

COBALT

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Cobalt is a strategic and critical metal used in many diverse industrial and military applications. The largest use of cobalt is in superalloys, which are used to make parts for gas turbine aircraft engines. Cobalt is also used to make magnets; corrosion and wear-resistant alloys; high-speed steels; cemented carbides 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; and magnetic recording media.

The United States is the world's largest consumer of cobalt, but has no mine or refinery production. The U.S. Government maintains significant quantities of cobalt metal in the National Defense Stockpile (NDS) for military, industrial, and essential civilian use during a national emergency. Since 1993, sales of excess cobalt from the NDS have contributed to U.S. and world supply. World cobalt production in 1997 approximately equaled that of 1996. Demand was strong, and prices remained high during the year.

With the exception of prices, NDS data, and reported production from foreign countries, all data in this report have been rounded to three significant digits. Totals and percentages were calculated from unrounded numbers.

Legislation and Government Programs

The Defense Logistics Agency (DLA) planned to have six cobalt offerings of approximately 450 metric tons each during fiscal year 1997 (October 1, 1996, through September 30, 1997). Alternating sealed bid and negotiated bid sales were scheduled for December 1996 and February, March, April, May, and September 1997. The sales program was interrupted in March when one of the companies participating in the bidding protested some of the sales parameters. Following resolution of the protest, DLA decided to offer only sealed bid sales and made awards in August and September. During fiscal year 1997, DLA sold 1,057 tons of cobalt valued at \$40 million. This equaled 39% of the 2,722-ton maximum allowed for sale under the Annual Materials Plan (AMP). The AMP for fiscal year 1998 was also 2,722 tons (6 million pounds) of cobalt. DLA planned to offer approximately 227 tons of cobalt on a sealed-bid basis on the third Wednesday of each month.

DLA held six cobalt offerings during calendar year 1997. Between January and December, DLA sold 1,684 tons of cobalt valued at \$64 million. On December 31, the total uncommitted cobalt inventory held by DLA was 16,508 tons (36.4 million pounds), and the quantity authorized for eventual disposal was 16,492 tons (36.4 million pounds). (*See tables 1 and 2.*)

In November, the President signed the National Defense Authorization Act for fiscal year 1998 (Public Law 105-85). This act granted new authority to dispose of 6,377 tons (14 million

pounds) of cobalt between 2003 and 2007. The disposals were intended to result in the following receipts: \$20 million during fiscal year 2003, \$30 million during fiscal year 2004, and \$34 million during each of fiscal years 2005, 2006, and 2007. Under the act, disposals must not result in undue disruption of the usual markets of producers, processors, or consumers of cobalt or avoidable loss to the United States.

Production

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 1997. For example, at the Stillwater Mining Co.'s Columbus, MT, metallurgical complex, matte from the precious metals smelter is processed at a base metals refinery built and commissioned in 1996. Nickel-copper-cobalt sulfate solution from the refinery is sold to Westaim Corp. of Edmonton, Alberta, Canada.

Formation Capital Corp., of Vancouver, British Columbia, Canada, continued to explore its Sunshine copper-cobalt-gold deposit in Lemhi County, ID. Formation Capital was considering a mine plan that would include underground mining followed by production of a cobalt concentrate at an on-site mill. The concentrate would be refined off site in south-central Idaho by pressure oxidation leaching or possibly by bioleaching, followed by purification by precipitation, ion exchange, and electrowinning to produce cobalt cathode. Crude copper sulfide, nickel-cobalt carbonate, and a gold-bearing pyrite concentrate would be produced as byproducts. Formation projected that it could begin production at 1,500 tons per year of cobalt by 2000 (Bending, 1998).

Fleck Resources Ltd., of Vancouver, British Columbia, Canada, performed preliminary metallurgical tests on sulfide concentrates from its 100% owned Dunka Road deposit in northeastern Minnesota. This deposit occurs in the Duluth Complex, a large layered mafic intrusion that contains copper, nickel, cobalt, platinum-group metals, gold, and silver. Fleck tested bacterial leaching to convert nickel, copper, and cobalt sulfides to soluble sulfates. Once in solution, the metals could then be extracted with standard solvent extraction and electrowinning processes (Fleck Resources Ltd., 1997).

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 were derived from a monthly voluntary survey of U.S. cobalt processors. Five of the seven companies canvassed for this survey responded. Estimates were made for the nonresponding companies. U.S. processors produced 1,490 tons of cobalt oxide and hydroxide, inorganic cobalt compounds, and organic cobalt compounds in 1997, a 15% increase from the revised 1,300 tons

produced in 1996. Because this figure includes production of intermediate forms, it does not represent net production. Shipments are defined as sales, transfers, or consumption to make end-use products, such as paint driers and catalysts. In 1997, shipments by U.S. processors included 1,790 tons of cobalt oxide and hydroxide, inorganic cobalt compounds, and organic cobalt compounds, a 6% increase from revised 1996 shipments of 1,690 tons. Two processors made extra-fine cobalt metal powder in the United States. Carolmet, owned by N.V. Union Minière S.A. of Belgium, made cobalt metal powder from imported 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.

U.S. cobalt supply included secondary cobalt from alloy scrap, cemented carbide scrap, and spent catalysts. Spent petroleum catalysts were treated by at least four companies in 1997—Amx Metals Recovery, Inc. in Braithwaite, LA, Dakota Catalyst Products Inc. of Williston, ND, Gulf Chemical and Metallurgical Corp. in Freeport, TX, and OMG Apex, Inc., in St. George, UT. The Dakota Catalyst plant closed during the spring because of financial constraints.

Consumption

Apparent consumption for 1997 (as calculated from net imports, consumption from purchased scrap, and changes in Government and industry stocks) was 20% higher than that calculated for 1996. (See table 1.) The increase was primarily because of a significant increase in cobalt imports. Increased cobalt consumption from scrap in 1997 was more or less counterbalanced by a decrease in shipments from the NDS.

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 tungsten carbide producers. For this survey, more than 100 cobalt consumers were canvassed on a monthly or annual basis. The USGS also canvassed 13 superalloy scrap recyclers to determine the consumption of secondary cobalt in superalloy production. Reported consumption and stocks data in tables 1 and 3 contain estimates to account for nonrespondents.

U.S. reported consumption for 1997 was 12% higher than reported consumption for 1996. As a whole, metallurgical industries consumed 15% more cobalt in 1997 than in 1996. On an industry-by-industry basis, consumption to make superalloys, steels, magnetic alloys, and cemented carbides was higher in 1997; while total consumption to make other alloys was basically the same during the last 2 years. Total reported cobalt consumption in chemical uses increased by 5% in 1997. Consumption in all chemical uses except paint driers increased in 1997 relative to 1996. (See table 3.)

Prices

Market prices for cobalt rose and fell four times during 1997. The average of high and low prices for U.S. spot cathode

(minimum of 99.8% cobalt), as reported by Platt's Metals Week, was lowest in March at \$19 per pound and highest in November at \$26 per pound. Platt's average annual U.S. spot cathode price for 1997 was \$23.34 per pound, down by 8% from that of 1996.

Platt's prices for Zambian cobalt (minimum 99.6% cobalt) and Russian cobalt (minimum 99.3% cobalt) paralleled the U.S. spot cathode price. In March, the spread in prices for the three grades of cobalt was narrowest. Zambian cobalt was only \$0.50 per pound less than cathode, and Russian cobalt was only \$0.75 per pound less. In December, the spread in prices for the three grades of cobalt was widest. Zambian cobalt was more than \$4 per pound less than cathode, and Russian cobalt was more than \$7 per pound less. This \$7 per pound price differential between cathode and Russian cobalt represents the greatest difference in prices between the two grades since Platt's began publishing prices for Russian cobalt in late 1995.

The reference price set by African producers La Générale des Carrières et des Mines (Gécamines) of the Democratic Republic of the Congo (Kinshasa) and Zambia Consolidated Copper Mines Ltd. (ZCCM) remained unchanged at \$27.50 per pound.

Foreign Trade

Seven countries supplied 91% of U.S. imports of unwrought cobalt and cobalt in chemicals. Norway was the leading supplier, followed by Finland, Zambia, Russia, Canada, Congo (Kinshasa), and Belgium. In 1997, the United States imported 26% more cobalt than it did in 1996. Compared with those of 1996, cobalt imports from Congo (Kinshasa), Finland, Norway, and Russia increased significantly; imports from Belgium and Canada decreased; and imports from Zambia were basically unchanged. (See tables 4 and 5.)

In 1997, the United States imported 129 tons, gross weight, of unwrought cobalt alloys valued at \$5.4 million. Four countries supplied more than 90% of these materials—Belgium (30%), Japan and Sweden (22% each), and Congo (Kinshasa) (16%). The United States imported 448 tons, gross weight, of cobalt matte, waste, and scrap, valued at \$7.9 million. Eight countries supplied 93% of these materials—the United Kingdom (26%), Germany (16%), Belgium (13%), Canada and the Netherlands (9% each), South Africa (8%), France (7%), and Japan (5%). The United States also imported 235 tons, gross weight, of wrought cobalt and cobalt articles valued at \$12.9 million. The leading suppliers of these materials were the United Kingdom (46%), Japan (21%), Germany (16%), Norway (7%), France (4%), and Canada (3%).

U.S. exports of unwrought cobalt and cobalt contained in chemicals decreased by 6% compared with those of 1996. In 1997, more than three-fourths of the cobalt metal and chemical exports was shipped to eight countries—Belgium, Brazil, Canada, France, Germany, Mexico, the Netherlands, and the United Kingdom. The remainder was shipped to 41 other countries. (See table 6.)

Exports also included 759 tons, gross weight, of wrought metal and cobalt articles valued at \$36.6 million. More than 80% of these materials was sent to seven countries—Hong Kong (31%), the United Kingdom (24%), the Netherlands (8%), Canada (7%), Japan (5%), and Germany and Sweden (4% each). The remainder was shipped to 34 other countries.

World Review

World cobalt production in 1997 basically equaled that of 1996. Refinery production reported by the eight Cobalt Development Institute (CDI) member producers was about equal to that of 1996. Total cobalt availability, as estimated from production by CDI members and non-members (excluding Russia), imports from Russia to other countries, and stockpile releases from the NDS, was 28,700 tons. World demand (excluding internal demand by the Commonwealth of Independent States) was estimated to be approximately 28,000 tons, a 12% increase over that of 1996 (Cobalt Development Institute, 1998).

Australia.—In January, QNI Ltd. began commissioning a new cobalt plant at its Yabulu nickel-cobalt refinery in Townsville, Queensland. The plant was designed to convert Yabulu's cobalt sulfide to cobalt oxide hydroxide, which would be sold as feedstock for the production of cobalt chemicals. Cobalt production from Yabulu during the 12-month period ending June 30, 1997, was 1,482 tons, a 4% increase from that of 1996. The refinery processed nickel laterites from PT Aneka Tambang in Indonesia, Hinatuan Mining Corp. in the Philippines, and four mining companies in New Caledonia (QNI Ltd., 1997a).

In September, QNI shareholders approved a merger with the nickel division of Billiton Plc of the United Kingdom, formerly part of South Africa's Gencor Ltd. As a result of the merger, QNI acquired Billiton Nickel's Cerro Matoso ferronickel operations in Colombia, joint-venture interests in the Lake Johnston and the Roundtop nickel sulfide projects in Western Australia, rights to use Billiton's nickel-processing technologies, and rights to exploration and development projects in Cuba, Canada, Indonesia, and South Africa (Platt's Metals Week, 1997a; QNI Ltd., 1997b).

WMC Ltd. produced an estimated 1,170 tons of cobalt in intermediate products as a byproduct of mining, smelting, and refining nickel sulfide ores in Western Australia (Matheson, 1998). The intermediate products were exported to be refined.

Outokumpu Australia Pty. Ltd. produced nickel concentrates from its Forrester Mine and concentrator southwest of Kalgoorlie in Western Australia. Outokumpu also received nickel concentrates from WMC's Mount Keith operation and the Outokumpu/Mining Project Investors Pty. Ltd. Silver Swan operation. Concentrates from these three nickel sulfide operations, containing an estimated 400 tons of cobalt, were exported to Finland for treatment at Outokumpu's Harjavalta refinery (Matheson, 1998).

Anaconda Nickel Ltd. completed the financing and moved forward with developing its Murrin Murrin nickel-cobalt project. The Murrin Murrin deposit, located between Leonora and Laverton, Western Australia, was reported to contain nickel laterite reserves of 132 million tons at 0.95% nickel and 0.06% cobalt. Anaconda planned to mine the deposit by open-pit methods and to produce nickel and cobalt metal powders by using the following process: pressure acid leaching, mixed sulfide precipitation and re-leaching, solvent extraction, and then hydrogen reduction and briquetting. The project was on schedule for commissioning the leach circuit in September 1998 and the refinery in December 1998. Stage I production was planned to be at rates of 45,000 tons per year of nickel and 3,000 tons per year

of cobalt. Anaconda was considering increasing the cobalt production to approximately 4,000 tons per year. Detailed engineering was underway for stage II of the project, which would increase production to 70,000 tons per year of nickel and 4,500 tons per year of cobalt. In addition, Anaconda began investigating two nearby laterite deposits. A feasibility study on the first of these, the Eucalyptus project, was scheduled for completion in September 1998, and a prefeasibility study on the Marshall Pool project was scheduled for completion in June 1998. Development of these deposits would increase Anaconda's total cobalt output to 12,000 tons to 15,000 tons per year (Monti, 1998).

Resolute Ltd. finalized the funding for its Bulong nickel-cobalt project and began work at the mine and plant site. The deposit, located east of Kalgoorlie in Western Australia, is a nickel laterite and has a reported resource of 140 million tons at 1.0% nickel and 0.09% cobalt. Ore would be refined by pressure acid leaching, followed by solvent extraction and electrowinning to produce nickel cathode and cobalt cathode. Resolute planned to develop the project in two stages—initial production of approximately 9,000 tons per year of nickel and 700 tons per year of cobalt, followed by an expansion to 22,000 tons per year of nickel and 1,700 tons per year of cobalt. The project was on schedule for commissioning in April 1998 (Platt's Metals Week, 1997d; Resolute Ltd., 1997).

Centaur Mining & Exploration Ltd. arranged full funding for its Cawse nickel-cobalt project and progressed with engineering design, metallurgical testwork, and project construction. The project is based on a laterite deposit northwest of Kalgoorlie in Western Australia. Centaur will mine the deposit by using open-pit methods and will produce two ore blends, one consisting of siliceous cobalt ore and a second consisting of a nickel-rich blend of limonite, talc, and nontronite. The ore blends would be combined and pressure acid leached. An intermediate nickel-cobalt hydroxide would be produced, and then re-leached in ammonia. Nickel would be recovered by solvent extraction and electrowinning. Cobalt would be produced as a sulfide, which would be sent elsewhere for further processing. The project was designed to produce as much as 11,000 tons per year of nickel and 1,800 tons per year of cobalt, although more cobalt could be produced by adjusting the process parameters. Centaur planned to begin full-scale mining in March 1998 and was on schedule for nickel and cobalt production during the third quarter of 1998 (Hellsten and Napier, 1998).

Calliope Metals Corp. continued work on a feasibility study for a nickel-cobalt refinery to be built in Gladstone, Queensland. The company planned to use Sherritt International Corp.'s pressure acid leaching technology to treat limonitic ore imported from New Caledonia. Initially, Calliope planned to produce a nickel-cobalt mixed sulfide. During the year, Calliope received a positive detailed engineering study for the mixed sulfide refinery and decided to expand the project to include metal production. The expanded refinery would be designed with production rates of approximately 20,000 tons per year of nickel and 2,000 tons per year of cobalt as briquetted metal powders (Calliope Metals Corp., 1997a, b).

Belgium.—Union Minière converted cobalt metal, residues, and other cobalt-bearing materials into cobalt metal powders, oxides, hydroxides, and salts at its facilities in Olen, Belgium. To

meet the increased demand for cobalt oxide to make rechargeable batteries, Union Minière planned to install a new furnace in 1998. Following installation of the furnace, Union Minière's cobalt oxide capacity would increase to 7,500 tons per year from the current 2,500 tons (Metal Bulletin, 1997e).

Brazil.—Cia. Niquel Tocantins produced cobalt cathode at its refinery in Sao Miguel Paulista, Sao Paulo State. The refinery used lateritic nickel ore from Niquelandia, Goias State, as feed.

Rio Tinto Plc progressed with construction of the mine, mill, and smelter complex at its Fortaleza de Minas nickel sulfide project in Minas Gerais State. During the year, Rio Tinto decided against building a refinery at Fortaleza. All the matte produced at Fortaleza was to be sold to Outokumpu Oyj for refining at its Harjavalta refinery in Finland. In December, Rio Tinto began commissioning the smelter (Metal Bulletin, 1997a).

Canada.—Falconbridge Ltd.'s smelter in Sudbury, Ontario, produced cobalt in nickel-copper matte from ores mined at the company's Sudbury operations and from custom feed materials. Matte from the Sudbury smelter was refined at Falconbridge's Nikkelverk refinery in Norway. In December, Falconbridge began producing concentrates at its Raglan Mine in the Ungava region of northern Quebec. Shipments of concentrates from Raglan to the Sudbury smelter were expected to begin during the first quarter of 1998 (Falconbridge Ltd., 1998).

Inco Ltd. produced cobalt oxide at its Thompson, Manitoba, refinery and cobalt cathode at its Port Colborne, Ontario, refinery from feed materials originating from nickel mines in Thompson, Manitoba, and Sudbury, Ontario, respectively. In 1997, Inco produced 1,500 tons of cobalt, a slight decrease from the 1,544 tons produced in 1996 (Cobalt Development Institute, 1998). In November, Inco announced plans to restructure its Ontario and Manitoba divisions to maximize profitability. The company planned to reduce capital expenditures and staff levels and to rationalize and close higher cost mines in Ontario and Manitoba in favor of advancing lower cost projects, such as Voisey's Bay in Labrador and Goro in New Caledonia (Inco Ltd., 1997a).

Inco continued exploration drilling and geophysical work on its Voisey's Bay nickel-copper-cobalt-sulfide deposit in northeastern Labrador. On the basis of drilling results from 1997, Inco was developing a new deposit model and revising its reserve estimate for the Ovoid section of the deposit. In December, Inco subsidiary Voisey's Bay Nickel Co. Ltd. submitted the environmental impact statement for the mine, mill, related facilities, and infrastructure for the Voisey's Bay project. Inco anticipated that owing to delays in the environmental review and approval process, initial production from the mine and mill would be delayed by at least 1 year, or until late 2000 at the earliest (Inco Ltd., 1997b, 1998a).

Sherritt International Corp. worked to remove bottlenecks and to improve production at its Fort Saskatchewan, Alberta, refinery. As a result of these efforts, the refinery's capacity was expanded by 14%, to approximately 2,600 tons. Sherritt postponed the annual maintenance shutdown and produced a record 2,496 tons of cobalt in 1997, a 20% increase from the 2,074 tons produced in 1996 (Sherritt International Corp., 1998). Most of the feed for the refinery was in the form of nickel-cobalt mixed sulfides from Moa Nickel S.A. of 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.

Cobatec Inc. (formerly Ego Resources Ltd.) recommissioned its hydrometallurgical cobalt refinery in North Cobalt, Ontario. Late in the year, Cobatec, which produces cobalt carbonate and nickel oxide, announced that it was going to receive Cuban nickel-cobalt sulfide precipitates under a long-term feed supply agreement with the Government of Cuba. Under the agreement, Cuba was to supply enough feed for Cobatec to produce 1,000 tons per year of contained cobalt and 2,000 tons per year of contained nickel (Cobatec Inc., 1997, 1998).

Canmine Resources Corp. continued its exploration of cobalt and nickel deposits in the Werner Lake Belt of southwestern Ontario-southeastern Manitoba. During the year, the Werner Lake cobalt project was brought to an advanced exploration stage. The deposit is a Precambrian calcic cobalt skarn. Ore encountered during exploration averaged 0.59% cobalt, although some sections assayed as high as 20% cobalt. Canmine developed an underground ramp into the deposit and stockpiled ore while it began construction of a test flotation mill. The company continued work on calculating the deposit's resources and began an engineering study on the feasibility of installing a pressure leach autoclave to upgrade the concentrate to cobalt carbonate. Production was planned to begin in mid-1998, with approximately 300 tons of cobalt in concentrate to be produced from test milling during the first year. The mine is being developed on a 50% joint-venture basis with Red Engine Resources Corp. (Canmine Resources Corp., 1997; Werner Lake cobalt deposits, Ontario, accessed February 5, 1998, at URL <http://www.canmine.com/werner.htm>).

China.—Cobalt was produced from domestic and imported raw materials. At Jinchuan, Gansu Province, cobalt metal was produced as a byproduct of nickel from the refining of domestic nickel sulfide ores. The Ganzhou cobalt refinery in Jiangxi Province produced cobalt metal and salts from cobalt arsenide concentrates imported from Morocco. Minor production sites included the Zibo Cobalt Works in Shandong Province, where cobalt metal was produced from iron ore from Shandong Province and copper ore from Shanxi Province.

Congo (Kinshasa).—Following a series of rapid military actions during late 1996 and early 1997, forces opposed to the former Government of Zaire assumed control in May 1997 and renamed the country the Democratic Republic of the Congo. Cobalt production decreased in 1997 partly because of the depletion of stockpiled cobalt hydrates and the poor state of the production facilities at Luilu (Mabolia, 1998). During the year, Gécamines continued to make arrangements with foreign companies and financial organizations to increase future cobalt production from the Congo. Gécamines worked to renovate the flooded KOV open-pit mine near Kolwezi in the Western Group and secured financing from a coalition of South African banks to develop two new high-grade cobalt open-pit mines—Tilwezembe in the Western Group and Kababankola in the Central Group (Mbaka, 1998; Platt's Metals Week, 1997b). In addition, Gécamines negotiated with South Africa's Iscor Ltd. on a project to rehabilitate the Kamoto underground mine in the Western Group. This mine, which suffered a major collapse in 1990, had been a major source of Gécamines' copper and cobalt ores. In mid-1997, KGHM Polska Miedz S.A. of Lubin, Poland, began production at the Mushosi and the Likashi copper-cobalt mines

(Mabolia, 1998; Platt's Metals Week, 1997c).

In April, OM Group and l'Enterprise Generale Malta Forrest SPRL (EGMF), a subsidiary of George Forrest International SA, signed an agreement with Gécamines to develop the Luiswishi copper-cobalt deposit 30 kilometers north of Lubumbashi. Under the agreement, EGMF would develop the mine and build a concentrator. Production was scheduled to begin in late 1997 at a rate of approximately 8,000 tons per year contained copper and 4,000 tons per year contained cobalt. All concentrates would be sent to OM Group's Kokkola refinery in Finland to be refined (OM Group, Inc., 1997b).

In June, OM Group announced that it had signed an agreement with S.A. Groupe George Forrest and Gécamines to build a smelter at Lubumbashi. The smelter would be used to upgrade slags stockpiled at Lubumbashi to a cobalt-copper alloy, which would be shipped to Kokkola to be refined. The feasibility and engineering work for the smelter had been completed at the time of the announcement. OM Group planned to begin production from the smelter in 1999. The stockpile was expected to be able to supply the smelter for 20 years at a production rate of 5,000 tons per year of contained cobalt (OM Group, Inc., 1997a).

In October, International Panorama Resource Corp. of Vancouver, British Columbia, Canada, received the results of a feasibility study on its Kambove-Kakanda tailings project. The project is a joint venture with Gécamines to produce copper and cobalt from raw materials located near Gécamines' Kambove and Kakanda concentrators. The feasibility study proposed a leaching-solvent extraction-electrowinning plant to produce at a rate of 3,500 tons per year of cobalt and up to 54,000 tons per year of copper. The project life would be 14 years. During the first 7 years, the plant would process stockpiled tailings from Kakanda. Production during the second half of the project would be from locally mined ore. Although the feasibility study showed the project to be economic as proposed, International Panorama was considering downsizing the project to attract financing. The company planned to investigate the economic viability of reducing the output to 1,000 tons per year of cobalt and 10,000 tons per year of copper and producing cobalt as an intermediate product. International Panorama was negotiating with mining companies and international banks to arrange financing and hoped to begin construction by mid-1998 and production by 2000 (International Panorama Resource Corp., 1997; Munford, 1998).

Tenke Mining Corp. (formerly called Consolidated Eurocan Ventures Ltd.) of Vancouver, British Columbia, Canada, began a full feasibility study on the development of copper-cobalt deposits at Tenke and Fungurume. The Tenke Fungurume concessions, located between the towns of Kolwezi and Likasi in the Shaba Province's copper belt, are owned by Tenke Mining (55%) and Gécamines (45%) under a joint-venture agreement. Tenke Mining was considering various funding options for the project and planned to finalize its funding strategy and to finish the feasibility study in June 1998. Production could begin in late 2000 at an initial rate of 100,000 tons per year of copper, followed by an increase to 200,000 tons per year of copper in the fifth year. Cobalt output would be dependent on sales contracts at approximately 5,000 tons per year during the initial phase, and increasing to 12,000 tons per year in later years (Tenke Mining Corp., 1998).

In addition to working on the feasibility study, Tenke Mining also explored the Dipeta syncline, a geologic structure located between the Tenke and the Fungurume deposits. In November, Tenke Mining reported that exploration results from Dipeta nearly doubled the resource estimate in the Tenke Fungurume concession to 419 million tons containing 18.4 million tons of copper and 898,000 tons of cobalt (Platt's Metals Week, 1997e).

In April, America Mineral Fields Inc. of Hope, AR, was awarded a joint-venture project with Gécamines to recover copper and cobalt from flotation tailings accumulated during past production at Kolwezi. America Mineral Fields began a technical feasibility study to evaluate the ore reserves, to evaluate the physical and chemical characteristics of the tailings for mining and metallurgical performance, and to consider the design and engineering for the project. At yearend, however, the project had not yet been formally ratified by the Congo Government and was in danger of being terminated (America Mineral Fields Inc., 1997a, b).

In September, First Quantum Minerals Ltd., of Vancouver, British Columbia, Canada, signed a joint-venture agreement with Gécamines to acquire a 51% interest in the Luilu and the Kingamyambo tailings dumps at Gécamines' Kolwezi district. The Luilu tailings dump was estimated to contain from 20 million to 30 million tons of tailings at 2% to 3% copper and 0.2% to 0.4% cobalt. The Kingamyambo sulfide tailings dump was estimated to contain from 15 million to 25 million tons of tailings grading 1% to 2% copper and 0.1% to 0.3% cobalt. According to the agreement, First Quantum will finance a feasibility study and develop a project to recover the copper and cobalt. The company began a detailed independent evaluation of the dumps that included drilling, assaying, and metallurgical testing of the tailings. In addition, it was pursuing similar agreements with Gécamines on other tailings dumps (First Quantum Minerals Ltd., 1997).

Côte d'Ivoire.—Falconbridge, Trillion Resources Ltd., and Société de Développement Minière de la Côte d'Ivoire (SODEMI) continued exploration work on nickel laterite deposits in western Côte d'Ivoire. Falconbridge completed a study on hydrometallurgical ore treatment and presented it to the joint-venture partners and the government (Falconbridge Ltd., 1998).

Cuba.—Moa Nickel S.A. mined nickel-cobalt laterites at Moa Bay and produced mixed sulfides containing 26,512 tons of nickel and cobalt, a slight increase from the 26,034 tons produced in 1996 (Sherritt International Corp., 1998). The mixed sulfides produced at Moa were refined by The Cobalt Refinery Co. Inc. in Fort Saskatchewan, Alberta, Canada. Moa Nickel S.A. and The Cobalt Refinery Co. are part of the Metals Enterprise, which is jointly owned by Sherritt International Corp. and General Nickel Co. S.A.

WMC continued negotiations with state-owned Commercial Caribbean Nickel S.A. to finalize detailed plans for a joint-venture project to evaluate and possibly develop the Pinares de Mayari West nickel laterite deposit in Holguín Province.

As part of the merger between QNI and Billiton (*see Australia section of this report*), QNI acquired Billiton's San Felipe nickel laterite project in the Camaguey Province. At the time of the merger, the contract to explore the San Felipe project area was awaiting approval by the Cuban Government (QNI Ltd., 1997b).

Nickel and cobalt of Cuban origin cannot be imported into the United States because of a U.S. embargo on imports from Cuba.

Finland.—OM Group, Inc., produced a record 5,000 tons of cobalt in cobalt metal powders, oxides, and salts, 20% more than the 4,160 tons produced in 1996 (Cobalt Development Institute, 1998). The Kokkola Chemicals Oy refinery processed cobalt-bearing materials from Gécamines' operations in Congo (Kinshasa); Outokumpu's Harjavalta refinery; QNI's Yabulu refinery in Queensland, Australia; and elsewhere.

Outokumpu was expected to produce 600 tons of cobalt metal powder at its Harjavalta nickel refinery in 1997 (Metal Bulletin, 1997b). Raw materials for the nickel refinery are imported from the Nikkel og Olivin Mine in Norway, the Mount Keith and the Forrestania Mines in Western Australia, and the Fortaleza nickel complex in Brazil.

Indonesia.—State-owned P.T. Aneka Tambang (Antam) exported lateritic nickel ore to QNI's Yabulu refinery in Queensland, Australia, for processing. Several companies worked with Antam on projects to explore and develop Indonesia's nickel-cobalt laterite resources. QNI began a study on a potential nickel and cobalt refinery that would use laterites from Obi and Halmahera Islands. Weda Bay Minerals Inc. of Vancouver, British Columbia, Canada, explored nickel laterites on Halmahera Island. BHP Minerals began a feasibility study on developing a lateritic nickel prospect on Gag Island.

Japan.—Sumitomo produced electrolytic cobalt, cobalt oxide, and cobalt salts as a byproduct of nickel at its Niihama Nickel Refinery in Ehime Prefecture. Sumitomo's 1997 metal production was 15% higher than that of 1996.

Madagascar.—Phelps Dodge Mining Co., of Phoenix, AZ, began environmental and feasibility studies on a nickel-cobalt laterite deposit located approximately 80 kilometers east of the capital city of Antananarivo in central Madagascar. An overall resource of approximately 168 million tons of ore at a grade of 1.11% nickel and 0.10% cobalt was reported to be indicated on the basis of detailed drilling and the results of past exploration in the area (Phelps Dodge Corp., 1998).

Mexico.—International Curator Resources Ltd. of Vancouver, British Columbia, Canada, continued its investigation of the Boleo copper-cobalt deposit near Santa Rosalia, Baja California. A prefeasibility study completed in September recommended an open-pit mine with production rates of 49,000 tons per year of copper, 16,600 tons per year of zinc, and 3,500 tons per year of cobalt during the first 10 years of a 17-year mine life. During the year, pilot plant studies of the acid leach-precipitation-flotation process to produce copper-cobalt concentrate were completed, and roasting parameters for the concentrate were optimized. Pilot plant studies of the final stage of the process, solvent extraction-electrowinning, were planned for 1998. In December, International Curator exercised its option to purchase a 100% working interest in the Boleo property (International Curator Resources Ltd., 1997, 1998).

Morocco.—Cie. de Tifnout-Tiranimine produced cobalt concentrates and cobalt metal. Cobalt concentrates from the Bou-Azzer Mine were exported to China for refining. Cobalt tailings from past mining operations at Bou-Azzer were pretreated at a plant near the mine, and then refined to cathode at a plant near the Guemassa Mine.

New Caledonia.—Lateritic nickel ore from J.C. Berton Mines, Nickel Mining Corp., Société Minière du Sud Pacifique, and Société des Mines de la Tontouta was exported to QNI's Yabulu refinery in Queensland, Australia, for processing. Nickel matte from Société Métallurgique Le Nickel's Doniambo smelter was sent to Eramet-SLN's refinery in Sandouville-LeHavre, France, where it was refined into nickel cathode, nickel chloride, and cobalt chloride.

In October, Eramet-SLN and QNI began a joint feasibility study for a nickel-processing plant to be built in the northern province of New Caledonia. The proposed plant would process lateritic ores from SLN's mines by using the hydrometallurgical process used at QNI's Yabulu refinery. The nickel-cobalt carbonate produced at the New Caledonian plant would be further refined at Eramet's Sandouville refinery and QNI's Yabulu refinery (Eramet Group, 1998).

Following completion of feasibility and environmental impact studies on its 85% owned Goro nickel-cobalt laterite project in southern New Caledonia, Inco announced that the project would be advanced to the next stage. The company planned to build a pilot plant to demonstrate and validate the proprietary pressure acid leaching-solvent extraction process it developed to treat the ores. The pilot plant was expected to be completed in early 1999. Inco was considering a commercial plant with an initial annual capacity of 27,000 tons of nickel and 2,700 tons of cobalt (Inco Ltd., 1998b).

Norway.—Falconbridge expanded the capacity of its Nikkelverk refinery to 4,000 tons of cobalt per year. Production in 1997 was 3,417 tons of cobalt cathode, a 10% increase from the 3,099 tons produced in 1996 (Cobalt Development Institute, 1998). Feedstock for the refinery was in the form of matte from company operations in Sudbury, Ontario, Canada, BCL Ltd. in Botswana, and elsewhere. Approximately three-quarters of the cobalt produced at Nikkelverk originated from custom feeds (Falconbridge Ltd., 1998).

Papua New Guinea.—Highlands Pacific Ltd. began a feasibility study of its 65% owned Ramu River nickel-cobalt laterite project; it planned to complete the study in 1998. A production rate of 33,000 tons per year of nickel and 2,800 tons per year of cobalt was being considered, with initial production beginning in the first quarter of 2001. Nord Pacific Ltd. owns the remaining 35% of the project, which is located in the Mandang region of Papua New Guinea (Metal Bulletin, 1997d).

Philippines.—Lateritic nickel ore from Hinatuan Mining Corp. was exported to QNI's Yabulu refinery in Queensland, Australia, for processing. In August, Hinatuan signed a long-term ore-supply agreement with Philnico Mining and Industrial Corp., 90% owner of the Nonoc nickel-cobalt mine and refinery complex in Surigao del Norte, Nonoc Island. Ore deliveries to Nonoc were scheduled to begin following the anticipated recommissioning of the refinery in 1999 (Metal Bulletin, 1997c).

During the year, Pacific Nickel Ltd. (formerly Arboyne NL) held negotiations with Kvaerner Metals Ltd. regarding the rehabilitation of the Nonoc refinery. Pacific Nickel Ltd.'s option to acquire a 100% interest in Pacific Nickel Holdings Ltd., owner of Philnico Mining and Industrial Corp., expired in early September 1997. At yearend, the status of the Nonoc project was not clear (Mining Journal, 1998).

Russia.—Russian cobalt continued to contribute to Western supply in 1997. Nickel and cobalt production in Russia involves a complex flow of ores, flotation concentrates, precipitates, and mattes between various production sites. The main feed materials are domestic nickel-copper sulfide ores, nickel laterite ores from Russia and Kazakstan, and imported nickel- and cobalt-bearing secondary materials. Refined cobalt is produced at four locations—Norilsk Nickel Joint Stock Co. refineries at Norilsk in Siberia and Monchegorsk on the Kola Peninsula, 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. Norilsk Nickel produces the majority of Russia's cobalt. In 1997, combined cobalt production from Norilsk's two refineries was 37.5% higher than that of 1996. Norilsk planned to reequip its cobalt production capacity, to increase future cobalt recovery by improving the process technology for treating nickel-pyrrhotite concentrates, and to begin producing cobalt salts at the Severonikel refinery in Monchegorsk (Interfax International Ltd., 1998).

South Africa.—South Africa produced cobalt from domestic mining operations and imported intermediate materials. Two companies produced refined cobalt as a byproduct of platinum mining and refining. Rustenburg Base Metal Refiners Pty. Ltd. produced cobalt sulfate, and Impala Platinum Ltd. produced cobalt metal powder.

In 1997, the Nkomati joint venture between Avmin Ltd. (75%) and the Anglo American Corp. of South Africa Ltd. (25%) began production at the Nkomati nickel sulfide mine in the Mpumalanga Province; cobalt was a byproduct.

Union Minière subsidiary Union Mineral Concentrators Pty. (UMC) treated imported low-grade cobalt-containing residues in Roodepoort, near Johannesburg. During the year, the plant was modernized, and UMC began producing cobalt chemicals (N.V. Union Minière S.A., 1998). Intermediate materials formerly produced by UMC had been refined at Union Minière's cobalt plant in Olen, Belgium.

In February, Colossal Resources Corp. announced that it had signed an agreement with Barplats Mines Ltd. of Johannesburg, South Africa, to acquire Barplats Refineries Pty. Ltd. Barplats Refineries' complex in Brakpan, South Africa, includes a base metals refinery and the buildings housing Colossal's cobalt pilot plant. Colossal intended to reengineer the refinery to upgrade the alloy from its Kabwe, Zambia, plant to cobalt chemicals or metal. The capacity of the refinery was expected to be about 720 tons per year of contained cobalt. It was to be operated by Colossal subsidiary SACOLCo Pty. Ltd. (Colossal Resources Corp., 1997).

Tanzania.—Sutton Resources Ltd. and Anglo American Corp. of South Africa entered into a joint-venture agreement regarding the Kabanga nickel-cobalt project in northwestern Tanzania. Under the agreement, Anglo American would operate the project and earn a 60% interest by completing a feasibility study, arranging some of the financing, and developing the mine.

Uganda.—Banff Resources, Ltd., of Vancouver, British Columbia, Canada, completed the financing arrangements and began construction on its Kasese cobalt project. Banff retained its 55% equity in the project, the Ugandan Government reduced its equity to 25%, and the remaining equity is owned by the International Finance Corp., Proparco (an affiliate of the French

Development Bank), and Ugandan shareholders. The Kasese project entails building a refinery to recover cobalt from pyrite concentrates stockpiled during past production at the Kilembe copper mine in southwestern Uganda. The refinery will use bioleaching followed by solvent extraction and electrowinning to produce cobalt cathode. Banff expected to complete construction of the refinery in November 1998 and to begin producing cobalt cathode during the first quarter of 1999. The stockpiled concentrates will support production at a rate of 1,000 tons of cobalt per year for about 10 years. As part of the project, Banff is also building a powerplant to supply electricity to the refinery (Troch, 1998).

In October, Banff completed a feasibility study on reopening the Kilembe Mine. The study concluded that it would not be economic to reopen the mine in the foreseeable future, but that it would be feasible to reprocess copper concentrate tailings stockpiled at Kilembe. Cobaltiferous pyrite concentrates produced from the copper tailings could provide an additional 4 years of feed for the Kasese refinery (Banff Resources Ltd., 1997).

Zambia.—ZCCM produced 3,949 tons of cobalt metal between January and December 1997, an 18% decrease from the 4,799 tons produced in calendar year 1996 (Cobalt Development Institute, 1998). The program to privatize state-run ZCCM, which began in late 1996, continued during 1997. Most of ZCCM's assets were divided into nine packages for sale by international tender to mining companies and investors. ZCCM planned to retain a minority interest in these operations, which would be managed by the incoming investors. In addition to the nine packages, several other items were for sale by separate negotiations. These included the Konkola Deep mining project, the Konkola North option agreement, and two technical support companies. By yearend, the privatization status of assets relating to cobalt was as follows.

ZCCM's Luanshya division (excluding the Ndola precious metals plant) was awarded to Binani Industries Ltd. of Calcutta, India. Recent production from the Luanshya and Baluba Mines, now incorporated as Roan Antelope Mining Corp. of Zambia Plc, was approximately 48,000 tons per year of copper and 1,200 tons per year of cobalt (Mining Journal, 1997).

The Chibuluma copper project was awarded to a South African consortium composed of Crew Development Corp. of Vancouver, British Columbia, Canada; Metorex Pty. Ltd. of Johannesburg, South Africa; Maranda Mines Ltd., a South African junior mining company; and Genbel Securities Ltd., a South African investment bank. The project is comprised of the Chibuluma West Mine, which has an approximate production of 9,500 tons per year of copper and 200 tons per year of cobalt, and the Chibuluma South ore body. Metorex was to operate the project, and ZCCM was to retain a 15% interest (Crew Development Corp., 1997).

The Chambishi Mine was awarded to Ivanhoe Capital Corp. of Singapore. Although Chambishi would be mined for copper and gold, additional resources within the Chambishi license area contain cobalt (Ivanhoe Capital Corp., 1997).

ZCCM signed an option agreement with Avmin Ltd. of Johannesburg, South Africa, for the Konkola North prospecting area. Under the agreement, Avmin would fund a 2-year exploration program and complete a prefeasibility study. Depending on the outcome of the prefeasibility study, Avmin

would do further investigation and produce a final feasibility study to gain the right to develop the deposit. Konkola North contains potentially economic copper-cobalt resources (Avmin Ltd., Company structure—Base metals, accessed July 10, 1998, at URL <http://www.avmin.co.za/obase.html>).

ZCCM and the Government of Zambia signed a memorandum of understanding with a consortium comprising Zambia Copper Investments Ltd. (ZCI), Gencor Ltd., and Falconbridge Ltd. regarding the Konkola project. ZCI is a Bermuda-registered investment holding company in which Anglo American Corp. of South Africa and De Beers have a 51% shareholding. Its major asset is a 27% holding in ZCCM. The memorandum gave the consortium the right to conduct a feasibility study on the project, which included the existing Konkola Mine and concentrator, the Mufulira smelter and refinery, and the Konkola Deep mining project (Falconbridge Ltd., 1997). ZCCM reported that prior feasibility studies indicated that the Konkola Deep deposit contained 257 million tons of ore grading 3.8% copper and 0.07% cobalt (Zambia Consolidated Copper Mines Ltd., 1997). At midyear, Gencor decided to withdraw from the consortium.

The Kafue Consortium was continuing negotiations on its bid for ZCCM's Nchanga and Nkana divisions. Kafue Consortium members included Noranda Mining and Exploration, Inc., of Toronto, Ontario, Canada; Avmin; Phelps Dodge Mining Co.; and the Commonwealth Development Corp., of London, England. The Nchanga division is ZCCM's largest producer of copper and cobalt. Cobalt concentrates from Nchanga are treated at ZCCM's two cobalt refineries, Nkana and Chambishi, both in the Nkana division. Thus, this bid represented about two-thirds of ZCCM's total copper production and all its refined cobalt output (Noranda Mining and Exploration, Inc., 1997).

Colossal Resources Corp.'s Qasim Mining Enterprises Ltd. processed smelter slag at its pyrometallurgical plant in Kabwe. At the plant, slag from ZCCM's Nkana division was upgraded to a cobalt-copper-iron alloy. In February, Colossal announced that it had signed an agreement to acquire Barplats Refineries Pty. Ltd. (See *South Africa section of this report.*)

Outlook

Cobalt supply is expected to continue to increase in the next few years. U.S. Government offers of cobalt from the NDS are expected to continue at the rate set each year under the AMP until the amount authorized for disposal has been sold. Many cobalt producers are expected to expand their output, and several new producers are planning to begin production in late 1998 or early 1999. The increased production will come from newly mined ore and the refining of stockpiled intermediate materials, such as tailings and slags.

World cobalt demand is also expected to increase. Superalloy production is forecast to increase with the growth in production of jet engines for commercial aircraft, spare engine parts, and land-based gas turbines for power generation. The demand for cobalt in superalloys will generally follow the trends in superalloy production. Increases in cobalt consumption are also expected in the following uses: rechargeable batteries, wear- and corrosion-resistant alloys, and hydroprocessing catalysts for oil refining (Field, 1998; Huston, 1998; Muzyka, 1996; Schenk, 1998; Seth,

1998; Wu, 1998).

In the medium to long term, however, the growth in supply is expected to exceed the growth in demand. If that occurs, then an oversupply situation would develop, and prices would decrease. Lower prices would limit some of the potential future supply by discouraging production from higher cost operations and from projects where cobalt production is discretionary (dependent on cobalt price.)

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TABLE 1
SALIENT COBALT STATISTICS 1/

(Metric tons cobalt content unless otherwise specified)

	1993	1994	1995	1996	1997
United States:					
Consumption:					
Reported	6,480 r/	7,110 r/	7,140 r/	7,470 r/	8,400
Apparent	7,350 r/	8,560 r/	8,740 r/	9,130 r/	11,000
Imports for consumption	5,950	6,780	6,440	6,710	8,430
Exports	795	1,360	1,300	1,660	1,570
Stocks, December 31:					
Industry 2/	810	910	818	770 r/	738
U.S. Government 3/	23,800	22,300	20,700	18,700	17,100
Price: Metal, per pound					
Average U.S. spot cathode 4/	\$13.79	\$24.66	\$29.21	\$25.50	\$23.34
Yearend producer 5/	\$18.00	\$25.00	\$27.50	\$27.50	\$27.50
World Production:					
Mine	21,900	17,800 r/	24,100 r/	26,800 r/	27,000 e/
Refinery	16,600	19,000	22,100	25,200 r/	25,700 e/

e/ Estimated. r/ Revised.

1/ Data are rounded to three significant digits, except prices.

2/ Stocks held by cobalt processors and consumers.

3/ Defense Logistics Agency. Includes material committed for sale pending shipment.

4/ Prices are annual averages reported by Platt's Metals Week.

5/ Price established by La Générale des Carrières et des Mines and Zambia Consolidated Copper Mines Ltd.

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

(Metric tons cobalt content)

	1996	1997
Sales:		
Fiscal year 2/	1,810	1,060
Calendar year	1,020	1,680
Shipments:		
Fiscal year 2/	2,200	1,440
Calendar year	2,050	1,620

1/ Data are rounded to three significant digits.

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

Source: Defense Logistics Agency.

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

(Metric tons cobalt content)

	1996	1997
Consumption by end use:		
Steel:		
Stainless and heat resisting	38	38
Tool	95	112
Superalloys	3,360 r/	4,060
Alloys (excludes steels and superalloys):		
Magnetic alloys	719 r/	778
Other alloys 3/	347 r/	342
Cemented carbides 4/	722	789
Chemical and ceramic uses:		
Catalysts	652	734
Driers in paints or related usage	733	556
Ground coat frit	391 r/	490
Pigments	191	201
Miscellaneous and unspecified 5/	228 r/	300
Total	7,470 r/	8,400
Consumption by form:		
Chemical compounds (organic and inorganic) 6/	1,710	1,700
Metal	3,770 r/	4,180
Purchased scrap	2,000 r/	2,530
Total	7,470 r/	8,400
Stocks, December 31: 7/		
Chemical compounds (organic and inorganic) 6/	275	206
Metal	313 r/	419
Purchased scrap	182	113
Total	770 r/	738

r/ Revised.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Includes estimates.

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

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

5/ Includes feed or nutritive additive, full-alloy steel, glass decolorizer, and mill products made from metal powder.

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)

	1996	1997
Metal: 2/		
Gross weight	5,760	7,070
Cobalt content 3/	5,760	7,070
Value	\$327,000	\$328,000
	thousands	
Oxides and hydroxides:		
Gross weight	824	1,130
Cobalt content 3/	593	815
Value	\$36,200	\$42,800
	thousands	
Other forms:		
Acetates:		
Gross weight	124	208
Cobalt content 3/	30	50
Value	\$1,760	\$2,480
	thousands	
Carbonates:		
Gross weight	61	54
Cobalt content 3/	28	25
Value	\$785	\$658
	thousands	
Chlorides:		
Gross weight	10	68
Cobalt content 3/	3	17
Value	\$102	\$872
	thousands	
Sulfates:		
Gross weight	1,070	1,670
Cobalt content 3/	288	450
Value	\$12,100	\$15,100
	thousands	
Total:		
Gross weight	7,850	10,200
Cobalt content 3/	6,710	8,430
Value	\$378,000	\$390,000
	thousands	

1/ Data are rounded to three significant digits, may not add to totals shown.

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

3/ Estimated from gross weight.

Source: Bureau of the Census, 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)
1996:												
Australia	--	--	--	10	7	\$337	--	--	--	10	7	\$337
Belgium	204	204	\$16,000	213	153	10,100	3	1	\$42	421	359	26,100
Brazil	47	47	2,200	--	--	--	--	--	--	47	47	2,200
Canada	927	927	54,300	60	43	2,580	28	13	585	1,010	983	57,500
Finland	561	561	34,100	408	294	16,700	1,160	311	13,500	2,130	1,170	64,300
France	29	29	3,040	20	14	1,760	--	--	--	49	43	4,800
Germany	100	100	7,640	2	1	152	--	--	--	102	102	7,790
Hong Kong	--	--	--	--	--	--	7	2	60	7	2	60
Japan	8	8	377	22	16	950	(5/)	(5/)	7	30	24	1,330
Netherlands	--	--	--	19	14	874	--	--	--	19	14	874
Norway	1,710	1,710	99,900	--	--	--	(5/)	(5/)	3	1,710	1,710	99,900
Russia	630	630	28,100	5	3	94	40	17	259	676	651	28,500
South Africa	10	10	601	4	3	182	--	--	--	14	13	783
Spain	--	--	--	17	12	519	--	--	--	17	12	519
United Kingdom	17	17	965	43	31	1,840	20	5	313	81	53	3,120
Zaire	396	396	21,200	--	--	--	--	--	--	396	396	21,200
Zambia	1,130	1,130	58,800	--	--	--	--	--	--	1,130	1,130	58,800
Other	(5/)	(5/)	45	-- r/	-- r/	-- r/	4	1	23	4 r/	1 r/	68 r/
Total	5,760	5,760	327,000	824	593	36,200	1,260	349	14,800	7,850	6,710	378,000
1997:												
Australia	--	--	--	5	4	116	--	--	--	5	4	116
Belgium	97	97	6,820	287	207	11,500	41	10	570	426	315	18,900
Brazil	131	131	5,530	--	--	--	2	1	26	133	131	5,550
Canada	949	949	45,400	--	--	--	17	8	397	966	957	45,800
Congo (Kinshasa) 6/	618	618	27,100	--	--	--	--	--	--	618	618	27,100
Finland	917	917	42,700	481	347	16,400	1,790	479	16,600	3,190	1,740	75,700
France	47	47	4,070	28	20	1,910	--	--	--	75	68	5,980
Germany	87	87	5,610	2	1	152	(5/)	(5/)	4	89	88	5,760
Japan	17	17	855	11	8	683	(5/)	(5/)	4	28	25	1,540
Mexico	--	--	--	--	--	--	4	2	76	4	2	76
Morocco	55	55	2,460	--	--	--	--	--	--	55	55	2,460
Netherlands	--	--	--	12	9	529	--	--	--	12	9	529
Norway	1,920	1,920	89,000	--	--	--	--	--	--	1,920	1,920	89,000
Russia	950	950	39,600	12	9	356	33	15	185	996	974	40,100
South Africa	98	98	4,410	(5/)	(5/)	9	4	1	50	102	99	4,470
Spain	1	1	56	4	3	135	--	--	--	5	4	190
United Kingdom	71	71	3,600	287	207	10,800	105	26	1,220	463	303	15,700
Zambia	1,110	1,110	50,900	--	--	--	--	--	--	1,110	1,110	50,900
Other	2	2	118	2	1	84	(5/)	(5/)	3	4	4	205
Total	7,070	7,070	328,000	1,130	815	42,800	2,000	542	19,200	10,200	8,430	390,000

r/ Revised.

1/ Data are rounded to three significant digits; may not add to totals shown.

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

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

4/ Estimated from gross weights.

5/ Less than 1/2 unit.

6/ Formerly Zaire.

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

TABLE 6
U.S. EXPORTS OF COBALT IN 1997, 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)
Argentina	7	\$264	18	\$378	--	--	--	--	20	\$642
Australia	8	271	4	147	--	--	--	--	11	417
Belgium	201	12,700	15	290	--	--	1	\$24	212	13,000
Brazil	47	1,270	16	685	88	\$1,130	31	420	88	3,500
Canada	230	6,980	12	318	37	337	2	22	248	7,660
Chile	--	--	15	462	--	--	--	--	11	462
Ecuador	1	24	2	72	1	15	2	20	3	131
Finland	1	42	53	1,400	--	--	--	--	39	1,440
France	65	2,100	1	25	--	--	--	--	65	2,120
Germany	61	2,680	(6/)	10	--	--	--	--	62	2,690
Japan	29	1,150	12	315	--	--	--	--	37	1,470
Korea, Republic of	5	188	36	628	--	--	1	12	31	828
Mexico	22	1,250	83	2,680	325	1,870	(6/)	5	160	5,810
Netherlands	112	3,850	195	5,390	--	--	--	--	252	9,240
Russia	20	76	--	--	--	--	--	--	20	76
Switzerland	24	1,040	5	82	--	--	--	--	27	1,120
Taiwan	8	102	5	47	4	56	--	--	13	205
Thailand	1	37	37	1,040	--	--	--	--	27	1,080
United Kingdom	174	5,270	9	255	--	--	--	--	180	5,520
Venezuela	--	--	14	423	2	25	--	--	11	448
Other	38	1,510	17	333	11	109	5	54	55	2,010
Total	1,050	40,800	548	15,000	469	3,540	42	556	1,570	59,900

1/ Data are rounded to 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 weight.

6/ Less than 1/2 unit.

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

TABLE 7
WORLD ANNUAL COBALT REFINERY CAPACITY
DECEMBER 31, 1997 1/ 2/

(Metric tons cobalt content)

Country	
Australia	2,000
Belgium	1,200
Brazil	500
Canada	5,000
China e/	1,500
Congo (Kinshasa) 3/	17,000
Finland e/	5,600
France	600
Japan	480
Morocco	300
Norway	4,000
Russia e/	8,000
South Africa e/	1,500
United States 4/	900
Zambia	5,000
Total	53,600

e/ Estimated.

1/ Data are rounded to three significant digits; may not add to total shown.

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

3/ Formerly Zaire.

4/ Standby capacity.

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

(Metric tons, cobalt content)

Country 3/	1993	1994	1995	1996	1997 e/
Albania e/ 4/	-- r/	-- r/	--	--	--
Australia 5/	1,900 r/	2,300 r/	2,500 r/	2,800 r/	3,000
Botswana 6/	205	225	271 r/	406 r/	334 7/
Brazil e/	400	400	400	400	400
Canada 8/	5,108	4,265	5,339	5,714 r/	5,700 7/
China e/	240	270	980	190 r/	250
Congo (Kinshasa) 9/ 10/	2,459	826 e/	1,647	2,000 e/	3,500
Cuba 11/	1,061 r/	972	1,591 r/	2,011 r/	2,082 7/
Kazakstan e/ 12/	600	300	300	300	300
Morocco 10/	397	419 r/	537 r/	565	722 7/
New Caledonia e/ 13/	800	800	800	800	800
Russia e/	3,500	3,000	3,500	3,300	3,300
South Africa e/	265 r/	358 r/	288 r/	350	380
Zambia 10/ 14/	4,840	3,600	5,908	7,900 e/	6,100
Zimbabwe e/	90	100	80 r/	95 r/	105
Total	21,900	17,800	24,100 r/	26,800 r/	27,000

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, 1998. 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, Germany, Indonesia, 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/ Calculated from reported and estimated weight of nickeliferous ore.

5/ Figures represent quantities of cobalt contained in intermediate or refined metallurgical products (cobalt sulfide, cobalt oxide-hydroxide, nickel-cobalt sulfide, nickel concentrate, and nickel matte) produced from Australian and imported ores. Cobalt content of lateritic nickel ore, nickel concentrate, and zinc concentrate originating in Australia was estimated as follows, in metric tons: 1993--1,300 (revised); 1994--1,200 (revised); 1995--1,300 (revised); 1996--1,400 (revised), and 1997--1,600.

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

7/ Reported figure.

8/ Figures represent the assay content of cobalt in concentrates produced. The cobalt content of all products derived from ores of Canadian origin, including cobalt oxide shipped to the United Kingdom for further processing and nickel-copper-cobalt matte shipped to Norway for refining, was reported as follows, in metric tons: 1993--2,150; 1994--1,846; 1995--2,016; 1996--2,150 (revised), and 1997--2,157.

9/ Formerly Zaire.

10/ Cobalt content of concentrates.

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

12/ Figures represent 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: 1993--not available; 1994--1,394; 1995--1,400; 1996--1,400, and 1997--1,400.

13/ Series represents estimated recoverable content of ores and intermediate metallurgical products exported from New Caledonia to France. Estimated cobalt content of total ores mined is 6,000 metric tons per year.

14/ Fiscal year beginning April 1 of that stated. Cobalt content of ore milled was as follows, in metric tons: 1993--9,480; 1994--6,747; 1995--8,849 1996--12,000 (estimated), and 1997--9,250.

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

(Metric tons, cobalt content)

Country 3/	1993	1994	1995	1996	1997
Albania: Oxide e/	1	--	--	--	--
Australia: Oxide hydroxide	--	--	--	--	1,453
Brazil: Metal e/	240	240	180	180	180
Canada: Metal, metal powder, and oxide	2,695	2,971	3,269	3,601 r/	3,738
China: Metal e/	190	200	240	230 r/	200
Congo (Kinshasa): 4/ Metal 5/	831	2,329	3,441	3,800 r/ e/	2,808
Finland: Metal powder and salts	2,200	3,000	3,610	4,160	5,000
France: Chloride	144	146	161	174	159
Japan: Metal	191	161	227	258 r/	264
Morocco: Metal e/	--	--	--	100	200
Norway: Metal	2,414	2,823	2,804	3,098	3,417
Russia: Unspecified e/	3,700	4,340	4,450	4,200 r/	4,100
South Africa: Metal powder and sulfate	243	258	190	242	261
Zambia: Metal 6/	3,705	2,482	3,577	5,126	3,949
Total	16,600	19,000	22,100	25,200 r/	25,700

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, 1998. 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, Belgium, Germany, and Slovakia may recover cobalt from imported materials, but production is not reported; available information is inadequate to make reliable estimates of production.

4/ Formerly Zaire.

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

6/ Fiscal years beginning April 1 of that stated.