Materials received authorization to acquire new materials for the NDS. The acquisitions were authorized through the end of fiscal year 2019 (September 30, 2019), and the first materials to be acquired were lithium-ion battery precursors. During the year, DLA Strategic Materials awarded a contract to a domestic producer to supply up to 750 kilograms (kg) of lithium-cobalt oxide (LCO) and

2,700 kg of lithium-nickel-cobalt-aluminum oxide (NCA), with delivery beginning in fiscal year 2015 (October 1, 2014, through September 30, 2015). The annual materials plans for fiscal year 2015, which represented the maximum amounts of materials that could be bought or sold during the year, limited the acquisitions of LCO and NCA to 150 kg and 540 kg, respectively (Defense Logistics Agency Strategic Materials, 2014; U.S. Department of Defense, 2015, p. 2, 29).

## Production

In September, Lundin Mining Corp. (Toronto, Ontario, Canada) began production of copper and nickel concentrates from the Eagle nickel-copper mine northwest of Marquette, MI, and a mill in Humboldt Township. Within 2 months of startup, the operation achieved commercial production. In 2014, Eagle produced nickel concentrate containing 4,300 t of nickel and an estimated 120 t of cobalt; the concentrate was sent by rail to smelters in North America or to ports for shipment overseas (Lundin Mining Corp., 2015a, p. 22, 58; 2015b, p. 1–3).

Stillwater Mining Co.'s PGM mining and refining operations in southeastern Montana produced negligible amounts of cobalt in nickel sulfate, which it sold to other companies (Stillwater Mining Co., 2015, p. 20).

PolyMet Mining Corp.'s Northmet project remained at the environmental review and permitting stage. The company expected that the final environmental impact statement would be published in 2015, after which it could begin a land exchange with the U.S. Forest Service and apply for construction and operating permits for the project. The NorthMet project was to be developed in two phases. Phase 1 comprised open pit mining of the NorthMet polymetallic deposit in the Duluth Complex of northeastern Minnesota and production of copper and nickel concentrates (table 7). During phase 2, a hydrometallurgical plant for the production of nickel-cobalt hydroxide and precious metals precipitate would be added (PolyMet Mining Corp., 2015, p. 14, 24–25).

Formation Metals Inc.'s fully permitted Idaho Cobalt Project comprised an underground cobalt-copper-gold mine and mill complex in the Idaho Cobalt Belt in Lemhi County and a hydrometallurgical plant in a location to be determined to refine the concentrates to cobalt cathode or battery-grade chemicals. Development of the project was on hold pending conclusion of financing. Once financing was completed, Formation planned to begin underground mine development and to construct the beneficiation and hydrometallurgical plants. Initial production was expected to take place about 14 months after commencing underground development (table 7) (Formation Metals Inc., 2015, p. 10, 12–15).

U.S. processors made cobalt chemicals and cobalt metal powder 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 2.

n.v. Umicore, s.a. (Brussels, Belgium) acquired CP Chemicals Group, LP, a producer of cobalt and nickel chemicals in Wickliffe, OH, and renamed the operation Umicore Specialty Materials Recycling. The plant processed secondary materials such as superalloy scrap and made chemicals for the catalyst and petrochemical refining industries (n.v. Umicore, s.a., 2015, p. 34, 77).

The sole U.S. producer of cobalt metal powder, Global Tungsten & Powders Corp. (GTP) of Towanda, PA, produced the cobalt metal powder as a byproduct of tungsten recovery from cemented carbide scrap. In August, GTP announced that it had formed a partnership with Umicore. Under the partnership, Umicore would toll process GTP's intermediate cobalt compound to cobalt metal powder, starting in mid-2015. U.S. production and shipments of cobalt metal powder were withheld to avoid disclosing company proprietary data (Global Tungsten & Powders Corp., 2014).

## Consumption

U.S. reported consumption of cobalt in 2014 was 6% more than that of 2013. Metallurgical industries used 6% more cobalt than they did in 2013, and cobalt consumption for chemical uses was 6% more than that of 2013. Reported consumption statistics were derived by the USGS from voluntary surveys of U.S. operations. Most of the cobalt chemical-use data 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, more than 60 cobalt consumers were canvassed on a monthly or annual basis. Reported consumption and stocks data in tables 1 and 2 include estimates to account for nonrespondents.

U.S. apparent consumption for 2014, as calculated from net imports, consumption from purchased scrap, and changes in Government and industry stocks, was 3% more than that in 2013 (table 1). The increase was a result of increases in net imports and scrap consumption in 2014 compared to those in 2013 and a drawdown of London Metal Exchange (LME) stocks in the United States.

## Prices

The annual average U.S. spot price for cathode (minimum of 99.8% cobalt), as reported by Platts Metals Week, was 12% more than that of 2013 (table 1). The overall price trend was upward, although prices fluctuated during the year. The lowest price range was \$12.00 to \$13.00 per pound in early January, and the highest price range was \$15.25 to \$16.25 per pound from late July through the end of August. The year ended at a price range of \$14.20 to \$14.80 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 \$14.12 per pound, and the annual average of weekly prices for Russian cobalt was \$14.06 per pound.

In 2014, the number of producers whose cobalt was approved for delivery on the LME cobalt futures contract remained at 15. Cobalt from Kasese Cobalt Co. Ltd. (Kasese, Uganda) was not accepted after February 12, 2014, however, and the brand was to be delisted after all stocks were depleted. Sherritt International Corp. (2015a, p. 9) reported that the amount of cobalt traded on the LME in 2014 (12,162 t) represented only 34% of global refined cobalt metal production and 15% of global refined production of cobalt metal and chemicals. Considering that base-metal contracts on the LME experience trading volumes of 50 or more times their production, the LME cobalt contract is still in the early stage of acceptance as a primary pricing mechanism. The annual average mean of cash buyer and cash seller prices and yearend LME inventory levels are listed in table 1 (London Metal Exchange Ltd., The, 2013, undated).

Electrolytic cobalt was also traded on China's Fanya Metal Exchange (Fanya Metal Exchange Co. Ltd., undated).

## Foreign Trade

Net import reliance as a percentage of apparent consumption is one measure of the adequacy of current domestic production to meet U.S. demand. Net import reliance is 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 originally imported or produced in the United States. In 2014, net import reliance as a percentage of apparent consumption was 75%. Because U.S. primary cobalt production was exported to be refined, this indicates that 75% of U.S. cobalt supply was from imports and stock releases of primary cobalt and 25% was from domestic or imported scrap.

In 2014, the United States imported 11,400 t of cobalt contained in metal and chemical compounds, valued at \$347 million, 9% more than the 10,500 t imported in 2013 (tables 3, 4). On the basis of cobalt content, 10 countries supplied 91% of U.S. imports. Norway was the leading supplier, followed by China, Japan, Finland, Australia, Russia, the United Kingdom, Zambia, Madagascar, and Belgium. The United States also imported unwrought cobalt alloys (1,040 t, gross weight, valued at \$33.4 million), cobalt waste and scrap (1,130 t, gross weight, valued at \$17.2 million), and wrought cobalt and cobalt articles (224 t, gross weight, valued at \$22.5 million).

U.S. exports of unwrought cobalt and cobalt contained in chemicals were 4,500 t, valued at \$111 million; 17% more by weight than the 3,850 t exported in 2013. As listed in table 5, on the basis of cobalt content, the leading destinations for these exports were Canada, Ireland, France, Germany, the United Kingdom, China, and Belgium. The United States also exported 1,790 t, gross weight, of wrought metal and cobalt articles valued at \$106 million.

## World Review

World cobalt mine and refinery production each increased in 2014 compared with production in 2013. On the basis of

tons of contained cobalt, China, Finland, and Japan had the largest increases in refinery production and Congo (Kinshasa), Papua New Guinea, and Philippines had the largest increases in mine production.

Cobalt was produced as a byproduct of copper, nickel, and other metals, and as a primary product. Primary cobalt production included the mine and refinery production of Morocco, the artisanal mining of the mineral heterogenite in Congo (Kinshasa), and the recovery of cobalt from previously stockpiled intermediate materials [for example, slags in Congo (Kinshasa)], which were processed primarily to recover cobalt.

Refinery capacity by country is listed in table 6. The table does not include plants that processed refined cobalt, plants that used secondary materials (scrap) as their main source of feed, or plants that produced a cobalt product that required further refining.

The following review by country focuses on operations that produced cobalt in 2014. Expansions to those operations, operation restarts, and greenfield projects that were forecast to begin producing between 2015 and 2019 are listed in table 7.

**Australia.**—In 2014, Western Australian cobalt mine production, which is a byproduct of the State's nickel industry, decreased by 7% (table 8). Australian production of refined cobalt, which included production from imported lateritic ore, increased by 9% (table 9).

The Palmer Nickel and Cobalt Refinery (owned by Australian businessman Clive Palmer, operated by Queensland Nickel Pty. Ltd.) in Townsville, Queensland, produced 2,519 t of refined cobalt as cobalt oxide hydroxide; 10% more than the 2,281 t produced in 2013. The refinery processed lateritic ore from the Brolga Mine in central Queensland; lateritic ore imported from New Caledonia and the Philippines; and an intermediate cobalt compound from Vale S.A.'s New Caledonia operation (Cobalt Development Institute, 2015a; Darton Commodities Ltd., 2015, p. 19).

BHP Billiton's Nickel West operations in Western Australia comprised nickel sulfide mines; concentrators, which processed ores mined by BHP Billiton and other companies; the Kalgoorlie smelter, where nickel matte was produced; and the Kwinana nickel refinery, which produced cobalt in intermediate nickel-cobalt sulfide. Darton Commodities Ltd. estimated that BHP Billiton's shipments of cobalt contained in intermediate nickel-cobalt sulfide to Jinchuan Group Co., Ltd. in China decreased from 637 t in 2013 to 112 t (Darton Commodities Ltd., 2015, p. 34).

Glencore plc had three nickel assets in Western Australia—Minara Resources Ltd.'s Murrin Murrin nickel-cobalt laterite mining and pressure-acid-leaching operation and Xstrata Nickel Australasia Operations Pty. Ltd.'s Cosmos and Sinclair nickel sulfide mines. In 2014, Murrin Murrin produced 2,900 t of cobalt metal (2,700 t in 2013). The increase in production was attributed to consistent plant availability. Approximately 200 t of Murrin Murrin's 2014 production was from third-party feed (100 t in 2013). The Cosmos and Sinclair Mines remained on care-and-maintenance status during the year. In late 2014 to early 2015, Glencore sold the Sinclair Mine to Talisman Mining Ltd. (Glencore plc, 2015, p. 55, 201).

First Quantum Minerals Ltd. (Vancouver, British Columbia, Canada) produced intermediate nickel-cobalt hydroxide from its

Ravensthorpe nickel-cobalt laterite mine and hydrometallurgical processing plant in Western Australia. In 2014, the plant produced 36,445 t of nickel and, based on the hydroxide containing 40% nickel and 1.4% cobalt, an estimated 1,260 t of cobalt (38,103 t nickel and an estimated 1,300 t cobalt in 2013). The decrease in production was attributed to a loss of production owing to a structural failure in the atmospheric leaching tank in December. Most of Ravensthorpe's hydroxide reportedly was sent to China, with lesser amounts sold to Brazil and India (First Quantum Minerals Ltd., 2015, p. 12, 31; Metal Bulletin Daily, 2015).

Panoramic Resources Ltd. produced concentrates containing 436 t of cobalt (412 t in 2013) from its Savannah underground nickel-copper sulfide mine operation in Western Australia. The concentrates were shipped to Jinchuan's operations in China under a long-term offtake agreement (Panoramic Resources Ltd., 2014, p. 3; 2015, p. 3, 27).

Mincor Resources NL mined nickel-copper sulfide ores from its North Kambalda and South Kambalda operations in Western Australia. All of the ore was toll processed by BHP Billiton at its Nickel West Kambalda concentrator and the resulting concentrate was sold to BHP Billiton under long-term agreements. In 2014, Mincor sold concentrate containing 191 t of cobalt (204 t in 2013). Most of the cobalt was produced from the Miitel and Mariners Mines at the South Kambalda operation; the McMahon and Otter Juan Mines at the North Kambalda operation closed in March (Mincor Resources NL, 2014, p. 2; 2015, p. 2).

In 2014, OJSC MMC Norilsk Nickel sold its Western Australian nickel assets. Poseidon Nickel Ltd. (Subiaco, Western Australia) agreed to purchase the Black Swan operation, which comprised the Black Swan open pit nickel sulfide mine, Silver Swan underground nickel sulfide mine, and beneficiation plant, and the Lake Johnston operation, which comprised the Maggie Hays and Emily Ann underground nickel sulfide mines and a beneficiation plant. Wingstar Investments Pty. Ltd. acquired the Avalon and Cawse nickel laterite projects (Evans, 2014; OJSC MMC Norilsk Nickel, 2015, p. 14; Poseidon Nickel Ltd., 2014, p. 30–32, 54).

Sun Metals Corp. Pty. Ltd. (a subsidiary of Korea Zinc Co. Ltd.), produced minor byproduct cobalt from its zinc refinery in Townsville, Queensland (Department of Natural Resources and Mines, 2014).

**Belgium.**—According to the Cobalt Development Institute (2015a), Umicore's 2014 cobalt refinery production increased by 8% to 5,850 t of contained cobalt from 5,415 t produced in 2013. Umicore converted various cobalt materials into a wide range of chemicals and metal powders at refineries in Olen, Belgium, and Ganzhou, China. The company also had cobalt processing plants, which made specialty chemicals or metal powders from refined cobalt or scrap, in Arab, AL, LaVergne, TN, and Wickliffe, OH; Bruges, Belgium; Fort Saskatchewan, Alberta, Canada; Jiangmen and Shanghai, China; and Cheonan, Republic of Korea.

**Botswana.**—In October, Norilsk announced that it planned to sell its share in Tati Nickel Mining Co. Pty. Ltd. to BCL Ltd. Tati (85% Norilsk, 15% Government of Botswana) mined the Phoenix open pit and produced nickel-copper sulfide

concentrates containing cobalt, which were toll smelted to high-grade matte by BCL in Botswana. BCL also smelted concentrate from its Selebi-Phikwe operation in Botswana (OJSC MMC Norilsk Nickel, 2015, p. 43, 56).

**Brazil.**—Votorantim Metais S.A. produced cobalt cathode at its Sao Miguel Paulista, Sao Paulo State, refinery from lateritic nickel-cobalt ore mined from Niquelandia, Goias State; from purchased nickel concentrates; and from cobalt intermediates from Congo (Kinshasa). Votorantim's nickel matte production at Fortaleza de Minas, Minas Gerais State, was suspended in September 2013 (Votorantim Industrial S.A., 2015, p. 62; Darton Commodities Ltd., 2015, p. 20).

Mirabela Nickel Ltd. produced 221 t of cobalt in nickel sulfide concentrate (277 t in 2013) from its Santa Rita open pit mine and concentrator in Bahia State. The concentrate was sold to Norilsk Nickel Harjavalta Oy and an international trading firm (Mirabela Nickel Ltd., 2015).

**Canada.**—Vale's global cobalt production was 3,743 t in 2014, 6% more than the 3,532 t produced in 2013. Vale produced 1,362 t (1,550 t in 2013) of refined cobalt metal at its Port Colborne, Ontario, refinery; 1,124 t (685 t in 2013) of cobalt in a cobalt intermediate product at its nickel operations in Canada and New Caledonia; and 1,257 t (1,297 t in 2013) of cobalt contained in other intermediate products and nickel concentrates. Vale's cobalt originated from company-owned nickel sulfide mines at Sudbury, Ontario, Thompson, Manitoba, and Voisey's Bay in northeastern Labrador; from a company-owned nickel laterite mine in New Caledonia; and from purchased feedstock materials. Vale reported that 833 t (853 t in 2013) of cobalt came from Ontario, 489 t (292 t in 2013) came from Manitoba, 952 t (1,256 t in 2013) came from Voisey's Bay, 1,384 t (1,117 t in 2013) came from New Caledonia, and 84 t (13 t in 2013) came from external sources (Vale S.A., 2014, p. 48; 2015, p. 45–46).

In 2014, Vale started nickel production at its hydrometallurgical facility in Long Harbour, Newfoundland and Labrador, Canada. The refinery was designed to have the following nominal capacities: 50,000 metric tons per year (t/yr) of nickel, 4,500 t/yr of copper, and 2,500 t/yr of cobalt. In 2014, the plant processed a blend of high-grade nickel concentrate from Voisey's Bay and nickel matte from PT Vale Indonesia Tbk. Other nickel concentrates from Voisey's Bay were shipped to Vale's operations at Sudbury and Thompson for smelting and refining. Vale was considering phasing out smelting and refining at Thompson, owing to Canadian sulfur dioxide emission standards that were expected to come into effect in 2015. Production might continue through 2019, however, subject to negotiations with Environment Canada (Vale S.A., 2015, p. 34–35).

Glencore reported that 800 t of the cobalt produced at its Nikkelverk refinery in Norway originated from concentrates produced from its mines at Sudbury, Ontario, and Raglan, Quebec. This was a 14% increase from the 700 t produced from its Canadian operations in 2013 (Glencore plc, 2015, p. 201).

The Fort Saskatchewan refinery, a joint venture of Sherritt and General Nickel Co. S.A., produced 3,210 t of cobalt as metal powder and briquettes in 2014, a slight decrease from the 3,319 t produced in 2013. Approximately 85% of the cobalt was from Cuba; the remainder was from purchased materials.

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., 2015a, p. 10, 55, 84).

The following nickel-copper sulfide operations may also have produced ores from which cobalt was later recovered: Canadian Royalties Ltd.'s (Jilin Jien Nickel Industry Co. Ltd.) Nunavik Nickel project in Nunavik, Quebec, and First Nickel Inc.'s Lockerby Mine in Sudbury, Ontario.

**China.**—China was the world's leading producer and consumer of refined cobalt. In 2014, China's imports of raw materials, production, and consumption increased from those of 2013. China's total production, including an estimate for Umicore's Ganzhou Yi Hao plant, was estimated to constitute more than one-half of world refined cobalt production. Seventy-three percent of China's consumption was used to make cathode materials for rechargeable batteries, primarily lithium-cobalt oxide lithium-ion batteries (Darton Commodities Ltd., 2015, p. 6, 36; Fan, 2015, p. 3–4, 8–9).

Numerous companies refined and (or) processed cobalt in China. As a result of consolidation in recent years, in 2014, more than 90% of China's refined cobalt was produced by 10 companies and 60% was produced by three companies—Jinchuan, Shenzhen GEM High-Tech Co. Ltd. (including subsidiary Jiangsu Cobalt Nickel Metal Co. Ltd.), and Zhejiang Huayou Cobalt Co. Ltd. Only a small portion of China's cobalt production originated from domestic mines. Most of the production was from imported cobalt concentrate and intermediate chemical compounds, the majority of which was sourced from Congo (Kinshasa). However, increasing amounts of cobalt raw materials were sourced from nickel operations (for example, nickel-cobalt hydroxide from Ravensthorpe in Australia and Ramu in Papua New Guinea) (Xu, 2014, p. 7; Darton Commodities Ltd., 2015, p. 8, 33–34; Fan, 2015, p. 3, 5, 7).

During 2009–11, a surplus of raw materials and refined cobalt accumulated in China, resulting in stocks estimated to contain more than 20,000 t of cobalt by yearend 2011. A comparison of imports during 2010–14, which were relatively steady, with production, which increased during that time period, suggests that levels of raw material stocks have declined (Darton Commodities Ltd., 2015, p. 33–36).

China's State Reserve Bureau (SRB) reportedly added cobalt to its national stockpile in 2014. In July, the SRB, at the request of the China Non-Ferrous Metals Industry Association, invited selected producing and trading companies to participate in a tender for cobalt metal. Estimates of the quantity purchased ranged from 80 to 300 t, which was less than market expectations of 1,000 t or more. The SRB reportedly had purchased about 200 t of cobalt metal from Jinchuan in 2013 (Darton Commodities Ltd., 2015, p. 36; Metal Bulletin Daily, 2014a).

**Congo (Kinshasa).**—Congo (Kinshasa) was the world's leading producer of mined cobalt and was estimated to represent more than one-half of global production. Some of the country's cobalt mine production was from copper-cobalt ores mined by traditional methods, and some was gathered by tens of thousands of artisanal miners by hand picking cobalt-rich ores. Some of Congo (Kinshasa)'s ores and concentrates were

exported, some were processed to intermediate materials (crude cobalt carbonate, crude cobalt hydroxide, or cobalt-bearing alloys, such as alliage blanc), and some were refined to cobalt metal. China was the leading destination for Congo (Kinshasa)'s cobalt exports. At yearend 2013, the Government of Congo (Kinshasa) announced a moratorium on its ban on exports of copper and cobalt concentrates until December 31, 2014. The justification for the moratorium was the inadequate power supply to process the concentrates in-country (Metal Bulletin Daily, 2014b).

State-owned La Générale des Carrières et des Mines SARL (Gécamines) held a minority interest in most of the copper-cobalt operations in Congo (Kinshasa). In 2014, Gécamines produced 500 t of refined cobalt at its Shituru refinery in Likasi, down from 700 t in 2013 (Cobalt Development Institute, 2015a).

Kamoto Copper Company SARL (KCC) (Katanga Mining Ltd., Gécamines, and La Société Immobilière du Congo) produced 2,784 t of cobalt cathode in 2014, 21% more than the 2,297 t produced in 2013. The increase was attributed to an increase in tons of concentrate processed and process improvements. The company's Luilu refinery processed concentrates produced at its Kamoto concentrator from ore extracted from its Kamoto underground mine, KOV open pit, and T17 open pit and underground mine. Glencore was KCC's majority shareholder and had offtake agreements for all of KCC's copper and cobalt output (Katanga Mining Ltd., 2015, p. 2, 4, 9–10, 24).

Boss Mining Sprl [70% Eurasian Resources Group B.V. (ERG) and 30% Gécamines] mined copper-cobalt ore from open pits at Mukondo Mountain and Kabolela and produced oxide and sulfide concentrates at the Kakanda concentrator. Boss Mining's oxide concentrates were exported, primarily to China; all of its sulfide concentrates were sent to the Chambishi Metals refinery in Zambia. Darton Commodities Ltd. (2015, p. 24) estimated a decrease in Boss Mining's cobalt production from 9,200 t in 2013 to 8,500 t in 2014. The decrease was attributed to reduced availability of oxide ore in the mines (Darton Commodities Ltd., 2015, p. 24).

In 2014, Tenke Fungurume Mining S.A.R.L. [Freeport-McMoRan Inc. (FCX), Lundin Mining, and Gécamines] produced 13,334 t of cobalt in hydroxide, 5% more than the 12,751 t in 2013. Some of the hydroxide was sold to the Freeport Cobalt refinery in Finland, some was sold under contract to customers in China and Europe, and some was sold on the spot market. The company forecast that it would sell 14,500 t of cobalt in 2015 (Lundin Mining Corp., 2015a, p. 35; 2015b, p. 23; Darton Commodities Ltd., 2015, p. 23).

Société Congolaise du Traitement du Terril de Lubumbashi (STL) (Groupe Forrest International and Gécamines) processed slag purchased from Gécamines via trading company Groupement du Terril de Lubumbashi (GTL). In 2014, STL (also known as the Big Hill smelter) processed stockpiled slag to produce an estimated 4,900 t of cobalt in alliage blanc. The alliage blanc was supplied to the Freeport Cobalt Oy refinery in Finland under a 2-year agreement signed in early 2013 (Darton Commodities Ltd., 2015, p. 25).

Mutanda Mining SPRL (Glencore and Fleurette Mumi Holding Ltd.) mined copper-cobalt oxide ore from open pits

near Kolwezi and produced 14,400 t of cobalt in concentrate and hydroxide, 5% more than the 13,700 t produced in 2013. The increase in production was the result of the operation running at near capacity throughout the year (Glencore plc, 2015, p. 54, 197).

Chemaf SPRL mined copper-cobalt ore from the Etoile open pit mine and produced concentrate using heavy media separation technology, which it processed at its solvent extraction–electrowinning (SX–EW) plant at Usoke in Lubumbashi. In 2014, Chemaf produced 2,006 t of cobalt in hydroxide or carbonate, 71% more than the 1,170 t produced in 2013. The company also operated a pilot cobalt electrowinning plant, which had the capacity to produce 50 t/yr of cobalt (Shalina Resources Ltd., undated).

Ruashi Mining Sprl (75% Jinchuan, 25% Gécamines) produced 3,885 t of cobalt in cobalt hydroxide (3,045 t in 2013) from its Ruashi operation east of Lubumbashi. Ruashi comprised a copper-cobalt oxide open pit mine, a mill, and an SX–EW refinery. The cobalt hydroxide was sold to Jinchuan (Jinchuan Group International Resources Co. Ltd., 2015, p. 23).

Société Minière du Katanga sprl (Somika) mined and beneficiated copper-cobalt ore and refined the concentrate at its hydrometallurgical copper refinery in Lubumbashi. In 2014, the refinery produced 4,747 t of cobalt hydroxide (Province du Katanga Division Provinciale de Mines, 2015).

China Railway Group Ltd. had two operating copper-cobalt mines in Katanga Province—Luishia and Minière de Kalumbwe Myunga. The company was also a partner in La Sino-Congolaise des Mines S.A. (Sicomines) (table 7) (China Railway Group Ltd., 2015, p. 20).

**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 intermediate nickel-cobalt sulfides, which were sent to the joint venture's Fort Saskatchewan refinery in Canada. In 2014, the sulfides contained 36,410 t of nickel and cobalt, slightly more than the 36,374 t produced in 2013 (Sherritt International Corp., 2015a, p. 84).

The Ernesto Che Guevara operation in Moa, Holguin Province, mined and processed nickel-cobalt laterites. In 2014, the processing plant reportedly was to undergo a major overhaul. Nickel and cobalt originating in Cuba cannot be imported into the United States because of the United States embargo on imports from Cuba (Thomson Reuters, 2014a; Sherritt International Corp., 2015a, p. 55).

**Finland.**—Freeport Cobalt Oy (FCX, Lundin Mining Corp., and Gécamines) produced 16% more cobalt at its refinery in Kokkola compared with production in 2013. The company produced a wide range of cobalt chemicals and metal powders by processing a variety of concentrates, secondary (scrap) materials, and intermediate cobalt materials, including intermediate cobalt hydroxides from the joint-venture partners' Tenke Fungurume operation in Congo (Kinshasa) and Norilsk's Severonikel refinery in Russia, intermediate cobalt sulfate solution from Norilsk's Harjavalta refinery, and alliage blanc from GTL's Bill Hill smelter in Congo (Kinshasa) (Darton Commodities Ltd., 2015, p. 10, 18, 25–26; Geological Survey

of Finland, 2015; OJSC MMC Norilsk Nickel, 2015, p. 43; Freeport Cobalt Oy, undated).

Norilsk's Harjavalta nickel refinery produced two cobalt products—cobalt sulfate and an intermediate cobalt sulfate solution. The refinery's main sources of feed in 2014 included high-grade matte from BCL in Botswana and Vale (origin not identified); nickel concentrates from Norilsk's Nkomati Mine in South Africa, Mirabela Nickel in Brazil, and First Quantum's Kevitsa Mine in Finland; and nickel-cobalt sulfide from Talvivaara Mining Co. Plc's operation in Finland. The nickel concentrates were toll smelted by Boliden AB prior to processing by Norilsk (OJSC MMC Norilsk Nickel, 2015, p. 42–43, 56).

First Quantum increased production at its Kevitsa open pit nickel-copper-PGM sulfide mine and beneficiation plant. In 2014, the plant produced nickel concentrate containing 9,433 t of nickel and, based on an estimated nickel-to-cobalt ratio of 21:1 in the ore reserves, an estimated 450 t of cobalt (8,963 t nickel and an estimated 430 t cobalt in 2013) (First Quantum Minerals Ltd., 2015, p. 32).

Talvivaara Sotkamo Ltd. (a subsidiary of Talvivaara Mining Co. Plc) operated the polymetallic sulfide mining and bioheap-leaching operation in Sotkamo in central Finland. In 2014, nickel production reportedly increased to more than 9,600 t (8,662 t in 2013). During January through June 2014, nickel-cobalt sulfide containing 142 t of cobalt was sold to Norilsk for processing at Harjavalta; sales data for the second half of the year were not available. Talvivaara Sotkamo filed for bankruptcy in early November and the mining and processing operation was to be sold. Talvivaara Mining's corporate reorganization proceedings, which began in late 2013, continued during 2014 (Talvivaara Mining Co. Plc, 2014, p. 4; 2015; Castrén & Snellman Attorneys Ltd., 2015).

In 2014, Boliden AB decided to change its business strategy for nickel at its Harjavalta smelter. Beginning in mid-2015, Boliden would cease toll smelting nickel concentrates owned by other companies and instead process purchased nickel concentrates and sell the resulting nickel matte. During the year, Boliden acquired Kuhmo Nickel Ltd. and its subsidiaries, including the Kylylahti copper mine in eastern Finland, from Altona Mining Ltd. (Boliden AB, 2015, p. 44, 109).

**France.**—The Eramet Group's production of cobalt chloride from its refinery at Sandouville was 29% less than production in 2013. Feed for the refinery was nickel matte imported from Eramet subsidiary Société Le Nickel's Doniambo smelter in New Caledonia (Cobalt Development Institute, 2015a).

**India.**—According to an estimate by the Cobalt Development Institute (2015a), India's cobalt production decreased by 66% from that of 2013. India's leading cobalt producer was Nicomet Industries Ltd. The company's products included cobalt metal and cobalt sulfate (Nicomet Industries Ltd., undated).

**Indonesia.**—PT Vale Indonesia Tbk produced cobalt-bearing nickel matte from lateritic ores at its integrated mining and smelting operation near Sorowako on Sulawesi Island. Vale Indonesia sold its matte production to Vale Canada Ltd. (80%) and Sumitomo Metal Mining Co., Ltd. (20%) under life-of-mine agreements. The matte was primarily sent to nickel refineries in Japan (Vale S.A., 2015, p. 36).

In January, PT Aneka Tambang Tbk (2015, p. 10–11) ceased exports of lateritic nickel-cobalt ore to comply with the Government of Indonesia's ban on exports of unprocessed minerals.

**Japan.**—Sumitomo's production of electrolytic cobalt at its Niihama nickel refinery increased by 33% from that of 2013. The refinery processed intermediate nickel-cobalt sulfides from the Coral Bay Nickel Corp. and Taganito HPAL Nickel Corp. plants in the Philippines and nickel matte from PT Vale in Indonesia and elsewhere (Cobalt Development Institute, 2015a; Darton Commodities Ltd., 2015, p. 16).

**Madagascar.**—The Ambatovy joint venture (Sherritt, Sumitomo Corp., Korea Resources Corp., and SNC-Lavalin Group Inc.) continued to ramp up production and reached commercial production early in the year. The Ambatovy project comprised mining nickel-cobalt laterite ore in east-central Madagascar and transporting slurried ore by pipeline to a processing plant and refinery located near the Port of Toamasina. In 2014, Ambatovy produced 40,267 t of nickel and cobalt in intermediate sulfide (29,248 t in 2013) and 2,915 t of cobalt metal (2,083 t in 2013) (Sherritt International Corp., 2015b, p. 13, 37).

**Morocco.**—Cie. de Tifnout Tighanimine (CTT) [a subsidiary of Groupe Managem (Casablanca)] mined cobalt arsenide ores and produced cobalt hydroxide at Bou-Azzer. The hydroxide was refined to cobalt cathode and oxide at CTT's Guemassa hydrometallurgical refinery north of Marrakech. CTT also had the capability to produce 500 t/yr of cobalt cathode from tailings generated during past mining operations at Bou-Azzer (Groupe Managem, 2015, p. 116).

**New Caledonia.**—Vale continued to ramp up production at its Vale New Caledonia project in the southern tip of New Caledonia's main island. The project comprised a nickel-cobalt laterite mine, a high-pressure acid-leaching processing plant, and a refinery. In 2014, Vale produced 1,384 t of cobalt from New Caledonia (1,117 t in 2013). Statistics from the Government of New Caledonia indicated that Vale produced 435 t of cobalt in carbonate (503 t in 2013). Following rampup, Vale New Caledonia was expected to have a nominal production capacity of 57,000 t/yr of nickel contained in nickel oxide and 4,500 t/yr of cobalt contained in an intermediate cobalt carbonate (Direction de l'Industrie, des Mines et de l'Energie, 2015; Vale S.A., 2015, p. 36, 46).

Lateritic nickel-cobalt ore was exported to the Palmer Nickel and Cobalt Refinery in Queensland, Australia, for processing. Nickel matte from Société Le Nickel's Doniambo smelter was sent to Eramet's refinery in Sandouville, France, where nickel products and cobalt chloride were produced.

**Norway.**—Glencore's production of cobalt cathode at its Nikkelverk refinery was 6% more than that of 2013. Twenty-two percent of the cobalt refined at Nikkelverk originated from Glencore's Sudbury and Raglan operations in Canada; the remaining feed was a mix of intermediate products and secondary (scrap) materials sourced from other companies (Darton Commodities Ltd., 2015, p. 11; Glencore plc, 2015, p. 201).

**Papua New Guinea.**—The Ramu Nickel joint venture (operated by majority owner Metallurgical Corporation of

China Ltd.) ramped up production from its Kurumbukari nickel-cobalt laterite mine and Basamuk high-pressure acid-leaching processing plant. In 2014, the operation more than doubled its production to 2,134 t of cobalt in intermediate nickel-cobalt hydroxide from 1,013 t in 2013. Ramu planned to bring the operation to full capacity (3,300 t/yr of cobalt) in 2016. The hydroxide was exported to China for refining (Highlands Pacific Ltd., 2015, p. 8–9).

**Philippines.**—Coral Bay Nickel (a joint venture among Sumitomo, Mitsui & Co., Ltd., Sojitz Corp., and Rio Tuba Nickel Mining Corp., listed in order of share) produced intermediate nickel-cobalt sulfide from its high-pressure acid-leaching operation at the Rio Tuba nickel laterite mine on Palawan Island. Taganito HPAL Nickel Corp. (Sumitomo, Nickel Asia Corp., and Mitsui, listed in order of share) produced intermediate nickel-cobalt sulfide from its high-pressure acid-leaching processing plant at Nickel Asia's Taganito laterite mine in the northeastern region of Mindanao Island. Sulfides from Coral Bay and Taganito were sent to Sumitomo's Niihama refinery in Japan.

**Russia.**—According to the Cobalt Development Institute (2015a), Norilsk produced 2,302 t of refined cobalt, 3% less than the 2,368 t produced in 2013. Norilsk mined and beneficiated nickel-copper sulfide ores, smelted the concentrates, and refined the matte on the Taimyr Peninsula and the Kola Peninsula. On the Taimyr Peninsula, Norilsk's Polar Division's Nickel Plant produced cobalt ingot from local ores. The company planned to close the Polar Division's nickel smelter and refinery and cease cobalt ingot production in 2016 (Darton Commodities Ltd., 2015, p. 18; OJSC MMC Norilsk Nickel, 2015, p. 33, 38–39, 233).

At Norilsk's Severonikel refinery at Monchegorsk on the Kola Peninsula, Kola MMC processed cobalt-bearing nickel materials originating from Kola, the Polar Division, and elsewhere to make an intermediate cobalt hydroxide. Some of the hydroxide was reportedly sent to Freeport Cobalt's Kokkola refinery and some was sold on the open market. During the year, Kola MMC continued to build a cobalt refinery at Monchegorsk for converting its hydroxide to high-grade cobalt cathode, and reportedly produced about 200 t of cathode at the associated pilot plant (table 7) (Darton Commodities Ltd., 2015, p. 18; OJSC MMC Norilsk Nickel, 2015, p. 40–41).

**South Africa.**—The Nkomati nickel sulfide mine (a joint venture of African Rainbow Minerals Ltd. and Norilsk) produced 1,096 t of cobalt in nickel concentrate in 2014, 5% less than the 1,159 t produced in 2013. Concentrate from Nkomati was refined at Norilsk's Harjavalta refinery. In October, Norilsk announced that it planned to sell its share in Nkomati to BCL in Botswana. As part of the sale agreement, BCL was to take over Norilsk's offtake agreement for Nkomati concentrate and Norilsk was to buy nickel matte from BCL to refine at Harjavalta (African Rainbow Minerals Ltd., 2014, p. 62; 2015, p. 58; Thomson Reuters, 2014b; OJSC MMC Norilsk Nickel, 2015, p. 56).

Cobalt was also produced as a byproduct from some of South Africa's PGM operations. Two companies produced refined cobalt. Rustenburg Base Metals Refiners (Proprietary) Ltd. (a subsidiary of Anglo American plc) produced cobalt sulfate at

its base-metals refinery near Rustenburg, North West Province. 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. Two other platinum producers—Lonmin plc and Northam Platinum Ltd.—operated base-metals refineries and produced intermediate nickel sulfate containing cobalt.

**Spain.**—Lundin Mining Corp. mined nickel-copper sulfide ore containing cobalt and precious metals from its Aguablanca open pit in Badajoz Province and produced nickel-copper concentrate containing 14% more nickel than that of 2013. The concentrate was all sold under one long-term contract. During the year, the company worked on developing an underground mine at the site (Lundin Mining Corp., 2015a, p. 36–37; 2015b, p. 22).

**Uganda.**—In June, a consortium led by Tibet Hima Industry Co. Ltd., which had been awarded the contract to rehabilitate the Kilembe copper-cobalt mine in mid-2013, formally took over the mine from former manager Kilembe Mines Ltd. In addition to rehabilitating the mine (table 7), the consortium planned to rehabilitate and increase the production capacity of the Mubuku hydropower dam and negotiated with the Government to take over management of Kasese Cobalt Co. Ltd. (KCCL). Until its closure in 2013, the KCCL refinery produced cobalt from stockpiled pyrite concentrates generated by past mining at Kilembe (Asimwe, 2014).

**Vietnam.**—During its first full year of production, Asian Mineral Resources Ltd. produced 223 t of cobalt in concentrate from its Ban Phuc nickel-copper sulfide mine and beneficiation plant in Son La Province (Asian Mineral Resources Ltd., 2014a, p. 3; 2014b, p. 3; 2014c, p. 3; 2015).

**Zambia.**—Cobalt is present in many of Zambia's copper deposits, but not all copper operations report their cobalt output. Zambian cobalt mine production was estimated to have decreased in 2014 compared with that of 2013 owing to a reported decrease in copper production (Lisulo, 2015). Production of refined cobalt, which was mainly from imported concentrates, decreased compared with that of 2013.

According to the Cobalt Development Institute (2015a), Chambishi Metals plc (90% ERG and 10% ZCCM Investments Holdings Plc) produced 4,317 t of cobalt metal at its Chambishi refinery, 14% less than the 5,000 t produced in 2013. The decrease was attributed to a blown transformer in late 2013 that resulted in the cobalt plant operating at less than 50% of normal levels in early 2014, roaster issues later in the year, and changes in feed, including reduced cobalt content. The main source of feed was copper-cobalt sulfide concentrate from Boss Mining's operations in Congo (Kinshasa) (Darton Commodities Ltd., 2015, p. 15).

Glencore's Sable Zinc Kabwe Ltd. copper electrowinning plant processed feed from third-party sources and produced 500 t of cobalt in hydroxide in 2014 (400 t in 2013). Mopani Copper Mines (Glencore, First Quantum, and ZCCM Investment Holdings, listed in order of share) kept its Nkana cobalt refinery on care-and-maintenance status in 2014 (Glencore plc, 2015, p. 197).

Konkola Copper Mines Plc (Vedanta Resources Ltd. and ZCCM Investments Holdings) (KCM) mined copper ores from its Nchanga and Konkola operations. Cobalt in concentrate, mainly from the Nchanga open pit, was processed to a copper-iron-cobalt alloy at the company's Nchanga copper smelter in Chingola. Darton Commodities Ltd. (2015, p. 27) estimated that KCM's production of cobalt in alloy decreased from 2,000 t in 2013 to 1,700 t in 2014, owing to lower feed grades, lower equipment availability, and power restrictions.

China Nonferrous Mining Corp. Ltd. (CNMC) mined and processed copper-cobalt ore in the Zambian Copperbelt through four majority-owned subsidiaries—NFC Africa Mining Plc. (NFCA), CNMC Luanshya Copper Mines Plc. (CLM), Chambishi Copper Smelter Ltd. (CCS), and Sino-Metal Leach Zambia Ltd. CCS smelted copper concentrates from NFCA, CLM, and other miners. CNMC completed the design for cobalt recovery from CCS's converter slag and high cobalt matte and began construction in early 2015 (table 7). The project was to have the capacity to process 100,000 t/yr of slag and 50,000 t/yr of matte (China Nonferrous Mining Corp. Ltd., 2015, p. 38).

Jinchuan and Consolidated Nickel Mines plc (CNM) signed a lease and royalty agreement, which gave CNM full operational control of the Munali nickel mine in southern Zambia. CNM planned to restart operations at the mine in the first half of 2015, following receipt of the necessary agreements and permissions from the Government of Zambia. Concentrate from the mine would be smelted in southern Africa (Consolidated Nickel Mines plc, undated a, b).

**Zimbabwe.**—The Mimosa platinum mine (Aquarius Platinum Ltd. and Impala Platinum Holdings Ltd.) produced 90 t of cobalt in concentrate (89 t in 2013). The concentrates were refined by Impala in South Africa (Aquarius Platinum Ltd., 2014, p. 13; 2015, p. 13).

Zimplats Holdings Ltd. reported that 58 t of cobalt was produced from its platinum operations in 2014 (comparable data were not available for 2013). The company announced plans to refurbish the base-metals refinery at its Selous Metallurgical Complex in Mashonaland West Province (Zimplats Holdings Ltd., 2014, p. 15; 2015, p. 4).

Bindura Nickel Corp. (BNC) operated the Trojan nickel sulfide mine and shipped concentrate to offtake partner Glencore. During the year, BNC made plans to restart its smelter in 2015 to produce a nickel leach alloy from concentrates produced at Trojan and other mines in Zimbabwe. The company's Shangani Mine and refinery remained on care-and-maintenance status (Mwana Africa PLC, 2014, p. 8–9, 58).

## Outlook

Trends in cobalt consumption closely follow those of global industrial production. Increasing consumption, particularly for rechargeable batteries and superalloys, is forecast to result in a compound annual growth rate of more than 5% per year through 2025. During the first half of 2015, the world production of refined cobalt was estimated to have been 11% higher than that of the first half of 2014. China showed a large increase in production, as did Katanga Mining in Congo (Kinshasa). The annual growth rate in world cobalt production is forecast to decrease between 2015 and 2019, however, as recently

commissioned operations reach maximum capacity. Without new producers entering the market in the medium term, or a major shift to battery chemistries with less cobalt, a period of undersupply could take place (Cobalt Development Institute, 2015b; Darton Commodities Ltd., 2015, p. 51; Searle, 2015, p. 6, 11, 14–15).

## References Cited

- African Rainbow Minerals Ltd., 2014, Integrated annual report 2014: Sandton, South Africa, African Rainbow Minerals Ltd., 270 p.
- African Rainbow Minerals Ltd., 2015, Interim results for the six months ended 31 December 2014: Sandton, South Africa, African Rainbow Minerals Ltd., 92 p.
- Aquarius Platinum Ltd., 2014, Fourth quarter 2014—Production results to 30 June 2014: Hamilton, Bermuda, Aquarius Platinum Ltd., 16 p.
- Aquarius Platinum Ltd., 2015, Second quarter 2015 production results—Production results to 31 December 2014: Hamilton, Bermuda, Aquarius Platinum Ltd., 17 p.
- Asian Mineral Resources Ltd., 2014a, Management's discussion and analysis—Quarter ended June 30, 2014: Toronto, Ontario, Canada, Asian Mineral Resources Ltd., August 22, 27 p.
- Asian Mineral Resources Ltd., 2014b, Management's discussion and analysis—Quarter ended March 31, 2014: Toronto, Ontario, Canada, Asian Mineral Resources Ltd., May 22, 27 p.
- Asian Mineral Resources Ltd., 2014c, Management's discussion and analysis—Quarter ended September 30, 2014: Toronto, Ontario, Canada, Asian Mineral Resources Ltd., November 28, 27 p.
- Asian Mineral Resources Ltd., 2015, Asian Mineral Resources provides Q4 2014 operational update: Toronto, Ontario, Canada, Asian Mineral Resources Ltd. news release, January 26, 5 p.
- Asimwe, Wilson, 2014, Kilembe Mines rehabilitation starts: New Vision, June 7. (Accessed July 8, 2015, at [http://www.newvision.co.ug/new\\_vision/news/1341497/kilembe-mines-rehabilitation-starts](http://www.newvision.co.ug/new_vision/news/1341497/kilembe-mines-rehabilitation-starts).)
- Boliden AB, 2015, Annual report 2014: Stockholm, Sweden, Boliden AB, 120 p.
- Castrén & Snellman Attorneys Ltd., 2015, Talvivaara Mining Company Plc—Administrator's supplemented draft restructuring programme—Unofficial translation: Helsinki, Finland, Castrén & Snellman Attorneys Ltd. public document, March 13, 8 p.
- China Nonferrous Mining Corp. Ltd., 2015, 2014 annual report: Beijing, China, China Nonferrous Mining Corp. Ltd., 176 p.
- China Railway Group Ltd., 2015, Annual report 2014: Beijing, China, China Railway Group Ltd., 204 p.
- Cobalt Development Institute, 2015a, 2014 production statistics: Cobalt News, no. 2, April, p. 3–5.
- Cobalt Development Institute, 2015b, 2015 first half production statistics: Cobalt News, no. 4, October, p. 3–4.
- Consolidated Nickel Mines plc, [undated]a, The Munali nickel mine: London, United Kingdom, Consolidated Nickel Mines plc. (Accessed March 13, 2015, at <http://www.cnmplc.co.uk/the-munali-nickel-mine/>.)
- Consolidated Nickel Mines plc, [undated]b, Who we are & what we do: London, United Kingdom, Consolidated Nickel Mines plc. (Accessed March 13, 2015, at <http://www.cnmplc.co.uk/who-we-are-what-we-do/>.)
- Darton Commodities Ltd., 2015, Cobalt market review 2014–2015: Guildford, United Kingdom, Darton Commodities Ltd., 56 p.
- Defense Logistics Agency Strategic Materials, 2014, Annual materials plan for FY 2015 for possible acquisition of new NDS stocks: Fort Belvoir, VA, Defense Logistics Agency Strategic Materials news release, October 2, 1 p.
- Department of Natural Resources and Mines, 2014, Cobalt opportunities in Queensland: Brisbane, Queensland, Australia, Department of Natural Resources and Mines, Geological Survey of Queensland. (Accessed November 10, 2015, at [https://www.dnrm.qld.gov.au/\\_data/assets/pdf\\_file/0016/238102/cobalt.pdf](https://www.dnrm.qld.gov.au/_data/assets/pdf_file/0016/238102/cobalt.pdf).)
- Direction de l'Industrie, des Mines et de l'Énergie, 2015, Productions et exportations minières & métallurgiques de la Nouvelle-Calédonie—Decembre 2014: Noumea, New Caledonia, Direction de l'Industrie, des Mines et de l'Énergie. (Accessed June 29, 2016, at [https://dimenc.gouv.nc/sites/default/files/statistiques\\_nc\\_2014\\_-\\_12.pdf](https://dimenc.gouv.nc/sites/default/files/statistiques_nc_2014_-_12.pdf).)
- Evans, Nick, 2014, Gardner buys Cawse, Avalon: The West Australian [Perth, Western Australia], May 23. (Accessed September 30, 2014, at <https://au.news.yahoo.com/thewest/wa/a/23755095/gardner-buys-cawse-avalon/>.)

- Fan, Runze, 2015, Analysis of Chinese cobalt market in 2014–2015: The Cobalt Conference, Cobalt Development Institute, Toronto, Ontario, Canada, May 20–21, presentation, 21 p.
- Fanya Metal Exchange Co. Ltd., [undated], Catalog: Fanya Metal Exchange Co. Ltd. (Accessed November 10, 2014, at [http://www.fyme.cn/uploads/soft/140807/11054\\_1459285901.pdf](http://www.fyme.cn/uploads/soft/140807/11054_1459285901.pdf).)
- First Quantum Minerals Ltd., 2015, 2014 Management's discussion and analysis: Vancouver, British Columbia, Canada, First Quantum Minerals Ltd., February 19, 40 p.
- Formation Metals Inc., 2015, Company presentation: Vancouver, British Columbia, Canada, Formation Metals Inc., January, 24 p. (Accessed February 20, 2015, at <http://www.formationmetals.com/i/pdf/CompanyPowerpointPresentation.pdf>.)
- Freeport Cobalt Oy, [undated], Recycling: Kokkola, Finland, Freeport Cobalt Oy. (Accessed February 2, 2015, at <http://www.freeportcobalt.com/products/chemical.html#recycling>.)
- Geological Survey of Finland, 2015, Metals and minerals production 2011–2014: Espoo, Finland, Geological Survey of Finland. (Accessed May 27, 2015, at <http://en.gtk.fi/information-services/mineral-production/finmipr1114.html>.)
- Glencore plc, 2015, Annual report 2014: Baar, Switzerland, Glencore plc, 204 p.
- Global Tungsten & Powders Corp., 2014, Global Tungsten & Powders announces strategic cobalt partnership with Umicore: Towanda, PA, Global Tungsten & Powders Corp. news release, August 25, 1 p.
- Groupe Managem, 2015, Management sustainability report 2014: Casablanca, Morocco, Groupe Managem, 141 p.
- Highlands Pacific Ltd., 2015, Annual report 2014: Brisbane, Queensland, Australia, Highlands Pacific Ltd., 67 p.
- Jinchuan Group International Resources Co. Ltd., 2015, Annual results announcement for the year ended 31 December 2014: Hong Kong, China, Jinchuan Group International Resources Co. Ltd. news release, March 27, 34 p.
- Katanga Mining Ltd., 2015, Management's discussion and analysis for the three months and years ended December 31, 2014 and 2013: Whitehorse, Yukon Territory, Canada, Katanga Mining Ltd., 37 p.
- Lisulo, Stuart, 2015, Zambia records decline in 2014 copper production: The Post [Lusaka, Zambia], February 1. (Accessed February 6, 2015, at <http://www.postzambia.com/news.php?id=5700>.)
- London Metal Exchange Ltd., The, 2013, Delisting of cobalt brand KCCL: London, United Kingdom, The London Metal Exchange Ltd. news release, November 13, 1 p.
- London Metal Exchange Ltd., The, [undated], List of all LME-approved brands by metal: London, United Kingdom, The London Metal Exchange Ltd. (Accessed March 18, 2015, via <https://www.lme.com/trading/warehousing-and-brands/brands/approved-brands/>.)
- Lundin Mining Corp., 2015a, Annual information form for the year ended December 31, 2014: Toronto, Ontario, Canada, Lundin Mining Corp., March 31, 64 p.
- Lundin Mining Corp., 2015b, Management's discussion and analysis for the year ended December 31, 2014: Toronto, Ontario, Canada, Lundin Mining Corp., February 18, 46 p.
- Metal Bulletin Daily, 2014a, China's SRB could buy about 1,000 tonnes of cobalt, sources say: Metal Bulletin Daily, no. 9364.4, July 17, p. 20–21.
- Metal Bulletin Daily, 2014b, DRC copper/cobalt concentrate export ban pushed back to year-end, ministry says: Metal Bulletin Daily, no. 9337.4, January 9, p. 16.
- Metal Bulletin Daily, 2015, First Quantum expects production restart at Ravensthorpe nickel mine by July 31: Metal Bulletin Daily, no. 9416.4, July 23, p. 5–6.
- Mincor Resources NL, 2014, Quarterly report for the period ended 30 June 2014: West Perth, Western Australia, Australia, Mincor Resources NL, 15 p.
- Mincor Resources NL, 2015, Quarterly report for the period ended 31 December 2014: West Perth, Western Australia, Australia, Mincor Resources NL, 17 p.
- Mirabela Nickel Ltd., 2015, Quarterly activity report for the period ended 31 December 2014: Perth, Western Australia, Australia, Mirabela Nickel Ltd., February 16, 5 p.
- Mwana Africa PLC, 2014, Annual report 2014: London, United Kingdom, Mwana Africa PLC, 80 p.
- Nicomet Industries Ltd., [undated], About us—Profile: Mumbai, India, Nicomet Industries Ltd. (Accessed March 13, 2015, at <http://www.nicomet.com/aboutus.htm>.)
- n.v. Umicore, s.a., 2015, Annual report 2014: Brussels, Belgium, n.v. Umicore, s.a., 196 p.
- OJSC MMC Norilsk Nickel, 2015, Annual report 2014: Moscow, Russia, OJSC MMC Norilsk Nickel, 239 p.
- Panoramic Resources Ltd., 2014, Quarterly report for the period ending 30 June 2014: Perth, Western Australia, Australia, Panoramic Resources Ltd., July 31, 31 p.
- Panoramic Resources Ltd., 2015, Quarterly report for the period ending 31 December 2014: Perth, Western Australia, Australia, Panoramic Resources Ltd., January 30, 33 p.
- PolyMet Mining Corp., 2015, Form 20–F for the fiscal year ended January 31, 2015: U.S. Securities and Exchange Commission, 61 p.
- Poseidon Nickel Ltd., 2014, Annual report 2014: Subiaco, Western Australia, Australia, Poseidon Nickel Ltd., 102 p.
- Province du Katanga Division Provinciale de Mines, 2015, Statistiques des notes de débit relatives à la redevance minière émises de janvier à décembre 2014: Lubumbashi, Congo (Kinshasa), Province du Katanga Division Provinciale de Mines, January 2. (Accessed April 21, 2015, at <http://www.congomines.org/wp-content/uploads/2015/03/Div-Mines-Statistiques-redevances-et-exportation-2014.pdf>.)
- PT Aneka Tambang Tbk, 2015, 2014 annual report: Jakarta, Indonesia, PT Aneka Tambang Tbk, 602 p.
- Searle, P.J., 2015, Cobalt—Market balance in 2020s?: The Cobalt Conference, Cobalt Development Institute, Toronto, Ontario, Canada, May 20–21, presentation, 21 p.
- Shalina Resources Ltd., [undated], Processing plants—Co precipitation plant: Dubai, United Arab Emirates, Shalina Resources Ltd. (Accessed September 8, 2015, at <http://www.shalinareources.com/cosx-plant.html>.)
- Sherritt International Corp., 2015a, 2014 annual information form: Toronto, Ontario, Canada, Sherritt International Corp., 97 p.
- Sherritt International Corp., 2015b, 2014 annual report: Toronto, Ontario, Canada, Sherritt International Corp., 142 p.
- Stillwater Mining Co., 2015, Form 10–K—2014: U.S. Securities and Exchange Commission, 115 p.
- Talvivaara Mining Co. Plc, 2014, Talvivaara Mining Company interim report for January–June 2014: Espoo, Finland, Talvivaara Mining Company Plc stock exchange release, September 30, 24 p.
- Talvivaara Mining Co. Plc, 2015, Talvivaara Mining Company report on operational and financial status and development for the period of January 2014–February 2015: Espoo, Finland, Talvivaara Mining Company Plc stock exchange release, February 27, 8 p.
- Thomson Reuters, 2014a, Cuba to cut nickel plant output for major overhaul: Havana, Cuba, Thomson Reuters, February 3. (Accessed February 4, 2014, at <http://www.reuters.com/article/2014/02/03/metals-cuba-nickel-idUSL2N0L812L20140203>.)
- Thomson Reuters, 2014b, Norilsk to sell African nickel stakes to Botswana's BCL for \$337 mln: Gaborone, Botswana, Thomson Reuters, October 20. (Accessed February 16, 2016, at <http://www.reuters.com/article/norilskafrika-ma-bcl-idUSL3N0SF54920141020>.)
- U.S. Department of Defense, 2015, Strategic and critical materials operations report to Congress—Operations under the Strategic and Critical Materials Stock Piling Act during fiscal year 2014: Fort Belvoir, VA, U.S. Department of Defense, January, 66 p.
- Vale S.A., 2014, Form 20–F for the fiscal year ended December 31, 2013: U.S. Securities and Exchange Commission, 161 p.
- Vale S.A., 2015, Form 20–F for the fiscal year ended December 31, 2014: U.S. Securities and Exchange Commission, 164 p.
- Votorantim Industrial S.A., 2015, Report 2014: Sao Paulo, Brazil, Votorantim Industrial S.A., 99 p.
- Xu, Aidong, 2014, China cobalt industry—Review in China: The Cobalt Conference, Cobalt Development Institute, Brussels, Belgium, May 21–22, presentation, 21 p.
- Zimplats Holdings Ltd., 2014, Integrated annual report 2014: St. Peter Port, Guernsey [United Kingdom], Zimplats Holdings Ltd., 179 p.
- Zimplats Holdings Ltd., 2015, Half year directors' report and condensed interim financial statements—31 December 2014: St. Peter Port, Guernsey [United Kingdom], Zimplats Holdings Ltd., 18 p.

## GENERAL SOURCES OF INFORMATION

### U.S. Geological Survey Publications

Cobalt. Ch. in Mineral Commodity Summaries, annual.  
 Cobalt. Ch. in United States Mineral Resources, Professional Paper 820, 1973.  
 Cobalt. International Strategic Minerals Inventory Summary Report, Circular 930-F, 1987.  
 Cobalt. Mineral Industry Surveys, monthly.  
 Cobalt (Co). Ch. in Metal Prices in the United States Through 2010, Scientific Investigations Report 2012-5188, 2013.  
 Cobalt—For Strength and Color. Fact Sheet 2011-3081.  
 Cobalt Recycling in the United States in 1998. Ch. in Flow Studies for Recycling Metal Commodities in the United States, Circular 1196-A-M, 2004.  
 Co-Cu-Au Deposits in Metasedimentary Rocks—A Preliminary Report. Open File Report 2010-1212.  
 Historical Statistics for Mineral and Material Commodities in the United States. Data Series 140.  
 Magmatic Sulfide-Rich Nickel-Copper Deposits Related to Picrite and (or) Tholeiitic Basalt Dike-Sill Complexes—A

Preliminary Deposit Model. Open File Report 2010-1179, 2010.  
 Ni-Co Laterite Deposits of the World—Database and Grade and Tonnage Models. Open File Report 2011-1058, 2011.  
 Sediment-Hosted Copper Deposits of the World—Deposit Models and Database. Open File Report 03-107, 2003.

### Other

Cobalt. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.  
 Cobalt. Mineral Profile, British Geological Survey, 2009.  
 Cobalt Development Institute.  
 DATAWEB. U.S. International Trade Commission.  
 DLA Strategic Materials, Defense Logistics Agency.  
 Federal Register, daily.  
 Materials Flow of Cobalt in the United States, The. U.S. Bureau of Mines Information Circular 9350, 1993.  
 Metal Bulletin, daily.  
 Roskill Information Services Ltd.  
 Strategic and Critical Materials Operations Report to Congress. U.S. Department of Defense.

TABLE 1  
 SALIENT COBALT STATISTICS<sup>1</sup>

(Metric tons, cobalt content, unless otherwise specified)

|   | 2010                 | 2011                 | 2012                 | 2013                 | 2014                 |
|---|----------------------|----------------------|----------------------|----------------------|----------------------|
| United States:                              |                      |                      |                      |                      |                      |
| Mine production <sup>c</sup>                | (2)                  | (2)                  | (2)                  | (2)                  | 120                  |
| Consumption:                                |                      |                      |                      |                      |                      |
| Reported                                    | 8,130                | 9,180                | 8,660                | 8,090 <sup>r</sup>   | 8,560                |
| Apparent                                    | 10,300               | 9,230                | 9,510 <sup>r</sup>   | 8,670                | 8,920                |
| Imports for consumption                     | 11,100               | 10,600               | 11,100               | 10,500               | 11,400               |
| Exports                                     | 2,640                | 3,390                | 3,760                | 3,850                | 4,500                |
| Stocks, December 31:                        |                      |                      |                      |                      |                      |
| Industry <sup>3</sup>                       | 630                  | 784                  | 730 <sup>r</sup>     | 821 <sup>r</sup>     | 984                  |
| London Metal Exchange (LME), U.S. warehouse | 23                   | 43                   | 51                   | 41                   | 9                    |
| U.S. Government: <sup>4</sup>               |                      |                      |                      |                      |                      |
| Metal                                       | 301                  | 301                  | 301                  | 301                  | 301                  |
| Lithium cobalt oxide                        |                      |                      |                      |                      |                      |
| metric tons, gross weight                   | --                   | --                   | --                   | --                   | 0.091                |
| Lithium nickel cobalt aluminum oxide        |                      |                      |                      |                      |                      |
| do.   | --                   | --                   | --                   | --                   | 0.080                |
| Price, metal                                |                      |                      |                      |                      |                      |
| U.S. spot <sup>5</sup>                      |                      |                      |                      |                      |                      |
| dollars per pound                           | 20.85                | 17.99                | 14.07                | 12.89                | 14.48                |
| LME, cash <sup>6</sup>                      |                      |                      |                      |                      |                      |
| do.   | XX                   | 16.01                | 13.06                | 12.26                | 14.00                |
| World:                                      |                      |                      |                      |                      |                      |
| Production:                                 |                      |                      |                      |                      |                      |
| Mine  | 110,000 <sup>r</sup> | 111,000 <sup>r</sup> | 104,000 <sup>r</sup> | 114,000 <sup>r</sup> | 123,000 <sup>c</sup> |
| Refinery                                    | 79,500               | 82,400               | 78,100               | 86,100 <sup>r</sup>  | 91,300               |
| Stocks, December 31, LME <sup>7</sup>       | 278                  | 304                  | 429                  | 560                  | 489                  |

<sup>c</sup>Estimated. <sup>r</sup>Revised. do. Ditto. XX Not applicable. --Zero.

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

<sup>2</sup>Negligible.

<sup>3</sup>Stocks held by cobalt processors and consumers.

<sup>4</sup>Defense Logistics Agency Strategic Materials.

<sup>5</sup>Annual average U.S. spot price for minimum 99.8% cobalt cathode reported by Platts Metals Week.

<sup>6</sup>Annual average mean of the cash buyer price and cash seller price, minimum 99.3% cobalt briquettes, cathode, ingot, or rounds, converted from dollars per metric ton.

<sup>7</sup>Stocks held in Asia, Europe, and the United States.

TABLE 2  
U.S. REPORTED CONSUMPTION AND STOCKS OF COBALT<sup>1,2</sup>

(Metric tons, cobalt content)

|  | 2013             | 2014  |
|--|------------------|-------|
| Consumption by end use:                                |                  |       |
| Steels   | 547              | 548   |
| Superalloys  | 3,770            | 3,930 |
| Alloys, excludes steels and superalloys:               |                  |       |
| Magnetic alloys  | 303              | 328   |
| Other alloys <sup>3</sup>                              | 397              | 573   |
| Cemented carbides <sup>4</sup>                         | 705              | 783   |
| Chemical and ceramic uses                              | 2,210            | 2,330 |
| Miscellaneous and unspecified                          | 161              | 63    |
| Total  | 8,090            | 8,560 |
| Consumption by form:                                   |                  |       |
| Chemical compounds, organic and inorganic <sup>5</sup> | 2,110            | 2,190 |
| Metal  | 3,820            | 4,170 |
| Purchased scrap  | 2,160            | 2,200 |
| Total  | 8,090            | 8,560 |
| Stocks, December 31: <sup>6</sup>                      |                  |       |
| Chemical compounds, organic and inorganic <sup>5</sup> | 239              | 342   |
| Metal  | W                | W     |
| Purchased scrap  | W                | W     |
| Total  | 821 <sup>r</sup> | 984   |

<sup>r</sup>Revised. W Withheld to avoid disclosing company proprietary data; included in "Total."

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

<sup>2</sup>Includes estimates.

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

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

<sup>5</sup>Includes oxides.

<sup>6</sup>Stocks held by cobalt processors and consumers.

TABLE 3  
U.S. IMPORTS FOR CONSUMPTION OF COBALT, BY FORM<sup>1</sup>

| Form                  | 2013                          |  |                      | 2014                          |  |                      |
|-----------------------|-------------------------------|--|----------------------|-------------------------------|--|----------------------|
|                       | Gross weight<br>(metric tons) | Cobalt content <sup>2</sup><br>(metric tons) | Value<br>(thousands) | Gross weight<br>(metric tons) | Cobalt content <sup>2</sup><br>(metric tons) | Value<br>(thousands) |
| Metal <sup>3</sup>    | 8,230                         | 8,230  | \$222,000            | 9,020                         | 9,020  | \$270,000            |
| Oxides and hydroxides | 2,420                         | 1,740  | 53,600               | 2,420                         | 1,740  | 57,700               |
| Other:                |                               |  |                      |                               |  |                      |
| Acetates              | 156                           | 37   | 1,220                | 239                           | 57   | 1,880                |
| Carbonates            | 542                           | 249  | 9,700                | 556                           | 256  | 9,460                |
| Chlorides             | 98                            | 24   | 515                  | 15                            | 4  | 155                  |
| Sulfates              | 597                           | 161  | 4,580                | 1,020                         | 276  | 7,960                |
| Total                 | 12,000                        | 10,500                                       | 291,000              | 13,300                        | 11,400                                       | 347,000              |

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

<sup>2</sup>Estimated from gross weight.

<sup>3</sup>Unwrought cobalt, excluding alloys and waste and scrap.

Source: U.S. Census Bureau.

TABLE 4  
U.S. IMPORTS FOR CONSUMPTION OF COBALT, BY COUNTRY<sup>1</sup>

| Country of origin  | Metal <sup>2</sup>         |   |                                | Oxides and hydroxides      |   |                                | Other forms <sup>3</sup>   |   |                                | Total                      |   |                                |
|--------------------|----------------------------|---|--------------------------------|----------------------------|---|--------------------------------|----------------------------|---|--------------------------------|----------------------------|---|--------------------------------|
|                    | Gross weight (metric tons) | Cobalt content <sup>4</sup> (metric tons) | Value <sup>5</sup> (thousands) | Gross weight (metric tons) | Cobalt content <sup>4</sup> (metric tons) | Value <sup>5</sup> (thousands) | Gross weight (metric tons) | Cobalt content <sup>4</sup> (metric tons) | Value <sup>5</sup> (thousands) | Gross weight (metric tons) | Cobalt content <sup>4</sup> (metric tons) | Value <sup>5</sup> (thousands) |
| <b>2013:</b>       |                            |   |                                |                            |   |                                |                            |   |                                |                            |   |                                |
| Australia          | 521                        | 521                                       | \$12,900                       | --                         | --  | --                             | --                         | --  | --                             | 521                        | 521                                       | \$12,900                       |
| Austria            | 13                         | 13  | 651                            | --                         | --  | --                             | --                         | --  | --                             | 13                         | 13  | 651                            |
| Belgium            | 21                         | 21  | 836                            | 609                        | 439                                       | \$14,300                       | 10                         | 4   | \$192                          | 640                        | 464                                       | 15,400                         |
| Brazil             | 328                        | 328                                       | 8,000                          | --                         | --  | --                             | 41                         | 12  | 475                            | 370                        | 341                                       | 8,470                          |
| Canada             | 266                        | 266                                       | 9,120                          | 52                         | 37  | 1,380                          | --                         | --  | --                             | 317                        | 303                                       | 10,500                         |
| China              | 1,860                      | 1,860                                     | 48,900                         | 285                        | 205                                       | 5,640                          | 135                        | 52  | 1,780                          | 2,280                      | 2,120                                     | 56,400                         |
| Congo (Kinshasa)   | --                         | --  | --                             | 83                         | 60  | 1,950                          | --                         | --  | --                             | 83                         | 60  | 1,950                          |
| Finland            | 380                        | 380                                       | 11,900                         | 369                        | 266                                       | 8,590                          | 760                        | 281                                       | 9,750                          | 1,510                      | 927                                       | 30,300                         |
| France             | 15                         | 15  | 765                            | --                         | --  | --                             | 85                         | 21  | 393                            | 100                        | 36  | 1,160                          |
| Germany            | 8                          | 8   | 364                            | 5                          | 3   | 409                            | 5                          | 1   | 32                             | 18                         | 13  | 805                            |
| India              | 6                          | 6   | 107                            | --                         | --  | --                             | 126                        | 34  | 1,250                          | 131                        | 39  | 1,360                          |
| Japan              | 838                        | 838                                       | 21,400                         | --                         | --  | --                             | --                         | --  | --                             | 838                        | 838                                       | 21,400                         |
| Korea, Republic of | 33                         | 33  | 809                            | 28                         | 20  | 381                            | --                         | --  | --                             | 60                         | 52  | 1,190                          |
| Madagascar         | 600                        | 600                                       | 15,900                         | --                         | --  | --                             | --                         | --  | --                             | 600                        | 600                                       | 15,900                         |
| Morocco            | 171                        | 171                                       | 4,440                          | --                         | --  | --                             | --                         | --  | --                             | 171                        | 171                                       | 4,440                          |
| Norway             | 1,310                      | 1,310                                     | 35,600                         | --                         | --  | --                             | --                         | --  | --                             | 1,310                      | 1,310                                     | 35,600                         |
| Russia             | 877                        | 877                                       | 22,600                         | --                         | --  | --                             | --                         | --  | --                             | 877                        | 877                                       | 22,600                         |
| South Africa       | 328                        | 328                                       | 10,100                         | --                         | --  | --                             | --                         | --  | --                             | 328                        | 328                                       | 10,100                         |
| Taiwan             | 1                          | 1   | 27                             | --                         | --  | --                             | 72                         | 19  | 471                            | 72                         | 20  | 498                            |
| Uganda             | 30                         | 30  | 709                            | --                         | --  | --                             | --                         | --  | --                             | 30                         | 30  | 709                            |
| United Kingdom     | 15                         | 15  | 640                            | 986                        | 710                                       | 20,900                         | 123                        | 37  | 1,440                          | 1,120                      | 762                                       | 23,000                         |
| Zambia             | 600                        | 600                                       | 15,200                         | --                         | --  | --                             | --                         | --  | --                             | 600                        | 600                                       | 15,200                         |
| Other              | 12                         | 12  | 623                            | 5                          | 3   | 34                             | 36                         | 10  | 228                            | 53                         | 25  | 885                            |
| <b>Total</b>       | <b>8,230</b>               | <b>8,230</b>                              | <b>222,000</b>                 | <b>2,420</b>               | <b>1,740</b>                              | <b>53,600</b>                  | <b>1,390</b>               | <b>472</b>                                | <b>16,000</b>                  | <b>12,000</b>              | <b>10,500</b>                             | <b>291,000</b>                 |
| <b>2014:</b>       |                            |   |                                |                            |   |                                |                            |   |                                |                            |   |                                |
| Australia          | 975                        | 975                                       | 27,400                         | --                         | --  | --                             | --                         | --  | --                             | 975                        | 975                                       | 27,400                         |
| Belgium            | 18                         | 18  | 724                            | 523                        | 376                                       | 13,300                         | 137                        | 37  | 725                            | 677                        | 431                                       | 14,800                         |
| Brazil             | 80                         | 80  | 2,300                          | 14                         | 10  | 144                            | 84                         | 25  | 1,080                          | 178                        | 115                                       | 3,520                          |
| Canada             | 120                        | 120                                       | 5,760                          | 1                          | 1   | 31                             | --                         | --  | --                             | 121                        | 120                                       | 5,790                          |
| China              | 1,400                      | 1,400                                     | 40,300                         | 364                        | 262                                       | 8,330                          | 280                        | 103                                       | 3,590                          | 2,040                      | 1,760                                     | 52,300                         |
| Congo (Kinshasa)   | 20                         | 20  | 568                            | 166                        | 120                                       | 4,210                          | --                         | --  | --                             | 186                        | 140                                       | 4,780                          |
| Finland            | 617                        | 617                                       | 21,600                         | 294                        | 212                                       | 7,210                          | 847                        | 285                                       | 9,450                          | 1,760                      | 1,110                                     | 38,300                         |
| France             | 27                         | 27  | 1,330                          | 1                          | 1   | 23                             | --                         | --  | --                             | 28                         | 28  | 1,360                          |
| Germany            | 30                         | 30  | 1,430                          | 5                          | 4   | 522                            | 5                          | 1   | 40                             | 40                         | 35  | 1,990                          |
| India              | --                         | --  | --                             | --                         | --  | --                             | 159                        | 43  | 1,410                          | 159                        | 43  | 1,410                          |
| Japan              | 1,120                      | 1,120                                     | 32,100                         | (6)                        | (6)                                       | 4                              | --                         | --  | --                             | 1,120                      | 1,120                                     | 32,100                         |
| Madagascar         | 589                        | 589                                       | 17,600                         | --                         | --  | --                             | --                         | --  | --                             | 589                        | 589                                       | 17,600                         |
| Mexico             | --                         | --  | --                             | --                         | --  | --                             | 23                         | 11  | 135                            | 23                         | 11  | 135                            |
| Morocco            | 117                        | 117                                       | 3,560                          | --                         | --  | --                             | --                         | --  | --                             | 117                        | 117                                       | 3,560                          |

See footnotes at end of table.

TABLE 4—Continued  
U.S. IMPORTS FOR CONSUMPTION OF COBALT, BY COUNTRY<sup>1</sup>

| Country of origin | Metal <sup>2</sup>         |   |                                | Oxides and hydroxides      |   |                                | Other forms <sup>3</sup>   |   |                                | Total                      |   |                                |
|-------------------|----------------------------|---|--------------------------------|----------------------------|---|--------------------------------|----------------------------|---|--------------------------------|----------------------------|---|--------------------------------|
|                   | Gross weight (metric tons) | Cobalt content <sup>4</sup> (metric tons) | Value <sup>5</sup> (thousands) | Gross weight (metric tons) | Cobalt content <sup>4</sup> (metric tons) | Value <sup>5</sup> (thousands) | Gross weight (metric tons) | Cobalt content <sup>4</sup> (metric tons) | Value <sup>5</sup> (thousands) | Gross weight (metric tons) | Cobalt content <sup>4</sup> (metric tons) | Value <sup>5</sup> (thousands) |
| 2014—Continued    |                            |   |                                |                            |   |                                |                            |   |                                |                            |   |                                |
| Norway            | 1,910                      | 1,910                                     | \$56,800                       | --                         | --  | --                             | --                         | --  | --                             | 1,910                      | 1,910                                     | \$56,800                       |
| Russia            | 930                        | 930                                       | 27,200                         | --                         | --  | --                             | (6)                        | (6)                                       | \$3                            | 930                        | 930                                       | 27,200                         |
| South Africa      | 389                        | 389                                       | 11,500                         | --                         | --  | --                             | --                         | --  | --                             | 389                        | 389                                       | 11,500                         |
| Sweden            | 19                         | 19  | 937                            | --                         | --  | --                             | --                         | --  | --                             | 19                         | 19  | 937                            |
| Taiwan            | (6)                        | (6)                                       | 18                             | --                         | --  | --                             | 132                        | 35  | 944                            | 132                        | 36  | 962                            |
| United Kingdom    | 23                         | 23  | 1,010                          | 1,040                      | 749                                       | \$23,700                       | 144                        | 46  | 1,870                          | 1,210                      | 818                                       | 26,600                         |
| Zambia            | 634                        | 634                                       | 17,300                         | --                         | --  | --                             | --                         | --  | --                             | 634                        | 634                                       | 17,300                         |
| Other             | 6                          | 6   | 282                            | 10                         | 7   | 195                            | 22                         | 7   | 212                            | 39                         | 20  | 688                            |
| Total             | 9,020                      | 9,020                                     | 270,000                        | 2,420                      | 1,740                                     | 57,700                         | 1,830                      | 593                                       | 19,500                         | 13,300                     | 11,400                                    | 347,000                        |

-- Zero.

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

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

<sup>3</sup>Includes cobalt acetates, cobalt carbonates, cobalt chlorides, and cobalt sulfates.

<sup>4</sup>Estimated from gross weight.

<sup>5</sup>Customs value.

<sup>6</sup>Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 5  
U.S. EXPORTS OF COBALT, BY COUNTRY<sup>1,2</sup>

| Country of destination | Metal <sup>3</sup>         |                                | Oxides and hydroxides      |                                | Acetates                   |                                | Chlorides                  |                                | Total                                     |                                |
|------------------------|----------------------------|--------------------------------|----------------------------|--------------------------------|----------------------------|--------------------------------|----------------------------|--------------------------------|---|--------------------------------|
|                        | Gross weight (metric tons) | Value <sup>4</sup> (thousands) | Gross weight (metric tons) | Value <sup>4</sup> (thousands) | Gross weight (metric tons) | Value <sup>4</sup> (thousands) | Gross weight (metric tons) | Value <sup>4</sup> (thousands) | Cobalt content <sup>5</sup> (metric tons) | Value <sup>4</sup> (thousands) |
| 2013                   | 3,500                      | \$97,000                       | 409                        | \$4,250                        | 236                        | \$2,050                        | 6                          | \$98                           | 3,850                                     | \$103,000                      |
| 2014:                  |                            |                                |                            |                                |                            |                                |                            |                                |   |                                |
| Argentina              | 23                         | 732                            | 9                          | 206                            | --                         | --                             | --                         | --                             | 30  | 938                            |
| Australia              | 43                         | 1,260                          | (6)                        | 11                             | --                         | --                             | --                         | --                             | 43  | 1,270                          |
| Austria                | 14                         | 253                            | --                         | --                             | --                         | --                             | --                         | --                             | 14  | 253                            |
| Belgium                | 180                        | 3,980                          | 75                         | 1,400                          | 48                         | 333                            | --                         | --                             | 245                                       | 5,720                          |
| Brazil                 | 15                         | 539                            | --                         | --                             | --                         | --                             | --                         | --                             | 15  | 539                            |
| Canada                 | 906                        | 10,500                         | (6)                        | 12                             | --                         | --                             | --                         | --                             | 906                                       | 10,500                         |
| China                  | 57                         | 1,840                          | 265                        | 1,600                          | --                         | --                             | --                         | --                             | 248                                       | 3,440                          |
| Colombia               | (6)                        | 14                             | 17                         | 374                            | --                         | --                             | --                         | --                             | 12  | 388                            |
| Czech Republic         | 12                         | 633                            | --                         | --                             | --                         | --                             | --                         | --                             | 12  | 633                            |
| Denmark                | --                         | --                             | 17                         | 30                             | --                         | --                             | --                         | --                             | 12  | 30                             |
| France                 | 746                        | 14,900                         | 1                          | 43                             | --                         | --                             | --                         | --                             | 747                                       | 14,900                         |
| Germany                | 257                        | 13,100                         | (6)                        | 5                              | (6)                        | 11                             | --                         | --                             | 258                                       | 13,100                         |
| Hong Kong              | 10                         | 565                            | 69                         | 831                            | --                         | --                             | --                         | --                             | 60  | 1,400                          |
| India                  | 86                         | 3,360                          | (6)                        | 11                             | 76                         | 643                            | --                         | --                             | 104                                       | 4,020                          |
| Ireland                | 752                        | 19,000                         | --                         | --                             | --                         | --                             | --                         | --                             | 752                                       | 19,000                         |
| Japan                  | 172                        | 7,160                          | (6)                        | 4                              | (6)                        | 4                              | --                         | --                             | 172                                       | 7,170                          |
| Korea, Republic of     | 103                        | 4,580                          | (6)                        | 12                             | 4                          | 65                             | --                         | --                             | 104                                       | 4,660                          |
| Luxembourg             | 26                         | 183                            | --                         | --                             | --                         | --                             | --                         | --                             | 26  | 183                            |
| Mexico                 | 5                          | 302                            | 10                         | 291                            | 43                         | 361                            | (6)                        | 9                              | 23  | 962                            |
| Netherlands            | 95                         | 3,080                          | 3                          | 70                             | --                         | --                             | --                         | --                             | 97  | 3,150                          |
| Niger                  | 9                          | 238                            | --                         | --                             | --                         | --                             | --                         | --                             | 9   | 238                            |
| Norfolk Island         | 20                         | 640                            | --                         | --                             | --                         | --                             | --                         | --                             | 20  | 640                            |
| Singapore              | 47                         | 2,750                          | 4                          | 177                            | --                         | --                             | (6)                        | 7                              | 50  | 2,930                          |
| South Africa           | 13                         | 475                            | --                         | --                             | --                         | --                             | --                         | --                             | 13  | 475                            |
| Switzerland            | 170                        | 2,230                          | --                         | --                             | --                         | --                             | --                         | --                             | 170                                       | 2,230                          |
| Taiwan                 | 26                         | 812                            | --                         | --                             | --                         | --                             | --                         | --                             | 26  | 812                            |
| Turkey                 | 23                         | 732                            | --                         | --                             | --                         | --                             | --                         | --                             | 23  | 732                            |
| United Kingdom         | 216                        | 5,670                          | 51                         | 443                            | --                         | --                             | (6)                        | 4                              | 252                                       | 6,120                          |
| Other                  | 48                         | 2,710                          | 13                         | 202                            | 10                         | 1,960                          | 1                          | 24                             | 60  | 4,900                          |
| Total                  | 4,070                      | 102,000                        | 536                        | 5,720                          | 181                        | 3,380                          | 3                          | 44                             | 4,500                                     | 111,000                        |

--Zero.

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

<sup>2</sup>In addition to the materials listed, the United States exported cobalt ores and concentrates and wrought cobalt and cobalt articles.

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

<sup>4</sup>Free alongside ship value.

<sup>5</sup>Estimated from gross weight.

<sup>6</sup>Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 6  
 WORLD ANNUAL COBALT REFINERY  
 CAPACITY, DECEMBER 31, 2014<sup>1,2</sup>

(Metric tons, cobalt content)

| Country                          | Capacity |
|----------------------------------|----------|
| Australia                        | 6,700    |
| Belgium                          | 1,500    |
| Brazil <sup>c</sup>              | 3,000    |
| Canada <sup>c</sup>              | 6,520    |
| China <sup>c</sup>               | 50,000   |
| Congo (Kinshasa) <sup>c, 3</sup> | 9,050    |
| Finland <sup>c</sup>             | 13,000   |
| France                           | 500      |
| India <sup>c</sup>               | 2,060    |
| Japan                            | 4,500    |
| Madagascar                       | 5,600    |
| Morocco                          | 2,250    |
| Norway                           | 5,200    |
| Russia <sup>c, 4</sup>           | 7,200    |
| South Africa <sup>c</sup>        | 1,500    |
| Uganda                           | 720      |
| Zambia                           | 8,800    |
| Total                            | 128,000  |

<sup>c</sup>Estimated.

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

<sup>2</sup>Includes standby capacity. Refinery products include cobalt metal, metal powders, oxides, and (or) salts.

<sup>3</sup>Capacities for Katanga Mining Ltd. and Shalina Resources Ltd. pilot plant were revised downward.

<sup>4</sup>Estimated standby capacity for OJSC Ufaleynickel was revised upward. Estimated capacity for OJSC Kola Mining and Metallurgical Co. pilot plant was added.

TABLE 7  
COBALT: SELECTED PROJECTS SCHEDULED FOR COMPLETION, BY YEAR, 2015–19<sup>1,2</sup>

| Projected year of first production | Country             | Project and company  | Project type                        | Principal metal | Ore/feed type   | Annual production capacity (metric tons, cobalt content) | Cobalt product                  |
|------------------------------------|---------------------|--|-------------------------------------|-----------------|---|--|---------------------------------|
| 2015                               | Australia           | Rocklands Group Copper<br>CuDeco Ltd.  | new mine and<br>beneficiation plant | copper          | copper-cobalt-gold<br>oxide and sulfide<br>ore            | NA   | Cobaltic-pyrite<br>concentrate. |
| 2015                               | Belgium             | Olen<br>n.v. Umicore, s.a.   | expansion of existing<br>refinery   | cobalt          | NA  | 1,500 <sup>3</sup>                                       | Cobalt metal powder.            |
| 2015                               | China               | Quzhou plant<br>Zhejiang Huayou Cobalt<br>Co., Ltd.  | new processing plant                | do.             | NA  | 10,000   | Cobalt salts.                   |
| 2015                               | Congo<br>(Kinshasa) | Project Minier, stage I<br>La Sino-Congolaise des<br>Mines S.A. (Sicomines)<br>[China Railway Group Ltd.,<br>La Générale des Carrières<br>et des Mines SARL<br>(Gécamines), Sinohydro<br>Corp., and Zhejiang Huayou<br>Cobalt Co., Ltd.] | new mine and<br>beneficiation plant | copper          | copper-cobalt ore   | NA   | Copper-cobalt<br>concentrate.   |
| 2015                               | Mexico              | El Boleo<br>Minera y Metalúrgica del<br>Boleo, S.A.P.I. de C.V.<br>(Korean Consortium <sup>4</sup> and<br>Baja Mining Corp.)   | new mine and refinery               | do.             | copper-cobalt-zinc-<br>manganese oxide<br>and sulfide ore | 1,700  | Cobalt cathode.                 |
| 2015                               | Russia              | Monchegorsk<br>OJSC Kola Mining and<br>Metallurgical Co. (OJSC<br>MMC Norilsk Nickel)  | new refinery                        | nickel          | cobalt hydroxide  | 3,000  | Do.                             |
| 2015                               | Turkey              | Gördes<br>Meta Nikel Kobalt A. Ş.<br>(Meta Nikel Kobalt<br>Madencilik Sanayi ve<br>Ticaret A. Ş. and Zorlu<br>Holding A. Ş.)   | new processing plant                | do.             | nickel-cobalt laterite<br>ore                             | 750 <sup>e</sup>   | Nickel-cobalt<br>hydroxide.     |
| 2015                               | Uganda              | Kilembe<br>Tibet Hima Industry Co. Ltd.<br>consortium <sup>5</sup>   | reopen former mine                  | copper          | copper-cobalt ore   | NA   | NA.                             |

See footnotes at end of table.

TABLE 7—Continued  
COBALT: SELECTED PROJECTS SCHEDULED FOR COMPLETION, BY YEAR, 2015–19<sup>1,2</sup>

| Projected year of first production | Country                   | Project and company  | Project type  | Principal metal | Ore/feed type                                   | Annual production capacity (metric tons, cobalt content) | Cobalt product                         |
|------------------------------------|---------------------------|--|---|-----------------|---|--|--|
| 2015                               | Zambia                    | Nkana Cobalt Plant<br>Mopani Copper Mines Plc<br>(Glencore plc, First Quantum Minerals Ltd., and ZCCM Investment Holdings Plc)   | expansion of existing refinery  | cobalt          | cobalt concentrates and intermediates           | 7,000 <sup>3</sup>                                       | Cobalt cathode.                        |
| 2015                               | Do.                       | Synclinorium<br>Mopani Copper Mines Plc<br>(Glencore plc, First Quantum Minerals Ltd., and ZCCM Investment Holdings Plc)   | expansion of existing mine  | copper          | copper-cobalt ore                               | NA   | Copper-cobalt ore.                     |
| 2016                               | Australia                 | Nova Nickel<br>Sirius Resources NL   | new mine and beneficiation plant                                      | nickel          | nickel sulfide ore                              | 850 <sup>6</sup>   | Nickel concentrate.                    |
| 2016                               | Congo (Kinshasa)          | Etoile Leach SX-EW <sup>7</sup> plant<br>Chemaf SPRL   | new refinery  | copper          | copper-cobalt tailings                          | 3,800 <sup>r</sup>                                       | Cobalt hydroxide.                      |
| 2016 <sup>f</sup>                  | Zambia                    | Cobalt Converter<br>Slag Recycling<br>Chambishi Copper Smelter Co., Ltd. (China<br>Nonferrous Mining Corp. Ltd. and Yunnan Copper Industry Group Co. Ltd.)<br>and Hunan Shijiyintianxinye Technology Co., Ltd. | adapt existing smelter  | cobalt          | copper-cobalt converter slag                    | 500–700 <sup>e</sup>                                     | Alliage blanc.                         |
| 2017                               | Canada                    | NICO<br>Fortune Minerals Ltd.  | new mine, relocated and refurbished beneficiation plant, and refinery | gold            | gold-cobalt-bismuth-copper ore                  | 1,860 <sup>r</sup>                                       | Cobalt sulfate and other cobalt salts. |
| 2017 <sup>e</sup>                  | Turkey                    | Caldag<br>Caldag Nikel Madencilik San. ve Tic. A. Ş.   | mine, atmospheric tank leach processing plant, and refinery           | nickel          | nickel-cobalt laterite ore                      | 900  | Cobalt cathode.                        |
| 2017 <sup>f,e</sup>                | United States (Idaho)     | Idaho Cobalt<br>Formation Metals Inc.  | new mine and refinery   | cobalt          | stratiform cobalt-copper-gold ore               | 1,260 <sup>r,6</sup>                                     | Cobalt sulfate.                        |
| 2017 <sup>f,e</sup>                | United States (Minnesota) | NorthMet, phase I<br>PolyMet Mining Corp.  | new mine and beneficiation plant                                      | copper          | copper-nickel-platinum-group-metals sulfide ore | 360  | Nickel concentrate.                    |

See footnotes at end of table.

TABLE 7—Continued  
COBALT: SELECTED PROJECTS SCHEDULED FOR COMPLETION, BY YEAR, 2015–19<sup>1,2</sup>

| Projected year of first production | Country          | Project and company  | Project type  | Principal metal | Ore/feed type              | Annual production capacity (metric tons, cobalt content) | Cobalt product    |
|------------------------------------|------------------|--|---|-----------------|----------------------------|--|-------------------|
| 2018 <sup>e</sup>                  | Australia        | Gladstone Nickel, stage 1<br>Gladstone Pacific Nickel Ltd.   | new mine, beneficiation plant, HPAL <sup>8</sup> processing plant, and refinery | nickel          | nickel-cobalt laterite ore | 5,000  | Cobalt metal.     |
| 2018 <sup>e</sup>                  | Congo (Kinshasa) | Project Mimier, stage 2<br>La Sino-Congolaise des Mines S.A. (Sicomines)<br>[China Railway Group Ltd., La Générale des Carrières et des Mines SARL (Gécamines), Sinohydro Corp., and Zhejiang Huayou Cobalt Co., Ltd.] | expansion of new mine and beneficiation plant; add new processing plant         | copper          | copper-cobalt ore          | 4,600 <sup>e</sup>                                       | Cobalt hydroxide. |
| 2018 <sup>e</sup>                  | Do.              | Roan Tailings Reclamation (formerly Kolwezi tailings)<br>Eurasian Resources Group, La Générale des Carrières et des Mines SARL (Gécamines), and Government of Congo (Kinshasa)   | new refinery  | do.             | copper-cobalt tailings     | 14,000   | Do.               |

<sup>e</sup>Estimated. <sup>f</sup>Revised. Do., do. Ditto. NA Not available.

<sup>1</sup>Estimated data are rounded to no more than three significant digits.

<sup>2</sup>Projects in feasibility or later stages of development in 2014. Actual startup dates may be postponed owing to economic or other factors. Additional projects might produce cobalt by 2019, but not enough information was available to include them.

<sup>3</sup>Total capacity following expansion.

<sup>4</sup>The Korean consortium comprises the following companies: Korea Resources Corp., L.S. Nikko Copper Inc., Hyundai Hysco Co. Ltd., SK Networks Co. Ltd., and Ijjin Copper Foil Co. Ltd., listed in order of ownership share.

<sup>5</sup>The consortium comprises the following companies: Chinalco Luoyang Copper (Aluminum Corp. of China Ltd.), Dongfang Electric Corp., Shanghai Baosteel Group Corp., Tibet Hima Industry Co. Ltd., and Yunnan Copper Industry Co. Ltd.

<sup>6</sup>Average production.

<sup>7</sup>SX-EW, solvent extraction–electrowinning.

<sup>8</sup>HPAL, high pressure acid leach.

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

(Metric tons, cobalt content)

| Country <sup>3</sup>             | 2010                 | 2011                 | 2012                 | 2013                 | 2014 <sup>e</sup>    |
|----------------------------------|----------------------|----------------------|----------------------|----------------------|----------------------|
| Australia <sup>4</sup>           | 3,852                | 3,848                | 5,870                | 6,410 <sup>r</sup>   | 5,978 <sup>5</sup>   |
| Botswana <sup>6</sup>            | 272                  | 149                  | 195                  | 248                  | 196 <sup>5</sup>     |
| Brazil                           | 3,139                | 3,623                | 2,900                | 3,500 <sup>r,p</sup> | 2,600                |
| Canada <sup>7</sup>              | 4,636                | 6,836                | 6,676                | 7,168 <sup>r</sup>   | 6,574 <sup>p,5</sup> |
| China <sup>e</sup>               | 6,380                | 6,800                | 7,500 <sup>r</sup>   | 7,200                | 7,200                |
| Congo (Kinshasa) <sup>e,8</sup>  | 60,000               | 59,000               | 51,000 <sup>r</sup>  | 56,000 <sup>r</sup>  | 63,000               |
| Cuba <sup>e,9</sup>              | 4,800                | 5,100                | 4,900                | 4,200                | 3,700                |
| Finland <sup>e</sup>             | 140                  | 500                  | 635                  | 750                  | 770                  |
| Indonesia <sup>e,10</sup>        | 1,600                | 1,600                | 1,700                | 1,700                | 1,300                |
| Madagascar <sup>e,11</sup>       | 165                  | 500                  | 630                  | 2,200                | 3,100                |
| Morocco <sup>e,12</sup>          | 3,110                | 2,160                | 2,000                | 2,000                | 2,100                |
| New Caledonia <sup>e,13</sup>    | 2,850                | 3,100                | 2,670                | 3,190                | 4,040                |
| Papua New Guinea <sup>14</sup>   | --                   | --                   | 469                  | 1,013                | 2,134 <sup>5</sup>   |
| Philippines <sup>e,15</sup>      | 2,100                | 2,000                | 2,700 <sup>r</sup>   | 2,700 <sup>r</sup>   | 4,600                |
| Russia <sup>e,16</sup>           | 6,200                | 6,100                | 6,300                | 6,300                | 6,300                |
| South Africa <sup>e</sup>        | 1,800                | 1,600                | 2,500                | 3,000                | 3,000                |
| United States <sup>e,16,17</sup> | --                   | --                   | --                   | --                   | 120                  |
| Vietnam                          | --                   | --                   | --                   | 25 <sup>r,e</sup>    | 223 <sup>5</sup>     |
| Zambia <sup>18</sup>             | 8,648 <sup>r</sup>   | 7,702 <sup>r</sup>   | 5,435 <sup>r</sup>   | 5,919 <sup>r</sup>   | 5,500                |
| Zimbabwe <sup>19</sup>           | 79                   | 174 <sup>r</sup>     | 195 <sup>r</sup>     | 319 <sup>r</sup>     | 358 <sup>5</sup>     |
| Total                            | 110,000 <sup>r</sup> | 111,000 <sup>r</sup> | 104,000 <sup>r</sup> | 114,000 <sup>r</sup> | 123,000              |

<sup>e</sup>Estimated. <sup>p</sup>Preliminary. <sup>r</sup>Revised. -- Zero.

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

<sup>2</sup>Includes data available through November 2, 2015. Figures represent recoverable cobalt content of ores, concentrates, or intermediate products from cobalt, copper, nickel, platinum, or zinc operations.

<sup>3</sup>In addition to the countries listed, Spain and Turkey are known to produce ores that contain cobalt, but information is inadequate to make reliable estimates of production. Poland produced copper ore containing 1,500 to 5,000 metric tons per year of cobalt, which was not recovered. Other copper-, nickel-, platinum-, or zinc-producing nations may also produce ores containing cobalt as a byproduct component, but recovery is small or nil.

<sup>4</sup>Cobalt content of lateritic nickel ore and nickel concentrate reported by the Government of Western Australia.

<sup>5</sup>Reported figure.

<sup>6</sup>Reported cobalt content of pelletized nickel-copper matte.

<sup>7</sup>Assay content of cobalt in concentrates produced.

<sup>8</sup>Cobalt content of concentrates, tailings, and slags.

<sup>9</sup>Determined from reported cobalt content of nickel-cobalt sulfide production and estimated cobalt content of ammoniacal liquor production.

<sup>10</sup>Cobalt content of nickel matte plus estimated cobalt in lateritic ore processed in Australia.

<sup>11</sup>Data for 2012–14 are estimated cobalt content of reported mixed sulfide production.

<sup>12</sup>Cobalt content of concentrate estimated from reported gross weight.

<sup>13</sup>Cobalt contained in the following materials: cobalt chloride produced in France from New Caledonian matte, cobalt carbonate and nickel hydroxide produced in New Caledonia, and lateritic nickel ore exported to Australia.

<sup>14</sup>Cobalt content of nickel-cobalt hydroxide.

<sup>15</sup>Cobalt contained in the following materials: nickel-cobalt sulfide produced in the Philippines and lateritic nickel ore exported to Australia.

<sup>16</sup>Cobalt content of concentrates.

<sup>17</sup>Negligible production prior to 2014.

<sup>18</sup>Data reported by the Bank of Zambia.

<sup>19</sup>Data for 2011–14 were reported by the Zimbabwe National Statistics Agency.

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

(Metric tons, cobalt content)

| Country  | 2010               | 2011               | 2012                 | 2013                 | 2014               |
|--|--------------------|--------------------|----------------------|----------------------|--------------------|
| Australia, metal powder and oxide hydroxide <sup>e,3</sup> | 4,117 <sup>r</sup> | 4,722 <sup>r</sup> | 4,859 <sup>r,4</sup> | 4,981 <sup>r</sup>   | 5,419              |
| Belgium, metal powder, oxide, hydroxide <sup>3,5</sup>     | 2,600              | 3,187              | 4,200                | 5,415                | 5,850              |
| Brazil, metal  | 1,369              | 1,614              | 1,750                | 1,871 <sup>r,p</sup> | 1,350              |
| Canada, metal, metal powder, oxide                         | 4,711              | 6,038              | 5,994                | 4,733 <sup>r</sup>   | 3,790 <sup>p</sup> |
| China, metal, metal powder, oxide, salts <sup>e,3,6</sup>  | 35,900             | 35,000             | 29,800               | 36,100               | 39,300             |
| Congo (Kinshasa), metal <sup>7</sup>                       | 4,222              | 3,103              | 3,021                | 3,007                | 3,284              |
| Finland, metal powder and salts <sup>8</sup>               | 9,429              | 10,627             | 10,562               | 10,798               | 12,551             |
| France, chloride <sup>3</sup>                              | 302                | 354                | 326                  | 308                  | 219                |
| India, metal and salts <sup>3</sup>                        | 1,187              | 1,299              | 800                  | 295                  | 100                |
| Japan, metal <sup>3</sup>                                  | 1,935              | 2,007              | 2,542                | 2,747                | 3,654              |
| Madagascar, metal powder                                   | --                 | --                 | 493                  | 2,083                | 2,915              |
| Morocco, metal and oxide                                   | 1,615              | 1,788              | 1,314                | 1,353                | 1,391              |
| Norway, metal <sup>9</sup>                                 | 3,208              | 3,067              | 2,969                | 3,348 <sup>r</sup>   | 3,500 <sup>e</sup> |
| Russia, metal <sup>3</sup>                                 | 2,460              | 2,337              | 2,186                | 2,368                | 2,302              |
| South Africa, metal powder and sulfate                     | 840                | 862                | 1,102                | 1,294                | 1,332              |
| Uganda, metal <sup>3</sup>                                 | 624                | 661                | 556                  | 376                  | --                 |
| Zambia, metal  | 5,026              | 5,746              | 5,665                | 5,000 <sup>3</sup>   | 4,317 <sup>3</sup> |
| World total  | 79,500             | 82,400             | 78,100               | 86,100 <sup>r</sup>  | 91,300             |

<sup>e</sup>Estimated. <sup>p</sup>Preliminary. <sup>r</sup>Revised. -- Zero.

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

<sup>2</sup>Includes data available through September 11, 2015. Figures represent cobalt refined from ores, concentrates, or intermediate products and do not include production of downstream products from refined cobalt.

<sup>3</sup>Production reported by the Cobalt Development Institute, except as noted.

<sup>4</sup>Production reported by the Cobalt Development Institute and Glencore International AG.

<sup>5</sup>Production from n.v. Umicore, s.a.; includes production from China that is not otherwise included in this table.

<sup>6</sup>Production from domestic and imported ores, concentrates, and intermediate materials; excludes production by n.v. Umicore, s.a. that is included under Belgium.

<sup>7</sup>Excludes production of cobalt in alloys, carbonate, hydroxide, and other materials that would require further refining.

<sup>8</sup>Production reported by the Geological Survey of Finland.

<sup>9</sup>Data for 2010–12 reported by Xstrata plc.; data for 2013–14 reported by the Geological Survey of Norway.