

COBALT

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Cobalt is a strategic and critical metal used in many diverse industrial and military applications. The United States remained the world's largest consumer of cobalt. With the exception of negligible amounts of byproduct cobalt produced as intermediate products from some mining operations, the United States did not mine or refine cobalt in 2000. Since 1993, sales of excess cobalt from the National Defense Stockpile (NDS) have contributed to U.S. and world supplies.

World refined cobalt production increased in 2000. Some of the increase was from new operations in Australia and Uganda and some was from a net increase in production by established producers. During the year, several established producers announced that they would participate in evaluating the potential development of a "second wave" of nickel-cobalt laterite projects in Indonesia and the Philippines.

World demand for cobalt in 2000 was estimated to be similar or slightly less than that of 1999 (Cobalt Development Institute, 2001b). Weekly cobalt prices fluctuated within a narrower range than those during recent years. Annual average prices continued the downward trend that began in 1996.

Salient U.S. and world cobalt statistics for 2000 and the previous 4 years are listed in table 1. With the exception of prices and reported production from foreign countries, all quantity and value data in this report have been rounded to no more than three significant digits. Totals and percentages were calculated from unrounded numbers.

Legislation and Government Programs

The Defense National Stockpile Center (DNSC), U.S. Department of Defense, held nine sealed-bid and three negotiated cobalt offerings during fiscal year 2000 (October 1,

1999, through September 30, 2000). During this period, the DNSC sold 2,720 metric tons (t) of cobalt cathode, granules, and rondelles valued at nearly \$78 million (table 2). This represented all of the 2,720-t (6-million-pound) maximum allowed for sale under the fiscal year 2000 Annual Materials Plan (AMP). As of the end of the fiscal year, 1,020 t of cobalt had been sold, but not shipped from the stockpile (U.S. Department of Defense, 2001). The AMP for fiscal year 2001 (October 1, 2000, through September 30, 2001) maintained the maximum allowable sale of cobalt at 2,720 t (Defense National Stockpile Center, 2000).

During 2000, DNSC held nine sealed-bid and three negotiated cobalt offerings and sold 3,080 t of cobalt cathode, granules, and rondelles valued at \$89 million. On December 31, the total uncommitted cobalt inventory held by the DNSC was 9,300 t, all of which was authorized for eventual disposal.

Production

With the exception of negligible amounts of byproduct cobalt produced from mining operations in Missouri and Montana, the United States did not mine or refine cobalt in 2000 (Stillwater Mining Co., 2001, p. 9; U.S. Minerals Management Service, 2001, Federal onshore—Collections by commodity/revenue type, CY 2000 Jan-Dec, accessed May 22, 2001, at URL <http://www.mrm.mms.gov/Stats/coll.htm>).

Formation Capital Corp. of Vancouver, British Columbia, Canada, continued to study the feasibility of developing its 100%-owned Idaho Cobalt Project in the Idaho cobalt belt. The project was to entail underground mining of cobalt-copper-gold ores in Lemhi County, ID, producing concentrates by using mineral flotation, and then refining the cobalt concentrate by

Cobalt in the 20th Century

In 1900, the principal source of cobalt ore was New Caledonia. Although few statistics are available, world cobalt production was probably less than 180 metric tons contained cobalt. This cobalt was used mainly as cobalt oxide in the manufacture of pigments and decolorizers for china, pottery, porcelain, and glass. U.S. apparent consumption was less than 30 tons of cobalt oxide, containing approximately 20 tons of cobalt. Eighty-nine percent of the U.S. supply of cobalt oxide was imported, and 11% was produced domestically from a byproduct of smelting lead ores mined in Missouri.

In 2000, most cobalt was produced as a byproduct of copper or nickel. World production of refined cobalt was 35,200 tons of contained cobalt. The principal sources of cobalt-bearing ores were Australia, Canada, Cuba, the Democratic Republic of the Congo [Congo (Kinshasa)], Morocco, New Caledonia, Russia, and Zambia. Cobalt was used in many diverse commercial, industrial, and military applications. The largest

use of cobalt was in superalloys, which were used to make parts for gas turbine engines. Cobalt was also used to make magnets; corrosion- and wear-resistant alloys; high-speed steels; cemented carbides (also called hardmetals) and diamond tools; catalysts for the petroleum and chemical industries; drying agents for paints, varnishes, and inks; ground coats for porcelain enamels; pigments; battery electrodes; steel-belted radial tires; airbags in automobiles; and magnetic recording media. The U.S. apparent consumption of cobalt was 11,700 tons in 2000. With the exception of negligible amounts of byproduct cobalt produced as intermediate products from some mining operations, the United States did not mine or refine cobalt in 2000. U.S. cobalt supply consisted of imports, cobalt-bearing scrap, releases from industry stocks, and sales of excess cobalt metal from the National Defense Stockpile.

using a pressure leaching process. In October, Formation Capital entered into an agreement with Sunshine Precious Metals, Inc. to purchase a hydrometallurgical refinery in Big Creek, ID. Formation planned to produce approximately 1,500 metric tons per year (t/yr) of cobalt as oxide, hydroxide, carbonate, and/or cathode, with initial production beginning in late 2003 (Formation Capital Corp., 2001a; b; c, p. 2-3, 8-10). Mining in the Idaho Cobalt Belt dates back to the late 1800s and extended until 1959, when the Blackbird Mine in Cobalt, ID, closed. Noranda Mining Inc. of Salt Lake City, UT, considered reopening the mine in the late 1970s to early 1980s, and Blackbird Metals Inc., a New York-based corporation, planned to buy and reopen the mine in the late 1980s to early 1990s. In both cases, the companies did not pursue their plans and the mine remains inactive.

During the year, U.S. Cobalt Inc. of Denver, CO, worked toward developing the Madison Mine, near Fredericktown, MO. Past production from the mine, which occurred intermittently from the mid-1800s to 1961, yielded cobalt, copper, lead, and nickel. U.S. Cobalt was considering two options for the project—building a fully integrated mine-mill-refinery on the Madison property or sending ores from the mine to be custom milled at a nearby facility, and then shipping the resulting cobalt-nickel concentrate to a smelter or refinery. In October, the company released a new resource estimate for the mine. Using a cobalt equivalent cutoff grade of 0.20%, the measured plus indicated resource was 6.6 million metric tons, grading 0.306% cobalt, 0.743% copper, and 0.470% nickel (U.S. Cobalt Inc., 2001, p. 10-13).

PolyMet Mining Corp. of Golden, CO, continued to study the NorthMet deposit under a lease agreement with USX Corp. of Pittsburgh, PA. NorthMet occurs in the Duluth Complex of northeastern Minnesota, a large layered mafic intrusion that contains, in order of relative abundance, copper, nickel, cobalt, silver, platinum-group metals, and gold. In August, PolyMet released the results from a continuous, fully integrated pilot-plant study of the pressure oxidation leaching process chosen to treat sulfide concentrates from the deposit. Leaching efficiencies for all metals except gold were equal to or greater than those obtained from laboratory scale testing of the process performed in 1999. In December, PolyMet announced that drilling results on the property indicated continuity and consistency in grade between the main ore body and a northeast extension of mineralization. PolyMet planned to complete a prefeasibility study by the end of the first quarter of 2001 (PolyMet Mining Corp., 2000a, b).

U.S. processors made cobalt chemicals and cobalt metal powders from cobalt metal and/or cobalt-bearing scrap. U.S. Geological Survey (USGS) data on chemical and metal powder production, shipments, and stocks were derived from a monthly voluntary survey of U.S. cobalt processors. Information from this survey was used to prepare the statistics on cobalt consumption and stocks in table 3. Five of the seven cobalt processors on this survey provided data. Estimates were made for plants for which data were not provided. Two processors made extra-fine cobalt metal powder in the United States. Carolmet Cobalt Products, a division of Union Minière, Inc., made cobalt metal powder from cobalt metal at its Laurinburg, NC, plant. Osram Sylvania Inc. made cobalt metal powder from scrap in Towanda, PA. Production and shipments of cobalt metal powder are withheld to avoid disclosing company proprietary data.

Consumption

U.S. apparent consumption for 2000, as calculated from net imports, consumption from purchased scrap, and changes in Government and industry stocks, was 9% higher than that calculated for 1999 (see table 1). In 2000, an increase in shipments of cobalt from the NDS was greater than the decreases in net imports and cobalt recovered from scrap.

U.S. reported consumption for 2000 was 3% higher than that for 1999. As compared with that of 1999, metallurgical industries consumed 8% more cobalt and the total reported cobalt consumption in chemical uses was 7% lower. Reported consumption was derived by the USGS from voluntary surveys of U.S. operations. Most of the data on cobalt chemical uses were obtained from the cobalt processors survey. A second survey covered a broad range of metal-consuming companies, such as superalloy, magnetic alloy, and cemented carbide producers. For this survey, nearly 90 cobalt consumers were canvassed on a monthly or annual basis. Reported consumption and stocks data in tables 1 and 3 contain estimates to account for nonrespondents.

Prices

U.S. spot prices for cathode (minimum of 99.8% cobalt), as reported by Platt's Metals Week, fluctuated between \$13 per pound and \$18 per pound. The lowest prices were reported in February, July, and December, and the highest prices were reported at the end of April-beginning of May and the end of September. Platt's average annual U.S. spot cathode price for 2000 was \$15.16 per pound, down by 11% from that of 1999. This price has steadily declined since 1995, when it was \$29.21 per pound (table 1).

Trends in Platt's prices for Zambian cobalt (minimum 99.6% cobalt) and Russian cobalt (minimum 99.3% cobalt) were more or less parallel to those for U.S. spot cathode. The annual average of weekly prices for Zambian cobalt was \$13.74 per pound, and the annual average of weekly prices for Russian cobalt was \$12.98 per pound.

Sales prices for 99.8% cobalt cathode reported by WMC Ltd. at its Internet web site provided some market transparency and became a benchmark for cobalt prices (Metal Bulletin, 2000d; Ryan's Notes, 2000). The trend in these prices was similar to that of Platt's U.S. spot cathode prices. WMC's lowest sales price was \$12.40 per pound in late July and its highest sales price was \$17.50 per pound in late September.

In October, OM Group Inc. announced that it had established an Internet web site for cobalt sales. OM Group's Internet sales were limited to spot sales of grade B cobalt briquettes, which contained a minimum of 99.8% cobalt. Sale prices during November and December ranged from \$12.40 per pound to \$13.00 per pound.

Foreign Trade

Net import reliance as a percent of apparent consumption is used to measure the adequacy of current domestic production to meet U.S. demand. Net import reliance was defined as imports minus exports plus adjustments for Government and industry stock changes. Releases from stocks, including shipments from the NDS, were counted as part of import reliance, regardless of whether they were imported or produced in the United States.

In 2000, net import reliance as a percent of apparent consumption was 78%. Because there was no measurable U.S. primary cobalt production in 2000, this indicates that 78% of U.S. cobalt supply was from imports and stock releases and 22% was from scrap, which would have been generated domestically or imported.

As shown in tables 4 and 5, in 2000, the United States imported 8% more cobalt than it did in 1999. Eight countries supplied 88% of U.S. imports of unwrought cobalt and cobalt in chemicals. Finland was the leading supplier, followed by Norway, Russia, the Democratic Republic of the Congo [Congo (Kinshasa)], Canada, Belgium, Brazil, and Zambia. Compared with those of 1999, cobalt imports from Belgium, Brazil, Canada, Finland, and Russia increased and imports from Congo (Kinshasa), Norway, and Zambia decreased.

In 2000, the United States imported 214 t, gross weight, of unwrought cobalt alloys valued at \$6.4 million. Five countries supplied more than 95% of these materials—Congo (Kinshasa) (45%), Sweden (16%), Belgium (15%), Japan (14%), and the United Kingdom (6%). The United States imported 550 t, gross weight, of cobalt matte, waste, and scrap, valued at \$4.1 million. Seven countries supplied more than 90% of these materials—the United Kingdom (43%), France (13%), Germany (11%), Canada (10%), Japan (6%), and Argentina and Belgium (5% each). The United States also imported 359 t, gross weight, of wrought cobalt and cobalt articles valued at \$18.8 million. The leading suppliers of these materials were Japan (30%); the United Kingdom (28%); Germany (11%); and Belgium, France, and the Netherlands (5% each).

U.S. exports of unwrought cobalt and cobalt contained in chemicals increased by 70% compared with those of 1999. As listed in table 6, 87% of the cobalt metal and chemical exports was shipped to nine countries—Belgium, Canada, France, Germany, Japan, Mexico, the Netherlands, the Republic of Korea, and the United Kingdom. The remainder was shipped to 41 other countries.

Exports also included 971 t, gross weight, of wrought metal and cobalt articles valued at \$37.8 million. Eighty-five percent of these materials was sent to eight countries—Germany (24%), the United Kingdom (23%), Japan (10%), India (9%), Belgium and Canada (6% each), the Republic of Korea (4%), and Netherlands (3%). The remainder was shipped to 35 other countries.

World Review

World refined cobalt production increased in 2000 as compared with that of 1999. Some of the increase in production was from new producers in Australia and Uganda and some was from a net increase in production by established producers. Refinery capacity by country is listed in table 7. Plants that reprocessed refined cobalt, that used secondary materials (scrap) as their main source of feed, or that produced a cobalt product that required further refining were not included.

Australia.—QNI Pty. Ltd. processed lateritic ore imported from Indonesia, New Caledonia, and the Philippines at its Yabulu nickel-cobalt refinery in Townsville, Queensland, and produced 1,520 t of cobalt as cobalt oxide hydroxide, approximately the same amount as the 1,539 t produced in 1999 (Cobalt Development Institute, 2001b). In May, QNI purchased a 40% direct joint-venture interest in the Ravensthorpe nickel project from Comet Resources Ltd. The project involved

building a front-end pressure acid leaching plant at Ravensthorpe on the southern coast of Western Australia. Lateritic ore from Ravensthorpe would be processed at the plant to produce an intermediate nickel-cobalt hydroxide, which would then be shipped to Yabulu for refining. During the year, the QNI-Comet joint venture performed laboratory scale and continuous pilot-plant testwork and made revised resource estimates for several of the deposits at Ravensthorpe. The front-end engineering and design phase of the project was expected to be completed during the second quarter of 2001 (Comet Resources Ltd., 2000). QNI planned to expand the Yabulu refinery to accommodate the increase in feed material. Future production from Ravensthorpe was estimated at approximately 35,000 t/yr of nickel and 1,300 t/yr of cobalt. The Yabulu refinery capacity might be increased to 65,000 t/yr of nickel and 3,000 t/yr of cobalt (Billiton plc, 1999).

WMC produced an estimated 800 t of cobalt in intermediate nickel-cobalt mixed sulfide at its Kwinana nickel refinery in Western Australia (WMC Ltd., 1999). The mixed sulfide was refined in Norway by Falconbridge Ltd. under a tolling agreement and the cobalt cathode was offered for sale by WMC on its Internet web site.

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

Anaconda Nickel Ltd. produced 925 t of cobalt as metal powder and briquettes from its Murrin Murrin nickel-cobalt laterite pressure acid leaching operation east of Leonora in Western Australia (Cobalt Development Institute, 2001b). The company cited engineering and materials problems as the causes for delays in commissioning the plant and ramping up production to the stage I design capacity of 45,000 t/yr of nickel and 3,000 t/yr of cobalt. Anaconda hoped to reach stage I capacity by the second half of 2001. During the year, Anaconda worked on a rolling expansion of the Murrin Murrin plant to the stage II capacity of 108,000 t/yr of nickel and 7,600 t/yr of cobalt. The company also studied the feasibility of developing its Mount Margaret project, northwest of Murrin Murrin. Anaconda's long-term (10 year to 15 year) plan was to produce more than 20,000 t/yr of cobalt from three nickel provinces—Murrin Murrin, the Mount Margaret and Murchinson deposits north of Murrin Murrin, and Cawse and Broad Arrow south of Murrin Murrin (Anaconda Nickel Ltd., 2000, 2001; Masterman, 2000; Reuters Ltd., 2000a).

Centaur Mining & Exploration Ltd. produced 998 t of cobalt contained in cobalt sulfide from its Cawse nickel-cobalt laterite pressure acid leaching operation northwest of Kalgoorlie in Western Australia. This represented approximately 67% of the 1,500 t/yr of cobalt design capacity of the refinery. Centaur reported that to reduce operating costs, significant capital expenditure would be required to increase production through debottlenecking and expansion. The company was considering doubling the rate of feed through the autoclave in the refinery. In December, Centaur terminated a preliminary agreement with Anaconda Nickel to study the feasibility of expanding Cawse's refinery capacity and began discussions with other resource corporations regarding various options for the Cawse nickel operations (Centaur Mining & Exploration Ltd., 2000, 2001). Capacity and production of cobalt sulfide from Cawse are not

included in tables 7 and 9 because the sulfide is an intermediate product that is upgraded by other cobalt refiners.

Preston Resources Ltd. produced 344 t of cobalt from its Bulong nickel-cobalt laterite pressure acid leaching operation east of Kalgoorlie in Western Australia. Approximately one-half of the cobalt, 170 t, was produced as cobalt cathode, and one-half was produced as an intermediate cobalt sulfide. Production did not reach the forecast levels of 8,100 t/yr of nickel and 700 t/yr of cobalt because of a series of technical problems with the refinery. Preston revised its best-case output to 9,000 t/yr of nickel and approximately 600 t/yr of cobalt. The company intended to work towards stabilizing output rather than expanding capacity as originally planned (Preston Resources Ltd., 2000a, b, 2001; Platts Metals Week, 2001a).

Titan Resources NL, West Perth, Western Australia, worked on developing a metallurgical process that used bacterial oxidation to recover base metals from sulfide ores. In August, Titan announced that it had held discussions with WMC regarding the possible application of the bioleaching process to WMC's currently [2000] subeconomic nickel resources (Titan Resources NL, 2000).

The Doe Run Co. of St. Louis, MO, a major lead producer, provided technical assistance to Compass Resources NL on its Browns lead-copper-cobalt-nickel sulfide project in Northern Territory. The Browns polymetallic deposit could be mined by using a conventional large-scale open pit method. Compass was considering a process that would entail grinding the ore, followed by bulk flotation to produce a mineral concentrate, which would be fed into a furnace where the lead would be fumed off and the cobalt, copper, and nickel would be converted to a sulfide matte. Metals in the matte would be dissolved by using an atmospheric acid leaching process. Copper and cobalt would be removed by using conventional solvent extraction-electrowinning (SX-EW) processes and nickel would be precipitated to a marketable product. Compass estimated an average cobalt production of 2,840 t/yr during the first 10 years of operation (Compass Resources NL, [undated], 2000 annual report—Operations review, accessed April 19, 2001, via URL <http://Compassnl.com>).

Black Range Minerals Ltd. completed a feasibility study on the Syerston nickel-cobalt-platinum laterite project approximately 400 kilometers northwest of Sydney in New South Wales. The study evaluated ore processing by pressure acid leaching, followed by SX-EW to produce nickel cathode and cobalt cathode. The proposed refinery was to have a design capacity of 20,000 t/yr of nickel and 5,000 t/yr of cobalt. Black Range evaluated several site locations for the refinery—Syerston, Broken Hill in western New South Wales, a site in China, and one in Malaysia—and determined that locating the refinery at one of the offshore sites would have the advantages of more attractive tax regimes and lower energy costs than those in Australia (Black Range Minerals Ltd., 2000, p. 4-5; 2001).

Belgium.—N.V. Union Minière S.A. converted cobalt metal, residues, and other cobalt-bearing materials into cobalt hydroxides, metal powders, oxides, and salts at its facilities in Olen. According to the Cobalt Development Institute (2001b), Union Minière's cobalt production increased by 17% in 2000, to 1,110 t, as compared with the 950 t produced in 1999. During the year, Union Minière began to build a new cobalt oxide plant in Olen to meet an anticipated increase in demand for raw materials for the rechargeable battery market (N.V. Union Minière S.A., 2001, p. 13).

Brazil.—Cia. Niquel Tocantins produced cobalt cathode at its refinery in Sao Miguel Paulista, Sao Paulo State. The refinery used lateritic nickel-cobalt ore from Niquelandia, Goias State, as feed. Production during the past 2 years increased significantly as a result of a 1998 expansion to the refinery that increased the cobalt capacity to 800 t/yr. Niquel Tocantins planned to complete an additional increase in the refinery's capacity in 2002, which would result in an increase in cobalt production to 1,100 t/yr (Metal Bulletin, 2000f, 2001).

Canada.—Falconbridge Ltd. produced 667 t of cobalt in concentrate from its Sudbury, Ontario, mines and 289 t of cobalt in concentrate from its Raglan Mine in Quebec. Nickel-copper matte produced at its Sudbury smelter was refined at the company's Nikkelverk refinery in Norway. In 2000, this matte contained 1,792 t of cobalt; 49% of the cobalt originated from ores produced at company mines, and 51% from custom feed materials, defined as feeds that did not originate from Falconbridge mines. Falconbridge's mine and smelter production were lower than those of 1999 as a result of a strike by production and maintenance workers at the company's Sudbury operations that began on August 1, 2000, and extended until February 20, 2001. During the strike, mining operations at Sudbury were reduced to 20% of normal production rates and smelting operations were reduced to 50% to 60% of prestrike rates (Falconbridge Ltd., 2001a, p. 17, 19).

Inco Ltd. produced cobalt oxide at its Thompson, Manitoba, refinery and cobalt cathode at its Port Colborne, Ontario, refinery from feed materials originating primarily from nickel mines in Thompson and Sudbury, respectively. In 2000, Inco produced 1,470 t of cobalt in Canada from both operations, a 4% increase from the 1,420 t produced in 1999 (Cobalt Development Institute, 2001b).

Inco's development of its Voisey's Bay nickel-copper-cobalt-sulfide deposit in northeastern Labrador continued to be delayed by an impasse between the company and the Province of Newfoundland and Labrador. The Provincial Government refused to give approval for the project without a guarantee that the ores would be refined within the Province, and Inco refused to commit to building the refinery in the Province before it was proven to be technically and economically feasible. During the year, Inco continued with exploration activities at Voisey's Bay to further define the deposit and explore new targets. Inco also continued research and development work on a proprietary hydrometallurgical process for Voisey's Bay sulfide concentrates (Inco Ltd., 2001, p. 18, 43).

The Sherritt International Corp.-General Nickel Co. S.A. joint venture's refinery in Fort Saskatchewan, Alberta, produced a record 2,855 t of cobalt in 2000, a 3% increase from the 2,770 t of cobalt in 1999. The increase in production was attributed to an increase in the cobalt content of feed used by the refinery (Sherritt International Corp., 2001, p. 20). Most of the feed was in the form of nickel-cobalt mixed sulfides from the joint venture's operations at Moa Bay, Cuba. As a result of a U.S. embargo on imports of products originating from Cuba, nickel and cobalt produced by Sherritt cannot be sold to U.S. customers.

Canmine Resources Corp. worked on planning, maintenance, engineering, and basic principal testing of processes for the hydrometallurgical refinery it purchased in late 1999. The North Cobalt, Ontario, refinery was to have an initial output of 300 t/yr of cobalt in carbonate or oxide. Canmine planned to begin production by processing feed materials produced by

other companies, including a stockpile of cobalt-silver bearing materials, which Canmine purchased from Agnico-Eagle Mines Ltd. in January 2000. Once details on financing had been finalized, Canmine planned to announce timelines for construction, commissioning, and ramp up of production at the refinery. Future expansions to 1,000 t/yr or 2,000 t/yr of cobalt were being considered, depending in part on the development of Canmine's Werner Lake cobalt project and Maskwa nickel project in southwestern Ontario-southeastern Manitoba (Canmine Resources Corp., 2000, 2001).

China.—An estimated 1,200 t of cobalt metal and chemicals was produced from domestic and imported raw materials (Cobalt Development Institute, 2001b). The largest Chinese cobalt producers were Jinchuan Non-Ferrous Metals Corp. and Ganzhou Cobalt & Tungsten Co., Ltd. Jinchuan produced cobalt cathode and downstream products from domestic nickel-copper-cobalt sulfide ores mined and refined at Jinchuan, Gansu Province. Ganzhou produced cobalt metal powders and salts at Ganzhou, Jiangxi Province. From the 1980s until 1999, this company imported and refined all of the cobalt concentrates produced in Morocco (see "Morocco" section of this report). Cobalt metal powder, oxides, salts, and other products were produced by a number of smaller producers and cobalt processors in China (Cie. de Tifnout Tiranimine, 2001; Song, 2001, p. 3-16).

Congo (Kinshasa).—In March, the Ministry of Mines issued a decree that revoked the contract that established Central Mining Group Corp. S.P.R.L., a joint venture between La Générale des Carrières et des Mines (Gécamines), the Government of Congo (Kinshasa), and Ridgepointe Overseas Developments Ltd. The joint venture had been established in 1998 to manage and rehabilitate the copper-cobalt operations in Gécamines' Central Group. As a result of its revocation, the assets of the joint venture were returned to Gécamines (Metal Bulletin, 2000b).

Gécamines and L'Enterprise Generale Malta Forrest S.P.R.L. produced copper-cobalt concentrates from the Luiswishi Mine, which were purchased by OM Group, Inc. for its Kokkola refinery in Finland under a long-term supply contract. The concentrates produced from Luiswishi were estimated to contain approximately 5,000 t/yr of cobalt (OM Group, Inc., 2001, p. 7).

During the fourth quarter, Gécamines, OM Group, and S.A. Groupe George Forrest completed construction of the Big Hill smelter at Lubumbashi and began producing a cobalt-copper alloy, which was shipped to OM Group's Kokkola refinery. The smelter used slag stockpiled at Lubumbashi as feed. The stockpile was expected to supply the smelter for 20 years at a production rate of 5,000 t/yr of contained cobalt (OM Group, Inc., 2001, p. 3, 7).

Congo Mineral Development Ltd. (CMD), a joint venture between America Mineral Fields Inc. and Anglo American plc, continued to work on the Kolwezi tailings project. During the year, CMD commissioned a pilot plant in Johannesburg, South Africa, to determine a suitable flow sheet for the SX-EW process and began collecting baseline data for the environmental impact study. CMD and Gécamines agreed to implement the project in two phases. In phase one, approximately 3 million metric tons per year (Mt/yr) of tailings would be treated to produce as much as 42,000 t/yr of copper and 7,000 t/yr of cobalt cathode. In phase two, the amount of tailings treated would be doubled. A full feasibility study on the project was to begin after CMD obtained the necessary decrees

from the President of Congo (Kinshasa). Upon receipt of these decrees, ownership of the Kolwezi tailings project would be transferred to a new company, KMT Sarl, which would be 60% owned by CMD and 40% owned by Gécamines. CMD had not yet received the decrees by yearend (America Mineral Fields Inc., 2001, p. 2-4, 7).

In late 1999, Melkior Resources Inc. and Gécamines agreed to create La Société Minière de Kabolela et Kipese (SMKK) to mine the Kabolela copper-cobalt and Kipese cobalt-gold-platinum deposits near the city of Likasi. SMKK was 60% owned by Melkior and 40% owned by Gécamines. By the end of 2000, the Kabolela Mine was in production and ore treated at the Kakanda concentrator yielded 27 t of cobalt in concentrates (Melkior Resources Inc., 2000a, b).

The rebellion by military factions dissatisfied with the Government of Congo (Kinshasa) that began in August 1998 continued into early 2001. Political uncertainty resulting from the ongoing civil war delayed the progress of the following joint-venture projects with Gécamines: First Quantum Minerals Ltd.'s copper-cobalt tailings projects at Kolwezi and Likasi; International Panorama Resource Corp.'s Kakanda copper-cobalt tailings project; Iscor Ltd.'s rehabilitation of the Kamoto Mine; and Tenke Mining Corp.'s development of copper-cobalt deposits at Tenke and Fungurume. Also delayed was the Mudima consortium's feasibility study on rehabilitating the mines and plants in Gécamines' Kolwezi Group West (First Quantum Minerals Ltd., 2001, p. 29; Tenke Mining Corp., 2001, p. 16; International Panorama Resource Corp., 2001; Iscor Ltd., [undated], Mining—Base metals—Overview, accessed April 2, 2001, at URL <http://www.iscorltd.co.za/mainframe.asp?imgname=01>). East Asia Gold Corp. abandoned all rights to claims under agreements with Gécamines to study and develop the Mukondo and Luisha properties (East Asia Gold Corp., 2000).

Côte d'Ivoire.—Falconbridge increased its option to earn interest in the Touba-Biankouma nickel-cobalt laterite project in western Côte d'Ivoire to 85% (Falconbridge Ltd., 2001a, p. 28).

Cuba.—Moa Nickel S.A., which was part of the joint venture between Sherritt and General Nickel, mined nickel-cobalt laterites at Moa Bay and produced mixed sulfides containing 29,520 t of nickel and cobalt, a 9% increase from the 27,020 t produced in 1999. The increase in production was attributed to the systematic upgrading, rehabilitation, and debottlenecking activities that have been undertaken since the inception of the joint venture (Sherritt International Corp., 2001, p. 20). The mixed sulfides produced at Moa were sent to the joint venture's refinery in Fort Saskatchewan, Alberta, Canada. Nickel and cobalt of Cuban origin cannot be imported into the United States because of a U.S. embargo on imports from Cuba.

QNI Pty. Ltd., a subsidiary of Billiton plc, constructed a pilot plant in Perth, Western Australia, to test the pressure acid leaching of nickel-cobalt lateritic ores from its development projects, which included the San Felipe project in the Camaguey Province (Billiton plc, 2000). The San Felipe project was being investigated as a joint venture with Geominera S.A., Cuba's mining investment company.

Finland.—OM Group produced 7,700 t of cobalt in cobalt metal powders, briquettes, oxides, and salts, 24% more than the 6,200 t produced in 1999 (Cobalt Development Institute, 2001b). The Kokkola Chemicals Oy refinery processed cobalt-bearing materials from Australia, Congo (Kinshasa), Russia, the United States, and Zambia (OM Group, Inc., 2001, p. 7). OM

Group planned to increase the refinery's capacity to 12,000 t/yr of cobalt (Metal Bulletin, 2000c).

In February, OM Group announced that it had reached an agreement to purchase the Harjavalta nickel refinery from Outokumpu Oyj. Outokumpu's nickel smelter was not included in the sale. Outokumpu planned to continue to smelt nickel concentrates for OM Group until its nickel mines were depleted, at which time Outokumpu would stop producing nickel. OM Group planned to find a new nickel-cobalt feed source for Harjavalta (see "Indonesia" section of this report) and to develop the Harjavalta refinery to be more closely integrated with the Kokkola refinery. Historically most of the nickel and all of the cobalt from Harjavalta have been further processed at Kokkola (OM Group, Inc., 2000b; Outokumpu Oyj, 2000).

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

India.—Three companies refined cobalt from imported raw materials. Nicomet Industries Ltd. produced cobalt cathode and various salts at its plant in Cuncolim, Goa State; Rubamin Ltd. produced cobalt cathode and various salts at its plant in Vadodara, Gujarat State; and Conic Metals Ltd. produced cobalt sulfate and carbonate at its plant in Mumbai, Maharashtra State. In addition to this refinery production, cobalt metal powder was recovered from cemented carbide scrap by Sandvik Asia Ltd. at a pilot plant in Pune, Maharashtra State, and spent catalysts from plants producing terephthalic acid, dimethyl terephthalate, and OXO alcohols were reprocessed by more than a dozen small cobalt chemical processors (Cobalt Development Institute, 2001a).

Indonesia.—State-owned P.T. Aneka Tambang (Antam) exported lateritic nickel-cobalt ore to QNI's Yabulu refinery in Queensland, Australia. Several companies, including QNI, worked on projects to explore and develop Indonesia's nickel-cobalt laterite resources.

In February, OM Group and Weda Bay Minerals Inc. announced that they had signed an agreement to pursue the development of nickel-cobalt laterite deposits on Halmahera Island. Under the agreement, the companies would work together to complete a feasibility study to evaluate the production of an intermediate product containing approximately 30,000 t/yr of nickel and 3,000 t/yr of cobalt. OM Group would purchase all of the production from the first phase of the project as feed for the Harjavalta refinery (see "Finland" section of this report). By midyear, Weda Bay Minerals had started the drilling program and metallurgical test work for the feasibility study (OM Group, Inc., 2000a; Weda Bay Minerals Inc., 2000).

In July, Falconbridge and The Broken Hill Proprietary Co. Ltd. (BHP) announced that they had reached a tentative agreement to form a joint venture to study the feasibility of developing the Gag Island nickel-cobalt laterite project. Several matters had to be resolved before the agreement could be finalized, including clarification of commercial arrangements with Antam, clarification of the forestry classification on Gag Island, and resolution of the scope of work for the feasibility study. During the second half of the year, BHP held discussions with Falconbridge and Antam to resolve these issues (Broken Hill Proprietary Co. Ltd., 2000; BHP Ltd., 2001).

Japan.—Sumitomo Metal Mining Co., Ltd., produced electrolytic cobalt, cobalt oxide, and cobalt salts as a byproduct of nickel at its Niihama nickel refinery in Ehime Prefecture.

Although not a large cobalt producing country, Japan was a significant cobalt consumer. The rechargeable battery industry was the largest consumer of cobalt in Japan. Manufacturers of cemented carbides, magnets, specialty steels and other alloys, and video tapes also consumed significant quantities of cobalt (Terada, 2000).

Mexico.—International Curator Resources Ltd. of Vancouver decided not to proceed with its Boleo copper-cobalt project near Santa Rosalia, Baja California. The decision was based on a combination of factors including the company's failure to persuade a partner to invest in the project, continued weak markets for the metals that would have been produced, and technical complexities of the deposit (International Curator Resources Ltd., 2001).

Morocco.—Cie. de Tifnout Tiranimine (CTT) mined cobalt-arsenic deposits at Bou Azzer and produced concentrates, which in past years were all exported to China to be refined. In 1996, Cobalt Metallurgie Bou Azzer (CMBA) built a pretreatment plant at Bou Azzer and a refinery at Guemassa to produce cobalt cathode from tailings generated by past mining operations. In 1999, CMBA installed a second plant at Guemassa and began refining domestic concentrates in addition to tailings. As a result, exports of concentrates to China were expected to decrease and domestic production of refined cobalt was expected to increase. In 2000, CTT and CMBA merged to form one company under the name Cie. de Tifnout Tiranimine. CTT's production of refined cobalt increased by more than 150% to 1,200 t, from the 472 t produced in 1999 (M'Hamdi, 1996; Cobalt Development Institute, 2000; Metal Bulletin, 2000a; Cie. de Tifnout Tiranimine, 2001).

New Caledonia.—Lateritic nickel-cobalt ore was exported to QNI's Yabulu refinery for processing. Nickel matte from Le Nickel-SLN's Doniambo smelter was sent to Eramet's refinery in Sandouville, France, where it was refined into nickel cathode, nickel chloride, and cobalt chloride.

During the year, Inco continued a pilot-plant program to test its proprietary pressure acid leaching-solvent extraction process on nickel-cobalt laterites from the Goro deposit in southern New Caledonia. In December, Inco decided to proceed with the next stage of development of the Goro project. Major activities were to be as follows: to complete a bankable feasibility study; to arrange financing, select an engineering construction consortium, and prepare basic and detailed engineering plans for a commercial-scale refinery; to continue test work at the pilot plant; to complete discussions with the Government of New Caledonia regarding fiscal and regulatory arrangements and secure permits for construction and operation of the refinery; and to bring a partner into the project. Inco was planning to build a refinery with the capacity to produce 54,000 t/yr of nickel and 5,400 t/yr of cobalt. Production was forecast to begin in late 2004 or early 2005. The project was 85% owned by Inco, with the remainder owned by Bureau de Recherches Géologiques et Minières, a French Government agency (Inco Ltd., 2000; 2001, p. 17, 42-43).

Argosy Minerals Inc., in a joint venture with Société des Mines de la Tontouta, studied the feasibility of using pressure acid leaching technology to develop the Nakety nickel-cobalt laterite deposits on the east coast of New Caledonia. During the year, Argosy acquired the rights to develop the nearby Bogota mining concessions and worked towards bringing a major joint-venture partner into the project (Argosy Minerals Inc., 2001, p. 1-9).

Norway.—In 2000, Falconbridge produced 3,431 t of cobalt at its Nikkelverk refinery, a 14% decrease from the 4,010 t produced in 1999. The decrease in production was attributed to a shortage of feed materials as a result of the strike by production and maintenance workers at company operations in Sudbury. In September, Falconbridge declared a full force majeure on cobalt shipments to the United States and Europe effective November 1 and on shipments to Japan effective December 1. This was amended to a partial force majeure on shipments to the United States and Europe for December. During 2000, 25% of the cobalt produced at Nikkelverk originated from Falconbridge mines in Canada and 75% originated from custom feeds, defined as feeds that did not originate at Falconbridge mines. The custom feeds included matte from BCL Ltd. in Botswana, scrap, and intermediate materials (Reuters Ltd., 2000b; Falconbridge Ltd., 2001a, p. 18-19; 2001b, p. 15-16).

Papua New Guinea.—During the year, the Ramu nickel-cobalt laterite project received all the permits necessary for its development. On the basis of a feasibility study completed in 1998, the project was to use pressure acid leaching technology to produce 33,000 t/yr of nickel metal and 3,200 t/yr of cobalt as cobalt sulfate. At yearend the project was undergoing a change in ownership structure. Once all transactions were completed, Ramu's ownership was to be as follows: 47.95% Highlands Pacific Ltd., 47.05% Orogen Minerals Ltd., and 5% landowners. The partners planned to bring an additional equity partner into the joint venture (Highlands Pacific Ltd., 2000).

Philippines.—Lateritic nickel-cobalt ore from the Philippines was exported to QNI's Yabulu refinery for processing (Platt's Metals Week, 2000b).

In February, Impala Platinum Holdings Ltd. (Implats) of South Africa announced that it had concluded a memorandum of understanding with Philippine company Philnico Developments Ltd. regarding the Nonoc nickel-cobalt laterite project. Philnico planned to convert the mothballed nickel-cobalt plant at Nonoc in Surigao del Norte, Nonoc Island, from an ammonia leach process to a pressure acid leach process. Under the memorandum of understanding, Implats would fund a bankable feasibility study, and then assuming a positive outcome, invest an additional \$75 million and contribute the nickel and cobalt assets of its base metals refinery in Springs, South Africa, to the project, in exchange for a 25% share. Mixed sulfides produced at Nonoc, containing approximately 41,000 t/yr of nickel and 4,000 t/yr of cobalt, would be sent to Springs to be refined. The capacity of the Springs refinery would be increased to handle the additional feed (Impala Platinum Holdings Ltd., 2000).

In April, Sumitomo Metal Mining Co. Ltd. agreed to begin a joint study with Rio Tuba Nickel Mining Corp. The study would examine the feasibility of using pressure acid leaching technology to produce a mixed nickel-cobalt intermediate from low-grade saprolitic and lateritic ores stockpiled at Rio Tuba's nickel mine on Palawan Island. Processing at a rate of 1 Mt/yr of ore was expected to yield 10,000 t/yr of nickel and 550 t/yr of cobalt (Metal Bulletin, 2000e; Reuters Ltd., 2000c).

Crew Development Corp., Vancouver, British Columbia, began a bankable feasibility study on a nickel-cobalt laterite deposit on Mindoro Island. Crew was considering building a refinery that would use pressure acid leaching to produce approximately 40,000 t/yr of nickel briquettes and 3,000 t/yr of cobalt briquettes. The project infrastructure would include an

overland pipeline to transport ore slurry from the mine to the refinery, a port, power station, and village to support the operation. Following completion of the study, Crew planned to find a partner to develop the project (Crew Development Corp., 2000b).

Russia.—Nickel and cobalt production in Russia involved a complex flow of ores, flotation concentrates, precipitates, and mattes between various production sites. The main feed materials were domestic nickel-copper sulfide and nickel-cobalt laterite ores and imported nickel- and cobalt-bearing secondary materials. Russia had the capacity to produce refined cobalt at four locations—RAO Norilsk Nickel refineries at Monchegorsk on the Kola Peninsula and Norilsk in Siberia, the Ufaleynickel Joint Stock Co. refinery at Verkhniy Ufaley in the Ural Mountains, and the Yuzhuralnickel Joint Stock Co. refinery at Orsk, also in the Ural Mountains (Roskill Information Services Ltd., 1995, p. 11-15).

Total Russian cobalt production was 22% higher than that of 1999 (Interfax Mining & Metals Report, 2001). Ninety-five percent of this production was by affiliated and dependent companies of RAO Norilsk Nickel. Norilsk Nickel's total production of cobalt in marketable products increased by 6.5% in 2000 compared with that of 1999. As compared with that of 1999, production of cobalt metal increased 24%, production of cobalt sulfate more than tripled, production of cobalt carbonate more than doubled, and production of cobalt oxides decreased (RAO Norilsk Nickel, 2001, p. 3, 20).

During the year, Norilsk Nickel approved a plan to develop the ore reserves and production capacity at the Pechenganickel Territorially Exclusive Structural Subdivision, which was a part of its Kola Mining and Metallurgical Co. subsidiary. Under the plan, production was expected to continue until 2015, which was a reversal of a previous plan to cease mining in that area by 2007 (RAO Norilsk Nickel, 2000).

Ufaleynickel commissioned a direct current arc furnace capable of producing 3,000 to 4,000 t/yr of granulated cobalt. The furnace was intended to replace an existing furnace and enable Ufaleynickel to produce granules in addition to the ingot it had been producing. The furnace's capacity was initially committed to tolling raw materials for Norilsk Nickel (Interfax Mining & Metals Report, 2000a; Metal Bulletin, 2000g).

In return for debt forgiveness, Yuzhuralnickel transferred its pyrometallurgical and hydrometallurgical plants to Yuzhpolimetal, a subsidiary controlled by gas provider Uraltransgaz. This left Yuzhuralnickel with nickel mining at the Buruktalskoye Mine in the Orenburg region and the Sakharinskoye Mine in the Chelyabinsk region and auxiliary and maintenance capacity. Late in the year, Yuzhuralnickel was considering toll-processing cobalt concentrates from Congo (Kinshasa) to improve the profitability of its cobalt production (Interfax Mining & Metals Report, 2000b, c, d).

South Africa.—Cobalt was mined as a byproduct from six platinum-group metal mines and as a coproduct from one nickel mine (Ngcai, 2001). Two South African companies produced refined cobalt as a byproduct of domestic platinum mining and refining. Rustenburg Base Metal Refiners Pty. Ltd. produced cobalt sulfate at its refinery near Rustenburg, Northwest Province. Impala Platinum Ltd. produced cobalt metal powder at its base metals refinery near Springs, Gauteng Province. Impala was considering expanding the capacity of the Springs refinery to 60,000 t/yr of nickel and 4,200 t/yr of cobalt to accommodate an increase in feed that would result from the

development of the Nonoc project in the Philippines (see “Philippines” section of this report).

During the fiscal year ending June 30, 2000, the Nkomati joint venture between Anglovaal Mining Ltd. (Avmin) and Anglo American produced 227 t of cobalt in concentrates from the Nkomati nickel sulfide mine in Mpumalanga Province. During the previous fiscal year, 211 t of cobalt in concentrates was produced. Avmin was considering expanding production from the mine (Anglovaal Mining Ltd., 2000).

Union Mineral Concentrators Pty., a Union Minière subsidiary, produced cobalt compounds from low-grade cobalt-containing residues in Roodepoort, near Johannesburg. During the year, Union Minière expanded the plant’s capacity and broadened the range of compounds produced (N.V. Union Minière S.A., 2001, p. 14).

International Metal Processing (Pty.) Ltd. worked on a 3-year redevelopment and extension program to enhance its cobalt-copper-nickel refinery in Brakpan, Gauteng Province. At the refinery, mineral concentrates were processed to produce cobalt cathode, metal powder, oxides and salts {International Metal Processing (Pty.) Ltd., [2000], Products produced, accessed May 8, 2001, at URL <http://www.intmetals.com/Products.htm>}.

Uganda.—Banff Resources Ltd., of Vancouver continued to focus its efforts on commissioning the Kasese cobalt refinery in southwestern Uganda. The refinery was designed to recover cobalt from stockpiled pyrite concentrates by using bacterial leaching followed by SX-EW. During the year, Banff made changes to the plant configuration to improve throughput, oxygen dispersal, and bacterial activity levels. By yearend, 420 t of cobalt cathode had been produced at Kasese, but throughput and production rates remained significantly below the engineered design capacity of 1,000 t/yr of cobalt (Banff Resources Ltd., 2001; Cobalt Development Institute, 2001b).

Zambia.—In March, the Government of the Republic of Zambia completed the privatization of Zambia Consolidated Copper Mines Ltd. (ZCCM) with the sale of ZCCM’s remaining assets. Mopani Copper Mines plc, which was owned by the consortium of First Quantum and Glencore International AG (90%) and ZCCM (10%), acquired ZCCM’s Mfulira division and certain assets of the Nkana division. The Mfulira division consisted of a copper mine, concentrator, smelter, and refinery. The Nkana assets included in the sale were the mine, concentrator, and cobalt plant, but not the smelter, copper refinery, and acid plant. Following acquisition, Mopani focused its efforts on restructuring, hiring, and training personnel and management, recapitalizing the operations, renegotiating supply contracts, purchasing spares and consumables, rehabilitating the plants and equipment, and underground mine development. Cobalt production from the Nkana cobalt plant was estimated to be 1,026 tons in 2000. The plant processed concentrates from Mopani’s Nkana concentrator, the Chibuluma Mine, and on a tolling basis, Konkola Copper Mines plc operations (First Quantum Minerals Ltd., 2000; 2001, p. 15, 23; Cobalt Development Institute, 2001b).

Konkola Copper Mines, which was 65% owned by Zambia Copper Investments Ltd., a subsidiary of Anglo American, 20% by ZCCM, and 7.5% each by CDC Financial Services (Mauritius) Ltd. and the International Finance Corp., acquired the assets of ZCCM’s Konkola division, including the Konkola Deep mining project; Nchanga division, with its Chingola refractory ore stockpiles; and Nampundwe pyrite mine. Following acquisition, Konkola Copper Mines began

refurbishing the assets, revalidating the feasibility study on the Konkola Deep mining project, and seeking long-term financing for the project (Zambia Copper Investments Ltd., 2001). Konkola Copper Mines was also granted a 5-year option to acquire ZCCM’s Nkana smelter, copper refinery, and acid plant. These assets were transferred to ZCCM (SmelterCo) Ltd., a wholly owned subsidiary of ZCCM, and were to be managed by Anglo American during the option period (Anglo American plc, 2000).

Chambishi Metals plc toll-refined copper-cobalt concentrates from mining operations in Zambia and heterogenite from Congo (Kinshasa) and produced 2,316 t of cobalt metal at its Chambishi cobalt plant. Production was impacted by lower than anticipated quantities and grades of feed materials. During the year, Chambishi worked on building a new smelter and matte leach facility at the plant. The new facility was designed to produce cobalt and copper from slag stockpiled at Nkana. Production from the new facility was expected to be 4,000 t/yr of cobalt and approximately 3,500 t/yr of copper. This would be in addition to the cobalt and copper produced by toll treating concentrates. At yearend, construction of the new facility was nearly completed and commissioning had begun. Production of the first salable metal from slag was planned for March 2001 (Anglovaal Mining Ltd., 2000, 2001; Cobalt Development Institute, 2001b).

Copper and cobalt production from Roan Antelope Mining Corp.’s Baluba and Luanshya mines decreased significantly from that of 1999 owing to financial problems that resulted in the Copperbelt Energy Corp. cutting the operation’s power supply on several occasions. In late November, Roan Antelope was put under receivership because of unpaid debts. In early 2001, it was announced that the company’s assets, including the Baluba and Luanshya mines, the Muliashi deposit, and approximately 10 Mt of smelter slag, would be put up for sale (Reuters Ltd., 2000d; Platts Metals Week, 2001b).

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

In late 1999, Orion Mining and Exploration Ltd. purchased and began rehabilitating the cobalt processing plant at Kabwe, which had been idle since 1998, when Colossal Resources Corp. ceased processing slag from the former ZCCM Nkana division. In 2000, Orion started processing slag imported from Congo (Kinshasa) and exporting the resulting cobalt alloy to China and Europe (Platt’s Metals Week, 2000a, c).

Outlook

World cobalt production is expected to continue to increase. Production from new plants in Australia, Congo (Kinshasa), and Uganda is expected to ramp up during the next few years and output from some established refineries is likely to increase from 2000 levels. In addition, there are numerous projects in the prefeasibility, feasibility, or development stage in Africa, the Asia/Pacific region, and North America that include cobalt production. In nearly all of the proposed projects in the Asia/Pacific region, cobalt would be produced as a byproduct of nickel. Progress on these projects will depend more on the nickel market than on the cobalt market.

Another component of world supply is U.S. Government sales of cobalt from the NDS. Offers of NDS cobalt are

expected to continue at the rate set each year under the AMP until the amount authorized for disposal has been sold. If the current (fiscal year 2001) AMP level of 2,720 t (6 million pounds) was maintained, and the amount of cobalt sold each year was close to the AMP level, then the NDS cobalt sales program could extend into 2004. However, the National Defense Authorization Act for Fiscal Year 1998 gave specific guidelines for cobalt disposals during fiscal years 2003 through 2007. During this 5-year period, cobalt disposals were required to result in receipts equal to the following amounts: \$20 million during fiscal year 2003, \$50 million during fiscal year 2004, \$64 million during fiscal year 2005, \$76 million during fiscal year 2006, and \$34 million during fiscal year 2007. As part of the Act, the DNSC was not permitted to dispose of more than 6,350 t (14 million pounds) of cobalt during the 5-year period, and each year the DNSC would not be permitted to dispose of more cobalt than necessary to meet the specified dollar amount (U.S. Department of Defense, 2001, p. 37). Future cobalt prices and efforts by DNSC to meet, but not exceed, specific dollar amounts could impact the amount of cobalt available for sale each year.

Future demand will dictate how much additional cobalt the market can bear. Superalloys, which are used to make turbine parts for jet engines and land-based electrical power generators, continue to be the largest market for cobalt. Demand for jet aircraft and smaller power stations has been strong and is expected to trend upwards. The rechargeable battery industry has been rapidly increasing the amounts of cobalt it uses in recent years. Future growth in cobalt demand by this industry will depend on a combination of factors including the overall demand for batteries, the types of batteries produced, the availability and price of cobalt, and cobalt's image in terms of its toxicity, recyclability, security of supply, and stability of its price (Burstow, 2000; Gellens, 2000; Cundy, 2001; Falconbridge Ltd., 2001a, p. 32; Southwood and Gray, 2001).

Cobalt supply and demand are believed to be roughly in balance and are expected to remain in balance until 2004 or 2005 (Searle, 2001). The general consensus, however, is that the future increase in cobalt supply will be at a greater rate than the increase in demand, and that a resulting surplus will put downward pressure on cobalt prices. Several analysts have forecast that prices will drop to the \$6 to \$10 per pound range in 2 to 5 years (Burstow, 2000; Bacon and others, 2001, p. 9; Searle, 2001; Southwood and Gray, 2001).

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TABLE 1
SALIENT COBALT STATISTICS 1/

(Metric tons, cobalt content, unless otherwise specified)

	1996	1997	1998	1999	2000
United States:					
Consumption:					
Reported	7,990	8,910	9,130	8,410 r/	8,700
Apparent	9,380	11,200	11,500	10,700	11,700
Imports for consumption	6,710	8,430	7,670	8,150	8,770
Exports	1,660	1,570	1,680	1,550	2,630
Stocks, December 31:					
Industry 2/	794	763	751 r/	738 r/	780
U.S. Government 3/	18,700	17,100	14,700	13,200	10,200
Price, metal, per pound 4/	\$25.50	\$23.34	\$21.43	\$17.02	\$15.16
World, production:					
Mine	26,200	27,200 r/	34,400 r/	30,600 r/	33,300 e/
Refinery	25,600	27,100 r/	30,900 r/	32,400 r/	35,200

e/ Estimated. r/ Revised.

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

2/ Stocks held by cobalt processors and consumers.

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

4/ Annual average U.S. spot price for minimum 99.8% cobalt cathode reported by Platt's Metals Week.

TABLE 2
U.S. GOVERNMENT NATIONAL DEFENSE STOCKPILE SALES AND SHIPMENTS 1/

(Metric tons, cobalt content)

	1999	2000
Sales:		
Fiscal year 2/	1,960	2,720
Calendar year	2,230	3,080
Shipments: 3/		
Fiscal year 2/	1,670	2,150
Calendar year	1,530	2,960

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

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

3/ Calculated from year end inventory levels.

Source: Defense National Stockpile Center.

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

(Metric tons, cobalt content)

	1999	2000
Consumption by end use:		
Steels	154	163 3/
Superalloys	3,830	3,800 3/
Alloys (excludes steels and superalloys):		
Magnetic alloys	794	544 3/
Other alloys 4/	291	1,020 3/
Cemented carbides 5/	755	760
Chemical and ceramic uses	2,530	2,360
Miscellaneous and unspecified	63 r/	63
Total	8,410 r/	8,700
Consumption by form:		
Chemical compounds (organic and inorganic) 6/	1,910	1,840
Metal	3,780	4,320
Purchased scrap	2,720	2,550
Total	8,410 r/	8,700

See footnotes at end of table.

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

(Metric tons, cobalt content)

	1999	2000
Stocks, December 31: 7/		
Chemical compounds (organic and inorganic) 6/	251	252
Metal	322	370
Purchased scrap	165	159
Total	738 r/	780

r/ Revised.

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

2/ Includes estimates.

3/ Data not comparable with those for 1999 because of a change in reporting.

4/ Includes nonferrous alloys, welding materials, and wear-resistant alloys.

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

6/ Includes oxides.

7/ Stocks held by cobalt processors and consumers.

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

(Metric tons unless otherwise specified)

	1999	2000
Metal: 2/		
Gross weight	6,800	7,210
Cobalt content 3/	6,800	7,210
Value thousands	\$229,000	\$213,000
Oxides and hydroxides:		
Gross weight	1,260	1,540
Cobalt content 3/	910	1,110
Value thousands	\$33,700	\$37,100
Other forms:		
Acetates:		
Gross weight	158	183
Cobalt content 3/	38	44
Value thousands	\$1,270	\$1,290
Carbonates:		
Gross weight	58	5
Cobalt content 3/	27	2
Value thousands	\$548	\$103
Chlorides:		
Gross weight	35	33
Cobalt content 3/	9	8
Value thousands	\$702	\$295
Sulfates:		
Gross weight	1,360	1,490
Cobalt content 3/	366	402
Value thousands	\$9,840	\$9,340
Total:		
Gross weight	9,670	10,500
Cobalt content 3/	8,150	8,770
Value thousands	\$275,000	\$261,000

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

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

3/ Estimated from gross weights.

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

TABLE 5
U.S. IMPORTS FOR CONSUMPTION OF COBALT, BY COUNTRY 1/

Country of origin	Metal 2/			Oxides and hydroxides			Other forms 3/			Total		
	Gross weight (metric tons)	Cobalt content 4/ (metric tons)	Value (thousands)	Gross weight (metric tons)	Cobalt content 4/ (metric tons)	Value (thousands)	Gross weight (metric tons)	Cobalt content 4/ (metric tons)	Value (thousands)	Gross weight (metric tons)	Cobalt content 4/ (metric tons)	Value (thousands)
1999:												
Belgium	144	144	\$6,720	264	190	\$7,620	--	--	--	408	334	\$14,300
Brazil	188	188	5,300	--	--	--	--	--	--	188	188	5,300
Canada	801	801	25,200	(5/)	(5/)	5	15	7	\$303	815	807	25,500
China	--	--	--	30	22	687	6	2	82	36	24	769
Congo (Kinshasa)	1,090	1,090	37,700	--	--	--	--	--	--	1,090	1,090	37,700
Finland	1,130	1,130	37,600	609	438	15,300	1,490	397	10,900	3,230	1,970	63,800
France	45	45	3,490	54	39	2,620	2	1	21	101	85	6,130
Germany	86	86	3,320	78	56	2,500	18	5	131	182	147	5,950
Japan	57	57	3,140	1	(5/)	43	(5/)	(5/)	6	58	57	3,190
Netherlands	--	--	--	--	--	--	32	8	646	32	8	646
Norway	1,550	1,550	48,800	--	--	--	--	--	--	1,550	1,550	48,800
Russia	733	733	22,900	--	--	--	(5/)	(5/)	4	733	733	22,900
South Africa	7	7	370	--	--	--	2	(5/)	14	8	7	384
United Kingdom	85	85	3,030	228	164	4,900	46	20	239	359	269	8,180
Zambia	879	879	31,100	--	--	--	--	--	--	879	879	31,100
Other	(5/)	(5/)	37	(5/)	(5/)	12	--	--	--	1	1	49
Total	6,800	6,800	229,000	1,260	910	33,700	1,610	440	12,400	9,670	8,150	275,000
2000:												
Australia	288	288	7,370	2	1	53	(5/)	(5/)	3	290	290	7,430
Belgium	118	118	4,820	411	296	11,300	2	1	25	531	415	16,100
Brazil	340	340	9,380	--	--	--	--	--	--	340	340	9,380
Canada	809	809	24,900	1	1	57	4	2	70	815	812	25,000
China	12	12	474	15	11	363	4	1	34	31	24	871
Congo (Kinshasa)	893	893	22,200	--	--	--	--	--	--	893	893	22,200
Finland	1,290	1,290	41,400	900	648	19,400	1,630	436	10,300	3,820	2,380	71,100
France	43	43	3,250	42	30	2,000	--	--	--	85	73	5,250
Germany	75	75	3,040	5	4	100	(5/)	(5/)	14	80	79	3,150
Japan	82	82	3,850	2	2	44	(5/)	(5/)	8	85	84	3,910
Morocco	62	62	1,570	--	--	--	--	--	--	62	62	1,570
Netherlands	10	10	284	--	--	--	--	--	--	10	10	284
Norway	1,470	1,470	42,900	--	--	--	--	--	--	1,470	1,470	42,900
Russia	1,100	1,100	32,100	--	--	--	11	3	100	1,110	1,100	32,200
South Africa	243	243	5,730	21	15	468	--	--	--	264	258	6,200
Uganda	41	41	1,220	--	--	--	--	--	--	41	41	1,220
United Kingdom	10	10	311	136	98	3,320	52	12	399	198	120	4,030
Zambia	318	318	7,510	--	--	--	--	--	--	318	318	7,510
Other	11	11	329	--	--	--	6	2	63	17	12	392
Total	7,210	7,210	213,000	1,540	1,110	37,100	1,710	457	11,000	10,500	8,770	261,000

-- Zero.

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

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

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

4/ Estimated from gross weights.

5/ Less than 1/2 unit.

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

TABLE 6
U.S. EXPORTS OF COBALT IN 2000, BY COUNTRY 1/ 2/

Country of destination	Metal 3/		Oxides and hydroxides		Acetates		Chlorides		Total	
	Gross weight (metric tons)	Value 4/ (thousands)	Gross weight (metric tons)	Value 4/ (thousands)	Gross weight (metric tons)	Value 4/ (thousands)	Gross weight (metric tons)	Value 4/ (thousands)	Cobalt content 5/ (metric tons)	Value 4/ (thousands)
Austria	20	\$164	(6/)	\$7	--	--	--	--	20	\$170
Belgium	602	23,800	15	131	--	--	2	\$39	613	24,000
Brazil	8	166	54	968	70	\$657	--	--	64	1,790
Canada	106	3,020	42	999	36	273	43	449	156	4,750
France	180	4,330	3	16	--	--	--	--	183	4,350
Germany	81	3,520	--	--	--	--	--	--	81	3,520
Hong Kong	55	2,150	11	427	--	--	--	--	63	2,580
Japan	124	4,900	24	277	1	15	--	--	141	5,190
Korea, Republic of	8	370	881	3,840	--	--	--	--	642	4,210
Mexico	27	1,150	16	519	233	1,470	--	--	94	3,140
Netherlands	199	5,710	139	2,320	--	--	--	--	299	8,030
Singapore	2	107	23	132	--	--	--	--	19	239
Switzerland	16	535	--	--	--	--	--	--	16	535
Taiwan	16	275	14	436	12	105	3	38	30	854
United Kingdom	39	2,440	(6/)	3	234	367	(6/)	6	95	2,820
Other	42	1,850	94	1,650	36	167	5	69	120	3,730
Total	1,520	54,500	1,320	11,700	623	3,050	53	601	2,630	69,900

-- Zero.

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

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

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

4/ Free alongside ship (f.a.s.) value.

5/ Estimated from gross weights.

6/ Less than 1/2 unit.

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

TABLE 7
WORLD ANNUAL COBALT REFINERY
CAPACITY, DECEMBER 31, 2000 1/ 2/

(Metric tons, cobalt content)

Country	Capacity
Australia e/	3,500
Belgium	1,200
Brazil	800
Canada	5,100
China e/	1,900
Congo (Kinshasa)	17,000
Finland	10,000
France	300
India	370
Japan	480
Morocco	1,200
Norway	4,500
Russia e/	8,000
South Africa e/	1,000
Uganda e/	500
Zambia	5,000
Total	60,900

e/ Estimated.

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

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

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

(Metric tons, cobalt content)

Country 3/	1996	1997	1998	1999	2000 e/
Australia e/ 4/	2,800	3,000	3,300	4,100 r/	5,600
Botswana 5/	408	334	335	331 r/	319 6/
Brazil e/	400	400	400	700	900
Canada 7/	5,714	5,709	5,861	5,323 r/	5,281 6/
China e/	190	200	40	250 r/	200
Congo (Kinshasa) e/ 8/	2,000	3,500	5,000 r/	6,000 r/	7,000
Cuba 9/	2,011	2,082	2,200	2,160	2,350
Kazakhstan e/ 10/	300	300	300	300	300
Morocco 11/	565	714	287	863 r/	1,305 6/
New Caledonia e/ 12/	1,100	1,000	1,000	1,100	1,100
Russia e/	3,300	3,300	3,200	3,300	3,600
South Africa e/	350	465 r/	435 r/	450 r/	585
Zambia 11/ 13/	6,959	6,037	11,900	5,640 r/	4,600
Zimbabwe e/ 14/	106	126	138 r/	121 r/	126 6/
Total	26,200	27,200 r/	34,400 r/	30,600 r/	33,300

e/ Estimated. r/ Revised.

1/ World totals and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through June 18, 2001. Figures represent recoverable cobalt content of ores, concentrates, or intermediate products from copper, nickel, platinum, or zinc operations. Morocco was the only country where cobalt was mined as a primary product.

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

4/ Quantities of cobalt contained in intermediate or refined metallurgical products produced from Australian and imported ores. Cobalt content of laterite nickel ore, nickel concentrate, and zinc concentrate originating in Australia was estimated as follows, metric tons: 1996--1,400; 1997--1,600; 1998--4,000; 1999--7,000; and 2000--5,100.

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

6/ Reported figure.

7/ Assay content of cobalt in concentrates produced. The cobalt content of all products derived from ores of Canadian origins, including cobalt oxide shipped to the United Kingdom for further processing and nickel-copper matte shipped to Norway for refining, was reported as follows, in metric tons: 1996--2,150; 1997--2,168; 1998--2,262; 1999--2,014 (revised); and 2000--2,013.

8/ Cobalt content of concentrates and tailings.

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

10/ Estimated cobalt content of only those ores from which it is assumed cobalt is recovered. Cobalt content of total ores mined is assumed to be as follows, in metric tons: 1996-2000--1,400.

11/ Cobalt content of concentrates.

12/ Quantities of cobalt contained in intermediate or refined metallurgical products (cobalt chloride, cobalt oxide hydroxide, and cobalt sulfide) produced from New Caledonian ores exported to Australia and France. Cobalt content of total ores mined is estimated as follows, in metric tons: 1996--12,200; 1997--13,600; 1998--12,500 (revised); 1999--11,000 (revised); and 2000--12,000.

13/ Data for 1996 through 1998 are for the fiscal years beginning April 1; data for 1999 through 2000 are for the calendar years.

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

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

(Metric tons, cobalt content)

Country 3/	1996	1997	1998	1999	2000
Australia: Metal (including metal powder) and oxide hydroxide	--	617	1,395	1,700 e/	2,600 e/
Belgium: Metal powder, oxide, hydroxide e/	1,200	1,200	1,200	950	1,110
Brazil: Metal	193	266	364	651 r/	792
Canada: Metal (including metal powder) and oxide	3,601	3,792	4,415	4,196 r/	4,376
China: Metal e/	230	470	410	300 r/	350
Congo (Kinshasa): Metal 4/	3,540	2,808	4,490	5,180 r/	4,320
Finland: Metal powder and salts	4,160	5,000	5,250	6,200	7,700
France: Chloride	174	159	172	181	204
India: Metal and salts e/	--	110	120	120	206
Japan: Metal	258	264	329	247 r/	311
Morocco: Metal	80	225 r/	242 r/	472 r/	1,200
Norway: Metal	3,098	3,417	3,851	4,009	3,433
Russia: Unspecified e/	4,200	4,100	3,500	3,600	4,400
South Africa: Metal powder and sulfate	244	316 r/	296	306	397
Uganda: Metal	--	--	--	77	420
Zambia: Metal 5/	4,612	4,403	4,837	4,236 r/	3,342
Total	25,600	27,100 r/	30,900 r/	32,400 r/	35,200

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

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

2/ Table includes data available through June 18, 2001. Figures represent cobalt refined from ores, concentrates, or intermediate products and do not include production of downstream products from refined cobalt.

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

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

5/ Data for 1996 through 1998 are for the fiscal years beginning April 1; data for 1999 through 2000 are for the calendar years.