Nickel

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Stainless steel accounted for more than 60% of primary nickel consumption in the world. In the United States, however, this percentage was only 47% because of the relatively large number of specialty metal industries in the country. Specialty uses included cupronickel alloys, electroless plating, electrolytic plating, high-temperature nickel-chromium alloys, naval brasses, and superalloys and related aerospace alloys. Manufacturers of rechargeable batteries have been using increasing amounts of nickel metal foam.

Nickel in excess of 8% is needed to produce the austenitic microstructure in 300-series stainless steels. The nickel content of some austenitic grades can be as high as 22%. Duplex (ferritic-austenitic) steels generally contain only 2.5% to 5.0% nickel. Sometimes, smaller quantities of nickel (0.2% to 3.8%) are incorporated into low alloy steels to improve their resistance to corrosion. Higher nickel prices since 2001 have encouraged substitution of duplex, ferritic, or martensitic stainless for some applications where austenitic was being used.

Global nickel demand has been growing by about 7% per year since 2000. A large part of this growth has been fueled by increased use of stainless steel worldwide and strong economic growth in China. Global demand for nickel in batteries has grown dramatically since 1995 but still accounts for less than 5% of total nickel demand. The world nickel industry was operating close to capacity in 2003.

Legislation and Government Programs

Decontamination of Radioactive Nickel Metal.—For more than a decade, the U.S. Department of Energy (DOE) has been exploring ways of reusing nickel metal scrap contaminated with trace amounts of natural and manmade radioactive isotopes. The DOE had about 15,700 metric tons (t) of nickel scrap in varying stages of decontamination at the end of 2003. About 9,700 t of volumetrically contaminated nickel ingots was stored at the DOE uranium enrichment facility in Paducah, KY. In December 2003, DOE shipped 2 rail cars carrying 16 metal containers of radioactive metal scrap from Paducah to a test disposal facility in Nevada, but some 44,000 t still remained at Paducah. Another 27,000 t of contaminated scrap may be deemed clean enough for burial. A DOE-funded economic development group was exploring ways of cleaning and recycling the Paducah nickel ingots for industrial use (American Metal Market, 2003).

Environmental Programs.—The Portable Rechargeable Battery Association, a nonprofit trade association, continued to expand its nationwide battery collection and recycling system. The nonprofit public service recycling program was being administered by Rechargeable Battery Recycling Corporation (RBRC) of Atlanta, GA. RBRC was supported by more than 300 manufacturer/marketer licensees at a network of 30,000 collection locations across Canada and the United States. Most of the spent nickel-cadmium (NiCd) and nickel-metal hydride (NiMH) batteries was being shipped to a pyrometallurgical reclamation facility operated by International Metals Reclamation Co., Inc. (Inmetco) (a subsidiary of Inco Limited) at Ellwood City, PA. In late 2003, RBRC decided to expand its program to include not only cellular telephone batteries but the telephones themselves (Rechargeable Battery Recycling Corporation, 2004§[1]).

New U.S. Coinage.—The U.S. Mint produced 2.28 billion commemorative quarters (25-cent coins) in 2003, down from 3.31 billion in 2002. The cupronickel-clad coins were part of the popular 50 State Quarters™ Program. A total of 21.30 billion quarters was minted between December 1998 and December 2003. Between 40 billion and 60 billion quarters will have been minted when the program ends in December 2008. Since each coin weighs 5.67 grams (g) and contains 8.33% nickel, 1,080 t of nickel ended up in the five commemoratives released in 2003. The U.S. Mint began releasing the new golden dollar coin in January 2000. Between January 2000 and December 2002, 1.43 billion dollar coins were minted. An additional 6.2 million were made in 2003. The dollar coin contains 2.0% nickel. The coin, which weighs 8.1 g, is clad with pure copper metallurgically bonded to outer layers of manganese brass containing 4% nickel (U.S. Mint, 2003§). The U.S. Mint began modifying the Jefferson nickel (5-cent coin) in late 2003 in commemoration of the bicentennials of the Louisiana Purchase and the expedition of Lewis and Clark in accordance with Public Law 108-15. Four new designs were to be minted, all solid cupronickel (U.S. Mint, 2004§, 2005§).

National Defense Stockpile.—There has been no nickel in the National Defense Stockpile since 1999.

Exploration

Duluth Complex of Minnesota.—Several mining companies have been actively exploring the Duluth Complex of northeastern Minnesota for platinum-group elements (PGE), copper, and nickel. Exploration efforts have accelerated in recent years because of the projected growth in demand for PGE for use in fuel cells and higher prices for nickel in 2003. The Duluth Complex covers 5,000 square kilometers (km^2) of territory in St. Louis, Lake, and Carlton Counties.

Mesaba Metals Project.—In 2001, Teck Cominco American, Inc. optioned the Mesaba copper-nickel-PGE deposit on the western edge of the Duluth Complex. The Canadian-owned

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

company was considering spending US$530 million to develop the very large low-grade resource. The proposed mining, concentrating, and refining operation would produce four products—a PGE concentrate, copper metal sheet, an impure byproduct concentrate of nickel-cobalt sulfide or hydroxide, and byproduct zinc sulfide or sulfate. The new company was to be called Mesaba Metals, LLC.

The Mesaba deposit is about 19 kilometers (km) south of Babbitt. Longyear Mesaba Company currently holds the mineral rights to most of the property. The State of Minnesota controls many of the remaining tracts. Geologists estimate that the Mesaba deposit contains more than 700 million metric tons (Mt) of resources that could be recovered by open pit mining. The resources average 0.46% copper and 0.12% nickel. An additional 300 Mt of higher-grade resources could be mined by underground methods (Cominco Ltd., 2001). The crushed ore was to have been railed 20 km to Hoyt Lakes and processed at a shuttered iron ore concentrating and pelletizing complex owned by Cleveland-Cliffs Inc. On September 23, 2003, the University of Minnesota's Bureau of Business and Economic Research presented the results of its economic impact analysis of the proposed Mesaba project—an analysis requested by the East Range Joint Powers Board and Teck Cominco. The construction impact would be US$30.5 million in 2005 and would increase to US$168.0 million in 2007 (University of Minnesota—Duluth, Bureau of Business and Economic Research, 2003). However, Teck Cominco had to completely reevaluate its plans for the Mesaba deposit when PolyMet Mining Corporation, a competitor, optioned part of the Hoyt Lakes facility from Cleveland-Cliffs on February 16, 2004. PolyMet has been evaluating the neighboring NorthMet copper-nickel-PGE deposit.

Production

Primary Production.—The United States did not have any active nickel mines in 2003. All of the country's needs were met by imports or recycling. Limited quantities of byproduct nickel were recovered at some copper and precious metal refineries. Stillwater Mining Company has been mining PGE and gold since 1986 from the Stillwater Complex at Nye in Montana's Beartooth Mountains. The ore is associated with the 45-km-long J-M Reef. The company's two mills (Nye and East Boulder) together processed 1.15 Mt of ore and subgrade material in 2003, with a combined mill head grade of 17 grams per metric ton (g/t) palladium and platinum. About 73% of the PGE came from the Stillwater Mine at the eastern end of the reef. The remaining 27% came from the new East Boulder Mine, which began production on January 1, 2002. Concentrates from the Nye and East Boulder mills were being trucked to the company's smelting and refining complex at Columbus, MT, where a filter cake containing approximately 60% palladium and platinum was being produced. In 2003, the refinery also produced byproduct nickel sulfate and shipped 636 t of nickel in solutions or crystals (Stillwater Mining Company, 2004a, p. 1-4; 2004b, p. 6-15).

In November 2002, Stillwater signed a definitive ownership agreement with MMC Norilsk Nickel, the largest producer of nickel and PGE in Russia. Under the agreement, Norimet (a wholly owned subsidiary of Norilsk Nickel) acquired a 51% interest in Stillwater and became the majority shareholder. On June 23, 2003, Stillwater issued 45.5 million shares of its common stock to Norilsk in exchange for US$100 million cash and 27.3 t (877,000 troy ounces) of palladium valued at US$148 million at the time. Stillwater also agreed to purchase 31.1 metric tons per year (t/yr) of palladium from Norilsk Nickel. The U.S. Federal Trade Commission approved the transaction on June 16. That same day, almost 83% of Stillwater's shareholders voted in favor of the sale. On September 3, Norimet acquired additional shares of common stock, giving the Russian company a controlling interest of 55.4% (Stillwater Mining Company, 2004b, p. 20-21).

Limited tonnages of primary nickel are recovered during the refining of some crude oils where it occurs as porphyrins or other organometallic compounds. The nickel content of crude oil is quite variable and reflects several factors, such as density of the oil, the sulfur content of the oil, the field location, geologic occurrence, and geologic age. The nickel is concentrated in flexicoke and other petroleum refinery residues; fly ash, ash sludge, slag, and boiler scale produced at oil-fired powerplants; and spent petroleum refinery catalysts.

Secondary Production.—Inmetco continued to produce nickel-chromium-iron remelt alloy at its metals recovery facility in Ellwood City, PA. Feed materials included chromium and nickel wastes generated by the stainless steel industry as well as filter cakes, solutions, and sludges from the plating industry. Other materials accepted include refractory brick, spent catalysts, and spent nickel-based batteries. Inmetco also reclaims large industrial cells that are used for backup power.

Spent catalysts are another U.S. source of nickel. Nickel incorporated into the structure of some catalysts (such as nickel molybdate) can be recovered when the spent catalyst is autoclaved and separated from its carrier. CS Metals of Louisiana, LLC recovered nickel from spent catalysts at its reclamation facility on the Mississippi River at Convent, LA. The bulk of the catalysts came from oil refining and petrochemical operations. The US$80 million facility, commissioned in October 2000, produces a nickel-cobalt byproduct. The plant has the capacity to produce 2,300 t/yr of contained nickel. CS Metals is owned by CRI Metal Products, Inc. (Houston, TX) (a wholly owned member of the Royal Dutch/Shell Group of companies) (Ryan's Notes, 2002).

Gulf Chemical and Metallurgical Corporation of Freeport, TX, also processes spent catalysts. The Freeport facility can treat nickel/molybdenum and cobalt/molybdenum hydrotreating catalysts that have been poisoned by nickel and vanadium. The nickel ends up as a crude nickel-cobalt alloy byproduct. The nickel-cobalt alloy is produced in an electric furnace and sold to nickel refineries.

Consumption

In 2003, demand for primary nickel in the Western World was reported to be 1.059 Mt, up by 3% from the 1.033 Mt (revised) of 2002. Demand was at an alltime high and broke the record set in 2002 (International Nickel Study Group, 2004a, b). U.S. apparent consumption of primary nickel was 118,000 t, or about 11% of Western demand. U.S. industry consumed an additional 93,400 t of nickel in scrap. Within the United States, the share of primary nickel consumed in the production of stainless and alloy steels increased to 51% in 2003 from 49% in 2002 and 40% in 2001. The significant gain from 2001 was attributed largely to the startup of the new meltshop of North American Stainless (NAS) at Ghent, KY, in February 2002. NAS is a wholly owned subsidiary of Acerinox, S.A. of Madrid, Spain—the third largest stainless steel producer in the world. In addition to Ghent, Acerinox has a 1.0-million metric ton per year (Mt/yr) meltshop at its Campo de Gibraltar plant near Cadiz, Spain (Acerinox, S.A., 2004).

U.S. demand for most nonferrous alloys remained weak. Markets for copper-nickel alloys were especially hard hit. Demand for superalloys—key fabrication materials for jet engines—increased slightly in spite of financial difficulties of many commercial airlines. Sales to the defense sector partially offset weak sales for commercial aircraft (Napier, 2004).

The estimated value of apparent primary nickel consumption in the United States in 2003 was US$1.13 billion, up from US$817 million in 2002. In contrast, apparent primary consumption dropped by 3% to 118,000 t from 121,000 t. The 39% increase in the value of primary consumption resulted because of a 42% increase in the London Metal Exchange (LME) cash price, which more than offset the 3% decline in apparent primary consumption. Total apparent primary consumption plus reported secondary consumption totaled 211,000 t.

Stainless Steel and Low-Alloy Steels.—In 2003, the United States and world demand for nickel continued to be driven by the stainless steel industry. Stainless steel producers accounted for 47% of primary nickel demand in the United States and more than 60% of primary demand in the world. Production of raw stainless steel in Western countries has almost doubled in the past 10 years, growing to 19.45 Mt in 2002 from 11.32 Mt in 1992 (Inco Limited, 2003c, p. 1-10). Because of the high utilization rate, additional melt capacity will have to be brought onstream by 2006 to accommodate the projected growth in demand for stainless steel. There also has been a shift to increasingly larger meltshops, with seven stainless steel companies now having meltshops with capacities larger than 900,000 t. Baosteel Group also was building a 720,000 t meltshop at its No. 1 works in Shanghai, China, scheduled to come onstream in April 2004 (Inco Limited, 2003c, p. 13-14).

Production of raw stainless steel and heat-resisting steel in the United States totaled 2.22 Mt in 2003, up slightly from 2.18 Mt in 2002. This tonnage was the highest annual production ever recorded for the United States and broke the previous record of 2.19 Mt set in 2000. Nickel-bearing grades accounted for 1.37 Mt or 62% of the total stainless steel production for 2003 (American Iron and Steel Institute, 2004a, p. 74-75; 2004b).

Superalloys and Related Nickel-Base Alloys.—About 27% of the primary nickel consumed in the United States was used to make high-performance superalloys and related nickel-base alloys for the aerospace, electric power, and petrochemical industries. U.S. production of superalloys was up 4% from that of 2002 because of improved sales to manufacturers of jet aircraft engines. Sales to manufacturers of turbines for land-based powerplants remained at 2000 levels.

Advanced Castings and Forgings Industry.—Nickel is used in a variety of brass, stainless steel, and superalloy castings. Nickel also is added to gray-iron castings to toughen the iron, promote graphitization, and improve machinability. The U.S. castings industry shipped an estimated 0.98 Mt of steel castings and 2.8 Mt of nonferrous castings in 2003. For comparison, iron castings shipments (gray, ductile, and malleable) were about 8.4 Mt. Several domestic foundries were forced to declare bankruptcy in the 2002-04 period, in part because of competition from East Asia.

Nickel-Based Batteries.—U.S. demand for nickel in rechargeable batteries may now exceed U.S. demand for several other important uses, such as copper-nickel alloys and coinage. U.S. imports of nickel-based batteries from China and Japan have been steadily growing.

Battery Manufacturing.—Cobasys LLC manufactures rechargeable NiMH batteries for electric, internal combustion engine (ICE)-hybrid electric, and fuel cell-battery hybrid vehicles. The main manufacturing plant is at Springboro, OH. Cobasys is a joint venture between ChevronTexaco Technology Ventures LLC and Energy Conversion Devices, Inc. Some of the other companies manufacturing nickel-based batteries in the United States were Eagle-Picher Technologies, LLC (Joplin, MO, and Colorado Springs, CO), Power Sion Inc. (Tampa, FL), Saft America, Inc. (Valdosta, GA), Sanyo Energy (U.S.A.) Corp. (San Diego, CA), and Yuasa America, Inc. (San Diego).

Electric and Hybrid Electric Vehicles.—Growing hybrid electric vehicle sales in North America have increased demand for nickel foam and specialty nickel metal powders, key components in nickel-based rechargeable storage batteries. In 2003, sales of new hybrid vehicles in the United States were estimated to be about 54,000 units. By mid-2004, more than 140,000 hybrid vehicles had been sold in the United States since 1999. Toyota Motor Corporation has produced more than 120,000 Prius sedans worldwide since 1997 and was preparing to manufacture 300,000 units per year at its plants in Japan. Some of the best opportunities for hybrid conversion may lie with vehicles that consume large amounts of fuel, such as city buses and full-size trucks. ISE Research-ThunderVolt, Inc. (San Diego) was using sodium metal/nickel chloride storage batteries (ZEBRA) in its new hybrid transit buses. The buses have a diesel-electric hybrid propulsion system (Hybrid & Electric Vehicle Progress, 2003).

Stocks

On December 31, 2003, U.S. consumer stocks of primary nickel (cathode, pellets, briquets, powder, etc.) totaled 4,910 t—9% more than the 4,510 t (revised) at yearend 2002. Stocks in LME warehouses moved irregularly during 2003, ending at 24,072 t. Monthly LME stocks peaked at 34,392 t on November 30. Data collected by the International Nickel Study Group indicated that, at yearend 2003, world nickel producers (excluding those in Austria, China, former Yugoslavia, and the Ural area of Russia) had approximately 92,800 t of nickel in primary products in stock. About 69% or 63,800 t of the producer material was Class I materials. Class I materials are refined products with a nickel content of 99% or greater (electrolytic cathode, pellets, briquets, rondelles, powder, etc.). All stocks in LME warehouses are Class I. Class II materials include ferronickel, oxide sinter, and East Asian utility nickel—products with a nickel content less than 99% (International Nickel Study Group, 2004b).

Prices

The January 2003 average cash price for 99.8% pure metal on the LME was US$8,026 per metric ton (US$3.641 per pound). The April average was US$7,910 per ton (US$3.588 per pound)—the low point for the year. The monthly average price rose during the summer and fall, eventually peaking in December at US$14,163 per ton (US$6.424 per pound). The average annual price was US$9,629 per ton (US$4.368 per pound). The average price in 2003 was 42% greater than the 2002 average of US$6,772 per ton (US$3.072 per pound).

World Review

The world's leading nickel producer was Norilsk Nickel, followed by Inco. Other major producers were BHP Billiton Plc of the United Kingdom, Eramet Group of France, Falconbridge Limited of Canada, and WMC Resources Limited of Australia. Price volatility since 2001 has made demand forecasting more difficult. The nickel industry has responded by becoming more competitive through recent corporate alliances and new developments in extractive metallurgy.

Australia.—In 2003, Australia was the third leading nickel-producing country in the world and was beginning to rival Canada. Most of the nickel properties under development are in the State of Western Australia. WMC was still the leading nickel producer in Western Australia, recovering 117,722 t of nickel in sulfide concentrate in calendar year 2003, up from 106,423 t in 2002 (WMC Resources Limited, 2004a).

Laterite Operations.—Three nickel laterite mining and processing operations have been commissioned in the Kambalda-Goldfields region since 1998—Bulong, Cawse, and Murrin Murrin. Together, the three will probably add about 60,000 t/yr of nickel to world production capacity.

On March 23, BHP Billiton announced that it would develop its Ravensthorpe project in Western Australia and expand production capacity at its Yabulu nickel-cobalt refinery near Townsville, Queensland, to accommodate the output from Ravensthorpe. The Ravensthorpe mine site is about 45 km inland from Western Australia's Southern Coast and about 155 km west of the Port of Esperance. When the Ravensthorpe/Yabulu project is completed, BHP Billiton will become the third leading nickel producer in the world after Norilsk Nickel and Inco. The capital cost of the integrated project is expected to be about US$1.4 billion. Of the cost, about US$1.0 billion would be required to develop the first of Ravensthorpe's three deposits and to build an onsite ore treatment facility (BHP Billiton Plc, 2004). The remaining US$350 million would be used to expand the Yabulu refinery, extending the life of the refinery by 25 years. The additional production could be available by yearend 2007. Yabulu will continue to process lateritic ores from other parts of the Asia-Pacific region. Since 1986, Yabulu has imported some 43 Mt of ore from Indonesia, New Caledonia, and the Philippines. When the expansion is completed, Yabulu will be able to produce 76,000 t/yr of nickel and 3,500 t/yr of cobalt.

About US$85 million has been spent on the Ravensthorpe project since 1998 for testwork and feasibility studies. Limited site activities have begun. The treatment plant will have two separate processing circuits—one for the iron-rich, high silica limonitic ores, and one for the underlying magnesium-rich saprolitic ores. Ravensthorpe is being designed to produce up to 220,000 t/yr of mixed nickel and cobalt hydroxide intermediate product.

Sulfide Operations.—WMC increased production at its three operations in Western Australia in response to strengthening nickel prices. WMC's smelter near Kalgoorlie produced 99,152 t of nickel in matte, up by 8% from 91,574 t in 2002. WMC continued to evaluate its Yakabindie deposit 25 km south of Mount Keith. The Yakabindie deposit, acquired in early 2001, contains an estimated 289 Mt of resources averaging 0.58% nickel. WMC has shown that large tonnage, low-grade nickel deposits can be mined successfully. More than 45% of WMC's current feed comes from its low-grade Mount Keith deposit in the Northern Goldfields region. According to WMC, Mount Keith has an estimated 299 Mt of proven and probable ore reserves (excluding stockpiles) averaging 0.56% nickel plus 176 Mt of additional resources averaging 0.55% nickel. In 2003, the Mount Keith operation produced concentrates containing 50,004 t of nickel. WMC's other two operations, Leinster and Kambalda, produced 41,806 t and 25,912 t of contained nickel, respectively (WMC Resources Limited, 2004b, p. 10, 30-31, 68).

In January 2003, Central Kalgoorlie Gold Mines Limited (CKGM) released updated information about its Sherlock Bay nickel-copper project on the northern coast of Western Australia. In mid-2003, CKGM (a junior exploration company headquartered in Perth) was reestablished as Sherlock Bay Nickel Corporation Limited (SBNC). Sherlock Bay mining tenements are in the heart of the West Pilbara about 65 km east-southeast of Karratha and Nickel Bay. Texas Gulf Inc. drilled parts of the Sherlock property in 1972-73 and identified 75 Mt of disseminated sulfide resources averaging 0.5% nickel and 0.1% copper. Subsequent drilling indicated that low-grade sulfide mineralization extends at least to a depth of 1,200 meters (m). Four separate ore zones have been identified along 2 km of strike. The nickel mineralization occurs in andesitic and rhyolitic rocks adjacent to the Sherlock ultramafic intrusion of Archean Age. On April 23, CKGM began drilling the northeast section of the Sherlock deposit at a point where the tabular ore body is steeply dipping (RM Capital Pty. Ltd., 2003; Central Kalgoorlie Gold Mines Limited, 2003§).

SBNC also has nickel leases in the Eastern Goldfields area of Western Australia. The company's Cat Camp tenements are 25 km northwest of the new Emily Ann nickel mine operated by LionOre Australia (Nickel) Ltd. The Emily Ann is about 110 km west of Norseman. LionOre began mining the Emily Ann in the fourth quarter of 2001 and commissioned the concentrating plant in the second quarter of 2002. Concentrate was being trucked

350 km to the Port of Esperance for shipment to Inco's Canadian operations (LionOre Mining International Ltd., 2003a§).

In January 2003, LionOre Nickel announced plans to develop the Maggie Hays nickel deposit 3 km south of Emily Ann. At that time, LionOre had a 31% interest in the Maggie Hays. In March, LionOre purchased the remaining 69% from its joint-venture partner BHP Billiton Plc. Maggie Hays is scheduled to begin production in the fourth quarter of 2004. According to LionOre officials, Emily Ann has 1.0 Mt of reserves averaging 3.41% nickel and an additional 0.6 Mt of indicated resources averaging 3.95% nickel. The Maggie Hayes property has 10.8 Mt of indicated resources averaging 1.50% nickel. The entire area is part of the Lake Johnston Greenstone Belt and has several promising gold exploration targets in addition to the nickel discoveries (LionOre Mining International Ltd., 2003c§).

On October 29, 2003, the Federal Court of Australia approved the merger of Dalrymple Resources NL and LionOre Mining International Ltd. The merger consolidated nickel and gold assets held by the two companies in the North Eastern Goldfields region, including the recently discovered Amorac and Waterloo nickel sulfide deposits. LionOre has grown dramatically since 1988 and is now ranked among the top 100 mining companies in the world (LionOre Mining International Ltd., 2003b§).

Australian Mines Ltd. launched a diamond drilling program at the Blair Mine site, 30 km southeast of Kalgoorlie, after an electromagnetic (EM) geophysical survey identified three strong EM targets in the vicinity of the mine. The Blair Mine has been on care and maintenance since 2001 when mining was suspended because of low nickel prices. Officials of Australian Mines Ltd. (formerly West Musgrave Mining Ltd.) believe that down-hole survey data indicate the presence of undiscovered high-grade massive sulfide mineralization. Drilling to date has identified 260,000 t of resources grading 2.6% nickel (MineBox, 2003§).

Brazil.—Companhia Vale do Rio Doce S.A. de C.V. (CVRD) was considering becoming a nickel producer. CVRD is the leading diversified mining company in the Americas in terms of value of mine production of nonfuel minerals and the world's leading exporter of iron ore. In July 2002, the mining giant announced that it had begun a prefeasibility study of the Vermelho (red) nickel deposits in the Serra dos Carajas of northeastern Brazil. The Vermelho laterites, discovered in 1974 during regional exploration of the Carajas area, contain 171 Mt of lateritic ore suitable for autoclaving that averages 1.74% nickel and 0.17% cobalt (Companhia Vale do Rio Doce S.A. de C.V., 2003). The laterites are mineralogically similar to the limonitic laterites of Western Australia and, like the Australian ores, may be amenable to pressure acid leaching.

The Vermelho nickel deposits are 50 km southeast of the existing Carajas iron ore mining complex. Preliminary plans call for a US$700 million, possibly hydrometallurgical, complex to be built adjacent to the proposed nickel mine. The positive prefeasibility study was completed in late 2003 and a bankable feasibility study was launched in early 2004. This second, more rigorous study will help management determine whether the lateritic ores will be converted into ferronickel, nickel oxide, or nickel cathode. The bankable feasibility study could be completed as early as January 2005, with construction beginning shortly afterward, and commissioning planned for late 2007. The plant would have a design capacity of 45,000 t/yr of contained nickel, with the bulk of the nickel going to foreign consumers. The finished products would be trucked 75 km to the Carajas railroad for transport to the Port of Ponta da Madeira. The Vermelho deposits could be an important source of nickel for Companhia Aços Especiais Itabira (ACESITA), which is the largest stainless steelmaker in Latin America and a significant consumer of nickel units. In 2002, ACESITA completed a US$100 million modernization and expansion program that raised the production capacity of its stainless operations to 850,000 t/yr of crude steel from 400,000 t/yr (Metal Bulletin, 2003).

Canico Resource Corporation began the second phase of an infill-drilling program at its Onca-Puma laterite property in Para State. The exploration concession is northeast of the town of Sao Felix do Xingu and about 80 km southwest of Carajas. Inco discovered the nickeliferous laterite deposits during the 1970s. The deposits lie beneath a series of low-lying hilltops and are close to the surface. Inco's original programs of auger drill sampling and test pitting revealed an inferred resource of at least 42 Mt of laterite grading about 2.3% nickel and 0.09% cobalt, based on a cutoff grade of 1.5% nickel. About 11 Mt of the resource lie within an indigenous reserve and would be excluded from the Canico project (Canico Resource Corp., 2003c, p. 2).

The total extent of the Onca-Puma nickel mineralization has not yet been determined. In September 2002, Canico began diamond drilling at the Puma West deposit. On January 20, 2003, Canico released updated resource data for both Puma West and the original Onca site. Combined inferred resources for the two projects have now grown to 53 Mt, averaging 2.2% nickel and 0.08% cobalt. Canico was planning to complete its feasibility study by late 2004. On February 25, Canico acquired 100% of the Brazilian company that holds the rights to Onca-Puma. Inco and Canico jointly managed the concession immediately prior to the February agreement. In exchange for relinquishing its rights to Canico, Inco received 18% of the issued common shares of Canico as well as a number of share purchase warrants (Canico Resource Corp., 2003a, b).

Nickel exploration intensified in several other regions of Brazil as well. CVRD signed exploration protocols with the State governments of Ceara and Piaui as part of the company's ongoing program to diversify into nonferrous metals mining. CVRD has begun evaluating nickeliferous laterite deposits at Capitao Gervasio Oliveira in the southeastern part of Piaui State. If the ongoing studies and tests are positive, CVRD is prepared to invest more than US$500 million in the proposed mine and adjoining pressure acid leaching complex. Company officials envision a hydrometallurgical plant that would produce about 35,000 t/yr of nickel metal—about 30% less than the proposed Vermelho plant and would come online 2 or 3 years after Vermelho (Kinch, 2003).

Solitario Resources Corp. has confirmed high-grade palladium-platinum mineralization with nickel at Pedra Branca in the State of Ceara. In early 2001, Solitario began drilling a number of geophysical anomalies associated with the Pedra Branca ultramafic complex to find near-surface zones enriched in PGE. The Pedra Branca complex is geologically similar to the Bushveld Igneous Complex of South Africa, the leading PGE producing ore system in the world and an important source of byproduct nickel; mines in the Bushveld Complex accounted for 57% of world primary PGE production in 2002 (Solitario Resources Corp., 2003b). Solitario became involved in the Pedra Branca project when it acquired Altoro Gold Corp. in 1999. Solitario initially focused its exploration efforts on the Esbarro deposit where previous drilling had encountered significant thicknesses of shallow PGE mineralization. The 1999-2000 drilling program was conducted under a joint-venture agreement with Rockwell Ventures Inc. (Solitario Resources Corp., 2001a). Rockwell Ventures already had mapped part of the Pedra Branca area and identified three other prospects in addition to Esbarro—Curiu, Ipuerias, and Trapia. Drilling intersected several ultramafic chromatite assemblages with nickel values ranging from 0.04% to 2.65% plus significant PGE values (Solitario Resources Corp., 2001b).

In June 2001, Rockwell Ventures pulled out of the Pedra Branca project, leaving Solitario in control of the property. In November 2001, Solitario launched its own drilling program and subsequently discovered additional mineralization in the Curiu and Trapia areas and identified two other mineralized areas—Cedro and Santo Amaro. Platinum values in the Cedro assemblages ranged from 0.32 to 1.22 g/t; palladium, 0.53 to 3.38 g/t; and nickel, 0.08 to 0.30% (Solitario Resources Corp., 2002). In February 2003, Solitario signed an agreement with Anglo American Platinum Corporation Ltd. (Anglo Platinum) allowing Anglo Platinum to earn a 51% interest in Pedra Branca by spending US$7 million during the next 4 years exploring the 20 PGE prospects identified to date. The project now covers an area 50 km long and 15 km wide. Anglo Platinum, the world's leading producer of platinum, can increase its share to 65% by completing a bankable feasibility study and arranging 100% project financing (Solitario Resources Corporation, 2003a, b).

Canada.—Key events of 2003 are summarized in the nickel chapter of the Canadian Minerals Yearbook (Bill McCutcheon, Natural Resources Canada, written commun. and unpub. data, 2004).

Manitoba.—In February 2002, Donner entered into an agreement with Falconbridge to help explore for nickel in northern Manitoba. Under the terms of the agreement, Donner can earn a 50% interest in Falconbridge's Stephens Lake project by expending Can$5 million on the project before the end of 2006. The Stephens Lake property is almost completely covered by glacial till and covers 3,700 km^2 on the northwest boundary of the Superior Craton. In the current exploration model, the Stephens Lake area is interpreted as an extension of the Thompson nickel belt. Donner and Falconbridge began jointly drilling selected magnetic and conductive anomalies in February 2003 (Donner Minerals Ltd., 2002; 2003a).

Newfoundland and Labrador.—In September 2002, all the stakeholders in the Voisey's Bay deposit of northeastern Labrador finally reached agreement on development after 6 years of negotiations. The deposit, found in 1993, is the most important base-metal discovery in Canada in more than 35 years (Danielson, 1995; Northern Miner, 1995). Inco acquired the Voisey's Bay deposit from Diamond Fields Resources Inc. through a complicated series of financial and stock transactions between 1994 and 1996 at a cost of US$3.7 billion (Dickie, 1996). In addition to developing the deposit, Inco also got agreement to construct a mill/concentrator at the mine site; startup a research and development program that would focus on hydrometallurgical processing technology; construct a hydrometallurgical demonstration plant at Argentia, Newfoundland, for evaluating the commercial feasibility of the new technology; and settling land claims with aboriginal groups in northeastern Labrador.

The concentrator was being designed to process 6,000 metric tons per day (t/d) of ore and could produce concentrate as early as 2006. Inco planned to commission the Argentia hydrometallurgical demonstration plant in 2006 and complete its feasibility studies at the plant by 2008. Construction of a commercial plant at Argentia would require an additional 3 years, with a projected commissioning date of 2011. A scale minipilot plant has been constructed at Inco's research facilities at Mississauga, Ontario, to test variations of the proposed hydrometallurgical process. If all goes well—the pilot plant is now on its fifth campaign—construction of the Argentia demonstration plant could begin in late 2004. The processing technology used in the full-scale plant will depend on the Argentia research and development results. Inco promised to process imported nickel concentrate at Argentia after the proposed plant is commissioned. The imported material would compensate the Province for concentrate shipped between 2004 and 2011 to Inco's smelters at Sudbury, Ontario, and Thompson, Manitoba (Government of Newfoundland and Labrador, Executive Council, 2002).

Since 2002, Inco and its subsidiary (Voisey's Bay Nickel Company Ltd.) have passed several milestones in the first phase of the three-phase project. Inco does not expect to complete the entire project before 2018 (Hand and Jones, 2004). In March 2003, Inco's management decided to proceed after receiving a positive bankable feasibility study from its consulting contractor, SNC Lavalin Group Inc. Crews have begun clearing a site for the concentrator, building roads, and constructing a permanent airstrip (Mining Journal, 2003a; Inco Limited, 2003§). The port was 15% complete at yearend 2003 and probably will be finished by late 2005. At that time, the operators will have stripped sufficient overburden to begin mining, and the concentrator should be finished.

The capital cost estimate for the initial phase has been revised upward to US$776 million from US$680 million. The first phase involves development of an open pit mine in the Ovoid deposit and construction of a 6,000-t/d plant producing three concentrates—cobalt, copper, and nickel. The mine and concentrator are expected to cost US$582 million. The Argentia demonstration hydrometallurgical plant would cost an additional US$134 million. The concentrates produced during the initial mining phase (2006 to 2011) will be processed at Inco's existing smelters at Sudbury and Thompson. The construction of special handling facilities at these two locations will cost US$47 million. The remaining US$13 million of the US$776 million will be spent on additional exploration in Labrador (Inco Limited, 2003b).

In December 2001, Donner Minerals Ltd. and Falconbridge agreed to jointly explore for nickel-copper sulfide deposits in Labrador. The goal of the exploration program, a 50-50 partnership, is to find Voisey's Bay-type deposits outside of the

Voisey's Bay and South Voisey Bay (SVB) project areas. Large areas of Labrador remain under-explored despite the Voisey's Bay staking rush of 1993-1998. Several promising mafic-ultramafic complexes (and adjoining skarns and sulfide-rich iron formations) may have been overlooked earlier because the ore deposit model for Voisey's Bay was not fully developed at the time (Vanguard Consulting Ltd., 2002; Donner Minerals Ltd., 2003a§).

Since 1996, Donner has been actively exploring an area 90 km south of the Voisey's Bay discovery site. Donner and its partners have spent in excess of Can$20 million on the exploration project and drilled more than 140 holes. Radiometric age dating and trace element geochemical studies indicate that the South Gabbro complex staked by Donner closely resembles some of the olivine-rich host rocks at Voisey's Bay. In 2003, Falconbridge had an option to earn a 50% interest in the SVB project by spending Can$23 million on exploration before the end of 2006. By yearend 2003, Falconbridge had spent about Can$4.0 million on the project. In April 2004, Falconbridge dropped its option but continued to work with Donner on other projects. Teck Cominco has been a major shareholder in Donner since 1996. Teck Cominco supported the SVB exploration program by underwriting Donner's share of the capital costs, buying additional shares of stock in Donner, and serving as lead contractor for the project (Donner Minerals Ltd., 2003b; 2003b§). Donner took the lead in simplifying the property ownership at SVB. In 2001, four of Donner's venture partners had consolidated their properties with part of Donner's holdings and placed the combined holdings under the control of a single company, South Voisey Bay Nickel Company Ltd. (Donner Minerals Ltd., 2002; Vanguard Consulting Ltd., 2002).

Ontario.—Additional production was projected to come from the Sudbury District of east-central Ontario. Several exploration and development projects were underway in the Sudbury Igneous Complex with new information and geologic interpretations of the complex's associated copper-nickel deposits being published. The Sudbury District has been an important source of cobalt, copper, nickel, and PGE for 120 years. More than 10 Mt of nickel has been recovered from the mining district since the initial discovery in 1883. The bulk of the sulfide ores is found intermittently along the base of the Sudbury Igneous Complex as complicated mixtures of sulfide assemblages, xenoliths, and impact breccias. In 2003, the Sudbury operations of Falconbridge processed 2.26 Mt of local ores with an average grade of 1.35% nickel and 1.48% copper (Falconbridge Limited, 2004b, p. 18). Inco, Sudbury's other principal nickel producer, had equivalent ore grades of 1.39% nickel and 1.53% copper for that year (Inco Limited, 2004, p. 10-13).

At least 10 copper-nickel deposits have been discovered along the margins of the Sudbury basin since 1990. Three recent discoveries—Kelly Lake, Nickel Rim South, and Totten—have spurred the expansion of exploration activities (Falconbridge Limited, 2002§).

Dynatec Corp. and FNX Mining Inc. have found additional resources of PGE together with copper, nickel, and gold at the McCreedy West Mine in the Sudbury District, which Inco operated from 1973 to 1999 and has since optioned to Dynatec and FNX Mining. The two companies have been exploring the "Precious Metals" (PM) deposit, which lies at depth near existing underground workings. Exploratory drilling indicates that the PM deposit extends from the 900 level to the 2200 level.[2] The ongoing infill drilling and exploration program is being used to establish resource estimates. An exploration ramp is being driven from the reconditioned haulage drift on the 1600 level toward the deposit, whose edge is calculated to be only 229 m (750 feet) away. The new ramp will be used to extract bulk samples for a feasibility study. Bulk sampling was scheduled to begin in January 2004. Development work also was underway on the 1450 level to provide drill access to the upper part of the deposit (Dynatec Corporation, 2003d§).

The PM feasibility study is part of a much larger exploration program funded by the Sudbury Basin Joint Venture [an enterprise owned by FNX Mining (75%) and Dynatec (25%)]. The joint venture was formed in January 2002 and was evaluating five properties in the Sudbury District. The five properties—McCreedy West, Levack, Norman, Kirkwood, and Victoria—all have produced copper, nickel, and PGE in the past. [The properties are listed in order of location going clockwise around the perimeter of the Sudbury Basin starting with the most redeveloped, McCreedy West.] Exploration and evaluation of the five properties were being carried out as part of a long-term agreement with Inco, their owner. Because the properties were optioned, the joint venture did not have to make a large upfront payment. To acquire a 100% interest in the five properties, the joint venture must incur exploration and development costs of Can$30 million during a 52-month period that began in January 2002. Some Can$14 million was spent in the first 16 months of exploration and rehabilitation. Inco has the right to process all the ore produced from the properties and has an option to buy back a 51% interest in any deposit discovered that contains more than 270,000 t of nickel equivalent.

The venture rehabilitated parts of the old McCreedy West workings in 2002 and early 2003 and, in May, began shipping about 400 t/d of ore to Inco's Clarabelle mill for processing. Initial production came from remnants and extensions of previously mined ore bodies. Shipments were expected to reach 1,000 t/d by mid-2004. The 3-month-long labor dispute that shut down Inco's Sudbury operations during the summer forced a temporary suspension of shipments to Clarabelle and led to a buildup of ore stocks at the mine but did not interrupt underground development of the McCreedy Inter Main and East Main deposits. According to officials of the venture, the Upper Main, Inter Main, and East Main deposits have a total of 1.24 Mt of probable reserves averaging 1.91% nickel and 0.23% copper. These resources are sufficient to sustain mining operations through 2007 (Dynatec Corporation, 2003a§, c§).

In September, the Sudbury Basin Joint Venture initiated a feasibility study of the Levack Mine, which currently is estimated to have 2.66 Mt of measured resources averaging 1.9% nickel and 1.0% copper plus 2.40 Mt of indicated resources averaging 1.8% nickel and 0.9% copper. The proximity of the Levack Mine to the McCreedy West Mine may

[2]The level designation represents the approximate distance in feet from the surface to the level.

help enhance the economic viability of both. Dynatec and FNX Mining expected to complete the feasibility study of the Levack Mine in 2004 (Dynatec Corporation, 2003b§).

Falconbridge planned to complete the bankable feasibility study of its Nickel Rim South property by yearend 2004 and present the results of the study to Falconbridge's board of directors in the first quarter of 2005. The property is approximately 3 km north of the Sudbury airport on the eastern edge of the basin. Surface diamond drilling indicates that the mineralization is extremely high grade. Geologists estimate that the deposit contains 11.7 Mt of resources grading 1.6% nickel, 3.7% copper, and 0.03% cobalt with significant PGE and gold values (Falconbridge Limited, 2004b, p. 19, 23).

On July 21, 2003, Falconbridge announced that the company's board of directors had approved development of the Montcalm nickel-copper deposit in northern Ontario (Cumming, 2003; Falconbridge Limited, 2003b, p. 6-7). The proposed mine site is 70 km northwest of Timmins. The Ontario Ministry of Environment still had to approve several operating permits and issue the necessary water treatment and discharge permits before full-scale development could proceed. Falconbridge has proposed discharging clean, treated mine water directly into the Groundhog River. Special trucks would haul the ore out of the proposed Montcalm Mine up along a ramp and out through a portal. The ore would then be trucked to the Kidd Creek smelter near Timmins for milling and then concentrating. The Canadian nickel producer has spent more than Can$16 million on the project. Company officials estimate that the project's capital investment costs will be about Can$142 million. The completed feasibility study indicates 5.1 Mt of resources averaging 1.46% nickel and 0.71% copper (Falconbridge Limited, 2003a; 2004b, p. 14).

Quebec.—More than 20 companies are actively exploring for nickel on the Ungava Peninsula (Northern Miner, 2003). Much of the work has focused on the early Proterozoic Cape Smith Fold Belt, which extends east-west across the northern tip of the peninsula. The 6-year old Raglan Mine is in the central-eastern part of the fold belt. Most of the latest exploration drilling has taken place to the west and south of Raglan. Because large areas of the region are covered by overburden, airborne electromagnetic and magnetic surveys have played an important role in the search for nickel. Some of the more promising targets are associated with two sedimentary formations—the Povungnituk Group and the Chukotat Group. The Povungnituk Group comprises tholeiitic (olivine-poor) basalts and sediments, while the Chukotat Group is mostly komatiitic (olivine-rich) basalt flows.

The West Raglan project area now covers approximately 720 km^2 of the Cape Smith Fold Belt. The eastern edge of the project area is about 80 km west of Falconbridge's Raglan Mine. In 2003, the Raglan Mine produced 25,110 t of nickel along with copper and cobalt in sulfide concentrate (Falconbridge Limited, 2004a, p. 14-16; 2004b, p. 18). The concentrate was shipped by sea to Quebec City and then railed to Falconbridge's smelter at Sudbury for conversion into matte. The Raglan deposit was discovered in the 1930s but was passed over on several occasions because of its extreme northern location. Falconbridge acquired the deposit in 1966 but did not decide to develop its resources until 1994. The Raglan Mine was commissioned in December 1997. At yearend 2003, the open pit and underground complex had 17.7 Mt of proven and probable reserves averaging 2.86% nickel and 0.78% copper (Falconbridge Limited, 2004b, p. 14).

In late 2002, the West Raglan project area comprised 1,646 contiguous claims covering about 68,000 hectares (168,000 acres) in the western part of the Cape Smith Fold Belt. At that time, Anglo American Exploration (Canada) Ltd. controlled the bulk of the claims. In January 2003, however, Knight Resources Ltd. (formerly Knight Petroleum Corp.) agreed to help Anglo American Exploration explore the project area. Under the January agreement, Knight Resources can earn a 49% interest in the project by spending Can$11.8 million on exploration and related work before December 31, 2006. After 2006, Anglo American Exploration can increase its interest to 70% from 51% by completing a bankable feasibility study of West Raglan (Knight Petroleum Corp., 2003).

Anglo American Exploration is in charge of exploration for the project and carried out the initial geologic mapping, geochemistry, and prospecting. In April 2003, Anglo American began an aerial survey of the project area using proprietary advanced, deep penetrating geophysical technology. The company was in the process of following up the US$400,000 airborne survey with ground geophysical surveys, detailed geologic mapping, and more geochemical surveys. The West Raglan peridotite unit may be related to a 3-km-long conductive trend identified by the airborne electromagnetic survey. Preliminary analysis of the electromagnetic survey indicated that the conductive anomaly lies 20 to 100 m below the surface. Six grab samples—collected at several locations along a 1.6 km section of the 3-km trend—had assays ranging from 1.13% to 3.42% nickel along with significant copper, cobalt, and PGE (Knight Resources Ltd., 2003).

On July 16, Knight Resources announced the discovery of significant nickel sulfide mineralization in an area now known as the Frontier Zone, 7 km west of Lac Chukotat. The mineralized boulders and rubble were discovered near the base of a peridotite unit thought to be part of the western extension of the Raglan Horizon (Knight Resources Ltd., 2003). The Raglan Horizon hosts the pentlandite-chalcopyrite-rich deposit currently being mined by Falconbridge near Katinniq. A second zone of sulfide mineralization—the Rain Day Zone—was found 5 km to the east of the Frontier Zone. In the summer and fall of 2003, crews drilled 18 holes in the West Raglan project area. Of the 18, 8 intersected significant nickel and copper mineralization. Much of the project area is still largely unexplored.

Donner acquired a 29% controlling interest in Knight Resources in January 2003—a few months before the West Raglan discovery. Donner also is actively involved in joint exploration ventures elsewhere in Canada with Falconbridge and Teck Cominco. (More information can be found under the "Newfoundland and Labrador" and "Manitoba" sections.)

In July, Novawest Resources Inc. and Cascadia International Resources Inc. began exploring 660 km^2 (255 square miles) in the central part of the Cape Smith Belt. The Novawest-Cascadia project area (now called the Raglan Assemblage) is situated between Falconbridge's holdings and Anglo American Exploration/Knight Resources' West Raglan area. Novawest and Cascadia spent 7 years assembling the strategically situated holdings. Sampling, geophysical surveying, and drill site preparation were underway in the Raglan Assemblage. The two partners were planning to spend more than Can$12 million on their Raglan project during the next 3 years (Novawest Resources Inc., 2003).

China.—Chinese battery manufacturing capability has expanded dramatically in the past decade. Much of the expansion has involved the creation of plants to manufacture NiMH batteries. The Chinese also are investigating the potential world automotive market for NiMH batteries.

On August 14, Inco announced that it had formed a joint venture with a Chinese developer to produce large volumes of high-quality nickel foam for the world market. The partners in the Chinese foam venture are Inco Asia Holdings (a subsidiary of Inco), Liaoning Wanzhong Real Property Development (a developer based in Dalian, China), and Korea Nickel Corp. (a Republic of Korea producer of utility nickel in which Inco has a 25% equity interest). The new company has been named Inco Wanzhong Advanced Technology Materials (Dalian) Ltd. Most nickel foam is used to fabricate positive electrode substrate for nickel rechargeable batteries. Some foam, however, is used as a catalyst or as a high-temperature, corrosion-resistant filter. Foam also is finding applications in emerging fuel cell technologies. Commercial foam is >99.8% pure nickel metal (by weight) and is available in a wide range of different thicknesses and pore sizes.

The joint venture has begun constructing a state-of-the-art nickel foam production plant in Dalian, a port on the Liaotung Peninsula (Inco Limited, 2003a). Inco has spent US$10 million on the project to date. The first units of the foam plant became operational in March 2004. The plant is designed to produce 2 million square meters per year of foam and employs electroplating technology licensed from the Harbin Institute of Technology in Heilongjiang Province. The bulk of the foam was being sold to manufacturers of rechargeable batteries in China and Japan. Most of the batteries, in turn, were being used to meet growing demand throughout East Asia. Nickel-base batteries are commonly used to power cordless telephones, digital cameras, electric bicycles and scooters, and handheld tools. Demand for much larger batteries for advanced hybrid vehicles—already a major end use for foam—is growing at an even faster rate than the overall battery market.

The Dalian plant will complement Inco's existing foam production facilities at Clydach, Wales, in the United Kingdom. The foam produced at Dalian, however, has some different characteristics than the foam produced at Clydach. The nickel metal feed at Clydach is produced onsite by the carbonyl process—a gaseous vaporization purification process. The two types of foams will supplement specialty nickel metal powders already being sold by Inco to battery manufacturers. In 1998, Inco spent US$14 million expanding the foam production line at Clydach.

Inco already has experience operating in China and has been producing nickel salts at Kunshan City in Jiangsu Province since 1997. The Kunshan facility near Shanghai—Jinco Nonferrous Metals Co., Ltd.—is a joint venture with Jinchuan Non-Ferrous Metals Corp. of Jinchang, Gansu Province. Inco has a 65% interest in the Kunshan operation; Jinchuan, 35%. The Jinchuan mine and refining complex has a production capacity of 60,000 t/yr of refined nickel and accounted for about 88% of China's total nickel production in 2002.

New Caledonia.—At yearend 2003, the Goro project was still on hold despite high nickel prices. Goro is at the southeastern tip of La Grande Terre, New Caledonia, about 40 km east-southeast of the territorial capital, Noumea. In September 2002, Inco began slowing the construction schedule for the laterite mining and processing complex so that design changes needed to ensure the economic viability of Goro could be incorporated at an early stage. In December 2002, Inco suspended construction work at Goro after capital costs were forecast to rise above US$2.1 billion—US$700 million more than the original estimate of US$1.4 billion. The cost estimate increases were attributed to unforeseen geotechnical problems and evolving design requirements based on feedback from onsite pilot-plant work. The mining and hydrometallurgical processing complex had been scheduled to begin production in late 2004. Inco has an 85% interest in the project, with the Government of France's Bureau de Recherches Géologiques et Minières (BRGM) holding the remaining 15%. A consortium of Japanese companies led by Sumitomo Metal Mining continued to express an interest in acquiring a 20% to 25% interest in Goro. Discussions were underway with Inco, who had spent about US$600 million on the project as of December 31, 2003, and had signed contracts committing an additional US$99 million for accruals, equipment, and services (Inco Limited, 2004, p. 54-55).

The Goro project has undergone extensive review and redesign since January 2003. SNC Lavalin and Foster Wheeler (Qld) Pty. Ltd. were aiding Inco in a comprehensive review. In December, Goro Nickel SA—Inco's New Caledonian subsidiary—awarded a US$39.5 million contract to the two engineering and construction companies for their help in the technical review and certain planning activities. SNC Lavalin and Foster Wheeler have formed a joint venture to better perform the review and planning activities. In early 2004, the design of the hydrometallurgical processing complex was simplified, reducing construction cost estimates by US$500 million. Several significant changes were made to the original 2002 designs. For example, the ore slurry will be heated directly instead of indirectly before being fed to the autoclaves. The redesigned plant will occupy a smaller area, resulting in considerable savings in concrete, piping, and steel. The current capital cost estimate is US$1.85 billion. The Government of France has agreed to finance US$350 million of the project's direct costs. The Government will also provide financing to Prony Energy to help build the power generating facilities needed by Goro. Any excess power would go to other electricity consumers on the island. Prony Energy is a consortium of a major French company on New Caledonia and local utilities.

The final decision on restarting the project was to be made in October 2004. If there are no serious construction delays, then Goro could begin producing nickel and cobalt by mid-2007. The plant would have a nameplate capacity of 60,000 t/yr nickel. Ramp-up to full capacity was expected to take 3 years, with 65% reached in the first year of operation, and 85%, in the second year. The capacity of the redesigned plant is 9% greater than the previous design estimate of 55,000 t/yr. Goro has enormous resources, allowing the operation to be incrementally expanded over time. Inco geologists estimate that Goro has 57

Mt of proven and probable reserves averaging 1.52% nickel and 0.12% cobalt. Inco also has identified 95 Mt of measured and indicated resources (Hand and Jones, 2004). Additional resources at Goro and the adjacent Prony deposit are expected to extend the life of the complex far beyond its planned 20 years (Compagnie des Mines de Xéré and others, 2002).

Russia.—MMC Norilsk Nickel Group—the world's leading producer of nickel and palladium—continued to restructure and diversify. The conglomerate played an important role in the economy of Russia, accounting for 1.9% of Russia's gross domestic product in 2002. Company officials estimated that Norilsk Nickel controlled 20% of world primary nickel production and more than 40% of world palladium production. Norilsk Nickel produced 238,800 t of primary nickel in 2003—about 96% of Russia's total nickel output for the year. Production was about 21,000 t greater than the 218,000 t reported for 2002. The group shipped an additional 70,000 t in 2003 from stocks. Of the 309,000 t shipped, 297,000 t, or 96%, was exported. Only 12,000 t was sold to domestic consumers (Rozhetskin, 2004).

The group's Polar Division is responsible for nickel mining, smelting, and refining operations on the Taimyr Peninsula of north-central Siberia. A second division, Kola MMC, oversees similar operations on the Kola Peninsula, bordering Finland. In early 2003, the group's board of directors approved a production investment plan that would ensure sustainability of the two mining and processing divisions until 2015. Two major goals for 2004 were to finish renovating the flash smelters at Nadezhda on the Taimyr Peninsula and to bring the Pelyatka natural gas field into full production. Some market analysts predict that the plan will be largely implemented because of the tight nickel market forecasted for the next 2 to 3 years, which reflects growing nickel consumption in China and the 6% growth in world stainless steel demand that took place in 2003. China has become a significant consumer of Russian nickel since 1999. In 2003, China reported receiving 23,707 t of unwrought nickel metal from Russia, up from 9,725 t in 2002. China also imported 684 t of Russian powder and flake, up from 270 t in 2002 (International Nickel Study Group, 2004a).

On March 18, 2003, the board of directors of Norilsk Nickel approved a modernization plan designed to increase the company's nickel production capacity by 10%. Under the plan, nickel production capacity would be increased to 240,000 t/yr of nickel from the current level of 218,000 t/yr (Mining Journal, 2003b; JSC MMC Norilsk Nickel, 2003a§, b§). Modernization was expected to cost between US$3.6 billion and US$5.3 billion. In March, Norilsk Nickel released 18,000 t of nickel from its 60,000 t stockpile. On April 8, the company announced that it was releasing an additional 18,000 t, lowering the stockpile to 24,000 t. The 60,000 t stockpile had been used as collateral to obtain a US$200 million secured loan arranged by a consortium of banks (JSC MMC Norilsk Nickel, 2003c§).

Spain and Portugal.—On January 20, 2003, Rio Narcea Gold Mines, Ltd. announced that it had signed a long-term offtake agreement with Glencore International AG. Glencore will purchase 100% of the nickel sulfide concentrate produced at Aguablanca until the year 2010. Commercial production was scheduled to start in December 2004. Specific terms of the agreement were not disclosed to protect confidential business information (Rio Narcea Gold Mines, Ltd., 2003e§).

In August 2003, Rio Narcea awarded the engineering contract for construction of the Aguablanca project to Fluor Corporation. Fluor was to be paid €17.1 million (approximately US$19.9 million at that time) plus $A21.8 million (approximately US$14.9 million). The contract for the open pit mine was awarded to the PEAL Group, an established Spanish contractor experienced in large-scale earth moving projects (Rio Narcea Gold Mines, Ltd., 2003a§). Because of high nickel prices, Rio Narcea accelerated work at Aguablanca, beginning full scale development in October. The magmatic sulfide deposit occurs in a gabbro-norite intrusive complex along the northern contact of the Santa Olalla granodiorite complex. The dominant ore minerals are chalcopyrite, pentlandite, and pyrrhotite. The ore also contains economically recoverable quantities of palladium and other PGE. The upper part of the deposit is brecciated and forms oxidized gossans where it outcrops at the surface. The Aguablanca Mine initially will be an open pit operation and have an onsite crusher and concentrator. The open pit would eventually reach a depth of 250 m and have a life of about 10.5 years. Mining would begin shifting to underground workings sometime after 2006. The proposed flotation plant would treat 1.5 Mt/yr of ore. Aguablanca is expected to produce approximately 8,200 t/yr of nickel and 6,400 t/yr of copper in concentrate. As of December 31, 2003, Aguablanca had 13.6 Mt of proven reserves averaging 0.66% nickel, 0.47% copper, and 0.48 g/t PGE. In addition, the deposit had 2.1 Mt of probable reserves averaging 0.62% nickel, 0.44% copper, and 0.45 g/t PGE (Rio Narcea Gold Mines, Ltd., 2004, p. 2).

Rio Narcea was planning to exploit the deposit's deeper resources within the next 5 years. In December 2003, Rio Narcea's board of directors approved the first phase of the underground part of the mining project. Engineers will initially drive a ramp to gain access to a mineralized zone below the bottom of the planned open pit. Construction of the ramp and the associated development work was expected to cost US$5 million and would take about 18 months to complete. The underground work would enable the company to complete infill drilling and help confirm the existence of additional zones of high-grade mineralization believed to have been displaced by faulting (Rio Narcea Gold Mines, Ltd., 2003b§). Construction was being financed by a US$47 million loan facility from Investec Bank (UK) Ltd. and Macquarie Bank Ltd. of Australia. Although construction costs had been estimated by the feasibility study to be US$62.5 million, owing to the strengthening of the euro against the dollar, capital expenditures for Aguablanca were revised upward to US$87 million. Rio Narcea has obtained subsidies from Spanish governmental agencies for development of Aguablanca (Rio Narcea Gold Mines Ltd., 2003c§, f§).

Besides Aguablanca, Rio Narcea is actively evaluating several other promising nickel properties in the Serra de Ossa (Portugal)-Sierra Morena (Spain) region. The company has identified at least 10 mineralized gabbro intrusives along the 150-km-long Olivensa-Monesterio antiform of Spain's Badajoz Province. Rio Narcea has applied to the Portuguese mining authorities for a license to explore two key districts in the Alentejo region bordering Badajoz Province. The license would cover a 927-km^2 block in the Campo Maior area and a 993-km^2 block in the Beja area. The Beja area includes a large ophiolite belt in contact with a mafic-ultramafic complex of olivine gabbros, anorthosites, norites, and troctolites. Outcrops of gossanous troctolite near Elvas in the Campo Maior area assayed up to 0.8% nickel and 0.5% copper. The Portuguese village of Elvas is 10 km west of the Spanish border and about 135 km northwest of Aguablanca (Rio Narcea Gold Mines, Ltd., 2003d§).

Rio Narcea has focused its exploration efforts on four targets in the Ossa-Morena Belt. The company has drilled 10 holes at the Tejadillas target, about 65 km west of Aguablanca. The most promising hole intercepted 0.2 m of sulfide mineralization averaging 1.4% nickel, 0.2% copper, and 675 g/t cobalt at a down-hole depth of 170 m (Rio Narcea Gold Mines, Ltd., 2003d§). Down-hole electromagnetic surveys were being conducted at Argallon, 60 km northeast of Aguablanca; at Olivensa, 110 km northwest of Aguablanca; and at Elvas on the company's Campo Maior property (Rio Narcea Gold Mines, Ltd., 2003d§).

Turkey.—European Nickel plc was formed in June 2000 to acquire and develop nickel laterite deposits in the Balkans. Much of the initial work involved reevaluating known nickel deposits in Albania that might be amenable to heap leaching with sulfuric acid. In March 2002, the company optioned the Caldag laterite deposit in western Turkey. The Caldag nickel deposit is 15 km north of the town of Turgutlu and 75 km northeast of the Port of Izmir. A rail line, a highway, water, and electric power are available at or near the mine site. The laterite deposit has 38 Mt of resources grading 1.14% nickel and 0.05% cobalt that may be suitable for heap leaching. Caldag is one of a number of subtropical laterites occurring in a broad belt of Jurassic-Lower Cretaceous ophiolite complexes that extends from Serbia southeast through Greece and Turkey to Cyprus and Syria. On June 28, 2004, European Nickel acquired full mineral rights to Caldag. If the heap-leaching trials are successful, European Nickel will begin a bankable feasibility study in mid-2005 to determine if the project can be scaled up to produce 15,000 t/yr of nickel in a mixed nickel-cobalt hydroxide product. Mining began on a trial basis in 2003. European Nickel has begun construction of the first of three pads, each holding 5,000 t of ore. Much of the leach pad construction was to be completed by mid-2004. Irrigation of the heaped ore with sulfuric acid was to begin in September 2004 (European Nickel plc, 2004§).

In 2003, European Nickel shipped some 40,000 t of ore to ferronickel producers in Greece and Macedonia. If the Turkish operation is successful, then the company will explore the possibility of developing similar operations in other regions of the ophiolite belt, possibly in Albania, Greece, or Macedonia. The company reportedly has examined eight other deposits in the Balkans.

Outlook

No primary product nickel producer is expected to be operating in the United States before 2015. Grupo Mexico and Stillwater will continue to recover limited amounts of byproduct nickel from their precious metals and base-metals refining operations in the Western States. Larger amounts of byproduct nickel also could be generated in Minnesota if Teck Cominco and/or PolyMet decide to proceed with their PGE projects in the Duluth Gabbro. Increased byproduct nickel production from North American PGE operations could materialize if current forecasts for fuel-cell-battery hybrid vehicles come true.

U.S. nickel consumers apparently will be dependent on foreign sources for at least two decades. The ongoing expansion of nickel laterite mining projects in Australia, Cuba, Indonesia, New Caledonia, and the Philippines will help meet the growing demand for nickel worldwide. Laterite projects also are under consideration in Brazil, Cote d'Ivoire, and Guatemala. The sulfide concentrate from Inco's state-of-the-art mill and concentrator at Voisey's Bay also will help meet the near-term growth in demand projected for nickel.

Nickel consumption in the United States is expected to grow by at least 3% per year as stainless steel increasingly substitutes other materials. One example is the adoption of corrosion-resistant stainless steel rebar for highway and bridge projects. Use of stainless steel in new home and building construction is expected to grow because of its resistance to fire and high winds. Growth in nickel demand by the domestic plating industry is expected to be minimal. A number of small U.S. plating operations reportedly have closed in recent years because of international competition. The aerospace industry will continue to use significant amounts of nickel, despite the short-term lull in commercial aircraft and jet engine production. Several new nickel alloys are currently being developed specifically for the aerospace industry where extreme temperatures are a challenge. Demand for nickel in electronics, stationary power sources, and grid-dependent electrical equipment is growing. Advanced nickel-based batteries are being developed for a wide range of ICE-electric hybrid vehicles—armored vehicles, automobiles, sport utility vehicles, trucks, and even railroad locomotives. Storage batteries will also be needed to capture the energy generated by many of the fuel cell systems being designed.

The North American stainless steel industry is expected to continue consolidation. In 2004, Allegheny Technologies Inc. (ATI) bought J&L Specialty Steel, LLC from Arcelor S.A. (J&L Specialty Steel, LLC, 2004). J&L manufactures flat-rolled stainless steel products and has plants in Midland, PA, and Louisville, OH. ATI was planning to integrate J&L's operations with those of its own steelmaking subsidiary (Allegheny Ludlum Corporation). Allegheny Ludlum is a leading U.S. producer of stainless steel plate, sheet, and strip, with a meltshop and other major steelmaking operations at Brackenridge, PA. The ATI subsidiary also produces nickel-based alloys, titanium metal, and titanium-based alloys. J&L's assets will complement Allegheny Ludlum's current capabilities and allow Allegheny Ludlum to better utilize its hot-rolling mill at Brackenridge. The integration will raise Allegheny Ludlum stainless steelmaking capacity by 15% to 20% (an increase of about 270,000 t/yr of slab). On March 16, 2004, Allegheny Ludlum and J&L successfully completed integration trials. Allegheny Ludlum planned to keep both the Brackenridge and Midland meltshops open (Allegheny Technologies Inc., 2004a, b).

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TABLE 1
SALIENT NICKEL STATISTICS[1]

(Metric tons of contained nickel unless otherwise specified)

	1999	2000	2001	2002	2003
United States:					
Mine production	--	--	--	--	--
Plant production	--	--	--	--	--
Secondary recovery from purchased scrap:					
From ferrous scrap	58,600	71,700	89,600	97,200 r	84,000
From nonferrous scrap	12,400	12,200	11,900 r	9,060 r	9,460
Shipments of purchased scrap[2]	93,000	123,000	141,000	137,000 r	129,000
Exports:					
Primary	7,440	8,150	8,450	6,520	6,330
Secondary	31,400	49,900	48,600	39,400	47,300
Imports for consumption:					
Ore	--	--	--	--	--
Primary	139,000	156,000	136,000	121,000	125,000
Secondary	9,480	10,700	8,760	9,110	11,500
Consumption:					
Reported:					
Primary	117,000 r	115,000	98,800	87,400 r	86,400
Secondary, purchased scrap[3]	71,000	84,000	102,000 r	106,000 r	93,400
Total	188,000	199,000 r	200,000	194,000 r	180,000
Apparent:					
Primary	140,000	147,000	129,000	121,000	118,000
Secondary, purchased scrap[4]	49,400	42,000	59,900 r	76,600 r	62,800
Total	190,000	189,000	189,000 r	197,000 r	180,000
Apparent primary plus reported secondary	211,000	231,000	230,000	227,000 r	211,000
Stocks, yearend:					
Government	--	--	--	--	--
Producers and traders	12,700	12,300	12,600	6,150	7,250
Consumer, primary	5,010 r	6,530 r	4,500 r	4,510 r	4,910
Consumer, secondary	5,070	7,910 r	9,760 r	9,160 r	3,980
Total	22,800	26,700 r	26,900 r	19,800 r	16,100
Employment, yearend:					
Mine	1	1	--	--	--
Smelter	6	(5)	--	--	--
Port facility	1	--	--	--	--
Price, cash, London Metal Exchange:					
Average annual dollars per metric ton	6,011	8,638	5,945	6,772	9,629
Average annual dollars per pound	2.727	3.918	2.696	3.072	4.368
Price, 18/8 stainless steel scrap, gross weight:[6]					
Average annual dollars per metric ton	615	811	623	692	927
Average annual dollars per long ton	625	824	633	703	942
World, mine production	1,170,000 r	1,290,000 r	1,350,000 r	1,350,000 r	1,400,000 e

[e]Estimated. [r]Revised. -- Zero.

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

[2]Defined as scrap receipts less shipments by consumers plus exports minus imports plus adjustments for consumer stock changes.

[3]More nearly represents amount consumed than does apparent secondary consumption.

[4]Internal evaluation indicates that apparent secondary consumption is considerably understated.

[5]The smelter at Riddle, OR, was decommissioned in 2000.

[6]Derived from the average of the Friday consumer buying price range for 18% chromium-8%, nickel scrap in bundles, solids, and clips, Pittsburgh, PA, in American Metal Market.

TABLE 2
NICKEL RECOVERED FROM PURCHASED SCRAP IN THE UNITED STATES, BY KIND OF SCRAP AND FORM OF RECOVERY[1]

(Metric tons of contained nickel)

	2002	2003
Kind of scrap:		
Aluminum-base[2]	3,200	2,840
Copper-base	1,940 r	2,120
Ferrous-base[3]	97,200 r	84,000
Nickel-base	3,920	4,510
Total	106,000 r	93,400
Form of recovery:		
Aluminum-base alloys	3,200	2,840
Copper-base alloys	2,950 r	3,070
Ferrous alloys	97,200 r	84,000
Nickel-base alloys	2,910 r	3,540
Miscellaneous and unspecified	--	3
Total	106,000 r	93,400

rRevised. -- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Primarily borings and turnings of wrought alloys, such as 2218, 2618, 4032, and 8280, or special casting alloys, such as 203.0.
[3]Primarily stainless and alloy steel scrap consumed at steel mills and foundries.

TABLE 3
REPORTED U.S. CONSUMPTION OF NICKEL, BY FORM[1]

(Metric tons of contained nickel)

Form	2002r	2003
Primary:		
Metal	71,500	69,900
Ferronickel	12,600	13,700
Oxide and oxide sinter[2]	1,690	146
Chemicals	521	1,810
Other	1,130	837
Total	87,400	86,400
Secondary, scrap[3]	106,000	93,400
Grand total	194,000	180,000

rRevised.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes chemical-grade oxide.
[3]Based on gross weight of purchased scrap consumed and estimated average nickel content.

TABLE 4
U.S. CONSUMPTION OF NICKEL, BY USE[1]

(Metric tons of contained nickel)

Use	2003								Grand total in 2002
	Metal	Ferronickel	Oxide and oxide sinter	Chemicals	Other forms	Total primary	Secondary (scrap)	Grand total	
Cast irons	54	W	--	--	16	70	390	460	427 r
Chemicals and chemical uses	737	--	W	1,660	--	2,400	--	2,400	1,280 r
Electric, magnet, expansion alloys	134	--	--	--	--	134	W	134	130
Electroplating, sales to platers	11,400	--	--	57	W	11,400	--	11,400	12,300
Nickel-copper and copper-nickel alloys	2,370	--	W	--	W	2,370	2,790	5,160	5,280 r
Other nickel and nickel alloys	11,600	W	W	--	65	11,600	2,930	14,600	14,200 r
Steel:									
Stainless and heat resistant	27,000	13,600	83	W	207	40,900	83,000	124,000	135,000 r
Alloys, excludes stainless	2,890	W	--	--	W	2,890	572	3,460	3,920 r
Superalloys	11,600	--	W	W	461	12,000	613	12,600	12,600 r
Other[2]	2,230	70	62	95	89	2,550	3,130	5,680	8,200 r
Total	69,900	13,700	145	1,810	838	86,400	93,400	180,000	194,000 r
Total all companies, apparent	XX	XX	XX	XX	XX	118,000	62,800	180,000	197,000 r

rRevised. W Withheld to avoid disclosing company proprietary data; included with "Other." XX Not applicable. -- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes batteries, catalysts, ceramics, coinage, other alloys containing nickel, and data indicated by the symbol "W."

TABLE 5
NICKEL IN CONSUMER STOCKS IN THE UNITED STATES, BY FORM, DECEMBER 31[1]

(Metric tons of contained nickel)

Form	2002	2003
Primary:		
Metal	3,340 r	3,510
Ferronickel	438 r	745
Oxide and oxide sinter	67	57
Chemicals	466 r	446
Other	205 r	152
Total	4,510 r	4,910
Secondary, scrap	9,160 r	3,980
Grand total	13,700 r	8,890

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

TABLE 6

U.S. EXPORTS OF NICKEL PRODUCTS, BY CLASS[1, 2]

Class	2002 Quantity (metric tons of contained nickel)	2002 Value (thousands)	2003 Quantity (metric tons of contained nickel)	2003 Value (thousands)
Primary:				
Unwrought:				
Cathodes, pellets, briquets, shot	1,740	$11,400	996	$8,540
Ferronickel	46	879	181	2,520
Powder and flakes	1,480	20,600	1,100	18,300
Metallurgical-grade oxide	685	2,830	160	1,950
Chemicals:				
Catalysts	1,610	53,800	1,930	76,100
Salts[3]	969	12,500	1,970	24,800
Total	6,520	102,000	6,330	132,000
Secondary:				
Stainless steel scrap	25,700	252,000	37,800	382,000
Waste and scrap	13,700	51,700	9,460	41,900
Total	39,400	304,000	47,300	424,000
Grand total	45,900	406,000	53,600	557,000
Wrought, not alloyed:				
Bars, rods, profiles, wire	482	6,890	1,690	17,400
Sheets, strip, foil	1,840	23,900	1,040	15,600
Tubes and pipes	248	2,300	168	1,410
Total	2,570	33,100	2,890	34,400
Alloyed, gross weight:				
Unwrought alloyed ingot	8,720	95,200	6,660	74,200
Bars, rods, profiles, wire	7,540	129,000	9,150	145,000
Sheets, strip, foil	6,760	101,000	4,620	67,700
Tubes and pipes	1,770	30,600	2,420	44,700
Other alloyed articles	4,290	104,000	3,050	95,200
Total	29,100	460,000	25,900	427,000

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

[2]The nickel contents are as follows: metallurgical-grade oxide, 77%; waste and scrap, 50%; and stainless steel scrap, 7.5%. The salts category contains the following: chemical-grade oxide, sesquioxide, and hydroxide, 65%; chlorides, 25%; and sulfates, 22%. Other salts and various catalysts are assumed to be 22% nickel.

[3]Excludes nickel carbonate (more information can be found in the Harmonized Tariff System Schedule B, export commodity code 2836.99.9050).

Source: U.S. Census Bureau.

TABLE 7
U.S. EXPORTS OF NICKEL PRODUCTS, BY COUNTRY[1]

(Metric tons of contained nickel)[2]

Country	2003									
	Cathodes, pellets, and briquets (unwrought)	Powder and flakes	Ferronickel	Metallurgical-grade oxide[3]	Waste and scrap	Stainless steel scrap	Chemicals	Total	Total in 2002	Wrought nickel in 2003[4]
Australia	--	4	--	--	52	(5)	7	63	109	18
Belgium	17	72	--	--	110	44	42	285	349	72
Brazil	186	14	--	--	--	105	15	320	253	13
Canada	83	251	--	105	7,210	2,740	1,500	11,900	14,100	80
China	--	4	104	(5)	69	6,210	173	6,560	5,280	9
Colombia	11	14	--	9	3	2	1	40	31	37
Finland	--	(5)	--	--	155	5,770	(5)	5,920	448	(5)
France	--	31	--	2	34	9	26	102	343	761
Germany	1	125	--	3	165	54	25	373	1,040	44
India	(5)	8	(5)	--	82	858	122	1,070	999	3
Italy	2	19	--	(5)	--	485	4	510	52	212
Japan	52	98	--	20	512	554	223	1,460	1,890	137
Korea, Republic of	--	54	7	--	--	6,360	627	7,050	6,570	31
Mexico	604	39	--	1	1	62	162	869	1,570	392
Netherlands	--	47	(5)	(5)	73	1,170	47	1,340	711	10
South Africa	--	(5)	--	8	92	2	13	115	88	1
Spain	--	--	--	--	--	2,580	3	2,580	1,580	(5)
Sweden	--	1	--	--	380	35	(5)	416	646	--
Taiwan	6	3	--	(5)	14	9,630	75	9,730	7,840	62
United Kingdom	20	64	70	9	446	500	59	1,170	686	820
Other	14	248	(5)	3	59	662	773	1,760	1,330	189
Total	996	1,100	181	160	9,460	37,800	3,900	53,600	45,900	2,890

-- Zero.

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

[2]The nickel contents are assumed to be as follows: metallurgical-grade oxide, 77%; waste and scrap, 50%; and stainless steel scrap, 7.5%. The chemicals category contains the following: chemical-grade oxide, sesquoxide, and hydroxide, 65%; chlorides, 25%; and sulfate, 22%. Other salts and various catalysts are assumed to be 22% nickel.

[3]Chemical-grade oxide is included in the "Chemicals" category.

[4]Excluded from "2003, total."

[5]Less than 1/2 unit.

Source: U.S. Census Bureau.

TABLE 8
U.S. IMPORTS FOR CONSUMPTION OF NICKEL PRODUCTS, BY CLASS[1]

Class	2002 Quantity (metric tons of contained nickel)[2]	2002 Value (thousands)	2003 Quantity (metric tons of contained nickel)[2]	2003 Value (thousands)
Primary:				
Unwrought:				
Cathodes, pellets, briquets, shot	97,200	$648,000	99,300	$863,000
Ferronickel	12,300	81,200	13,100	109,000
Powder and flakes	6,970	67,900	9,130	91,900
Metallurgical-grade oxide	1,230	8,180	91	835
Chemicals:				
Catalysts	1,280	41,700	1,610	64,900
Salts[3]	1,590	16,000	2,190	23,100
Total	121,000	864,000	125,000	1,150,000
Secondary:				
Stainless steel scrap	6,080	49,400	6,690	70,200
Waste and scrap	3,030	18,000	4,790	37,600
Total	9,110	67,400	11,500	108,000
Grand total	130,000	931,000	137,000	1,260,000
Wrought, not alloyed:				
Bars, rods, profiles, wire	468	6,470	289	4,760
Sheets, strip, foil	296	6,550	183	5,840
Tubes and pipes	115	1,750	187	2,780
Total	879	14,800	659	13,400
Alloyed, gross weight:				
Unwrought alloyed ingot	2,540	25,100	1,910	17,200
Bars, rods, profiles, wire	7,870	88,400	8,280	97,100
Sheets, strip, foil	3,710	45,600	3,540	42,500
Tubes and pipes	2,850	42,200	2,770	45,600
Other alloyed articles	1,810	39,400	1,770	74,600
Total	18,800	241,000	18,300	277,000

[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]The nickel contents are as follows: metallurgical-grade oxide from Australia, 90%; elsewhere, 77%. The salts category contains the following: chemical-grade oxide, sesquioxide, and hydroxide, 65%; chlorides, 25%; sulfates, 22%; and other salts which are assumed to be 22% nickel. The typical catalyst is assumed to have a nickel content of 22%. Waste and scrap is assumed to be 50% nickel; stainless steel scrap, 7.5% nickel.
[3]Excludes nickel carbonate (more information can be found at Harmonized Tariff Schedule of the United States subheading 2836.99.5000).

Source: U.S. Census Bureau.

TABLE 9
U.S. IMPORTS FOR CONSUMPTION OF NICKEL PRODUCTS, BY COUNTRY[1]

(Metric tons of contained nickel)[2]

Country	2003: Cathodes, pellets, and briquets (unwrought)	2003: Powder and flakes	2003: Ferronickel	2003: Metallurgical-grade oxide[3]	2003: Waste and scrap	2003: Stainless steel scrap	2003: Chemicals	2003: Total	Total in 2002	Wrought nickel in 2003[4]
Australia	11,200	762	--	26	9	--	10	12,000	10,400	3
Austria	--	(5)	--	--	--	--	--	(5)	6	93
Belgium	--	93	--	--	39	(5)	163	296	316	2
Brazil	1,140	--	--	--	16	52	--	1,210	842	--
Canada	35,600	3,700	--	65	1,250	4,220	57	44,900	59,400	23
China	--	12	--	--	--	--	82	94	103	13
Colombia	--	--	2,870	--	2	9	--	2,890	2,550	--
Dominican Republic	--	--	8,010	--	--	9	--	8,020	6,720	--
Finland	4,500	1,970	--	--	19	1	1,130	7,620	4,640	--
France	1,550	(5)	--	--	666	9	782	3,000	2,300	147
Germany	56	82	--	(5)	610	7	345	1,100	1,160	255
Japan	--	56	5	--	115	9	430	614	473	100
Mexico	1	--	--	--	56	2,220	11	2,290	1,470	--
Netherlands[6]	18	--	--	--	9	--	463	491	531	3
New Caledonia	--	--	1,670	--	--	--	1	1,670	1,100	--
Norway	17,300	--	--	--	27	--	--	17,300	8,550	1
Russia	25,500	1,750	534	--	--	--	--	27,800	24,200	--
South Africa	179	156	--	--	6	--	3	344	356	--
United Kingdom	692	461	14	(5)	1,640	7	134	2,950	1,160	11
Venezuela	--	--	--	--	47	36	--	83	1,690	--
Zimbabwe	716	--	--	--	--	--	--	716	1,140	--
Other	779 [7]	88	2	--	280	115	189	1,450	650	8
Total	99,300	9,130	13,100	91	4,790	6,690	3,800	137,000	130,000	659

-- Zero.

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

[2]The nickel contents are assumed to be as follows: metallurgical-grade oxide from Australia, 90%; elsewhere, 77%. The chemicals category contains the following: chemical-grade oxide, sesquioxide, and hydroxide, 65%; chlorides, 25%; sulfates, 22%. Other salts and various catalysts are assumed to be 22% nickel. Waste and scrap is assumed to be 50% nickel, and stainless steel scrap, 7.5% nickel.

[3]Primarily oxide, rondelles, and sinter.

[4]Excluded from "2003, total."

[5]Less than 1/2 unit.

[6]The different nickel metal products (cathode, powder, etc.) are apparently material that has transited through bonded warehouses in the Netherlands, including warehouses overseen by the London Metal Exchange.

[7]Includes 740 metric tons of unwrought nickel that transited through warehouses in Singapore.

Source: U.S. Census Bureau.

TABLE 10
NICKEL: WORLD MINE PRODUCTION, BY COUNTRY[1, 2]

(Metric tons of nickel content)

Country	1999	2000	2001	2002	2003
Australia, content of concentrate	119,600 r	166,500 r	205,000 r	207,800 r	210,000
Botswana, content of ore milled	37,605 r	38,420 r	26,714 r	28,600 r	32,740
Brazil, content of ore	41,522	45,317	47,097	45,029	45,000 e
Burma, content of ore	76	40	40 e	30 e	30 e
Canada, content of concentrate	186,236	190,793	194,058	189,297 r	162,756 p
China[e]	49,500	50,300	51,500	53,700 r	60,000
Colombia, content of laterite ore	39,274	58,927	52,962	58,196	70,844
Cuba, content of oxide, oxide sinter, oxide powder, sulfide, and ammoniacal liquor[3]	64,308 r	68,064 r	72,585 r	71,342 r	74,018 p
Dominican Republic, content of laterite ore	39,997	39,943	39,120	38,859	45,400 e
Finland, content of concentrate	70	3,347	2,200	2,500	2,700
Greece, content of laterite ore	16,050	19,535	20,830	22,670	21,410
Indonesia, content of laterite ore	89,111	98,200	102,000	123,000 r	143,000
Kazakhstan, content of laterite ore[e, 4]	--	30	3,200	3,000	3,000
Macedonia, content of ferronickel produced	1,900 e	--	2,970 r, e	5,149 r	5,555 p
Morocco, content of nickel sulfate	--	84	151	109	126
New Caledonia, content of ore	110,062	128,789	117,554	99,650	111,895
Norway, content of concentrate[5]	2,965	2,538	2,529	1,700	--
Philippines, content of ore	20,689	17,388	27,359	26,532	21,150
Russia, content of ore[e]	300,000	315,000	325,000	310,000	315,000
South Africa, content of concentrate	36,202	36,616	36,443	38,546	40,842
Turkey, content of laterite ore	--	--	--	--	640
Ukraine, content of laterite ore[e]	--	--	1,500	2,000	2,000
Venezuela, content of laterite ore	--	2,540	13,600	18,600 r	20,700
Zimbabwe, content of concentrate	11,164	8,160	10,120	8,092	9,517
Grand total	1,170,000 r	1,290,000 r	1,350,000 r	1,350,000 r	1,400,000
Of which:					
Content of concentrate	356,000	408,000 r	450,000 r	448,000 r	426,000
Content of ore and ore milled	510,000 r	545,000 r	544,000 r	510,000 r	526,000
Content of laterite ore	184,000	219,000	233,000	266,000 r	307,000
Content of ferronickel produced	1,900	--	2,970 r	5,150 r	5,560
Content of nickel sulfate	--	84	151	109	126
Content, unspecified and/or undifferentiated	114,000 r	118,000	124,000	125,000 r	134,000

[e]Estimated. [p]Preliminary. [r]Revised. -- Zero.

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

[2]Insofar as possible, this table represents recoverable mine production of nickel. Where actual mine output is not available, data related to a more highly processed form have been used to provide an indication of the magnitude of mine output and this is noted parenthetically. North Korea may have an active nickel mine, but information is inadequate to make reliable estimates of output. Table includes data available through July 29, 2004.

[3]The Government of Cuba reports plant production on a contained nickel plus cobalt basis. The tonnages shown in this table for Cuba have been adjusted downward to correct for the cobalt. The cobalt content was determined to be 1.16% for granular and powdered oxide, 1.21% for oxide sinter, 7.56% for sulfide precipitate, and 33% for leach ammoniacal precipitate.

[4]Mining operations in Aqtobe Province ship laterite ore north to metallurgical plants in the Russian part of the Ural Mountains.

[5]A/S Nikkel Og Olivin halted mining operations in October 2002. Outokumpu Oyj sold its 70% interest in the Norwegian mining company to Boliden AB on December 30, 2003.

TABLE 11
NICKEL: WORLD PLANT PRODUCTION, BY COUNTRY AND PRODUCT[1, 2]

(Metric tons of nickel content)

Country and product[3]	1999	2000	2001	2002	2003
Australia:					
Metal	73,400 [r]	98,700 [r]	116,900 [r]	120,800 [r]	129,000
Unspecified[4]	10,200 [r]	13,500 [r]	11,200 [r]	11,400 [r]	10,000 [e]
Total	83,600 [r]	112,200 [r]	128,100 [r]	132,200 [r]	139,000 [e]
Austria, ferronickel[e]	1,700	1,700	1,600	1,500	1,500
Brazil:[5]					
Ferronickel	6,502	6,347	5,768	6,011	6,400 [p]
Metal	16,429	16,906	17,663	17,676	18,000 [e]
Total	22,931	23,253	23,431	23,687	24,400 [e]
Canada, unspecified[6]	124,260	134,225	140,591	144,476	124,418 [p]
China, metal[e]	44,400	50,900	49,500	52,400 [r]	64,700
Colombia, ferronickel	28,260 [r]	27,730 [r]	38,438 [r]	43,987 [r]	47,868 [p]
Cuba, oxide sinter and oxides[7]	38,339 [r]	39,516 [r]	40,701 [r]	38,738 [r]	42,282 [p]
Dominican Republic, ferronickel	24,455	27,829	21,661 [r]	23,303	27,227
Finland:					
Metal	51,948	50,087	51,275	56,600	52,300
Chemicals	4,143	3,711	3,700	3,600	3,600
Total	56,091	53,798	54,975	60,200	55,900
France:					
Metal	9,458	10,100	11,033	9,444	9,138
Chemicals	2,244	2,176	2,000	2,000 [e]	2,000 [e]
Total[8]	11,702	12,276	13,033	11,444	11,138
Greece, ferronickel	13,462 [r]	17,126 [r]	16,870 [r]	19,230 [r]	18,000
Indonesia, ferronickel	9,385	10,111	10,302	8,804	8,933
Japan:					
Ferronickel	67,166	74,753	68,113 [r]	74,418 [r]	74,804
Metal	30,481	36,230	32,526	32,297 [r]	34,991
Oxide sinter	34,482	47,020	50,771 [r]	48,950 [r]	52,700
Chemicals	2,570	2,721 [r]	2,394 [r]	1,820	2,084
Total	134,699	160,724 [r]	153,804 [r]	157,485 [r]	164,579
Korea, Republic of, metal	(9)	(9)	(9)	(9)	(9)
Macedonia, ferronickel	1,900 [e]	--	2,970 [r, e]	5,149 [r]	5,555 [p]
Morocco, chemicals	--	84	151	109	126
New Caledonia, ferronickel	45,289	43,914	45,912	48,650	50,666 [p]
Norway, metal	74,137	58,679	68,221	68,530	77,183
Poland, chemicals[10]	641 [r]	732 [r]	704 [r]	744 [r]	750
Russia:[e, 11]					
Ferronickel	9,000	7,000	8,000	8,000	8,000
Metal	215,000	225,000	230,000	219,000	239,000
Oxide sinter	12,000	14,000	12,000	10,000	10,500
Chemicals	2,000	2,000	2,000	2,000	2,500
Total	238,000	248,000	252,000	239,000	260,000
South Africa:					
Metal	28,345	30,900	30,500	31,646	25,500 [e]
Chemicals[12]	7,855	5,716	5,943	6,900 [r]	15,342
Total	36,200	36,616	36,443	38,546 [r]	40,842
Taiwan, metal	(9)	(9)	(9)	(9)	(9)
Ukraine, ferronickel[e]	--	650	2,500	6,000	10,000
United Kingdom, metal	39,467	37,976	33,817	33,790	34,000 [e]
Venezuela, ferronickel	--	40	9,700	15,500	17,200
Zimbabwe, metal:					
Refined from domestic materials[13]	9,106	6,678	7,440	8,092	9,517
Toll refined from imported materials[14]	10,676	12,931	12,084	10,812 [r]	3,140
Total	19,782	19,609	19,524	18,904 [r]	12,657

See footnotes at end of table.

TABLE 11--Continued

NICKEL: WORLD PLANT PRODUCTION, BY COUNTRY AND PRODUCT[1, 2]

(Metric tons of nickel content)

Country and product[3]	1999	2000	2001	2002	2003
Grand total	1,050,000	1,120,000 r	1,160,000 r	1,190,000 r	1,240,000
Of which:					
Ferronickel	207,000	217,000 r	232,000 r	261,000 r	276,000
Metal	603,000 r	635,000 r	661,000	661,000 r	696,000
Oxide sinter	84,800 r	101,000 r	103,000 r	97,700 r	105,000
Chemicals	19,500 r	17,100 r	16,900 r	17,200 r	26,400
Unspecified	134,000 r	148,000 r	152,000 r	156,000 r	134,000

[e]Estimated. [p]Preliminary. [r]Revised. -- Zero.

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

[2]Table includes data available through July 29, 2004.

[3]In addition to the countries listed, North Korea is believed to have produced metallic nickel and/or ferronickel, but information is inadequate to make reliable estimates of output levels. Several countries produce nickel-containing matte, but output of nickel in such materials has been excluded from this table to avoid double counting. Countries producing matte for export are listed in table 12.

[4]Class II products with a nickel content of less than 99%. Includes oxides and oxide sinter. Excludes intermediate nickel-cobalt sulfide matte, regulus, and speiss for for further refining.

[5]Brazil produced nickel carbonate (an intermediate product), in metric tons: 1999--17,153; 2000--17,223; 2001--17,063; 2002--18,100 (revised); and 2003--18,000 (estimated).

[6]Nickel contained in products of smelters and refineries in forms, which are ready for use by consumers. Figures include the nickel content of nickel oxide sinter exported to the Republic of Korea and Taiwan. More information can be found in footnote 8.

[7]Cuba also produces nickel sulfide, but because it is used as feed material elsewhere, it is not included to avoid double counting. Combined output of processed sulfide and ammoniacal liquor precipitate was, as follows, in metric tons of contained nickel: 1999--25,969 (revised); 2000--28,548 (revised); 2001--31,884 (revised) 2002--32,604 (revised); and 2003--31,736 (preliminary). More information can be found in table 12.

[8]Reported by Eramet for Sandouville. Excludes secondary production from spent rechargeable batteries.

[9]Nickel metal production for the Republic of Korea and Taiwan are not included because the production is derived wholly from imported metallurgical-grade oxides and to include them would result in double counting. Metal estimates are as follows, in metric tons: Republic of Korea: 1999--20,235; 2000--29,890; 2001--26,429 (revised); 2002--30,337 (revised); and 2003--31,000. Taiwan: 1999-2000--10,000; 2001--11,500; and 2002-03--11,000.

[10]Nickel content of nickel sulfate ($NiSO_4$~$6H_2O$). Most of the nickel sulfate was a byproduct of the concentrating, smelting, and refining of domestically mined copper ores. Some production, however, may have been derived from imported nickeliferous raw materials that were blended with the domestic copper concentrates.

[11]Includes production from sulfidized concentrates shipped from Cuba for toll refining.

[12]Includes nickel sulfate plus exported metal in concentrate.

[13]Data represent production from domestic nickel ore.

[14]Previously published as "Other, metal." Data represent production from imported Botswanan matte as well as from South African nickel sulfate.

TABLE 12

NICKEL: WORLD PRODUCTION OF INTERMEDIATE PRODUCTS FOR EXPORT, BY COUNTRY[1, 2]

(Metric tons of nickel content)

Country	1999	2000	2001	2002	2003
Matte:					
Australia[3]	28,190	41,771	34,978	25,762 r	38,216
Botswana	22,898	24,218 r	22,454	23,896	27,400
Brazil[4]	9,306	8,475	10,249	6,274	6,300
Canada[e, 5]	52,000	36,000 r	48,000 r	50,000	45,000
China, exports[e, 6]	1,210	430	-- r	--	4,530
Indonesia[7]	45,400	59,200	62,600 r	59,500 r	70,200
New Caledonia	11,353	13,549	13,061	11,217	10,857
Russia[e, 8]	114	517	97	88 r	--
Total	170,000	184,000 r	191,000 r	177,000 r	203,000
Other, Cuba:[9]					
Sulfide precipitate	24,977 r	27,288	29,914	30,858	29,620 p
Ammoniacal liquor precipitate	992 r	1,260 r	1,970 r	1,746 r	2,116 p
Total	25,969 r	28,548 r	31,884 r	32,604 r	31,736 p

See footnotes at end of table.

TABLE 12--Continued

NICKEL: WORLD PRODUCTION OF INTERMEDIATE PRODUCTS FOR EXPORT, BY COUNTRY[1, 2]

[e]Estimated. [p]Preliminary. [r]Revised. -- Zero.

[1]Table includes data available through July 29, 2004. Data represent nickel content of matte and other intermediate materials produced for export.

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

[3]Total matte production on a contained nickel basis, in metric tons, was as follows: 1999--79,668; 2000--103,019; 2001--96,550; 2002--91,574; and 2003--107,000. Figures exclude toll-refined material.

[4]Represents the output of the Fortaleza smelter. All of the Fortaleza matte is being shipped to Finland for further processing.

[5]Estimated nickel content of reported exports.

[6]Chinese exports were estimated to have a nickel content of 63%. Total matte production on a contained nickel basis, in metric tons, was estimated to be as follows: 1999--50,100; 2000--57,000; 2001--59,000; 2002--59,200 (revised); and 2003--63,000.

[7]Represents the nickel output of the Soroako smelter. The Soroako matte, which also contains cobalt, is being shipped to Japan for further processing.

[8]Russian export figures reported primarily by the importing countries of France and Norway. Russian exports to Norway were estimated to have a nickel content of 40%.

[9]Corrected for coproduct cobalt.

TABLE 13

NICKEL: NEW LATERITE PROJECTS SCHEDULED FOR COMPLETION, BY YEAR, BEFORE 2015

Projected year of first production	Country and state/province	Project and company	Resource grade (percentage of nickel)	Estimated resources (thousand metric tons)[1]	Annual production capacity (metric tons of contained nickel)	Nickel product
2005	Philippines, Mindanao	Adlay-Cagdianao-Tandawa (BHP Billiton Plc. and Case Mining and Development Corp.)	1.61	6,000	5,000	Ore.
2005	Philippines, Palawan	Rio Tuba [Coral Bay Nickel Corp. (Sumitomo consortium)]	1.26	16,000	10,000	Ni-Co sulfide.
2006	Australia, Western Australia	Ravensthorpe (BHP Billiton Plc.)	0.80	150,000	45,000	Ni-Co hydroxide.
2007	Brazil, Goias	Barro Alto (Anglo American plc.)	1.84 1.20	30,000 90,000	60,000	Ferronickel.
2007	New Caledonia, Southern	Goro (Inco Ltd., Bureau de Recherches Geologiques et Minieres, and Sumitomo consortium)	1.57	200,000	60,000	Ni oxide.
2007	Madagascar	Ambatovy (Dynatec Corp. and Phelps Dodge Corp.)	1.10	190,000	60,000	Metal.
2007	Turkey, Manisa	Caldag (European Nickel plc. and BHP Billiton Plc.)	1.39 1.12	3,500 34,000	20,000	Leachate precipitate.
2008	Brazil, Para	Vermelho (Companhia Vale do Rio Doce S.A. de C.V.)	1.23	220,000	45,000	Metal or oxide.
2009	do.	Onca-Puma (Canico Resource Corp.)	2.22	33,000	25,000	Matte or oxide.
2009	Cuba, Holguin	Pinares de Mayari West (Government of Cuba)	1.10	400,000	40,000	Metal, oxide, or ferronickel.
2009	New Caledonia, Northern	Koniambo (Falconbridge Ltd. and Societe Miniere du Sud Pacifique S.A.)	2.13 2.20 1.60	140,000 160,000 130,000	60,000	Ferronickel.
2010	Cuba, Camaguey	San Felipe (BHP Billiton Plc. and Government of Cuba)	1.30	250,000	45,000	Metal or oxide.
2010	Indonesia, Halmahera Island	Weda Bay (Weda Bay Minerals, Inc. and PT Aneka Tambang)	1.35	220,000	48,000	Ni-Co sulfide.
2010	New Caledonia, Northern	Nakety-Bogota (Argosy Minerals, Inc. and Societe des Mines de la Tontouta)	1.47 1.50	88,000 140,000	52,000	Ni-Co intermediate.
2011	Australia, Western Australia	Mount Margaret [Minara Resources Ltd. (formerly Anaconda Nickel Ltd.)]	0.78	170,000	45,000	Ni-Co hydroxide.

See footnotes at end of table.

TABLE 13--Continued
NICKEL: NEW LATERITE PROJECTS SCHEDULED FOR COMPLETION, BY YEAR, BEFORE 2015

Projected year of first production	Country and state/province	Project and company	Resource grade (percentage of nickel)	Estimated resources (thousand metric tons)[1]	Annual production capacity (metric tons of contained nickel)	Nickel product
2012	Australia, New South Wales	Syerston (Black Range Minerals Ltd.)	0.65	96,000	18,000	Ni-Co sulfide concentrate.
2012	Guatemala	Sechol (Jaguar Nickel Inc.)	1.40	37,000 [2]	NA	Ni-Co intermediate.
			1.50	100,000		
2013	Papua New Guinea, Madang	Ramu River [China Metallurgical Construction (Group) Corp., Highlands Pacific Ltd., and Mineral Resources Development Co.]	0.91	76,000	33,000	Metal.
			1.01	67,000		
2013	Philippines, Mindoro Island	Sablayan (Crew Development Corp.)	0.94	72,000	40,000	Do.
2014	Australia, Queensland	Marlborough/Gladstone (Pearce Matheson Group)	1.02	210,000 [2]	25,000	Do.
2014	Australia, Western Australia	Kalgoorlie and North Kalgoorlie--Ghost Rocks, Goongarrie, and Kalpini (Heron Resources Ltd.)	0.74	290,000	45,000	Ni-Co hydroxide.
			0.74	600,000		
2015	Cote d'Ivoire	Biankouma, Touba, and Sipilou (Falconbridge Ltd. and Societe d'Etat pour le Developpement Minier)	1.57	120,000	45,000	Ni-Co intermediate or ferronickel.
			1.40	140,000		
2015	Indonesia, Maluku	Gag Island (BHP Billiton Plc. and PT Aneka Tambang)	1.35	240,000	30,000	Intermediate, metal, or ferronickel.
2015	New Caledonia, Southern	Prony (Inco Ltd., Bureau de Recherches Geologiques et Minieres, and Sumitomo consortium)	1.50	NA [2]	NA [2]	Ni oxide.
2015	Papua New Guinea, Oro	Wowo Gap (Resource Mining Corp. Ltd.)	1.09	31,000	45,000	Metal.
			1.44	18,000		
			1.02	18,000		

NA Not available.
[1]Gross weight, dry. "Estimated resources" are rounded to no more than two significant digits.
[2]New resource estimate in progress.

Sources: Company annual reports, presentations, and press releases; CRU International, Ltd.

TABLE 14
NICKEL: NEW SULFIDE PROJECTS SCHEDULED FOR COMPLETION, BY YEAR, BEFORE 2015

Projected year of first production	Country and state/province	Project and company	Resource grade (percentage of nickel)	Estimated resources (thousand metric tons)[1]	Annual production capacity (metric tons of contained nickel)	Nickel product
2003	Australia, Western Australia	Cosmos Deeps (Jubilee Mines NL)	7.35	410	12,000	Concentrates.
			3.90	110		
2003	Canada, Ontario	McCreedy West/Levack (FNX Mining, Inc. and Dynatec Corp.)	1.90	2,700	3,200 [2]	Ore.
			1.80	2,400		
			2.00	980		
2004	Australia, Western Australia	Maggie Hays (LionOre Australia Ltd.)	3.55	480	(3)	Concentrates.
			1.41	10,000		
2004	do.	Sally Malay (Sally Malay Mining Ltd.)	1.74	3,700	8,000	Do.
2004	Spain, Extremadura Province	Aguablanca (Rio Narcea Gold Mines Ltd.)	0.67	23,000	10,000	Do.
2005	Canada, Ontario	Montcalm (Falconbridge Ltd.)	1.46	5,100	8,000	Do.
2006	Australia, Western Australia	Forrestania-Flying Fox, New Morning and Diggers South (Western Areas NL)	5.60	430	7,000	Do.
			1.67	1,700		
2006	Canada, Labrador	Voisey's Bay (Inco Ltd.)	2.88	31,000	50,000	Concentrates, initially.
			1.29	97,000		
			0.98	14,000		
2007	Australia, Western Australia	Sherlock Bay (Sherlock Bay Nickel Corp. Ltd.)	0.49	33,000	8,000	Precipitated leachate.
2007	Canada, Ontario	Norman-North, Whistle Pit, and '2000' (FNX Mining, Inc. and Dynatec Corp.)	0.95	(4)	NA	Ore.
2008	Australia, Western Australia	Honeymoon Well (Mining Project Investors Pty. Ltd. and OM Group, Inc.)	0.82	140,000	30,000	Concentrates, initially.
2008	do.	Yakabindie (WMC Resources Ltd.)	0.58	290,000	40,000	Ore.
2008	United States, Minnesota	NorthMet (PolyMet Mining Corp.)	0.11	810,000	7,100	Byproduct concentrate of Ni-Co hydroxide.
2009	Australia, Western Australia	Cosmos South, Alec Mairs, Anomaly 1 (Jubilee Mines NL)	0.74	36,000	10,000	Concentrates.
2009	Canada, Ontario	Nickel Rim South (Falconbridge Ltd.)	1.60	14,000	10,000	Do.
2009	Tanzania, Kagera region	Kabanga (Barrick Gold Corp. and Falconbridge Ltd.)	2.60	26,000	30,000	Do.
2009	United States, Minnesota	Mesaba (Teck Cominco American, Inc.)	0.12	300,000	20,000	Byproduct concentrate of Ni-Co sulfide or hydroxide.
2011	Australia, Western Australia	Waterloo and Amorac (LionOre Australia Ltd.)	(4)	(4)	NA	Concentrates.
2011	Canada, Manitoba	Maskwa (Mustang Minerals Corp.)	1.27	2,900 [4]	3,800	Do.

NA Not available.
[1]Gross weight, dry. "Estimated resources" are rounded to no more than two significant digits.
[2]Recent feasibility studies indicate that this figure could be tripled to 10,000 metric tons per year (t/yr).
[3]The massive sulfide ores at Maggie Hays would be shipped to the neighboring Emily Ann concentrate plant. The concentrate plant would be upgraded to 500,000 t/yr of ore to handle the additional feed.
[4]Resource estimate in progress.

Sources: Canadian Minerals Yearbook 2002; company annual reports, presentations, and press releases; and CRU International, Ltd.